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Impact on the Greek S&T System**

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### **Abstract:**

This paper focuses on the impact of EU-funded collaborative research networks at a national level using a combined method approach, social network analysis and in-depth case study work. First, it examines the participation intensity and role of the Greek organizations in the research network established through the Information Society Technologies priority of the European Community's 4th, 5th and 6th Framework Programmes. Furthermore, it attempts to assess the impact of the IST research network on the diffusion and deployment of innovation in Greece.

Some interesting results with significant policy implications arise:

a) Greece exhibits high participation intensity in the EU-funded IST network, b) there are Greek organizations that have assumed an influential role in the network through time, in addition, they are also critical to the connectivity of the more peripheral Greek actors to the IST network, c) the value of the network, lies for the most part in indirect or 'behavioural' effects than in immediate project outputs measured in terms of commercialized products or services, d) however, while the knowledge obtained through the network assists organizations to gain better understanding of the market and identify future deployment opportunities this is not always possible due to the lack of sufficient infrastructure and national policies to support market introduction.

### **Keywords:**

### **Jel codes:**

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## 1. Introduction

Networks –different institutions that are linked together for a time limited, specific purpose—are increasingly acknowledged as an important tool for knowledge creation and diffusion. Over the last two decades, technology and innovation policies of the EU have been promoting the creation of R&D networks under the Framework Programmes (FPs) on Research and Technological Development (RTD). Since their inception in 1984, Framework Programmes have been basic pillars of European scientific and technological development, integration and cohesion by supporting all kinds of R&D in high technology sectors; fostering the participation of European organizations in cross-border partnerships and creating a sense of European “togetherness” in science and technology (Caloghirou et al. 2004).

This paper, using social network analysis, examines the presence and role of Greek organizations in the collaborative research networks in the area of Information Society Technologies (IST) established during the Forth, Fifth and Sixth Framework Programmes of the European Community. Furthermore, by undertaking case study evidence, it attempts to explore the impact of Greek participation in these networks on the diffusion and deployment of innovation at a national level.

Even though EU FPs have attracted a lot of research and evaluation studies, relatively little effort has been directed to the study of networks formed in the context of Framework Programmes. However, four earlier studies have made considerable progress in mapping the EU-funded IST research networks and in examining their structural characteristics (J. Stefan Institute 1999; RAND Europe 2005; CESPRI 2006; Protogerou et al. in press). They have found that (1) the EU IST collaboration networks exhibit high connectivity which has been strengthened through time, especially since the introduction of new funding instruments (Integrated Projects and Networks of Excellence) in FP6, (2) they have a ‘scale-free architecture’ underlining the extensive power of relatively few actors (mainly universities and research centres), (3) they display “small world properties” and therefore may be considered as relatively efficient mechanisms

of knowledge creation and diffusion, (4) there is a significant overlap of participants for consecutive FPs and recurring patterns of collaboration among the same organizations, (5) their participants are also likely to be members of other European networks such as COST<sup>1</sup> and EUREKA, and (6) they manage to attract key global industry actors.

While these studies focus on the effectiveness of research IST networks at a European level, an open question remains about how effective they can be at a national level. Our work partially addresses this issue as it concentrates on the impact of the EU-funded IST network at a national level by examining the case of Greece. More specifically, the main aim of this paper is to investigate the participation and networking activity of Greek organizations and try to understand the effectiveness of the research network on the diffusion of technological knowledge and the deployment of innovation at a national level. In doing so, it attempts to complement and integrate social network analysis with in-depth examination of organizations participating in the research network. Therefore, by using two different levels of analysis, the general (network ) level and also the level of individual participating entities, this work may offer a more complete picture of the effectiveness of the EU-funded IST networks. Our findings indicate that:

- Greece does not only participate intensively in the EU-funded IST network but its presence is also important in terms of central actors.
- The role of these central actors is also critical in keeping the more isolated or peripheral Greek organizations connected to the IST network.
- The value of the network mainly lies in its 'indirect outputs' such as new knowledge creation and diffusion, development of skills, building of new relationships and trust and keeping up with the major technological developments, rather than the 'immediate output' in the form of commercialized products.

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<sup>1</sup> COST (Cooperation in Science and Technology) aims at the coordination of nationally funded pre-competitive research on a European level. EUREKA is a pan-European network for market-oriented, industrial R&D. Both of these initiatives target at complementing Framework Programmes.

- IST networks contribute positively to the identification of promising opportunities in the Greek market. However, the diffusion of the innovative results and knowledge acquired through the participation of Greek organizations in these networks could be further improved by national policies supporting innovation deployment.

The remainder of the paper is organized as follows. Section 2 summarizes the key features, objectives and impact of the EU Framework Programmes, the background and strategic goals of the IST programmes through time and presents some facts on the performance of Greece in the FPs. Section 3 provides a description of the methodology and data. Section 4 presents the main findings resulting from social network analysis and case study work and section 5 includes conclusions and policy implications.

## **2. Framework Programmes**

The Framework Programmes have been part of the European research and innovation policy since their introduction in 1984. Originally conceived as research support mechanisms enhancing scientific excellence and industrial competitiveness they have evolved into a more sophisticated set of instruments supporting research efforts towards the accomplishment of broader socio-economic objectives. In 2000, this expansion of objectives has led to the creation of a platform for the development of the European Research Area. Up to now six Framework Programmes have been concluded and the seventh (2007-2013) has been recently launched, encouraging scientific and technological collaboration among organizations originating from all member countries of the European Union.

The first three FPs represented programmes that were supply or technology oriented. Their main aim was to promote the competitiveness of European industries by raising their technological level through the establishment of R&D collaborations among firms and public research institutes. Joint research activities were supposed to assist firms to advance their technological know-how and solve generic research problems that had wide applications across

many economic sectors. (Peterson and Sharp 1998). However, in the early nineties a new theoretical conceptualization of the innovation process gained importance and began to influence the EU policy advisory circles. Under this new perception, innovation is understood as a complex, interactive knowledge-sharing process that involves a wide set of heterogeneous actors. This new systemic model provides novel directions for the Science Technology and Innovation policy and in particular collaborative R&D. Therefore, the latest Framework Programmes seem to have shifted their emphasis from supply-side factors to diffusion-oriented projects, greater learning skills and increased knowledge diffusion among Europeans.

Subsidized Research Joint Ventures (RJVs) that have been established through project-based ventures in the European Research Area are a special case of R&D partnerships. These research partnerships are contractual agreements among independent entities such as firms, universities, research institutes and other organizations generally aimed at undertaking joint work towards specific goals in a pre-defined area. The research effort undertaken in the context of an RJV is mainly of pre-competitive nature, which essentially means that the fact that two or more organizations are sharing and developing new technological knowledge does not necessarily lead to joint product development.

A set of R&D partnerships can be understood as a network of actors that are directly or indirectly interconnected. A direct connection stems from participation in a specific RJV. Indirect connections are developed when information or knowledge exchanged in one partnership is also implicitly entered in other partnerships as well. In sum, the networks formed in the context of FPs are the result of self-organized partnering by participating entities under the thematic priorities and funding rules imposed by EU. They can be characterized as exploration networks since they are mainly focused on pre-competitive research and they can provide valuable information on the organizational fabric and social infrastructure of European science and technology.

The impact of EU Framework Programmes has been addressed in numerous studies since the early 1980's. In general, however there is no direct evidence confirming their contribution to furthering the European industrial

competitiveness, i.e. their major objective. The reasons include conceptual and methodological problems in evaluation studies stemming from the fact that they are part of the political processes for formulating these programmes, as well as problems related to the attribution of effects<sup>2</sup> and pre-competitiveness (Luukkonen 1998). Furthermore, while FPs have acquired a growing importance in terms of budget during the last twenty years, they still represent approximately 5-10% of the research activities funded by national sources in the respective Member States and cannot be expected as such to achieve great impact. However, the aforementioned funding shares do not apply equally to all EU countries (for example Greece receives much greater EU funding compared to other bigger and R&D intensive countries) and are further augmented in specific technological areas and sub-sectors such as thermonuclear fusion, nanotechnologies or global change (Mitsos 2007).

While much criticism has been made of EU research programmes, for instance they have been recently criticised for putting “too much emphasis on various types of ‘networking’, ‘interactions with the local environment’, or ‘attention to user needs’ suggesting that they should be more focused on “policy measures aimed at strengthening basic research and, at the opposite end, at strengthening European corporate actors”(Dosi et al. 2006, 1451), there is enough evidence to point to positive impacts (Barker and Cameron 2004). More specifically, the FPs seem to have a role in the promotion of common technical standards and the share of costs and risks inherent in new technology development (Luukkonen 1998; Caloghirou et al. 2004). They also have significant intangible or indirect effects regarding the enhancement of knowledge capabilities and skill sets, technological learning, access to complementary expertise, or the formation of new networks (of both research and more market-oriented varieties), which appear to be more prominent than direct commercializable outputs (Guy et al. 2005; Polt et al. 2008).

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<sup>2</sup> This issue is especially relevant in the FPs, as they can indeed be considered as forming part of a portfolio of R&D projects rather than discrete, standalone activities.

## **2.1 The IST-RTD Programmes**

Innovation in information and communication technologies is critical to Europe's competitiveness and economic welfare. However, Europe is still lagging behind in ICT research investments. The relevant research effort in USA is three times as much as in Europe and in Japan it is two times as much. The EU IST –RTD programmes offer an opportunity to aggregate the fragmented research efforts of the member states, influence regulatory regimes and standards setting and assert leadership as illustrated by success stories such as the GSM standard. Even though the EU-funded ICT research represents 5% of total RTD investment by member states in these technologies, it represents in many IST fields up to 25% of the high-risk and long-term research endeavor. It constitutes, therefore, an essential component of the total EU research activity.

Research in information and communication technologies within Framework Programmes was initiated with ESPRIT in FP1. In FP2, RACE (on communications technologies) and three individual Telematics research programmes were added. The latter three merged under FP3, whilst RACE and ESPRIT continued to exist as separate programmes. In FP4, ESPRIT and Telematics were carried on, while a new programme on Advanced Communications Technologies and Services (ACTS) was included in the framework. The ACTS, Telepathic and ESPRIT IV Programmes in the FP4 had a common strong user orientation as well as a focus on the development of applications with a view of implementation and commercial exploitation in a short period after the termination of the funded projects.

These three research activities were brought together and extended under FP5 (1999-2002) into the "Information Society Technologies" (IST) programme, to provide a single and integrated programme that reflected the convergence of information processing, communications and media. The IST programme in FP5 had a stronger focus on long and medium-term research and a clearer engagement for pre-competitive technology development. Thus, a major difference between FP4 and FP5 were the lower expectation for commercial deployment soon after the end of projects. Furthermore a significant difference



between FP5 and previous programmes was the enhancement of a closer articulation between research and policy needed for a coherent and inclusive information society. However other fundamental objectives, such as to promote the development of European solutions and technologies, to enhance European competitiveness and economic development, to encourage the cooperation of companies, universities and research laboratories from different European countries in pursuit of common technological goals remained more or less the same between the two FPs.

In the 6<sup>th</sup> Framework Programme, Information Society Technologies was one of the seven priority themes within the specific programme for “Integrating and strengthening research and technology developments in the European Research Area”. The political climate which influenced the objectives of the IST priority in FP6 was quite different from FP5, since at that time the foundations for the European Research Area had been laid and the Lisbon and Barcelona Councils had set out a basis for making Europe the world's most competitive and dynamic economy.

The IST Thematic Priority objectives exhibited a clear shift toward longer-term technology development and a major change in the instruments for its implementation. More specifically, two new funding mechanisms, Integrated Projects (IP) and Networks of Excellence (NoE) were introduced in FP6 alongside with the traditional instruments. Both of them were aimed at structuring and integrating European research better than the earlier mechanisms. This was mainly to result from a radical increase in the scale and size of the research projects, and in terms of consortium size.

## **2.2 Some facts on Greek performance in EU research programmes**

The participation of Greek organizations in the competitive EU research programmes dates back to the beginning of the 80's. The success percentage rate of Greek organizations measured as the number of participations in awarded projects is relatively high right from the first FP. The share of Greek to total participation ranges from 2.4% in FP1 to 3.3%<sup>3</sup> in FP6 which practically

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<sup>3</sup> The estimation of Greek participation in FPs is based on data drawn from the STEP to RJVs database.

means that Greece holds the ninth position, on average, in terms of participation intensity among a wide variety of participating countries.

The share of the Greek research community in EU RTD projects and funding is at a much higher level than its size, as measured by the GERD (Gross Domestic Expenditures on R&D) or the number of researchers. While the share of Greek GERD does not exceed 1% of the EU15 GERD, Greece is estimated to attract around the 3% of the Framework Programme budget (2.26% of the Framework Programme funding) with annual inflows from 90 to 100 mil € towards Greek organizations. These funds almost represent the 10% of the research funding in Greece, one of the highest percentages in Europe confirming the 'aggressiveness' of the Greek RTDI system (European Communities, 2008). Indeed, the high percentage of Greek researchers having studied abroad, their strong networking capacity especially with the Greek diaspora and 'old' colleagues that they had during their studies abroad combined to the limited national R&D funds led them to seek funding from international sources. The EU Framework RTD programmes provided the means to access additional funds for research. Furthermore, their highly competitive selection procedures opened the gates of international cooperation to the most competent Greek research teams (Inno-Policy Trend Chart 2007).

Data on Greek participation during 1981-1987 indicate that Greek organizations started in the EU research programmes by targeting research areas such as information and communication technologies, industrial materials and technologies, renewable energy sources, biotechnology and the environment. However, there was a preference noted towards ICT which continued across all the following EU FPs. The latest available data indicate that in FP6 Information Society Technologies is the

field with the highest number of Greek participations and the highest funding, reaching up to 3.87% of the total EU funds for that field (GSRT 2007).

Figure 1 illustrates the participation intensity of Greek organizations in the first six FPs broken down by research area. Five broad thematic areas of research were designated in order to register each research joint venture in a specific activity area.

This figure indicates that Greek organizations exhibit a clear preference for participation in research partnerships related to Information and Communication Technologies (41% of overall Greek participation). More interestingly, Greek participation in EU-funded ICT research exceeds by far the corresponding European participation.

*Figure 1 around here.*

This preference to IST research activity may be attributed to increased competencies and skills of Greek research teams in this specific field, as well as to the fact that firms belonging to the ICT sector (especially ICT services) appear to more active in participating in EU FPs compared to firms activated in other sectors of the Greek economy.

Despite the fact that the participation of Greece is more or less stable in the IST initiatives funded under the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> FPs, its access to funding has been significantly improved through the years. More specifically, the share of funding received by research consortia with at least one Greek partner has increased from 22.9% to 39% of the total IST funding (source: STEP to RJs Databank).

### **3. Methodology and data**

#### **3.1 Description of the dataset**

In this study, the assessment of the Greek presence in EU- funded RJs in the Information and Communication Technologies area is based on a dataset drawn from the most recent version of the STEP to RJs Databank which is developed and maintained by LIEE/NTUA. This is an extensive database presently including detailed information on all collaborative cross-national research projects funded by the European Commission from FP1 to FP6. The primary information source for the database construction is CORDIS, the official information service of the European Commission which contains a great deal of information on research projects and their participants. However, the processing of the raw data into a usable form is a complicated and lengthy undertaking (for a detailed view see Roediger-Schluga and Barber 2008). A major difficulty encountered during the database construction was the inconsistency of raw data retrieved from CORDIS. Apart from correcting incoherent spelling in

organizations names, particular attention was given to cleaning in detail the poor quality data on organization types. Furthermore, wherever possible, missing information regarding the geographical/regional location of organizations was added in the dataset.

The paper's dataset comprises RJVs belonging to the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> Framework Programmes (1994-2006) in the area of Information and Communication Technologies. More specifically the research collaborations under study belong to the ESPRIT 4, TELEMATICS 2C and ACTS Programmes of the 4<sup>th</sup> FP and the IST thematic priority of the 5<sup>th</sup> and 6<sup>th</sup> FPs. The available information on FP6 includes all RJVs which were initiated up to December 2006. In total, the dataset contains detailed information on 4419 research projects and 13 847 different participating entities.

### **3.2 The social network analysis tool**

In general, from a collaborative perspective, networks can be defined as a set of actors linked by a set of social and business relationships that create strategic inter-organizational opportunities. More specifically, in the case of the examined IST-RJV networks, organizations such as firms, universities and research institutes get connected by policy-driven cooperative relationships that allow them to access new resources, to augment their core capabilities and complementary assets and to engage in innovative activities to develop new ICT technologies.

The IST networks we are studying, are formed by organizations that are joined together by their membership in the same research projects, i.e. they are affiliation networks. Affiliation networks are often represented simply as unipartite (one-mode) graphs of actors joined by undirected edges. Although the representation of an affiliation network (an essentially two-mode network) as a unipartite graph may lead to the loss of certain information, the methods for studying two-mode affiliation networks are less developed than those for studying one-mode networks (Wasserman and Faust 1994).

Our analysis will be based on the unipartite graphs of organizations involved into research partnerships. We assume that there is an equal role played by all

partners participating in the same project, i.e. we do not assign any particular role to organizations acting as prime contractors in the R&D consortia.

We use social network analysis tools to study the role of Greek organizations in the IST network formed between FP4 and FP6 (1994-2006) as well as the structure of the IST sub-network constructed by the Greek organizations that have participated in EU-funded IST partnerships during the same period.

### **3.3 In-depth interviews**

In order to investigate the relationship between FP-driven IST network and innovation, a number of case studies were conducted in different types of organizations located in the Attica region. The selection of Attica was based on our analysis of the Greek participation in the EU-funded IST networks which indicated that the role of this region in terms of shaping the overall country's participation intensity is critical. More specifically, the organizations established in the Attica region account for 71.7% of the Greek entities participating in the IST network and for 71.3% of their overall participation during the period 1994-2006. Therefore, the Greek membership is highly dependent on organizations activated in the Attica region. Furthermore, a recent study has also indicated that Attica is among the top EU-15 regions in terms of participation intensity in FP6 IST-RTD projects (Malerba et al., 2006).

Seven in-depth interviews were carried out so as to assess the effectiveness of European IST-RTD projects in facilitating the development and deployment of IST technologies in this specific Greek region. Each interview followed a three part protocol with specific themes for discussion which also allowed for free comments. The first part concerned the patterns of participation of the interviewed organizations in IST-RTD projects. The second one was related to the role of these networks in developing innovative ICT products and services as well as their impact at a regional level. The third part concerned their usefulness as mechanisms for the development and deployment of innovative products or services.

## 4. Empirical results

### 4. 1 Participation intensity and role of Greek organizations in the EU-funded IST research networks

The basic characteristics of the overall (87 countries in total) and the Greek participation in IST RJVs during the period 1994-2006 are displayed in Table 1. This table shows that while the share of Greek actors in the dataset is small (4%), they participate in 26% of the overall projects indicating their significant presence in the FPs for the period examined. Moreover, it shows that Greek organizations tend to participate in larger projects in terms of average duration, number of partners and budget.

*Table 1 around here*

Table 2 summarizes the overall participation in EU-funded IST RJVs by organizations based in different countries indicating also RJV coordinators. While entities originating from a wide variety of countries have participated in the examined network, it is obviously entities from EU member states that have dominated participation. Germany ranked first both in terms of participation intensity and total number of participating entities. At the second place, organizations from the UK are somewhat more than those of France, whereas French organizations slightly outnumber those of UK in terms of participation. The increased participation intensity of these three countries can be explained taking into consideration their size and population as well as their R&D intensity and innovation performance (for example see European Innovation Scoreboard 2008). Most interestingly, Greece, despite its small size and lagging innovative performance relative to the EU 15/27 average, exhibits a significant number of participations and participating entities ranking in the 6<sup>th</sup> and 7<sup>th</sup> position respectively among 87 countries in total.

*Table 2 around here*

The overall Greek presence in the IST research networks seems to be more or less stable for the period examined both in terms of participating entities and intensity of participation. For the needs of the database, participating

organizations were designated into the following types (i) “firm” (combining industry and consultancy); (ii) “university” (all educational institutions); (iii) “research centre” (various research foundations) and (iv) “other” (combining government, hospitals, libraries, museums, city councils etc.). The entities that are included in the “other” category are mainly users –rather than developers– of the information and communication technologies.

*Figure 2 around here*

As shown in Figure 2, the majority of the Greek participating entities in the three FPs examined are firms. The share of firms seems to be stable across the different periods while the share of universities is actually doubled. The right part of Figure 2, which depicts participation intensity by organization type, designates that the share of participation for educational institutions and research centres has increased across FPs (from 15.1% in FP4 to 34.4% in FP6) while the opposite holds for industry, since the relevant percentages reveal a decreasing intensity across FPs (from 63.9% in FP4 to 39% in FP6). Therefore, Greek universities and research centres assume a more active role in IST networks through time compared their firm counterparts.

Research work undertaken up to now on the networks formed under EU Framework Programmes, has confirmed that they are highly dependent on a core of central actors which gain in connectedness and significance over time by their repeated participation in different FPs (e.g. Protogerou et al. in press). These actors are usually located in strategic or central positions within the network and therefore are those that are extensively involved in relations with other actors (Burt 1980; Wasserman and Faust, 1994). They may also have greater access and control over resources and in consequence they are likely to be highly associated with innovative activity (Powel et al. 1996; Rogers, 1995; Bell, 2005).

We next focus on the participation of the most central players per country in the IST RJVs network. The identification of these prominent actors was based on social network analysis and more specifically on the calculation of four centrality measures for each entity, namely degree centrality, eigenvector centrality,

betweenness centrality and closeness centrality. Each of these four measures quantifies a different aspect of centrality:

Although degree centrality is one of the simplest centrality measures it is also a highly effective measure of prominence or power. In many social settings actors exhibiting multiple connections with other actors tend to be more powerful.

A more sophisticated version of degree centrality is eigenvector centrality. This index does not only address the quantity but also the quality of direct connections an actor has. In this way, connections to actors who are themselves well connected are more influential than connections to poorly connected actors. Therefore having a large number of connections does not necessarily give advantage to a specific actor, it also matters to whom it is connected. The eigenvector centrality of node  $i$  is the sum of its connections to other nodes, weighted by their degree centrality.

Betweenness centrality refers to the number of times an actor is located on the geodesic path between two other actors (Wasserman and Faust, 1994). In a network where information is diffused, an organization that exhibits a high degree of betweenness centrality can act as a gatekeeper and therefore has the potential to control the flows of information between other organizations (Freeman, 1979; Knoke and Kuklinski, 1982). Closeness centrality focuses on how close an actor is to all other actors in a network, indicating that actors occupying central network positions can quickly communicate information to others (Wasserman and Faust, 1994). Closeness centrality is lower for nodes that are more central in the sense of having a shorter network distance on average to other nodes.

The above mentioned 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. Since we are interested in the core actors of the network we focus the analysis on the sub-groups including the top 1% and top 5%<sup>4</sup> of the organizations on the basis of their joint ranking. Table 3 presents

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<sup>4</sup> These two sub-groups were chosen arbitrarily. However, their removal from the IST networks resulted in a significant drop of their giant component initial size and in addition both groups accounted for a



the participation intensity of the most central organizations in the EU 15 countries.

*Table 3 around here*

The table indicates that although a small number of entities from each country assume a central role in the network (numbers in parentheses next to entities indicate the share of central entities as a percentage of the total number of entities originating from each country) their participation intensity is disproportionately higher (numbers in parentheses indicate the share of the most central actors' participations in the total number of participations of each country). For Greece, this general observation seems to hold even more prominently as a small number of central actors, which represent just 7.1% of the total number Greek participating entities, accounts for 42% of the total Greek memberships. Therefore, this finding points out that the presence of Greece in the IST RJV network is quite prominent and becomes even more important when the most central actors are taken into account.

In Figure 3 it is illustrated the top1% sub-network of central actors.

*Figure 3 around here*

The size of each node is directly related to its centrality (which is based on the aforementioned centrality measures), i.e. more central organizations are represented with larger nodes. The location of each organization in the network's visualization is generally related to its distance from each other node. Therefore, organizations in the periphery of this sub-network are those exhibiting larger paths (characteristic path lengths) in their connections. In figure 3 the Greek actors are represented with yellow nodes. In their majority they are Universities and research centers (6 and 3 of them respectively), while only two of them are firms. This finding seems to be in line with other studies which indicate that universities and research centres assume a more central position in the EU-funded IST networks over time (e.g. Protogerou et al. in press). Although the role of Greek actors seems to be differentiated within this sub-

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significant fraction of the total networks' ties. We used different cut-off points than the two adopted to check for robustness and the main results remained unchanged.

network, as some of them are located in its periphery while some others are positioned towards its core, their overall influence in the IST network's connectivity seems to be quite important.

It is important to note at this point that Greece also ranks second among the EU 15 countries in terms of the lowest clustering coefficient in the top 1% and top 5% central actors sub-networks (0.112 and 0.272 respectively). Central actors with low clustering coefficients<sup>5</sup> can also be characterized as 'hubs' since they are actually linking neighbouring network parts that would be otherwise disconnected.

However, the role of the Greek central organizations appears to be even more important for the connectivity of the Greek IST sub-network, i.e, the network which is formed by Greek organizations participating in the IST research joined ventures funded within the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> FPs. More specifically, they display the 5<sup>th</sup> and 4<sup>th</sup> largest share of cross-border connections<sup>6</sup> within the top1% and top 5% central actors' sub-networks respectively, indicating that they have established a significant amount of links with external important actors and therefore their role is critical for the connection of the Greek sub-network to the rest of the IST network.

The critical role of the Greek central actors for the connectivity of the entire Greek sub-network is further explored if we assess the network characteristics before and after the removal of these actors. We have tested the robustness of the Greek sub-network to the removal of the most central organizations in order to better understand their critical role in maintaining the network's connectivity. Our findings suggest that the network properties are significantly affected by the removal of central nodes (Figure 4). More specifically the giant component<sup>7</sup> drops considerably, the characteristic path length<sup>8</sup> is almost doubled and the

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<sup>5</sup> The clustering coefficient estimates the probability that two neighbouring nodes of a give node are neighbours themselves and is a measure of local network structure. The clustering coefficient C for the Greek central actors as a whole is the average coefficient over the number of Greek central nodes.

<sup>6</sup> The cross-border connections between central organizations are calculated as the ratio between existing links to potential ones.

<sup>7</sup> 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.

<sup>8</sup> The average geodesic distance (which is defined as the length of the shortest path between two organizations in the network) in a connected graph is its *characteristic path length*.

network density (the proportion of potential links that have been actually observed) and mean degree are also significantly decreased. This vulnerability to the elimination of the prominently connected nodes indicates that they are crucial to the IST Greek sub-network's coherence. Their removal changes significantly the network's topology and therefore decreases significantly the ability of less well-connected nodes to maintain their links to the European IST network.

*Figure 4 around here*

#### **4.2 The impact of FP-driven IST research networks on innovation in Greece: evidence from in-depth interviews**

Lengthy face to face interviews were carried out in seven different organizations which have participated in EU-funded IST projects. The sample is indicative of the ICT research actors in Greece and is comprised of three firms, two universities, a public research institute and a non-profit research foundation. In the case of universities, we came in contact with the professors in head who acted as scientific coordinators of research projects in the specific laboratories. In both the research institute and the non-profit research foundation we contacted the institute directors and the people in head of the respective research departments. In firms we had interviews either with the head of the R&D department or the head of the European Project's Management department.

At the National Technical University of Athens we visited the Knowledge and Database Systems Laboratory (KDBS) which belongs to the Electrical and Computer Engineering School. Its activities are focused on theoretical and applied research in the area of database and information systems. At the Athens University of Economics and Business we contacted the IRIS (Interdisciplinary Research on the Information Society) research group. It focuses on the study of inter-organizational systems, that is, systems that link together different groups of people or organizations, using innovative information and communication technologies.

The Institute for Language and Speech Processing is a public research institute which carries out applied research in speech processing, text processing and language learning technologies. Its mission is mainly to support basic research, promoting on the other hand the development of new products in the form of laboratory prototypes. The Lambrakis Foundation is a non-profit R&D institution of public interest. It has initiated many research pilot programmes on the application of new technologies and their impact on learning and the organisation of school education.

Exodus SA, a member of the Piraeus Bank Group of Companies, is one of the major software solutions companies in Greece.

Intracom SA is a leading regional developer and manufacturer of telecommunications systems and a global supplier of integrated solutions and professional services.

SingularLogic Group is an information technology group of companies with a leadership position in the development of business software and the provision of integrated information technology solutions, both for the private and the public sector. Table 4 summarizes the profile of the interviewed organizations.

*Table 4 around here*

In terms of organization of the R&D activity, the university laboratories and the research institutions have their own research teams that are responsible for the management and realization of IST projects. Intracom SA has a big R&D department which is oriented towards cooperation with universities and research centers in Greece and abroad, and is also in charge of research and development in the context of IST projects. The other two firms of our sample, i.e. Exodus, SingularLogic, have small European Projects' Management Departments, which are primarily involved in project management, while R&D activity is mainly supported on an ad hoc project basis by the technical departments.

#### ***4.2.1 Participation of the interviewed organizations in IST research joint ventures***

Table 5 indicates that all interviewed organizations participated repeatedly in the FPs examined. Furthermore, all organizations pointed out that in many cases there was a certain degree of continuity between projects which belong to different FPs. For example, the Institute of Language and Speech Processing pointed out that its previous participation in two successful FP5 projects (IMUTUS and CIMVUS) was succeeded by its membership in two closely related FP6 projects (VEMUS, REVEAL THIS respectively). More specifically, VEMUS (Virtual European Music School), which aimed at developing and thoroughly validating an open, highly interactive and networked multilingual music tuition framework for popular instruments, has built on the results, the existing platform and tools developed and preliminarily validated in the context of the successful IMUTUS FP5 project. Moreover, the project consortium has slightly changed between the two projects, as the partners' technological complementarities and their relation of trust constituted two important factors for their effective cooperation through the years.

The interviewed organizations have cooperated with all types of partners in the IST-RTD research network. More specifically:

The Knowledge and Database Systems Laboratory has cooperated with all kinds of organizations. However, universities and international firms, such as small software houses, have been its most frequent network partners.

The IRIS Group has primarily collaborated with firms, several large ones and many SMEs usually engaged in software development. To a smaller extent its partners have been universities and public research institutes.

The Institute of Language and Speech Processing has been mainly cooperating with universities and research centers all over Europe. They have also collaborated with firms (mostly with SMEs) which are active mainly in language technology and to a lesser extent in publications.

The Lambrakis Foundation has mainly collaborated with organizations such as universities and public research centers which are activated in educational

issues, educational technology etc. It has also collaborated with firms a small number of which are SMEs.

The three interviewed firms tend to collaborate mostly with other firms (in their majority SMEs) and to a smaller extent with universities and research centres.

Most of the interviewees also reported that the major part of their partners in RTD-IST projects is located abroad. Moreover, they also stated that physical location does not have a critical impact on the type of innovation or development pursued.

Table 6 illustrates the principle aim of the projects in which each organization participated. It appears that universities participate in projects that are either more research or development oriented depending on their own priorities. Lambrakis Foundation participates mainly in development projects. This is in compliance with the nature and scope of this organization which is aiming at the diffusion of innovative educational practices and methodologies and the shaping of the policy making agenda. The same seems to apply for the interviewed firms, which stated that they are involved in projects that mainly promote the development of innovative products or services. All of them also mentioned that they are doing “common sense R&D”, i.e. they explained that they are trying to get involved in research activities that are up to a certain degree, in line with their commercial interests and on the other hand support the acquirement of specific knowledge and technological capabilities that could be exploited at a later stage to develop innovative products and services.

#### ***4.2.2 The impact of the IST network in the development and deployment of innovative products and services***

All interviewees assessed the role of IST-RTD network in advancing innovative ICT products, and services as very important. They also stressed that the network added value to the development and deployment process of innovative products, in direct or indirect ways.

The direct network impact, which was described as commercial deployment or development of modules that can be readily used for the expansion or the

development of an improved ICT product or service, is generally less extensive or significant compared to the indirect impact. All institutions pointed out that even if the development work in the IST-RTD projects leads to a prototype, it appears that in practice much further work and resources should be allocated in order to transform this prototype to one suitable for commercial deployment.

The indirect effect was described as the skills and knowledge diffused through the network, as well as the relations and trust built between partners. In particular, the interviewed firms emphasized the importance of the technological knowledge diffused during a project to their future involvement in the deployment of innovative ICT products in the Greek market. For example, all organizations emphasized that the knowledge accumulated through the network can be used for the improvement of services provided by the Greek public sector. All organizations, also stressed the importance of knowledge diffusion to the improvement of their human capital's capabilities and skills. Finally, the relations structured in the network context have been proved beneficial not only to the formation of future IST-RTD collaborations, but also to co-operations concerning the development and commercial deployment of other novel products or services in the Greek context.

The Exodus SA interviewees explain the value of technological knowledge diffusion:

*“The company, especially when it was still small in size, had very much relied on IST projects to come in contact with certain technological areas and concepts (for example, web-based or business intelligence applications). Therefore its technological profile was actually built on its participation in this network of research co-operations. Furthermore, through this process, our company acquired a more spherical and long-term technological approach regarding its engagement with future innovative projects in the Greek business environment, whereas otherwise it would have adopted just a short-term commercial deployment perspective. ....The technological knowledge conveyed in the context of a project is based on the osmosis process developed*

*among partners and is very much depended on the certain project objectives, which on their own can be very important” ....*

#### **4.2.3 Network Contribution to the identification of deployment opportunities**

Almost all interviewed organizations estimated that IST-RTD networks contribute positively to the identification of opportunities in the Greek environment and beyond that.

Exodus SA pointed out that their participation in EU-funded research projects has assisted them to track new opportunities in the local market. For example, they were the first company in Greece to create an electronic version of a well-known newspaper, or to develop solutions related to business intelligence, i-mode and e-learning applications for specific customers. Another example of ICT diffusion has to do with the enhancement of the results of a previous IST project in order to build an e-learning application for the Syzefxis project, which aims at the development and modernization of the Public Sector telecommunication infrastructure.

The Knowledge and Databases Management Lab of NTUA underlined that they have always been able to identify opportunities for ICT diffusion as a result of their participation in specific research projects. For example, they mentioned that they created an interactive database that promoted on-line communication between the Ministry of Transport and Communications and the Centers for Technical Vehicle Control all over Greece.

Lambrakis Foundation highlighted that its participation in EU-funded research projects has been proved catalytic to the identification of opportunities for ICT diffusion in the area of primary and secondary education. In particular, three years ago the Foundation launched a novel “portal” (e-paideia.net), addressing the needs of the school communities and making a distinctive use of culture and recent technological developments in the areas of education.

Intracom SA stressed that although the importance of IST-RTD networks to ICT diffusion is critical, only several isolate parts of the company moved to that



direction by identifying and exploiting specific opportunities. An example of regional impact was the deployment of the first broadband wireless network in the period 1998-2000 in the Attiki region.

SingularLogic reported that their participation in IST-RTD networks does not add any particular value to the identification of opportunities at least in the Greek market as their network of customers is very extended ( and usually people come to them than the opposite). Furthermore, although these networks might be helpful in the identification of opportunities beyond Greek borders it doesn't seem to be an easy accomplishment.

Furthermore, all interviewees stressed that a very significant mechanism for the diffusion of ICT products and services could be government projects aiming at the design and implementation of innovative products or services for the citizen and the business community. Most interestingly, interviewed organizations also reported that they have not coordinated activities related to the development and deployment of innovative products or services, in cooperation with other regional institutions or agencies. Only one organization, the Lambrakis Foundation, stated that it was leading a cultural and developmental initiative of eight non-profit foundations, which are based in Athens, aiming at offering online services primarily related to educational issues, such as online libraries for children and teachers, educational games, innovation networks etc. Finally, most interviewees confirmed the absence of explicit links between national or regional strategies and participation in IST research. More specifically, they stated that, at least to their knowledge, there are no regional strategies, promoting participation in IST research, development and deployment networks. They also stressed that this is a critical issue with significant policy implications as organizations (e.g. firms), no matter how large or influential they may be, cannot have an effect on.

#### ***4.2.4 Main obstacles and difficulties in participation***

The majority of interviewees did not identify severe obstacles or difficulties concerning their participation in IST-RTD networks. However, it was also stated that coordination costs get higher when many new partners join a research

consortium, a fact which may be related to cultural differences, the information flow system within the consortium etc. Therefore, the existence of previous cooperation among the majority of project partners certainly reduces this kind of cost. Some organizations also indicated that Integration Projects (IP instruments) with lots of partners can sometimes bring about high coordination effort and cost. Finally, the role of project coordinator in the selection of the most suitable partners (from the phase of the project proposal) was recognized as decisive by the best part of interviewees.

Finally, several organizations stressed that sometimes there is a mismatch between partners' objectives resulting in cooperation problems within the project, while some other put emphasis on the intellectual property rights problems that arise when the issue of commercial deployment of project results comes up. The director of the Institute of Language and Speech Processing explains:

*“In most cases when an IPR problem comes up between organizations that have developed a technology on an IST project basis, it cannot be resolved. It is therefore a frequent phenomenon that organizations prefer to abandon their efforts for commercial deployment than allow one of their partners to appropriate the rents of commercialization”*

SingularLogic SA pointed out that perhaps the problem of cooperation related to commercial deployment and IPR, could be resolved through the collaboration of SMEs with fresh ideas which are not competing in the same market. For example:

*“A Greek and a Hungarian firm could find a common research field or develop two separate but complementary products, which if they are put together in each market they may create competitive advantage for both firms. This scenario of cooperation may lead to a more flexible deployment agreement”*

## **5. Conclusions and policy implications**

This paper, using social network analysis, examines the collaborative networks formed under the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> Framework Programmes (1994-2006) in the area of Information Society Technologies focusing on the participation of Greece and the presence of Greek central actors in these networks. Furthermore, using case study evidence based on lengthy face to face interviews conducted with Greek actors participating in the IST-RTD network we are attempting to explore the impact of EU research partnerships on innovation diffusion and deployment.

Our findings suggest that Greece participates intensively in the EU-funded IST network, indicating that EU FPs have provided a systematic process for reaching the goal of inclusion of peripheral countries in European research and development. However, the presence of Greece in the IST network is not only prominent in terms of connections, but it is also important in terms of central actors. The role of these actors is critical in maintaining the ties of the smaller and more isolated or peripheral members of the IST network. This is evident in the case of the Greek IST sub-network, where the presence of these central organizations increases its connectivity to other external central actors, thus helping both to disseminate knowledge and to provide access to complementary resources and new technological and market opportunities.

All interviewees emphasized that the role of the IST-RTD network is significant in advancing innovative ICT products or services in either direct or indirect ways. As direct network impact they described the development and commercial deployment of modules that can be readily used for the expansion or the development of an improved ICT product or service. On the other hand, as indirect network effects they specified the knowledge and skills diffused through the network, the establishment of new relationships and trust, as well as keeping up with major technological developments. In sum, it was pointed out by all interviewees that the IST-RTD networks' value, which are primarily promoting pre-competitive research, lies for the most part in the learning effects that occur between partners and the impact that these may have on their capacity to innovate in the future. Therefore, although the immediate project

outputs, measured in terms of patents and commercialized products, processes or services may be limited, the indirect or intangible network effects, “beneath” the innovation outputs are of major importance to the participating entities. This finding is line with a recent study which examined the factors affecting the extent and speed of commercial exploitation of results of cooperative R&D funded by the 5<sup>th</sup> and 6<sup>th</sup> FPs. This study showed that although FPs seem to have a significant impact on innovation output, their direct effect in the sense of supporting quickly commercializable research does not seem to be their defining characteristic (Polt et al. 2008).

The majority of the interviewed organizations estimated that the IST-RTD networks contribute positively to the identification of opportunities in the Greek environment and beyond that. More specifically, they stressed that they have used the technological knowledge and skills acquired during their participation in the network for the creation of products and services designed for the Greek market. However, they also pointed out that deployment opportunities could be further enhanced if other mechanisms for the diffusion of ICT products and services could be present such as spin-off companies or government projects aiming at the design and implementation of innovative products and services for the citizen and the business community. Thus, there is a need to improve the “ecosystem” of R&D in Greece by strengthening public demand and procurement for innovative goods and services and by increasing the availability of finance (seed capital, business angels and venture capital) to support the growth of small but highly innovative firms. Innovations in Greece fail in a great extent because there are not related early enough with users and potential customers. This could be a group of early adopters in the case of mass market or big reference clients in a business or industrial market (public or private) (Doxiadis, 2006). However, there are barriers to the deployment of new science-based and innovative applications related to the structure and nature of the Greek ICT sector itself. The Greek ICT sector and especially the IT segment is comprised of a large number of small firms operating in a relatively small market where “everyone sells everything”. In such a context R&D activity is limited to a small number of firms, which collaborate with universities in a

longer-term perspective. Most of the participating firms in research joint ventures with universities are doing so on an occasional basis (FEIR/IOBE 2006).

All interviewees also emphasized that to their knowledge there are no regional strategies aiming at the promotion of participation in the IST research networks and furthermore there is no cooperation with regional or national institutions for the coordination of activities related to the development and deployment of innovative products or services. Therefore, national authorities could play a critical role in developing strategies for the economic development and ICT diffusion and by providing supporting mechanisms for national and regional cooperation and collaboration. Hence, the diffusion of innovative results and knowledge acquired through the participation of Greek organizations in EU-funded IST networks will be further enhanced by national policies aiming at the exploitation of complementarities between European research joint venture networks and national diffusion programmes.

Finally, all interviewees referred to the cost and effort required for the coordination of large-scaled projects, as well as to the IPR problems arising when the issue of commercial deployment of project results comes up. Both issues are well known to the European Commission, however, further efforts should aim at simplifying participation and making IPR rules more flexible in order to adapt to the specific requirements of particular projects.

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### Tables

Table 1: Descriptive statistics for the total and Greek participation in IST RJVs (1994-2006)

	Total	Greek
No of organizations	13 847	547
No of participations	35 355	2053
No of projects	4419	1144
Average duration (months)	27.27 (8.58) *	28.02 (8.44)
Average budget per project (million €)	2.71 (3.38)	3.42 (4.73)
Average funding per project (million €)	1.49 (1.86)	1.89 (2.3)
Average no of participating organizations per project	8.21 (5.53)	9.15 (5.88)
Average projects per organization	2.19 (4.56)	3.64 (10.99)

\* Standard deviation in parenthesis

Table 2: Participation in IST RJVs (1994-2006)

Country	Participations	% participations	Entities	% entities	Prime Contractor	% prime contractors
Germany	5468	15.5%	2065	14.9%	780	17.4%
France	4533	12.8%	1614	11.7%	677	15.1%
UK	4468	12.6%	1672	12.1%	610	13.6%
Italy	4185	11.8%	1513	10.9%	569	12.7%
Spain	2668	7.5%	1088	7.9%	421	9.4%
<b>Greece</b>	<b>2053</b>	<b>5.8%</b>	<b>547</b>	<b>4.0%</b>	<b>287</b>	<b>6.4%</b>
Netherlands	1550	4.4%	620	4.5%	225	5.0%
Belgium	1447	4.1%	545	3.9%	248	5.5%
Sweden	1057	3.0%	449	3.2%	94	2.1%
Switzerland	933	2.6%	310	2.2%	20	0.4%
Austria	916	2.6%	392	2.8%	96	2.1%
Finland	830	2.3%	354	2.6%	62	1.4%
Portugal	681	1.9%	295	2.1%	44	1.0%
Denmark	584	1.7%	274	2.0%	65	1.5%
Ireland	563	1.6%	223	1.6%	66	1.5%
Norway	558	1.6%	257	1.9%	64	1.4%
Poland	368	1.0%	173	1.2%	24	0.5%
Israel	334	0.9%	166	1.2%	46	1.0%
Hungary	283	0.8%	136	1.0%	13	0.3%
Czech Republic	233	0.7%	125	0.9%	11	0.2%
Slovenia	159	0.4%	67	0.5%	6	0.1%
Bulgaria	138	0.4%	78	0.6%	1	0.0%
Romania	128	0.4%	84	0.6%	3	0.1%
United States	111	0.3%	75	0.5%	0	0.0%
Cyprus	103	0.3%	47	0.3%	3	0.1%
Luxembourg	100	0.3%	56	0.4%	15	0.3%
Other	904	2.6%	622	4.5%	31	0.7%
<b>Total</b>	<b>35 355</b>		<b>13 847</b>		<b>4481</b>	

Table 3: Participation of the most central organizations per country in the IST RJV network (1994-2006)

Country	Network of top 1% most central actors				Network of top 5% most central actors			
	Participations	% of total	Entities	% of total	Participations	% of total	Entities	% of total
Germany	1223	21.7	24	1.1	2196	38.9	122	5.6
France	843	18.5	14	0.8	1760	38.6	103	6.0
Italy	682	16.4	17	1.1	1500	36.0	104	6.6
UK	618	14.1	18	1.0	1604	36.5	112	6.4
<b>Greece</b>	<b>502</b>	<b>24.5</b>	<b>11</b>	<b>1.8</b>	<b>863</b>	<b>42.0</b>	<b>44</b>	<b>7.1</b>
Spain	416	15.5	9	0.8	742	27.7	42	3.7
Belgium	367	24.7	5	0.9	552	37.2	22	3.9
Netherlands	260	16.8	8	1.2	567	36.6	35	5.4
Sweden	138	13.2	3	0.7	364	34.7	27	5.9
Austria	133	14.3	3	0.8	282	30.2	16	4.0
Finland	102	12.2	3	0.8	314	37.6	24	6.5
Portugal	54	7.9	2	0.6	212	30.9	19	6.0
Denmark	23	3.9	1	0.3	141	24.0	13	4.5
Ireland	16	2.8	1	0.4	168	29.9	18	7.7
Luxembourg	0	0	0	0.0	11	11.7	1	1.8

Table 4: The interviewed organizations' profile

Company/Institution	Type	Employees' number	Foundation Year	Interviewee
National Technical University of Athens, Knowledge and Database Management Lab (KDML/NTUA)	University	33	1992	<i>Professor, Lab director</i>
Research centre of the Athens University of Economics and Business (IRIS Group/ELTRUN e-business center)	University	13	1991	<i>Associate Professor, Scientific Coordinator of the IRIS group</i>
Institute for Language and Speech Processing	Public research institution	105	1991	<i>Institute Director Senior Researchers</i>
Lambrakis Foundation	Non-profit research institution of public interest	33	1991	<i>Deputy Director General Head of Research Dpt</i>
Exodus SA	Firm	100	1994	<i>CTO Head of R&amp;D Dpt</i>
SingularLogic SA	Firm	300	1984	<i>Head of European Projects Management Dpt</i>
Intracom SA	Firm	2565	1977	<i>Director of European Research Programmes Dpt</i>

Table 5: Participation of interviewed organizations in IST-RTD projects

Organization	Core research activity	FP6	FP5 and FP4
Knowledge and Database Systems Laboratory/NTUA	Digital libraries technologies	1	11
IRIS group/ ELTRUN e-business centre	Governance of networked organisations, e-Government models, legal and socio-economic issues, change management	2	4
Institute for Language and Speech Processing	Language technology	3	15
Lambrakis Foundation	European quality standards for the continued professional development of teachers in ICT in education	2	12
Exodus SA	Design of dynamic ecosystems networks	3	14
SingularLogicSA	Business software, mobile services to citizens, smart home solutions	4	6
Intracom SA	Broadband access, home networks, multimedia, systems integration	10	97

Table 6: Principle aim of projects

Organization	Research	Development	Commercial Deployment
Knowledge and Database Systems Laboratory/NTUA	80%	10%	10%
IRIS group/ ELTRUN e-business centre	10%	80%	10%
Institute for Language and Speech Processing	20%	40%	40%
Lambrakis Foundation	0%	70%	30%
Exodus SA	10%	60%	30%
SingularLogic SA	20%	70%	10%
Intracom SA	20%	75%	5%

## Figures

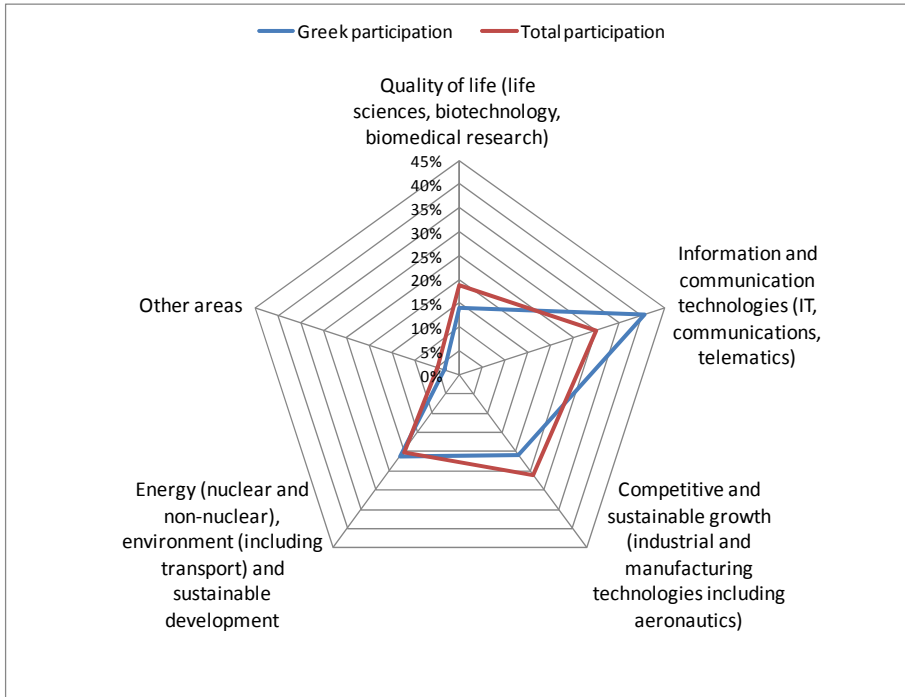


Figure 1: Breakdown of Greek participation per research area in six FPs (1984-2006)

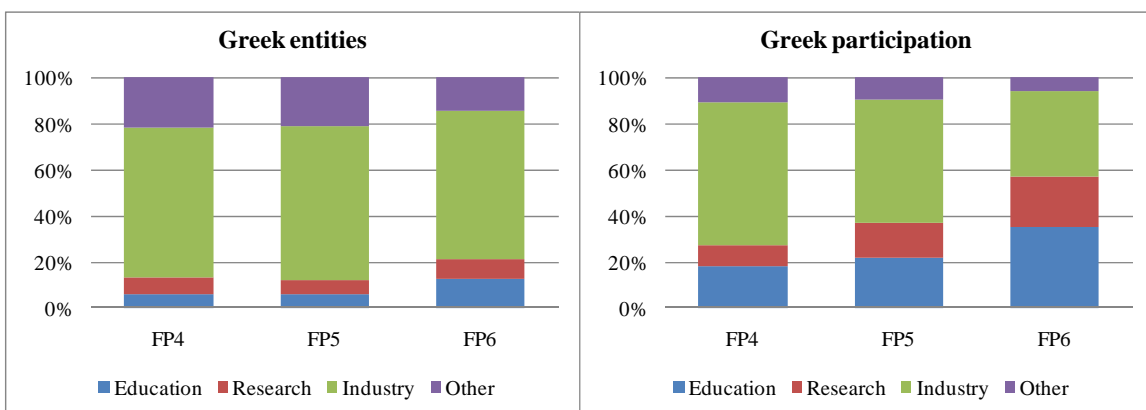


Figure 2: Distribution of Greek entities and their participation by organization type

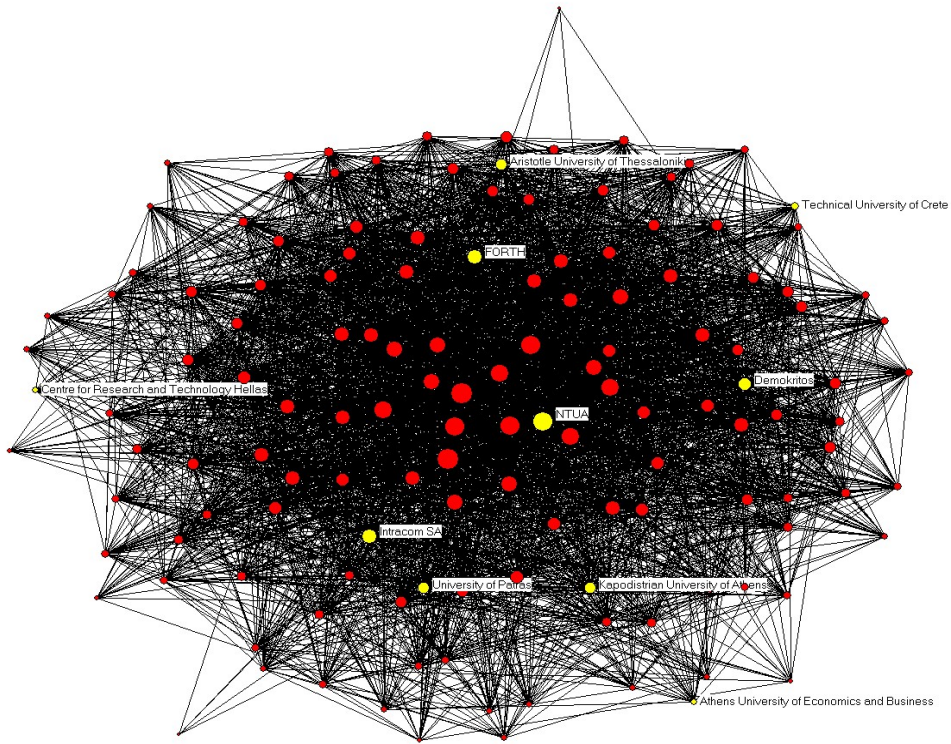
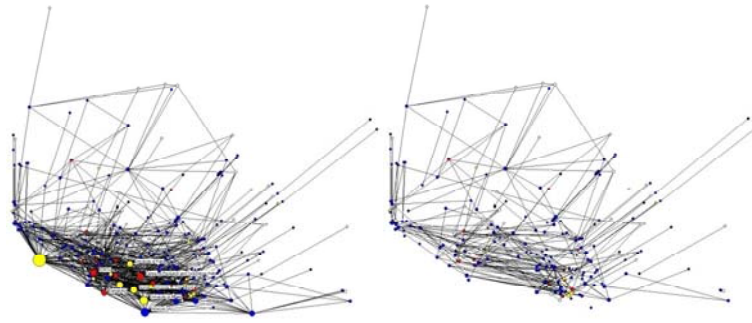


Figure 3: Visualization of the top 1% most central actors in the RJV-IST network (Greek organizations are represented by yellow nodes)



	Greek sub-network	Greek sub-network (after the removal of central actors)
Nodes	547	520
Edges	2965	1504
Density (x100)	0,81	0,36
No of Components	101	207
Giant Component (Size)	418	211
% Giant Component	76,40%	40,00%
Characteristic path length	3,201	6,314
Clustering coefficient	0,724	0,566
Mean degree	4,42	1,89

Figure 4: The critical role of certain central actors to the Greek sub-network's coherence and connectivity to the European IST network (universities are represented by yellow nodes, research institutes by red nodes and firms by blue nodes)