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Publicly-funded collaborative R&D networks as drivers for promoting knowledge-intensive entrepreneurship: an exploratory exercise

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Abstract

This paper?s main aim is to examine the potential of EU-funded research collaborative networks in promoting and enhancing knowledge-based entrepreneurship. It does so by offering some empirical evidence on the characteristics and participation intensity of young knowledge-intensive firms in EU-funded research joint ventures, the structural properties of the created networks, the network role of young firms, and the interaction patterns developed among them and other research actors.

We use social network analysis tools in order to describe the structural characteristics and the evolution of this network over time, to study the network position and role of newly-established firms during the period examined and to investigate the collaboration patterns developed among them and other network research actors (ego networks). In this way we are examining the potential of the specific networking environment to allow newly-established participating firms 1) to gain access to a considerable amount of resources 2) to develop relationships with actors exhibiting a high degree of diversity. Analysis results indicate that these young firms can have access to an increased and diversified amount of resources and thus EU-funded research networks can be considered as drivers advancing knowledge-intensive entrepreneurship. In addition, detailed qualitative data based on information acquired from the firms? websites and the

homepages of the research projects they are involved provide better understanding of the young firms? network role and the ways they use to get into the research network.

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1st paper draft

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This paper's main aim is to examine the potential of EU-funded research collaborative networks in promoting and enhancing knowledge-based entrepreneurship. It does so by offering some empirical evidence on the characteristics and participation intensity of young knowledge-intensive firms in EU-funded research joint ventures, the structural properties of the created networks, the network role of young firms, and the interaction patterns developed among them and other research actors.

The empirical analysis is based on network data of 289 newly-established firms which at the same time participate in research projects funded by EU under the Framework Programme during the period 2002-2009.

We use social network analysis tools in order to describe the structural characteristics and the evolution of this network over time, to study the network position and role of newly-established firms during the period examined and to investigate the collaboration patterns developed among them and other network research actors (ego networks). In this way we are examining the potential of the specific networking environment to allow newly-established participating firms 1) to gain access to a considerable amount of resources 2) to develop relationships with actors exhibiting a high degree of diversity. Analysis results indicate that these young firms can have access to an increased and diversified amount of resources and thus EU-funded research networks can be considered as drivers advancing knowledge-intensive entrepreneurship. In addition, detailed qualitative data based on information acquired from the firms' websites and the homepages of the research projects they are

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1. Introduction

Entrepreneurship studies have been concerned with the role of networks for a considerable time. Essentially, these studies reflect a consensus on the importance of networks for providing entrepreneurs with an abundance of diverse information and access to a large pool of resources and opportunities.

Our main aim in this paper is to explore the potential of EU-funded collaborative research networks in promoting and enhancing knowledge-intensive entrepreneurship (KIE). In the context of this study KIE is associated with four basic characteristics: it concerns new firms (new ventures); new ventures that are innovative; new ventures engaging in activities that are knowledge intensive; and finally, new ventures that are not to be found solely in high-tech industries. In other words, a new venture that draws upon and integrates knowledge (both in-house and externally generated) in order to pursue and exploit innovative opportunities is a KI venture; moreover, it is a venture that can be found in diverse industries (including low-tech industries and services) (Malerba and Mckelvey, 2011). The EU-funded research collaborative networks are policy-driven networks characterized by heterogeneity in terms of participating actors (firms, universities, research centres and other actors which are mainly technology users), interaction patterns and knowledge flows. Therefore, they are assumed to promote the creation and diffusion of new knowledge and innovation. Furthermore, subsidized research joint ventures can provide potential benefits to participating organizations such as R&D cost sharing, continuity of R&D effort and access to finance, further development of their resource base and access to complementary resources and skills. These benefits can be proved significant drivers of growth by opening up new market and technological opportunities especially for young companies.

The paper's empirical part is based on network data of 289 newly established firms which at the same time participate in research projects funded by EU under the Framework Programme during the period 2002-2009.

We use social network analysis tools in order to describe the structural characteristics and the evolution of this network over time, to study the network position and role of newly-established firms during the period examined and to investigate the collaboration patterns developed among them and other network research actors (ego networks). In this way we are examining the potential of the specific networking environment to allow newly-established participating firms 1) to gain access to a considerable amount of resources 2) to develop relationships with actors exhibiting a high degree of diversity. Empirical results indicate that newly-established firms participating in EU-funded projects:

- are embedded in highly interconnected networks where they can have access to a large amount of technological knowledge and information held by other actors;
- have the potential to develop relationships and thus exchange technological knowledge and expertise with actors exhibiting a high degree of diversity (in terms of type, sector and centrality position);
- often get into the network through their connections with organizations holding very central network positions. Connecting to a prestigious incumbent does not only provide superior quality resources, but also works as a signal to future collaborations.

The fact that these young firms can have access to an increased and diversified amount of resources constitutes an indication that EU-funded research networks can be considered as suitable tools for enhancing entrepreneurial outcomes (firm performance, mergers, formation of alliances etc).

Furthermore, detailed qualitative data based on information acquired from some the firms' websites and the homepages of the research projects they are involved in help us shed some light on these firm's network role and how they get connected in the research networks. More specifically the collected they are involved indicate that:

- they appear to be highly innovative and knowledge intensive;
- in general, they participate in research projects that are closely related to their activities and in-house R&D and therefore these partnerships may foster their ability of developing and launching specific commercial projects;
- it seems that in some cases they may enter research partnerships more easily because of their university origin or because of their founders' affiliations to certain institutions (in such cases parent universities and institutions are project coordinators);
- their increased participation in EU-funded research joint ventures may also be related to their research intensive orientation;
- their exact technological specialized knowledge and capabilities often make them attractive partners to network incumbents and therefore facilitate their network entry.

Over the last few years several studies have attempted to examine and map the structural features of the research collaborative networks funded by the EU Framework Programmes. One of the main findings of this stream of research regards the key position and central role that some large, well-established industrial firms play through time. In this paper an attempt is made to shed light on the role and participation of newly-founded firms which are primarily small but with a strong potential to increase the network value and effectiveness by offering specialized technological knowledge and complementary capabilities as well as a fresh and innovative perspective.

The paper unfolds as follows. The subsequent section begins with a general overview of technology collaborations in the context of EU-funded research joint ventures (RJVs) and continues with presenting why networks are important for entrepreneurship in general and knowledge-intensive entrepreneurship in particular. The third section provides a description of the dataset. The fourth section presents the empirical analysis and discusses the results obtained, while the last section includes a conclusion of the research findings.

2. Theoretical background

2.1 EU-funded research projects as a networking environment for young firms

Success in knowledge-intensive industries depends on organizational learning and commercialization of technologies across different networks. Science and technology networks emerge as a new organizational mode in environments of complex technologies and rapid technological advance. Vonortas and Zirulia (2010) made an extensive review on business network literature and found out that, in general, there is a positive, significant relationship between firms' participation in networks and their performance measured by sales, growth, patents or survival. This general finding also holds for young and knowledge-intensive firms too. More specifically, literature review reveals that network strategy is an important element for determining entrepreneurial outcomes of knowledge-intensive firms especially in highly competitive environments were cooperation with leading firms allows them to have access to fundamental resources. This cooperation process is stimulated by two interrelated aspects: the start-up attractiveness as partner which is based on holding resources that are of increased value to established firms, and its ability to choose good partners that works as a signal for future collaborations (Vonortas and Zirulia, 2010).

The past three decades have witnessed a massive increase of cooperative innovation agreements involving firms, universities, and other research institutes in various combinations (Vonortas, 2009). They are considered to promote innovation as: First, they enable and enhance inter-organizational learning by accelerating and supporting the diffusion of new technological knowledge. Second, they promote access to complementary resources, which is an important requirement for the creation of complex technological systems. Third, they establish an organizational setting that also creates a real surplus or synergy in the process of resource creation by allowing the blending of different technological capabilities. In such a setting innovation processes come across wide-ranging technological opportunities which otherwise would not exist (Pyka and Küppers, 2002).

Collaborative research networks have gained momentum in the policy agenda of EU as they are perceived as an integral part of its efforts to develop the European Research Area (ERA). Since their inception in 1984, Framework Programmes (FPs) have been basic pillars of European scientific and technological development, integration and cohesion by supporting all kinds of R&D in high technology sectors and promoting cross-border, interdisciplinary networking activity. The collaborative research networks developed under the FPs embody the added value of bringing together different types of participating entities (firms, universities, research centres and government agencies) from different countries and with complementary expertise in productive research joint ventures (RJVs) under the thematic priorities and funding rules imposed by the EU.

Over the last few years several studies have attempted to examine and map the structural features of the research collaborative networks funded by the EU Framework Programmes (Breschi and Cusmano, 2004; Barber et al. 2006; Roediger-Schluga and Barber 2008; Protogerou et al. 2010; Protogerou et al. 2012). The main findings of these studies can be summarized as follows:

- EU-funded research activity has been characterized by a considerable growth in terms of participating entities and participations resulting in substantially large networks.
- The networks' connectivity is highly dependent on a core of influential actors mainly universities, research centers and large-sized firms, which have strengthened their positioning and strategic role through the years. Newcomers (such as small firms) get access to FPs often through joining projects led by larger and more reputed organizations. Therefore it can be assumed that although basic networks remain stable they are also able to attract new partners through time.

- The networks analyzed display ‘small-world properties’ i.e. they may be considered as relatively efficient mechanisms of knowledge creation and diffusion.

Empirical evidence indicates that, in general, there is a downward trend in industrial participation in FPs through time (Protogerou et al., 2012). A serious disincentive for industrial participation is in many cases the contract conditions on intellectual property rights. In addition, administrative complexities and bureaucracy tend to further deter industry involvement (European Communities, 2009). For example, the FP6 Evaluation Report (2009) suggests that that “there are strong indications that the pharmaceutical, chemical and biotech industries in Europe found that the FP is too time consuming and too slow for them to be able to participate” (p 22.).

Most importantly, only a very small fraction of the most dynamic SMEs has been participating in EU-funded research projects (Breschi and Malerba, 2009) while they rarely assume central network positions (Protogerou et al., 2010). For example, empirical work suggests that in EU-funded collaborative networks promoting research in emerging ICT activities the presence of young small firms is limited. Furthermore, only a limited number of small and medium sized firms acquire equally important network positions to their larger, well-established counterparts (Protogerou et al., 2013). The powerful position of these young innovators can be attributed to their significant role in the creation and diffusion of knowledge in the specific technological areas as in some cases they may be substituting science actors in the production of new complex technological knowledge (Windrum, 2002). For example, in the case of m-commerce applications the role of content developers which are mainly small entrepreneurial companies is very important for the creation of new business to business or business to consumer services and therefore they may bring into the network new ideas and resources essential for the creation of new innovative activities.

Although EU-funded networks appear to facilitate the creation and dissemination of new knowledge we cannot make a concrete conclusion about their innovative performance in terms of direct commercializable outputs. However, the primary objective of FPs is the support of set research infrastructure which may then influence the competitiveness of European industry indirectly by allowing them to undertake highly competent research. Therefore, the essential result of these projects may be the production of intangibles, know-how and learning. In other words, their output may be mainly 'behavioural' in character aiming at the improvement of knowledge, capabilities and strategies of the participating entities (Luukkonen 2002).

Arnold et al. (2008) report that the FP impact largely depends on the industrial activity studied. They confirm that when the objectives of the FP-funded research consortia are closer to the market and the participation of large firms is significant, like in ICT or automobiles, the economic impact is higher. On the contrary, in life sciences and energy the most important impact of the FP is mainly related to the increasing technological capabilities of small and medium-sized firms. In general, empirical evidence on the impact of FPs on industrial partners indicates that their main contribution lies in the improvement of firms' scientific and technological capabilities and not directly on their economic performance. However, a recent study by Colombo et al. (2009) suggests that FPs can be beneficial to high-tech start-ups in terms of their total factor productivity as long as research consortia involve industrial partners originating from a variety of countries and these countries are closer to world knowledge sources. Furthermore, Barajas et al. (2011) empirically show that research cooperative activity has a positive impact on the technological capacity of firms, captured through intangible assets and the technological capacity of firms is positively related to their productivity. Thus this study indicates the need to capture the economic value of intangible assets (e.g. innovative and technological capabilities) produced through FPs which in turn affect firms' economic performance and entrepreneurial outcomes.

2.2. Entrepreneurship and networks

In recent years, there is an increasing appreciation of the utility, application and importance of networks in the entrepreneurship research. Studies reflect a consensus that a key benefit of networks for entrepreneurship is the access they provide to an abundance of information and a variety of resources held by other actors, that entrepreneurs must get involved in networks and use these ‘powerful’ assets (Drakopoulou Dodd et al., 2006).

Two important parameters defining the role of networks in the entrepreneurial context are related to the content of network relationships, and the structure or pattern that emerges from crosscutting ties. These characteristics are pivotal in models seeking to explain the process of network evolution during entrepreneurial activity and the impact of networks on entrepreneurial outcomes (Hoang and Antoncic, 2003; Slotte-Kock and Coviello, 2009).

An important characteristic of networks in entrepreneurship research has to do with their content, i.e. the nature of interpersonal and inter-organizational relationships and resource access they provide. Network content changes throughout the lifetime of an entrepreneurial venture. During the early phases of a venture’s life entrepreneurs are particularly concerned with building personal networks in order to overcome the liability of newness, to mobilize necessary resources such as information and knowledge and promote the emerging business. At this stage entrepreneurs often mobilize different networks such as commercial contacts (e.g. ties to venture capitalists or professional service organizations) and social relationships, like family and friends, to acquire knowledge and capital resources such as funds, materials, key talent and market information (Schutjens and Stam, 2003). A number of studies also indicate that firm founders consistently use networks to identify business opportunities, to get ideas and collect information (Hoang and Antoncic, 2003).

The reliance on networks is not constrained to the start-up phase. More strategic networks emerge later in the life of the firm when issues such as growth and profit making arise. Once the operating foundation has been established the entrepreneur/founding team becomes more aware of the strategic aspects of the networks which tend to consist of relations with customers, suppliers or competitor organizations and can be important conduits for information and know-how. For example, Lechner and Dowling (2003) found that at this stage entrepreneurs try to increase sales by developing marketing networks and leverage their technological base by co-opetition.

Relationships can also have a reputational or signaling content (Hoang and Antoncic, 2003). Under the uncertain and dynamic conditions that entrepreneurship takes place, entrepreneurs are in search of legitimacy to reduce this perceived risk by developing links with well-reputed individuals or organization. On the other hand, resource holders (potential investors and employees) are likely to look for information that assists them to assess a venture's underlying potential. In this line of reasoning, Stuart et al. (1999) showed that biotech firms with prominent alliance partners had the ability to public faster and at a higher market valuation. Furthermore, when such linkages are developed sector-wide they can indicate a munificent environmental context and therefore can further spur start-up activity.

Another defining characteristic of a network perspective within entrepreneurial research is network structures, their dynamics i.e. the way they change to adapt to the specific needs of a venture as time goes by and their impact on entrepreneurial phenomena.

A variety of measures originating from the network analysis literature have been used to explore relationship patterns within a network structure in order to uncover the differential positions of entrepreneurs and their ventures.

Network structure has been explored in terms of reciprocity, reachability, centrality of the entrepreneur, and network size as measures that reflect the amount of resources an actor can access (Hoang and Antoncic, 2003) and enable an understanding for the potential for innovation (Ahuja, 2000). Network structure has also been examined in terms of the strong tie-weak tie dichotomy first proposed by Granovetter (1973). The notion of weak ties, in particular, describes the extent to which actors can gain access to new information and knowledge through ties that lie outside their immediate cluster of contacts. Complementary to the benefits of weak ties are the potential benefits of bridging structural holes. An actor bridging structural holes brings together otherwise disconnected parts of the network and its position provides an opportunity to wield power or influence those unlinked to the broader network. The opportunity for diverse, non-redundant ties, spanning structural holes can also enhance an actor's exposure to novel information and may in turn spur learning and improve internal capabilities and firm performance. There has also been observed an increase in the number of studies examining the concept of social capital in relation to entrepreneurship. Social capital has been perceived as a set of social resources embedded in relationships and the resources available to different actors via their connections.

3. Dataset preparation

The empirical part of this paper was based on a dataset which was constructed using four specific criteria. First, the selected firms were young companies set up between 2002 and 2007. Second, they originate from ten European countries representing different socioeconomic models. Third, these firms belong to different sectors (high-tech, low-tech and knowledge-intensive business services). Fourth, the specific companies have participated at least once in the collaborative research projects funded by EU during the 6th and 7th Framework Programmes (2002-2009[1]). The firms eligible for this research were newly established, i.e. they were setup between 2002 and 2007 and therefore their presence in EU research partnerships was indentified at a comparable time frame (i.e. 2002 onwards).

In particular, the acquired information was extracted from two broader datasets:

a) the STEP-to-RJVs database which is developed and maintained by LIEE/NTUA and includes detailed information on research joint ventures established in the context of the seven European Framework Programmes (1984-2009). Primary information for the STEP-to RJVs

[1] At present STEP to RJVs contains information on EU-funded research partnerships launched up to the end of 2009.

is drawn from the EU CORDIS (Community Research and Development Information Service) database;

(b) the AMADEUS database, from which we selected an initial population of 300,000 newly-established-firms was drawn.

Initially the constructed dataset included information on 402 firms that appeared both in the Amadeus population and the STEP-to-RJVs database.

However an extensive cleaning of the dataset was carried out to correct:

the firms' year of establishment because during the AEGIS survey implementation phase it was proved that many firms that were originally included in the population as newly established they had just changed their name or their legal status. The result of this process was the reduction of the initial sample from 402 to 289 firms, and

inoncistencies in firm details (name, number of employees, primary activity)

The cleaning process was based on the matching of firm demographics included in the dataset (provided by the AMADEUS database) with available information mainly from the firms' websites.

The outcome of the above-mentioned cleaning process was that finally only 289 of them were actually newly established and therefore eligible for our research.

Furthermore, using the information provided by the 289 firms' websites we created two additional fields related to the academic qualifications of the founder or founding team (Ph.D holders) and the type of corporate action (academic spin-off or not).

All in all the dataset used for the empirical analysis of the specific deliverable includes information on 289 young firms, their partners and the EU-funded research projects they participate in. In particular, participating organizations, that were partners of the selected firms, were categorized into the following types: (i) "firm" (combining industry and consultancy); (ii) "education" (universities and other educational institutions); (iii) "research" (various research institutes) and (iv) “other” (combining government, hospitals, libraries, museums, city councils etc.). The entities that were included in the “other” category are mainly users –rather than developers– of the project related technologies.

Available dataset information includes:

- organization code
- country of origin
- organization type (industry, research, education, other)
- number of participations in FP6 and FP7

Furthermore for the newly-created firms there is additional information on

- year of incorporation
- size (number of employees)
- sector (primary activity)
- parent organization (university or research-centre spin-off)
- highest academic qualification of founder(s) (Ph.D holders)

We should emphasize here that the information on new firms originating from universities and research centres and on the educational qualification of founder(s) was extracted from their corresponding websites and cannot be considered as full or representative of the 289 firms. However, taking into consideration the fact that approximately all these firms had very well-organized homepages there is a good reason to believe that the details provided are accurate and therefore can help us to better understand the nature of these firms in terms of knowledge-intensity and research orientation.

4. Empirical results

4.1 Descriptive statistics results

Figure 1 shows a distribution of the newly-created firms in terms of employees. Small and very small firms account for the largest part of young firms that participate in the research joint ventures under study. However, there is a small share of firms that exhibits a high number of employees. More specifically, the share of firms exceeding 50 and 250 employees is 8% and 1% respectively. As far as spin-off firms are concerned, Figure 1 illustrates that they are even smaller in size as 96% of them have less than 50 employees. Furthermore, 53% of spin-off companies employ less than 4 people.

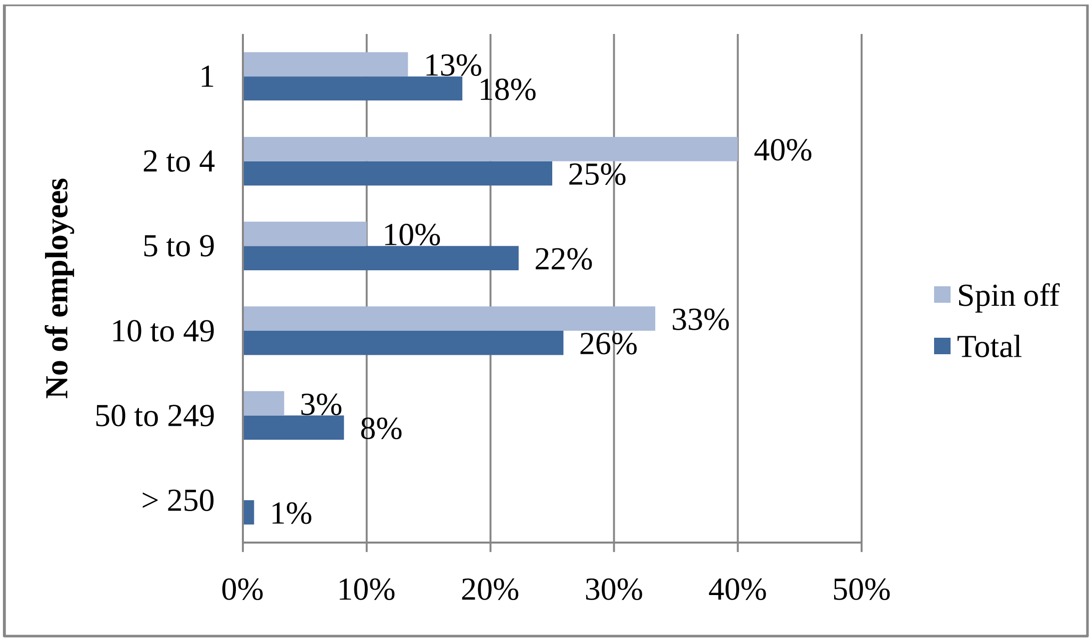

Figure 1. Firm size in terms of employees' number (N=222)

The created dataset contains information on 374 research projects and 4,117 different participating organizations. Among these participating entities we have identified 289 newly-established firms that exhibit, in total, 483 participations (311 in FP6 and 172 in FP7).

Table 1. Descriptive statistics of the dataset

	FP6	**FP7**	**FP6&7**
no of young firms	203	118	289
no of projects	231	143	374
no of participations	311	172	483
average no of participants per project (st.dev.)*	18.4 (13.0)	13.9 (8.2)	16.8 (11.8)
average no of projects per participant (st.dev.)	1.53 (1.01)	1.46 (0.93)	1.67 (1.37)
years of operation per participation	3.45	3.23	3.03

*standard deviation in parenthesis

However, only 15% of the young firms identified participate in more than two EU research partnerships funded during the period examined. This finding is in line with the average participation rate of newly-established firms (average number of projects per firm) which is 1.53 in FP6 and 1.46 in FP7. Nevertheless, the fact that FP6 and FP7 are characterized by a smaller number of projects with larger consortium sizes (mainly Integrated Projects and Networks of Excellence that are dominated by academic and research institutions) explains the high average number of participants per project.

Looking at the average years of operation per participation, we find out that a critical time period of three years is required, on average[2], before a newly-established firm is able to join this kind of R&D collaborative networks. This finding may be attributed to the fact that young entrepreneurial ventures need some time to develop certain administrative and project management procedures as well as the necessary research resources and technical knowledge needed to become attractive partners to dominant network players.

Figure 2 illustrates a distribution of the selected firms based upon both their year of incorporation and their participation intensity in EU collaborative research projects. This Figure also indicates the repeated participations i.e. participations in two, three, or more different projects. It is clear that the number of firms per year is analogous to their actual participation. In addition looking at the overall distribution of the year of incorporation that

[2] This general trend is confirmed by checking the start dates of the relevant research joint ventures. It is observed that for the majority of firms research projects begin at least three years after their set-up.

depicts firm's age, a significant correlation between age and participation intensity can be observed i.e. the earlier a firm is founded, the higher participation intensity it shows. This makes sense because older firms have more time and resources than younger ones to return back to FPs and therefore exhibit repeated participations.

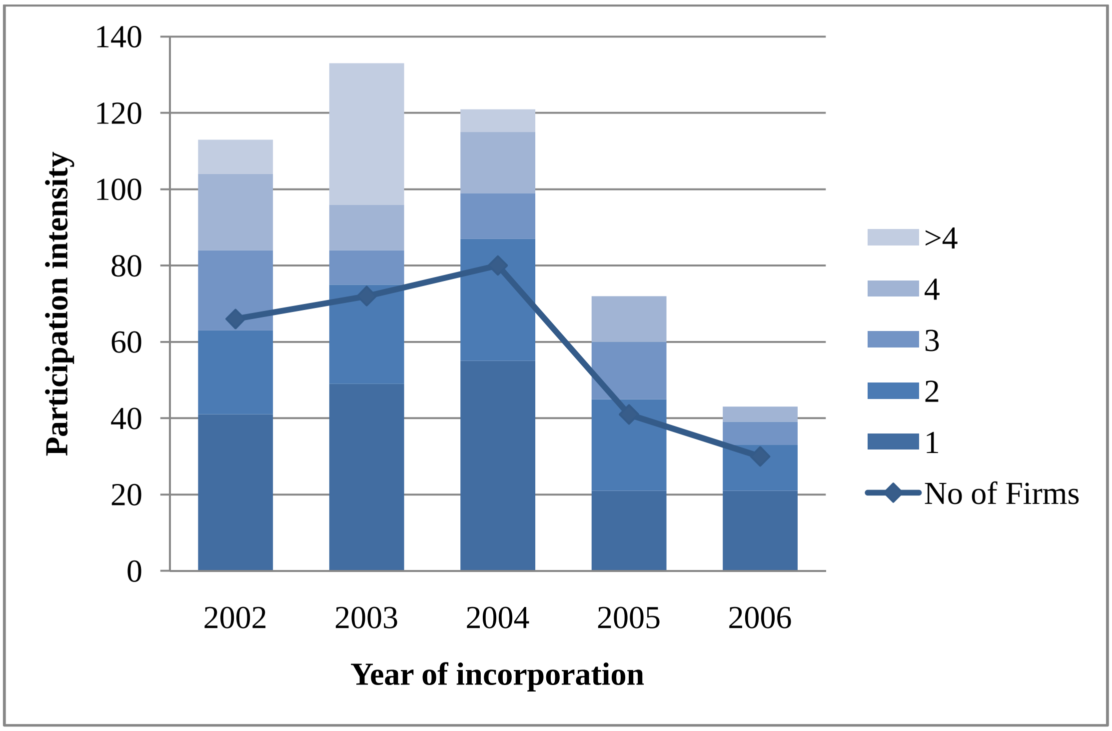

Figure 2: Participation intensity per year of incorporation

In order to better understand the type of new firms participating in RJVs and their respective role in EU-funded collaborative networks we have collected additional information from each firm's website on its parent organization and the highest educational attainment of its founders (Ph.D degree). In particular we were interested into identifying academic (universities and research centres) spin-offs as we assumed that these firms are more research intensive and therefore are likely to have a more concrete orientation towards participating in R&D networks (see Appendix[3]). Furthermore, we assumed that their participation in RJVs might be assisted in some cases by their close relation to academia as some of the core actors

[3] The Appendix provides information on the company name, year of establishment, parent university or research centre, sector, and number of participations in EU-funded research joint ventures for those spin-offs that we were able to identify among the 289 young firms.

in the networks examined are prestigious universities and research centers (Protogerou et al. 2010).

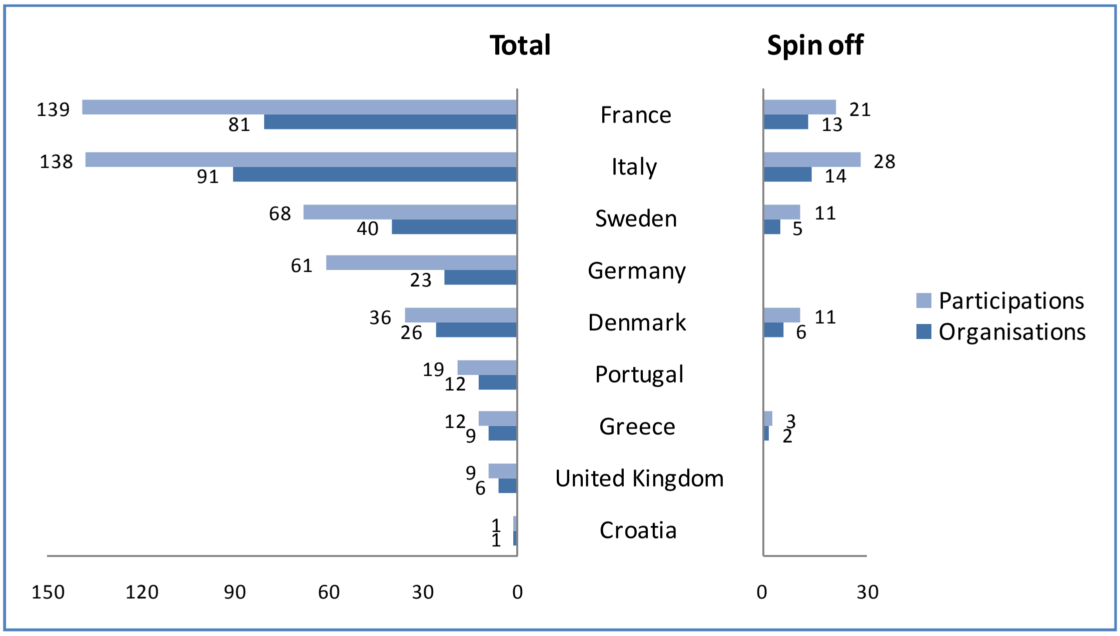

Figure 3. Distribution of young firms and their participations per country

Figure 3 represents the distribution of newly-established firms per country and their total number of participations in FP6 and FP7. The countries represented in Figure 3 are those in which the AEGIS survey was carried out[4]. It is obvious that there is a wide variation in participation intensity across these countries. France, Italy and Sweden appear to participate more than the other selected countries. Germany and Denmark hold the next two positions respectively; however, Danish participations are significantly outnumbered by German ones although these two countries have a similar number of participating young firms.

These findings tend to illustrate a different picture from the results of a study examining the FP networks from their inception until 2009 (see Protogerou et al, 2011), in which, large countries, in general terms those with the largest population, research resources and capacity, are dominant in terms of participating entities and number of participations.

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[4] Nevertheless, no firms originating from Czech Republic were found at the matching procedure, thus, Czech Republic is not included in Figure 3.

Finally only in a few countries there is a slight presence of spin-off firms. The majority of them comes mainly from France, Italy and secondly from the Nordic countries.

Table 2 shows the distribution of newly-established firms by sector and their respective participations in EU Framework Programmes. The majority of firms are classified in knowledge-intensive business services (KIBS) sectors accounting for 81%, followed by firms activated in high-tech sectors with a total share of 18%. The overwhelming presence of KIBS compared to high-tech manufacturing maybe partly related to the original population of firms of the AEGIS survey drawn from the Amadeus Database.

Only a few firms belong to low-tech sectors, however, their scarce participation may be resulting from the fact that the thematic research areas prioritized and funded by EU Framework Programmes mainly concern high-technology activities.

Table 2 Distribution of young firms and their participations per sector

Sector (Nace 1.1)	Spin-offs		Founder(s) with PhD		Total	
	Organizations	Participations	Organizations	Participations	Organizations	Participations
High Tech	**6 (15%)**	**11 (15%)**	**7 (15%)**	**13 (13%)**	**49 (17%)**	**86 (18%)**
Chemical industry (24)	1 (3%)	1 (1%)			3 (1%)	4 (1%)
ICT manufacturing (30, 31, 32, 33)	5 (13%)	10 (14%)	7 (15%)	13 (13%)	37 (13%)	65 (13%)
Manufacture of machinery and equipment (29)	-	-	-	-	9 (3%)	17 (4%)
Low Tech	**-**	**-**	**-**	**-**	**6 (2%)**	**8 (2%)**
Food, beverages and tobacco (15, 16)	-	-	-	-	2 (1%)	2 (0.4%)
Paper and printing (21,22)	-	-	-	-	1 (0.4%)	1 (0.2%)
Textile and clothing (17, 18, 19)	-	-	-	-	3 (1%)	5 (1%)
KIBS	**34 (85%)**	**63 (85%)**	**40 (85%)**	**85 (87%)**	**234 (81%)**	**389 (81%)**
Computer & related activities (72)	13 (33%)	26 (35%)	9 (19%)	20 (20%)	80 (28%)	135 (28%)
Other business services activities (74.1, 74.2, 74.3, 74.4, 74.5, 74.8*)	3 (8%)	6 (8%)	4 (9%)	18 (18%)	73 (25%)	128 (27%)
Research and experimental development (73)	17 (43%)	28 (38%)	26 (55%)	44 (45%)	79 (27%)	122 (25%)
Telecommunications (64.2)	1 (3%)	3 (4%)	1 (2%)	3 (3%)	2 (1%)	4 (1%)
Total	**40 (100%)**	**74 (100%)**	**47 (100%)**	**98 (100%)**	**289 (100%)**	**483 (100%)**

* Selection of most 4-digits sectors. Only some 74.87 (other activities) excluded

Distribution of firm participation per thematic area (table 3) reveals some interesting findings. New firms participate quite intensively in the thematic area of Information & Communication Technologies both in FP6 and FP7. Moreover a significant number of participations are observed in the areas of (i) Life sciences, genomics and biotechnology for health, (ii) Nanosciences, nanotechnologies, materials & new production technologies and (iii) Sustainable development, global change and ecosystems. The differences in participation intensity per thematic area may be partly attributed to the amount of EU-funding dedicated to each technological area, for example the area of ICTs receives the largest amount of funding compared to the rest of thematic areas, attracting therefore a larger number of organizations. Furthermore, young firms' involvement may not be favoured by all thematic priorities (e.g. socioeconomic research) and all instruments (e.g. NoEs). Looking at the corresponding values for spin-off firms and firms that have at least one founder with high academic qualifications (Ph.D) we can see that there is a polarization in R&D development sectors such as "research and experimental development" (NACE 1.1: 73) and "computer & related activities" (NACE 1.1: 72). Furthermore, there is no spin-off or firm with founder(s) who holds a Ph.D degree in the low-tech sector.

Lastly, it appears that both spin-off and firms with founders holding Ph.D degrees exhibit on average a more frequent participation in EU-funded RJVs (1.9 and 2.1 participations per firm, respectively) compared to the remaining firms (1.6).

Table 3. Distribution of projects and firm participations per thematic area

Thematic areas of FP6	Projects	Partici-pations	Thematic areas of FP7	Projects	Partici-pations
Life sciences, genomics and biotechnology for health	47 (20%)	55 (18%)	Health	22 (15%)	25 (15%)
Information society technologies	97 (42%)	134 (43%)	Information & communication technologies	63 (44%)	81 (47%)
Nanotechnologies and nano-sciences, knowledge-based multifunctional materials & new production processes & devices	31 (13%)	51 (16%)	Nanosciences, nanotechnologies, materials & new production technologies	19 (13%)	25 (15%)
Aeronautics and space	10 (4%)	11 (4%)	Transport (including aeronautics)	17 (12%)	19 (11%)
			Space	2 (1%)	2 (1%)
Food quality and safety	5 (2%)	5 (2%)	Food, Agriculture and Fisheries, Biotechnology	6 (4%)	6 (3%)
Sustainable development, global change and ecosystems	41 (18%)	54 (17%)	Environment (including Climate Change)	5 (3%)	5 (3%)
			Energy	5 (3%)	5 (3%)
			Socio-economic Sciences and the Humanities	1 (1%)	1 (1%)
			Security	3 (2%)	3 (2%)
TOTAL FP6	**231**	**310**	**TOTAL FP7**	**143**	**172**

Additional evidence on spin-off companies highlighting their role in EU-funded research networks

The role of spin-off companies in RIVs is highlighted using some information provided by their homepages and the websites of the EU projects they are involved. We have chosen two biotechs and one ICT firm on the basis of their participation intensity - the two companies have been involved repeatedly in FP6 and FP7 while the third one has participated only twice but having a coordinator's role.

Fluxome Sciences A/S

Fluxome was founded in 2002 as a spin-off company of the Technical University of Denmark (DTU), having developed a cutting edge platform in industrial biotechnology using novel metabolic engineering and fermentation methods. In 2003 the company initiates research and development collaborations with several global ingredient companies. In 2004 it files key patents on production of specific nutraceuticals in yeast. In 2005 Fluxome received substantial venture capital in order to pursue the strategy of developing the company into a significant player within industrial biotechnology. In 2006 a professional and internationally experienced management team with excellent industry connections has headed the company, and in 2008 it receives € 13 million in venture capital. In 2009 it moves to its new headquarters in Copenhagen, opens a sales office in USA and has a successful commercial market introduction through the developing of mature results. In 2010 Fluxome introduced a new product in to the market (resveratrol). In 2001 Fluxome receives 3.6 M $ along with Aarhus University Hospital and a number of other universities in Denmark and US for conducting long-term research in specific applications of resveratrol. Today, the company employees 27 people. It also holds more than 30 patents or patent applications worldwide and further applications are in the pipeline.

Fluxome has participated in five EU-funded research projects which are closely related to the company's basic research activities. Two of these projects were coordinated by the Chalmers University of Technology (Sweden). It is important to note that Fluxome's participation to the projects may have been facilitated by the fact that its founder is also professor in systems biology at Chalmers.

However, the company has a very strong research and innovation orientation and is very likely that has exploited the knowledge produced during these research partnerships to develop and launch its commercial products.

Vironova AB

Vironova is a Swedish biotech company which was established in 2005 based on research performed by its founder at the Karolinska Institute. Vironova AB is dedicated to the development of novel antiviral therapeutics and virus diagnostics products to combat and prevent the spread of viral diseases. Based on proprietary technology to analyze viruses in digital images acquired by transmission electron microscopy. Vironova also provides services for the pharmaceutical industry that is able to cut time and costs in viral related R&D and production of biologicals.

Offered as software products, the platform technology provides automated identification of groups of viruses for which reliable diagnostic tools are lacking, e.g. viruses linked to bioterror and pandemics. Vironova was found to participate in two EU-funded research projects.

It is important to point out that the company was the scientific coordinator of both these projects which are developing a novel antiviral strategy for combating influenza.

Currently, Vironova has initiated a drug development project against influenza; therefore, its participation to the specific research projects is closely related to one of its in-house lines of research. .

Evidence SRL

Evidence was established at the end of 2002 as a spin-off of the ReTiS Lab of the Scuola Superiore Sant'Anna (Pisa, Italy) by a group of researchers with expertise in real-time scheduling analysis, control systems, and multiprocessor scheduling techniques.

In particular, it provides innovative software solutions for the design the development of real-time embedded systems, with a special focus on multi-core hardware platforms. These systems can be used in different industries such as aerospace, automotive, railway and transportation and energy. The company has participated in 7 EU-funded research projects (2 of them are NoEs) where it has contributed to the development of real-time embedded operating systems collaborating either with universities and large-firms or with innovative SMEs.

The Scuola Superiore of Sant' Anna has participated in four out of the seven research projects and therefore can have facilitated the company's involvement in them. However, Evidence seems to be an attractive partner on its own right because of its specialization in multi-core hardware platforms.

4.2 Social network analysis results

Table 4 presents the structural characteristics of the FP6 and the cumulative FP6 and FP7 networks that are formed by nodes participating in research projects with at least one newly-established firm in the project consortium.

Table 4: Structural network features

	FP6	FP6& FP7*
Nodes	3,101	4,117
Edges	53,982	70,616
No of Comp	13	9
Size of GC	3012	4055
% of GC	97.1	98.5
Density (x100)	1.12	0.83
Clustering coefficient	0.922	0.902
Characteristic path length	2.908	2.915
Diameter	6	6

*data for FP7 are available up to December 2009.

There are various indicators that measure the social distance among organizations participating in a network. One such property is the size of the giant component. A component is a maximal subset of nodes (organizations) of any graph and any edges (links) between them that forms a connected sub-graph, i.e. all its points can 'reach' one another through one or more paths, but have no connections outside the sub-graph. Another measure is the geodesic distance, which is defined as the length of the shortest path between two organizations in the network. The average geodesic distance in a connected graph is the characteristic path length. Furthermore, the 'longest shortest path' or the largest geodesic distance between any pair of nodes is the graph diameter.

Both networks examined (FP6 and cumulative FP6 and FP7) are found to be tightly interconnected. The examination of the number of nodes in the largest component of the graphs representing the two networks designate that they are highly connected. The giant or largest components found cover a very extensive area of the relevant graphs and contain 3,008 organizations in FP6 (97.1% of all organizations), and 4,055 organizations in FP6&FP7 (98.5%). In addition, all the remaining components are very small. The characteristic path length and the network diameter indicate that the average shortest path between any two nodes is just three steps, while the average longest path is six steps.

The abovementioned findings point out that the vast majority of organizations participating in these EU-funded projects are, directly or indirectly, interconnected via collaboration. The distance between any two nodes is relatively small indicating the capacity to reach easily other network partners and favouring knowledge flow and information diffusion among nodes. Furthermore, network size is relatively large taking into consideration the large number of participating nodes and links developed between them (3,101 different organizations and 53,982 links interconnecting them in FP6) and the relatively small number of the corresponding research partnerships (approximately 280).

The above mentioned structural characteristics can be used as measures of the amount of resources an actor can access through direct as well as indirect ties. The implication for the firms we are examining is that they are embedded in a network where they can have access to a large amount of resources (technological knowledge and information) held by other actors and therefore this may have an influence on their entrepreneurial outcomes (Hoang and Antoncic, 2003).

Figure 4 provides an indication of the diversity of resources a firm can access. The left-hand side of the figure shows that newly-established firms participating in EU-funded networks have the potential to develop relationships and exchange technological knowledge with a variety of organizations including firms (42% of their total ties account for linkages with other firms), universities (30%), and research institutes (22%). However, on average, an educational institution develops 2.9 (3) links with young firms while an industrial actor forms 1.7 ties.

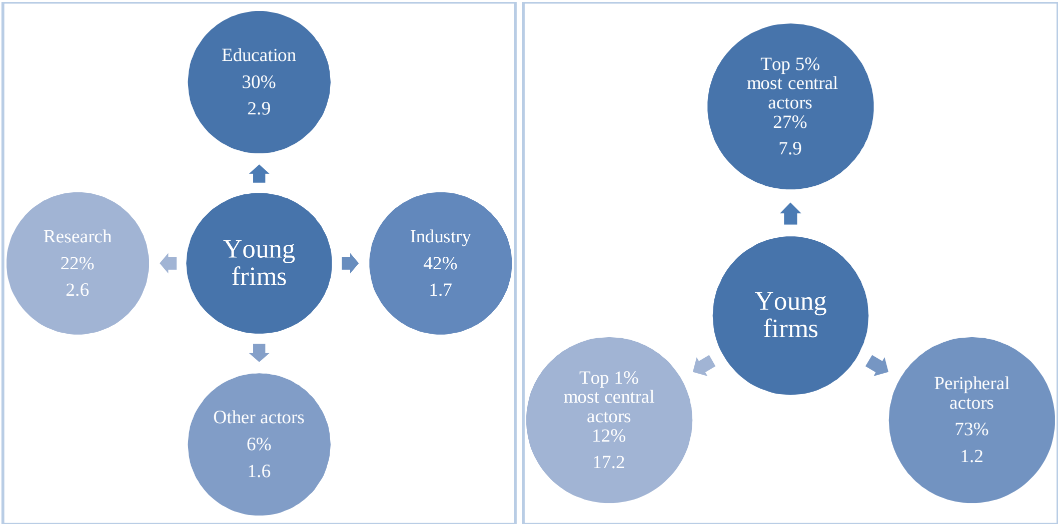

Figure 4: The diversity of young firms' collaborators

Furthermore, new firms develop more crosscutting ties with peripheral actors (73%) than with organizations holding prominent network positions (27%). However, the fact that approximately three out of their ten links is directed towards powerful network actors is an important finding having in mind that the total number of central organizations is quite small (number if top 1% actors are in total 39). Most interestingly, a top 1% central actor[5] is related on average with 17 newly-established firms while a non-top network participant is related with just one firm. This finding is directly related to the fact that the network has a scale-free distribution, i.e. a small number of powerful network participants get connected to a large number of peripheral actors.

The degree distribution, P(k) estimates the probability that a randomly selected node has k links (Barábasi et al. 2002). The degree distribution for the giant components of the cumulative network developed under FP6 and FP7 is depicted in Figure 5. The illustrated histogram indicates that the distribution is highly skewed, i.e. the majority of organizations have a small number of direct links, whereas only a small proportion of actors demonstrate a large number of connections. Such degree distributions follow a power-law $P(k) \sim k^{-\gamma}$ with

[5] Top 1% and top 5% central actors are important network nodes for the cumulative EU-funded research network covering a 25-year period (FP1 to FP7). [5] These two subgroups were chosen arbitrarily. However their removal from the network resulted in a significant drop of the giant component's initial size and in addition both groups accounted for a significant fraction of the total network's ties.

scaling exponent γ taking a value between 2.1 and 4 (Barábasi and Albert, 1999) which suggest "scale-free" distributions of the relevant graphs. This finding indicates that the network's connectivity is controlled by a few organizations that tend to acquire a large number of ties which can be considered as network hubs and tend to be pivotal for the sustainability of network coherence.

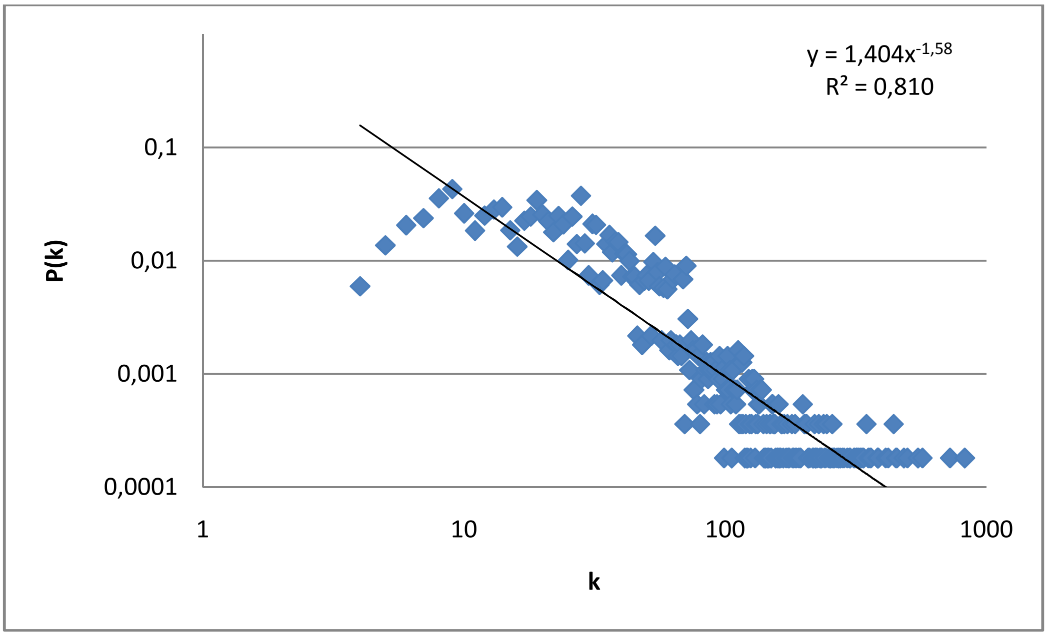

Figure 5: Degree distribution of the cumulative FP6&FP7 network (exponent γ=1.6)

Evidence suggests that this network architecture is driven by a preferential attachment mechanism (Breschi and Cusmano, 2004; Protogerou et al., 2010) which suggests that there is a higher probability that a new node will get connected to a node already exhibiting a large number of connections. Thus, highly connected nodes become even more connected, generating a power-law degree distribution. This growing network model is particularly relevant for new firms because it explicitly considers an evolving network with new nodes coming in over time. When the newcomer in the network is a young knowledge-intensive firm it can be assumed that its attractiveness may be related to its specific technological competences and knowledge to which large incumbents wish to have access to.

Table 5 shows the 15 organizations that have developed the largest number of ties with young firms in the network under study. By constructing the ego networks of the individual companies we gained an insight on the specific actors to whom the young firms are connected to.

Table 5: The organizations most frequently connected with young firms

Rank	Name	Links with KIE firms	Global centrality group	Global centrality rank	Type	Country	FP6	FP7	FP 6&7
1	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	47	Top 1%	1	Research	Germany	403	141	543
2	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	38	Top 1%	2	Research	France	428	144	413
3	NATIONAL TECHNICAL UNIVERSITY OF ATHENS	32	Top 1%	5	Education	Greece	164	46	210
4	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	26	Top 1%	16	Education	Switzerland	151	63	214
5	CONSIGLIO NAZIONALE DELLE RICERCHE	25	Top 1%	6	Research	Italy	236	88	324
6	COMMISSARIAT A L'ENERGIE ATOMIQUE	22	Top 1%	8	Research	France	210	100	310
7	INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM VZW	18	Top 1%	80	Research	Belgium	89	45	134
8	CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	17	Top 1%	9	Research	Spain	186	46	232
9	THE CHANCELLOR, MASTERS & SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	16	Top 1%	24	Education	United Kingdom	148	61	209
10	DANMARKS TEKNISKE UNIVERSITET	15	Top 1%	54	Education	Denmark	93	53	146
11	LUNDS UNIVERSITET	15	Top 1%	15	Education	Sweden	159	38	197
12	VALTION TEKNILLINEN TUTKIMUSKESKUS	15	Top 1%	4	Research	Finland	150	82	232
13	IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE	14	Top 1%	10	Education	United Kingdom	146	57	203
14	INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE	14	Top 1%	56	Research	France	106	44	150
15	UNIVERSIDAD POLITECNICA DE MADRID	14	Top 1%	12	Education	Spain	101	44	145

An interesting finding is that the organizations most frequently connected with newly-established firms are research institutes and universities which hold very important positions not only in the network under study but also in the cumulative network that has been built during the 25-year period between the FPs inception (1984) and FP7 up to 2009. Important network actors are the so-called network hubs. A hub is a node with a large number of connections that is highly influential by joining nodes that would otherwise be disconnected. We capture the notion of network hub by using four indicators: degree centrality, eigenvector centrality, betweenness centrality and closeness centrality. These centrality indices were calculated for all organizations and a synthetic index has been produced by the joint rankings of organizations in terms of these four indicators[6]. Hubs have been defined as the top 1% of the organizations on the basis of this ranking. The examination of links formed between network hubs and young firms indicates that in their majority are with different firms (as mentioned before some time is needed before young firms obtain a more stable presence in these networks). In addition, the largest share of links with KIE firms is directed, as expected, to large countries, as these countries have the largest population of most central actors. However, we observe that some powerful network players from smaller countries (e.g. Greece, Belgium, Sweden, and Finland) have also developed a relatively significant number of links with knowledge-intensive young firms.

5. Concluding remarks

This paper attempts to shed some light on the potential of EU-funded research collaborative networks in fostering knowledge-intensive entrepreneurship. It does so by offering some empirical evidence on the characteristics and participation intensity of young knowledge-intensive firms in EU-funded research joint ventures, the structural properties of the created networks, the network role of young firms, and the interaction patterns developed among them and other research actors.

Empirical results show that small and very small companies account for the largest part of young firms that participate in EU-funded research collaborative networks. Only a few young firms belong to low-tech sectors, however, their extremely limited participation is related to the fact that the thematic research areas prioritized in EU Framework Programmes mainly concern high technology activities. However, it is very likely that low-tech firms are participating in these collaborative research projects as technology users i.e. their main aim is

[6] The centrality indices and the synthetic index produced for the network hubs were based on data pertaining to the STEP-to-RJVs database for the period 1984-2009.

to acquire new technological knowledge that can be embodied and applied into traditional activities (e.g. food and textile industry).

Our findings suggest that young firms established between 2002 and 2007 have a rather limited presence in EU FPs. However, our data also indicate that a critical time period of approximately three years is required, before a newly-established firm is able to join this kind of R&D collaborative networks. These results may be attributed to the fact that young entrepreneurial ventures need some time to develop certain administrative and project management competences as well as the necessary research resources and technical knowledge to become attractive partners to dominant network players. Furthermore, due to the fact that the networks under study have a strategic orientation it is more likely that young firms develop R&D cooperative strategies and thus decide to get connected in such networks later on in their lifetime.

Spin-offs exhibit on average a more frequent participation in EU-funded RJVs compared to the remaining firms. Some qualitative data based on information acquired from spin-offs' websites and the homepages of the research projects they are involved indicate that in general they participate in research projects that are closely related to their in-house R&D and therefore these partnerships may foster their ability of developing and launching specific commercial projects. It seems that in some cases they may enter research partnerships more easily because of their university origin or because of their founders' affiliations to certain institutions (in such cases parent universities and institutions are project coordinators). The spin-off companies' increased participation in RJVs may also be related to their research intensive orientation. Furthermore, their exact technological knowledge and capabilities often make them attractive partners to network incumbents and therefore facilitate their network entry.

The vast majority of organizations participating in these EU-funded projects are, directly or indirectly, interconnected via collaboration. Therefore the young firms under study are embedded in highly interconnected networks where they can have access to a large amount of technological knowledge and information held by other actors. Furthermore, newly established firms participating in EU-funded networks have the potential to develop relationships and thus exchange technological knowledge and expertise with actors exhibiting a high degree of diversity (in terms of type, sector and centrality position). The fact that these newly established firms can have access to an increased and diversified amount of resources makes EU-funded research networks suitable tools for enhancing entrepreneurial outcomes (firm performance, mergers, formation of alliances etc) (Hoang and Antoncic, 2003).

Moreover, although these firms are forming collaborative ties with other peripheral actors, they often get into the network through their connections with organizations holding very central network positions. These organizations, mainly prestigious universities and research institutes, usually organize research within the network and hold important resources and technological capabilities. Thus, their cooperation with leading organizations allows them to have access to fundamental resources i.e. an important element for determining their entrepreneurial outcomes especially in highly competitive environments. Finally, connecting to a prestigious incumbent does not only provide superior quality resources, but also works as a signal to future collaborations.

Nevertheless, young firms could also be considered as attractive partners to large incumbents due to their specific technological competences and knowledge. Therefore, although the presence of focal partners is crucial for the stability of the network, the participation of more new entrants, such as the young small firms we have examined in this paper, should by facilitated by the FP Programmes because these firms can increase network variety by bringing in fresh and innovative ideas. Another policy implication could be related to the need of boosting the participation of low-tech knowledge-intensive firms as their further involvement in FPs as technology users can upgrade the entrepreneurial quality and content of low-tech sectors in Europe.

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Appendix

No	Company name	Year of incorporation	Parent organization	Sector	Participations
1	Beactica AB	2006	Uppsala University	Research and experimental development	5
2	UJF-FILIALE	2004	University Joseph Fourier	Other business services activities	5
3	FLUXOME SCIENCES A/S	2002	Technical University of Denmark (DTU)	Research and experimental development	4
4	EVIDENCE SRL	2002	Scuola Superiore Sant'Anna	Computer and related activities	4
5	MICROTECH SRL	2005	Scuola Superiore Sant'Anna of Pisa	Telecommunications	4
6	ROBOTECH SRL	2004	Scuola Superiore Sant'Anna	ICT manufacturing	3
7	CONGENIA SRL	2004	University of Milan and the European Institute of Oncology	Research and experimental development	3
8	RE:LAB S.R.L	2004	**University of Modena**	Research and experimental development	3
9	HELIOS BIOSCIENCES	2002	CNRS	Research and experimental development	2
10	CLINICAL GENE NETWORKS AB	2003	Karolinska Institutet	Research and experimental development	2
11	COGNIUM SYSTEMS	2005	Institut Pasteur	Computer and related activities	2
12	CLIMPACT	2003	Institut Pierre-Simon-Laplace	Other business services activities	2
13	STREAMEZZO	2004	France Telecom R&D	Computer and related activities	2
14	NEUROKIN	2003	CNRS	Research and experimental development	2
15	DOSISOFT	2002	Institut Gustave Roussy and Institut Curie	Research and experimental development	2
16	TRACIT TECHNOLOGIES	2003	CEA-LETI	ICT manufacturing	2
17	BIOGENOMICA	2004	National Center of Scientific Research "Demokritos"	Research and experimental development	2
18	GEOMATIONS S.A.	2004	Agricultural University of Athens	ICT manufacturing	2
19	SCRIBA NANOTECNOLOGIE S.R.L.	2005	Consiglio Nazionale delle Ricerche	Research and experimental development	2
20	PROTERA S.R.L.	2003	University of Florence	Research and experimental development	2
21	NOMOR RESEARCH GMBH	2004	Institute for Communications Engineering	Research and experimental development	2

No	Company name	Year of incorporation	Parent organization	Sector	Participations
22	Vironova AB	2005	Karolinska Institute	Computer and related activities	2
23	QUMAT TECHNOLOGIES AB	2002	Lund University	Research and experimental development	1
24	MESH-TECHNOLOGIES A/S	2003	University of Southern Denmark.	Computer and related activities	1
25	ENFOR A/S	2006	Danish Technical University	Computer and related activities	1
26	SORTECH AG	2002	Fraunhofer-Institute	Manufacture of machinery and equipment	1
27	RIBOTASK APS	2006	University of Southern Denmark	Chemical industry	1
28	AFFICHEM	2005	INSERM	Research and experimental development	1
29	QUVIQ AB	2006	Chalmers University	Computer and related activities	1
30	LABORATOIRE PHILIPPE DAVIOUD	2004		Research and experimental development	1
31	SMOLTEK AB	2006	Chalmers University of Technology	Other business services activities	1
32	VECTALYS	2005	Institut Pasteur	Research and experimental development	1
33	SENSIBLE SOLUTIONS SWEDEN AB	2004	Mid-Sweden University's Electronics Design Divis	Other business services activities	1
34	AEQUOTECH SRL.	2005	University of Ferrara	Research and experimental development	1
35	M3S S.R.L.	2005	University of Genoa	Computer and related activities	1
36	M.D.P. MATERIALS DESIGN & PROCESSING S.R.L.	2003	University of Perugia	Research and experimental development	1
37	**PROMOSCIENCE SRL.**	2004	SISSA	Computer and related activities	1
38	ORGANIC SPINTRONICS S.R.L.	2003	CNR - Italian National Research Council	Research and experimental development	1
39	MICRO PHOTON	2003	Politecnico di Milano	ICT manufacturing	1
40	KALY-CELL	2004	Université de Franche-Comté	Research and experimental development	1
41	MODELWAY S.R.L.	2004	Polytechnic of Turin	Computer and related activities	1