Analysis of Networks in European Framework Programmes (1984-2006)

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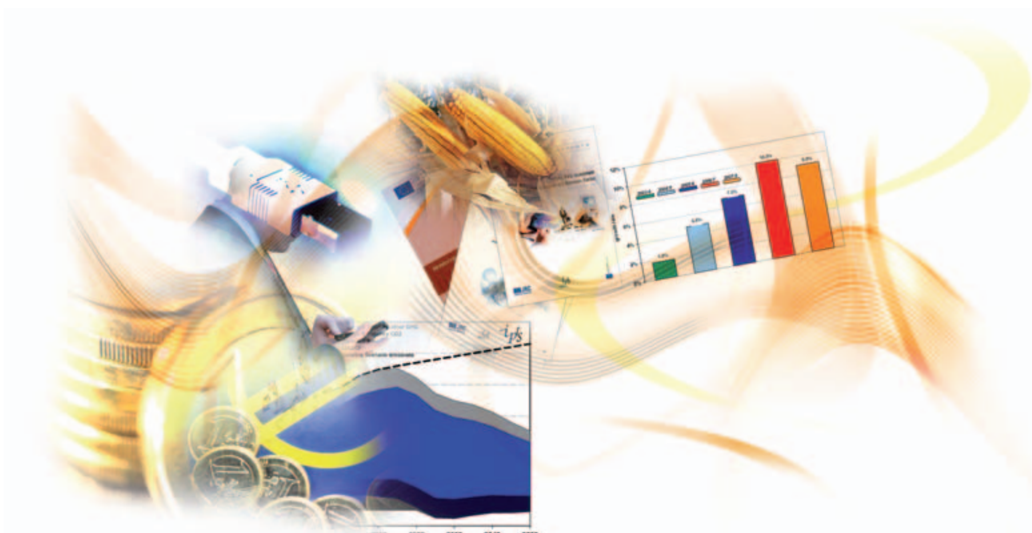

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About this report

In line with the Europe 2020 vision, there is an increasing need for adequate analytical tools to monitor progress towards the European Research Area (ERA).

The projects “Network analysis study on participations in Framework Programmes” conducted by ARC sys (now AIT Austrian Institute of Technology), under the framework of the European Techno-Economic Policy Support Networks (ETEPS)[1] and “Centrality Analysis in Research Networks” done by the Knowledge for Growth Unit of the Institute for Prospective and Technological Studies (IPTS), Joint Research Centre (JRC), European Commission[2], respond to the on-going need for data and analytical insights on the characteristics and evolution of the ERA.

The present report presents the synthesised findings of the abovementioned studies. More specifically, it applies *novel methodological tools* to data on European *Framework Programme (FP) participations* to advance our understanding of transnational networks of collaborative research.

The FP is the main instrument of EU research policy. With €17.5bn devoted to FP6 (rising to €51bn in FP7) it funds a substantial proportion of collaborative research activity in the EU and is, by far, the most prominent funding mechanism for *transnational* research globally.

Therefore the analysis of the structure of European networks of collaboration in the FPs, from FP1 to FP6, is a valuable tool in understanding the contribution of European policies in transforming the fabric of research within the ERA, as well as in identifying a possible backbone for the ERA.

Traditional indicators of transnational research collaboration are limited to cross-tabulations of co-participation in the FP (as well as co-publications and co-patenting in bibliometrics) at high levels of aggregation (national/regional). By contrast, the use of social network analysis methods takes into account the *relative position* of individual research actors in collaborative networks, and thus affords greater analytical detail.

1 This project was performed under the Specific contract Nr. C. 150083. X32 implemented under the framework contract Nr. 150083-2005-02 BE
2 This project was performed under the FP 7 contract COH7-AA-2008-232064

Executive summary

Analysing the collaboration structures of the European Framework Programmes (FPs) is an important analytical tool for the overall evaluation of results and impact of R&D policies in the EU and for informing future policy development.

FPs have been pivotal for transforming informal nation-based networks of research collaborations within epistemic communities of academics and industrial researchers into formal collaboration arrangements between organisations at European level. The networks formed by the organisations have become almost as important an outcome of FPs as the scientific and technological results of research projects conducted by them.

The analysis of the characteristics and structural properties of the networks, built through the six Framework Programmes, implemented until 2006, provides a plausible indication whether this new fabric of European Research and Technology Development (RTD) has become more cohesive and integrative during the past more than 20 years. It is valuable for understanding the contribution of European policies for transforming the fabric of research within the ERA, as well for identifying the emergence of a possible backbone of key research organisations in Europe. The study aims to explore this kind of issues by exploiting the richness of FP collaboration data using advanced methods of social network analysis.

The above analysis of structural features of FP5 and FP6 networks suggests several implications for ERA. First of all, comparing the evolution of the FPs over time, we observe extensive instrumental and structural change. For the same type of instruments and for the same themes, the networks emerging are more integrated and more tightly knit. This could be interpreted as a signal of self-reinforcing pan-European thematic communities built on trust and a common operational framework that has evolved to its present state alongside the FP. Secondly, the overall success of the FP, in involving research teams from new member states and integrating smaller peripheral communities into wider European networks, is compatible with the view that it is contributing to the construction of the 'backbone' of the ERA.

The identification of three kinds of networks as resulting from different types of sub-programmes – small world networks, distributed clusters networks and networked communities – has further repercussions for the implementation of ERA.

Small world networks tend to favour knowledge diffusion and building up of expertise across time but might be less effective to foster wider integration because of the difficulties that new players have in joining them. According to FP data for FP5 and FP6, small world networks (with high clustering) emerge in sub-programmes that are strongly oriented towards applied research and development. Such kind of networks are known for their resilience and their resistance to change due to the filtering apparatus of using highly connected nodes (or 'hubs'), and their high effectiveness in relaying information while keeping the number of links required to connect a network to a minimum.

Distributed cluster networks are found in programmes with a strong exploitative component and knowledge transfer functions. Such networks are less clustered than small world networks and represent a balance of expertise accumulation and integration, with lower barriers to joining in. Favouring the advancement of knowledge and efficient transfer within relatively closed cliques, they represent an interesting tool for ERA.

Finally, there are very evenly distributed network structures, the so-called ‘networked communities’ with a lower clustering coefficient, which are associated with basic research. Such networks are better suited for cutting-edge research and allow a tighter integration since links are easily formed. However, they may be less suited for an efficient diffusion and exploitation of knowledge.

Generally speaking, different kinds of networks represent different answers to ERA priorities. Positioned in between the two main purposes of knowledge creation and of knowledge diffusion, there are irreducible trade-offs in opting for different kinds of orientations of sub-programmes in future FPs.

We identify the following main dimensions along the lines of which different network types are relevant: building strengths and the cohesion of the European Research Area.

The actors that play a key role for achieving both dimensions are universities. In many thematic areas, they are at the core of the networks built by the FPs through time, and have increased their centrality and share of participations. Because of the stability in the top positions and the wide representation of some of universities in different thematic networks, they play a double role of furthering both excellence and of contributing to cohesion. Together with Research and Technology Organisations (RTOs), universities form the building blocks of the ERA, acting as harbours of stability. Stability over time also suggests that policy interventions will need to take into account the specificities of these top actors and the networks in which they participate. It is therefore important that their central role is recognised in any discussion on the future evolution of the ERA.

The analysis of Integrated Projects (IP) and Networks of Excellence (NoE) in specific topics is of particular interest from an ERA perspective, as they were tasked with strengthening the ERA by enhancing collaboration at programmatic level. Both aimed at the facilitation of common research agendas, at the integration of smaller research communities and new member states and at the promotion of virtual centres of excellence that are visible at a global scale. In accordance with the expectations attached to them, we found that they favoured large projects with many participants, but it remains to be seen whether these large-scale networks will have a structural effect on ERA after the end of funding.

Organisation rankings by theme indicate wide variation across themes but, within a given theme, relative homogeneity across instruments. Within each theme, we can distinguish between a core of stable presences in the top ranks and others that are rather volatile. Core organisations have played the role of integrator and coordinator in the building a European-level research agenda for a given topic.

Consistent with the ERA vision that sees coordination and cooperation as contributing to existing strengths and integrating the knowledge periphery, the ‘top of the top’ universities participating in FP6 in those instruments are spread across different countries, large and small, generic and specialised universities are all involved in the FPs.

The role of the FP in structuring the ERA could be enhanced by the suitable design of instruments that are tailored to the needs of thematic communities. Our analysis points to significant differences in the resulting networks across thematic priorities. We also observe that the exact shape of the knowledge triangle is thematically conditioned: the composition of resulting networks varies in terms of leading organisation type, with Aerospace at one extreme (where industry is dominant) and Life Sciences at the other (where academia dominate). The even mix of organisation types represented in the top ranks of ICT is indicative of a priority that is conducive to knowledge sharing between different organisation types. Energy and Environment has allowed a better integration of new organisations in the FP networks. This can be seen as a consequence of the public-good nature of much of the knowledge produced and diffused in this programme; a characteristic that requires more inclusive networks to be built. As such, this priority might represent an example of how the FP could contribute to the tackling of 'Grand Challenges'.

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Chapter 1: Introduction

The move towards the European Research Area (ERA) is at the core of the political process since the Lisbon Agenda (European Commission 2000a). Several initiatives have been taken since then to foster its development. In 2007, the Green Paper for the ERA (European Commission 2007) identified the six axes along which ERA should focus to create the necessary conditions for a European internal market for research. The need for excellent national and European research organisations and the creation of the framework conditions and incentives to knowledge sharing are two of these axes of action. On 2 December 2008, the Council of the European Union has adopted a common 2020 vision for the ERA (European Council, 2008), which alongside with the need for better competition stressed the need to reinforce cooperation and coordination. In July 2009 in the Lund Declaration[3] Member States adopted 'Grand Challenges' as approach to coordinate policy initiatives to achieve the ERA Vision 2020. It defines as essential the promotion of cross-border cooperation, the strengthening of networks of excellent and of less developed research organisations to enhance the overall competitiveness of European research.

Monitoring the move towards the ERA is therefore pivotal in this political process. Novel methodological tools applied to data on the European collaboration contribute to tackling the challenges posed by a monitoring system that is not only based on the traditional input and output measurement. Beyond the analysis of co-publication and co-patenting, usually used as proxies for research collaboration, there are other sources of data that can be mobilised, like the data on public funding awarded to European R&D activity. At European level there are five major sources of public funding for collaborative endeavours: The European Framework Programme, the major European scheme for funding transnational research, the inter-governmental framework COST, the schemes promoted or managed by the European Science Foundation, and the EUREKA. The European Research Council is also an important and interesting source of funding at European level, but is distinguished from the previous ones because it does not require collaboration across European countries. Its aim is to promote competitiveness based on excellence at the European level.

The focus of this study is on the analysis of networks promoted by the past six European Framework Programmes (1984-2006). The main objective is to advance our understanding on transnational networks of collaborative research, identify the relevant networks, as well as the role played by the most central organisations in those networks. The study of the networks promoted by the other above mentioned European research funding sources would complement this analysis. A feasibility study has been done, but will not be reported here.

European Framework Programme is the main instrument of European research policy. It has been conceived as an instrument of transnational collaborative research aimed at improving the international competitiveness of European industry, while at the same time strengthening EU cohesion. Since FP6 it serves as the key instrument to foster the ERA.

Although our intention is not to do the historical account of the European Framework Programmes, it is important here to recall its origins, and its role in promoting research collaboration across research organisations of the European Member States, as well as the rupture

3 http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf

introduced in the range of both geographical and modes of collaboration of research organisations. The FPs are one of the answers of Europe to the challenges posed by the knowledge production of generic technologies, like the information and communication technologies or biotechnology, developed through the combination of different disciplines and skills through collaboration of heterogeneous actors (Callon, Larédo et al. 1995). The development of these technologies imply a cooperative process between knowledge producers and consequently the implementation of novel processes for sharing knowledge and resources in order to cope with the need of reducing lead times and the fast pace of technology development and diffusion (Onida and Malerba 1989; Freeman 1991).

European Framework Programmes were modelled based on the success of ESPRIT I, the information technologies (IT) programme for collaborative research at the European level, created in 1982 by the European Commission. ESPRIT was promoted by the Commissioner for Industry, Étienne Davignon, with the support and advice from the European Round Table of the twelve biggest European companies in the IT sector. The First Framework Programme for Research and Technology Development (RTD) was created two years later, which included the ESPRIT programme and other sub-programmes in a variety of topics, to address the development of generic technologies within a multi-annual framework. Since then other FPs have been implemented regularly with an enlarged scope and a diversified set of funding instruments. The rationale behind was that universities, research institutes and firms (even competitors) from Member States should work in cooperation to reduce the technology gap of Europe in relation to the United States and Japan and increase its competitiveness. Therefore the projects funded by the FP focus either on the development of new technologies and products or on the development of technological standards. The projects have to be carried out by a consortium of research organisations, from at least two different countries, preferably with the involvement of knowledge producers, exploiters and users.

FPs were pivotal in changing the traditional nation-based informal research collaboration within epistemic communities into formal arrangements between research organisations at the European level. The durable networks of research collaboration formed by the organisations participating in FPs are almost as important as the scientific and technological outcomes of research projects supported by them.

The collaborative links established by the European projects can be equated to paths through which the knowledge circulates between the organisations, and eventually joint knowledge is produced. The analysis of the characteristics and structural properties of these networks can plausible give an indication on the nature and characteristics of the new fabric of European RTD, and on the degree of its cohesiveness and integration. In addition, the analysis sheds light on the contribution of the European research policies to the transformation of research within the ERA and aims at identifying a possible backbone.

The main objective of the study was to exploit the richness of FP data through social network analysis (structure of research networks and actors centrality) to contribute to the process of monitoring the move towards the ERA. The research questions addressed in the study were the following:

1) Does the density of collaborative organisational links increase over time?
2) Is it possible to identify optimal network structures by areas of research and funding instruments?
3) Is it possible to identify a backbone of core research organisations in the European Research Area?
4) Who are the key players in the FPs, and where are they located within the FP networks?

The report is structured in the following way. The next chapter introduces the methodology adopted. The second part of the report, which includes chapters three to six, presents an aggregate view of collaborative research networks in the FPs and closer look at thematic sub-networks including distribution of core organisations by theme, instrument, country and organisation type. The third and last part, which contains chapters seven to eight, examines the feasibility of extending the analysis conducted in the present study and outlines potentially interesting future research directions. Finally, it elaborates on some policy implications for the ERA emanating from the study's findings.

Chapter 2: Methodology

The study employs a combination of quantitative and qualitative methods. The produced metrics are the result of the application of social network analysis to joint research projects sponsored by the six Framework Programmes executed until 2006. The analysis of the networks and the interpretation of the results were supported by extensive use of publicly available secondary sources, such as the evaluation reports of the framework programmes and a review of relevant academic literature.

This section describes succinctly the methodological approach. First, it describes the process applied in the retrieval and cleaning of FP data and documents the problems identified and the choices taken. Then, it explains how social network analysis was applied and briefly presents the chosen network metrics and the ranking methods used.

2.1 Data sources

The Austrian Institute of Technology (AIT) developed the EUPRO database built on available data in the CORDIS projects database (Barber et al. 2008). CORDIS, the Community Research and Development Information Service, maintains online databases of FP-funded research (e.g. http://cordis.europa.eu/fp6/projects.htm). The CORDIS database is run by a subcontractor who receives raw data from different General Directorates (DGs) in charge of thematic areas of the FP. The project data was retrieved from CORDIS by AIT, and then cleaned, standardised and consolidated into the EUPRO database (version 1.0.3), which was used in this project to calculate the network metrics.

The CORDIS projects database contains a great deal of information about FP-funded research projects and project participants. In principle, the CORDIS projects database contains information on: 1) project objectives and achievements, 2) project costs and 3) total funding, 4) start and end date, 5) contract type, 6) a standardised subject index, and a freely specified index, and 7) information on the call in which the project was funded. On project participants, it ideally lists information on 8) the participating organisation, 9) the actual participating department, 10) contact person, 11) complete contact details, 12) organisation type and 13) URL. Until the recent change of the front end of the database, it also included email addresses, telephone and fax numbers of contact persons, as well as information on the organisation size. However, in practice, and according to the experience of AIT in retrieving data from CORDIS, the records are rarely complete[4].

The process of retrieving and cleaning CORDIS data is cumbersome as information is not immediately available and can change over time. In fact, there are delays before information on projects and participants becomes available. For instance, a sizeable amount of information on FP6 was only available in 2006, the last year of its existence. Secondly, information is not available on strength and duration of partner's involvement in each project or on partner changes during a project's lifetime – the only way to find out is to retrieve the data regularly from the CORDIS projects database.

Data on organisation types is available for 77% of the records, but tend to be inconsistent.

4 The project records are complete on 94% on contract types, 95% on start date and 93% on end dates and about 89% on information on sub-programme (ideally corresponding to specific calls). Other fields have lower level of completeness like information on project acronyms (50%), objectives (55%), project costs (48%), project funding (53%), project status (96%) and achievements (15%).

In principle, there are seven organisation types (Education, Research, Industry, Government, Consulting, Non-Commercial and Other). In practice, participants choose the organisation type (or a combination of types) they deem appropriate. As a result, raw data on participant's lists varies from two to six different organisation types for the same organisation.

In addition to this, the available raw data on participating organisations tend to be inconsistent. Organisations may be spelled in up to four languages (e.g. the case of Swiss organisations), and labelled non-homogeneously. Entries may range from large corporate groupings, such as EADS, Siemens and Philips, or large public research organisations, such as CNR, CNRS and CSIC, to individual departments and labs. Moreover, organisations are subject to change, which may reflect in changing organisation names. Department labels are in general incoherent, ranging from the organisation name to meaningful subunits like faculties, subsidiaries, institutes, centres, laboratories, to unidentifiable acronyms. The labels not only represent different organisational scales, but are also apparently self-selected by project participants resulting in an inconsistent labelling of organisations that partake in multiple projects. Information on older entries and the substructure of firms tends to be less complete.

Because of raw data shortcomings, the application of a fully automated standardisation method was not feasible. Rather, the data had to be cleaned and completed manually, in a four step process involving: 1) identification of unique organisation name; 2) identification of unique organisation type; 3) creation of economically meaningful sub entities, and 4) regionalisation.

In step one the boundary of organisations was defined by its legal entity and entries assigned to unique organisations using the most recent available organisation name. In this process, all available additional contact information was used and missing information completed.

In step two, organisation types were homogenised. Cleaning and completing this information improves the quality of raw data considerably. The process itself is relatively straightforward; the only challenge is the distinction between public and industrial research centres.

Step three was key for the mitigation of the bias that arises from different organisation scales at which participants appear in the dataset. Ideally, the laboratory or organisational unit that participates in each project is taken, but in practice, this information is only available for a subset of records, particularly for firms. Taking the definition of an organisation as a coherent bundle of resources (or competencies), sub-entities of large organisations in general are created to operate in fairly coherent activity areas. Therefore, universities were disaggregated whenever possible into faculties or schools and large public research organisations into institutes or research fields. Due to incomplete information on the organisational structure of firms, it was not feasible to define meaningful sub-entities representing different activity areas of the firm. Thus, sub-entities for global corporations firms were taken for the country-specific subsidiaries[5]. Apart from the analyses on the positioning of key universities in different themes and instruments in Chapter 6, we have used in the present study the lowest organisational level of aggregation, i.e. the sub-entities of organisations.

The final step was the regionalisation of the dataset according to the European NUTS classification system[6], ideally down to the NUTS3 level, using information on postal codes

5 Though we have information on different department or sections, it is often not possible to assign them to broader divisions or departments. The definition of country specific subsidiaries as sub-entities is appropriate when we assume that subsidiaries in different countries act in different research fields.

6 European Commission (2005), Nomenclature of territorial units for statistics - NUTS Statistical Regions of Europe. http://europa.eu.int/comm/eurostat/ramon/nuts/home_regions_en.html.

or the information on the regional localisation of each participant.

The cleaned database, EUPRO database (version 1.0.3), used in this report comprises information on 50,590 projects. It covers the period from 1984 (first project starting dates) to 2025 (last scheduled project end date). At its present state of standardisation, the database includes 49,624 separate organisations that were involved in at least one project. This figure increases to 55,555 when sub entities are considered. Information on these projects was retrieved from the CORDIS projects database in January 2007. Data on the first four FPs is complete according to the CORDIS website. In FP5, a handful of R&D projects are still missing (161 projects). For FP6 the existing data appears quite representative. Considering for FP6 only sub-programmes that support mainly collaborative research[7], the database includes about 90% of all FP6 projects[8].

2.2 Network analysis and centrality measures

Networks metrics and actor metrics were calculated in order to capture the networks that can be pivotal in the emerging ERA. Network metrics were calculated for the organisations as nodes. The classification applied is the type of organisation according to the typology defined by the European Commission. For the themes, the option was to keep the thematic organisation of sub-programmes to avoid a complex reconstruction of fields in technologies that combines several scientific disciplines.

The analysis was done in two levels of aggregation. One level focused on the networks of the FP, ignoring the sub-division on themes or instruments, while in the other the themes were crossed with instruments to have an in-depth analysis of actors and networks in each of them.

At the aggregated level, network metrics were calculated to identify the structural features and characteristics of networks built by each FP. The characteristics of networks were then compared over time to understand their evolution towards a more integrated or fragmented status. The key nodes (organisations) that form part of the backbone of the ERA were identified for every FP. A ranking of the position of such key organisations in the European landscape had to go beyond simple counts of participations. To decide if an actor is a core player it is necessary to calculate centrality measures that show how well actors are connected, and identify which role they are performing in the network (Wassermann and Faust 1994). Several centrality measures, some of them recently developed, were applied in the study, as well as a composite indicator developed for ranking organisations and topics.

At disaggregated level, characteristics and behaviour of actors were identified through network metrics in a group of funding instruments in four main topics. The rationale for the selection of topics and funding instruments is described in the next section. As for the aggregated level at the topic and instrument levels, the core players in the scientific and technological communities were identified through rankings based on centrality measures. The definitions of network metrics used in the study are reported in Box 1.

To facilitate rankings, we developed a simple composite indicator of centrality measures. The centrality measures selected for the indicator combined the different types of connectedness with role and positioning in the landscape. The four centrality measures were local [Degree Centrality] and global connectedness [Closeness Centrality], the ability to control information

7 FP6-MOBILITY focuses primarily on research grants for individual researchers.

8 For some programs the sysres EUPRO database includes up to 90% of the FP6 projects (FP6-COORDINATION, FP6-INFRASTRUCTURE, FP6-CITIZENS, FP6-IST, and FP6-INNOVATION), 60-80% of the projects are retrieved for FP6-FOOD, FP6-INCO, FP6-NMP, FP6-SOCIETY, FP6-AEROSPACE and FP6-SUSTDEV). 40-50% of the projects are missing in FP6-LIFESCIHEALTH, FP6-SME, FP6-NEST and FP6-POLICIES.

Box 1 - Network metrics definitions

Network metrics

Number of vertices N: a vertex (in social network theory also referred to as a node) represents an organisation

Number of edges M: an edge (in social network theory also referred to as a link) represents a participation in a joint project

Measures of fragmentation of the network

Number of components is the components connected in sub-networks. Thus, a higher number of components is associated with a higher fragmentation of the network.

N for largest component is the number of vertices in the largest component.

Share of total N (%) is the fraction of the vertices in the largest component in the total number of vertices.

M for largest component is the number of edges in the largest component.

Share of total M (%) is the share of the edges in the largest component in the total number of edges.

N for 2nd largest component is the number of vertices in the second largest component.

M for 2nd largest component is the number of edges in the second largest component.

Other structural measures for the network

Clustering coefficient: For a given vertex the clustering coefficient measures the local density of a network by indicating the extent to which its direct neighbours are also connected. The clustering coefficient of a network is the mean clustering coefficient of all vertices (Watts and Strogatz 1998).

Diameter of largest component: The distance between two vertices is the shortest path between them. The diameter of a network is the longest distance between any two of its vertices. It can be interpreted in the context of information flow through the whole network.

Characteristic path length of largest component: l denotes the characteristic path length, i.e. the average distance between pairs of vertices; it can be interpreted in the context of information flow.

Mean degree: The degree of a vertex denotes the number of its direct neighbours; for the o-graph this means the overall number of partners of an organisation, for the p-graph the overall number of linked projects.

Fraction of N above the mean (%): the share of vertices with degree higher than the mean degree; indicative of the skewness of the degree distribution.

Mean vertex size P: In the o-graph P denotes the mean number of projects of an organisation.

Standard deviation of P: a measure of the width of the distribution of P; indicative of the skewness of the distribution of vertex sizes.

Centrality measures

Degree centrality is defined as the ratio of degree ki and the maximum degree k in a network of the same size (i.e., the total number of edges connected to a vertex). Actors with a high number of direct links hold strong collaborative experience and dispose of direct access to different information stocks (local reach).

Eigenvector centrality accords each vertex a centrality that depends both on the number and the quality of its connections by examining all vertices in parallel and assigning centrality weights that correspond to the average centrality of all neighbours.

Closeness centrality of a vertex is defined as the inverse of the mean geodesic distance (i.e., the mean length of the shortest path) from this vertex to every other vertex in a connected graph. Actors, which are connected by shortest paths to all other actors, have the possibility to spread quickly information within the network (global reach).

Betweenness centrality of a vertex can be defined as the fraction of geodesic paths between any pair of vertices on which this vertex lies. It is measured by the frequency of one actor positioned on the shortest path between other groups of actors arranged in pairs. Those actors, who are located on the shortest paths between many actors, therefore hold a key position for controlling the flow of information within the network (gatekeeper function).

flow in the network [Betweenness Centrality] and connectedness to other central nodes [Eigenvector Centrality]. These were combined into a composite centrality ranking or a weighted centrality index. It merges normalised values of different metric indicators (i.e. centrality measures) to an aggregated index by a linear-additive combination.

To explore structural features of FP networks in relation to the functions on knowledge production and circulation, an experiment was done using FP5 and FP6 networks. Structural characteristics of knowledge-related functions were identified. Then an aggregation of network characteristics was done in order to define which type of networks is built in the thematic sub-networks of FPs. More details on this experiment can be found in Chapter 4 – Thematic networks and their functions.

In the following sections, the terminology about roles and properties of actors are defined as follows: ''core'' for the organisations that had a much higher degree centrality than the average, ''central'' for the ones ranked by the composite indicator, ''key'' for organisations ranked by number of participations in FPs projects.

2.3 Selection of topics and instruments in FPs

Choices were taken for the analysis at disaggregated level in order to achieve meaningful results in a reasonable period and resources, taking into account the complexity of six multi-annual Framework Programmes with a time span of more than 20 years. As is natural over such a long period, rationales and specific objectives of European research policy shifted, with a corresponding impact on the modes of implementation and priorities assigned to thematic areas. In accordance with our emphasis on the recent evolution of the ERA, and due to resource limitations, a decision was taken to constrain the analysis to the three latest FPs (FP4, 5 and 6), and then for a subset of themes and instruments.

Theme and instrument selection is not a trivial task. The three last FPs selected vary considerably in rationale, priorities and type of instrument. The solution found was to use FP6 as a point of reference and look backwards to previous FPs for themes and instruments that display continuity. The final selection included the following themes: Aerospace (AERO), Energy and Environment (ENV), Information and Communication Technologies (ICT), and Life Sciences (LIFESCI).

It has to be noted that it is not intended to compare FP4, 5 and 6 as a whole, or even (because of the rather tenuous link between FPs) a one-for-one comparison between specific thematic programmes with intended 'follow-up' programmes, but to have an exploratory analysis of networks evolution over time.

Aside from the establishment of broad thematic priorities, early FPs adopted a generic approach to the implementation of joint research undertakings (shared costs actions). The desire to better serve the needs and increase the participation of excellent actors from across the research spectrum as well as to serve greater political aims (such as the creation of the ERA) led to the customisation of contracts into purpose-minded *'instruments'*.

Starting in FP6, several cross-cutting instruments were introduced including Integrated Projects (IP), Specific Targeted Research Projects (STREP) and Networks of Excellence (NoE)[9]. IP aim at generating the knowledge required to increase Europe's competitiveness or to address major societal needs. Specifically, IP address the needs of exploratory projects (including long-term or "risky research") that are often innovation-related

9 The description that follows draws heavily from EC, "Classification of FP6 Instruments". (ftp://ftp.cordis.europa.eu/pub/fp6/docs/annex_on_instruments.pdf) and Marimon, (2004), "Evaluation of the effectiveness of new instruments in Framework Programme VI". (http://ec.europa.eu/energy/evaluations/doc/2004_research_fp6.pdf).

and require the concentration of considerable resources, both human and financial. Although IP are objective driven, the implementation of projects is subject to a certain amount of flexibility, reflecting their exploratory nature.

STREP (the post-FP6 evolution of shared costs actions – identified here as Cost Shared Contracts, CSC) fund collaborative research and technology development projects that address European competitiveness and societal needs. In contrast to IP, STREP is limited in scope, focusing on a single issue and is often monodisciplinary. They are also generally smaller than IP in terms of resources, reflecting the less ambitious and more piecemeal strategic approach of STREP projects.

By virtue of their characteristics, IP and STREP are generally considered as particularly suitable to collaborations between industry, public research organisations and universities. STREP in particular are usually preferred by small- and medium-sized enterprises (SMEs).

The NoE instrument envisages the durable integration of the participant's research capacities, while potentially supporting their joint research activities. As such, NoE have been conceived with the explicit aim of tackling fragmentation and reaching the critical mass needed to structure excellent research. NoE are framed according to disciplines or clearly defined research themes. NoE are generally targeted at universities and more basic-type research organisations, though some companies also make use of this instrument.

Our choice was to focus on these four instruments as they combine continuity (STREP) and rupture with the introduction of more policy-driven research instruments (IP, NoE). The Marie Curie actions were also considered a potentially interesting instrument but the information contained in the CORDIS database was found to be insufficient for identifying network links. In addition, the database contains no information on the direction of mobility, as it does not systematically distinguish between source and host organisations.

Chapter 3: Networks of collaborative R&D in the FPs

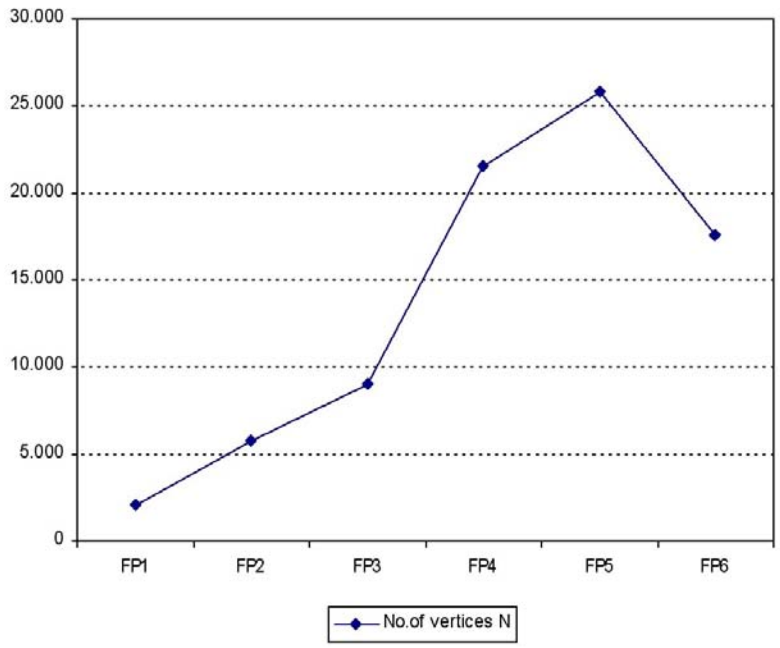
3.1 Structural features of FP networks

European projects are establishing and expanding collaborative links between organisations, which can be equated as paths through which knowledge circulate and diffuse between organisations, and joint knowledge might be produced. The analysis of the characteristics and structural properties of the networks built by the six framework programmes, implemented until 2006, can give some plausible indication on whether this new fabric of European RTD is more cohesive and integrated.

FP networks are increasing in size

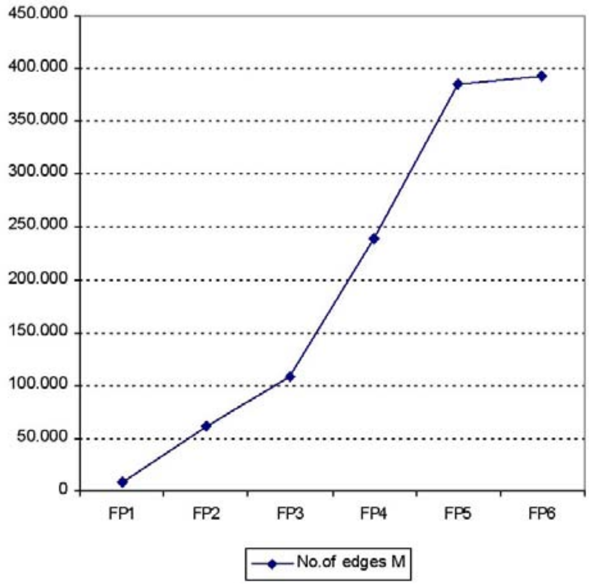
Network analysis can provide several measures and identify the characteristics of the collaboration promoted by the FPs over time. The number of vertices or nodes (M) and of edges or ties (N) in a network relates to its size and degree of connectedness. If M is increasing, it means that more organisations are participating in projects funded by FP and becoming engaged in the collaborative effort. Figure 1 shows that the number of organisations has grown fast until FP5, from 2,116 in FP1 to 25,840 in FP5, and decrease in FP6 to 17,632. There might be two explanations for this sharp decrease in FP6 shown in the data. First as we mentioned before, the EUPRO database is not yet complete for FP6, second there is certainly a decrease even if not so sharp related to a lower success rate in FP6 (number accepted proposals in relation to the number of submitted ones) in comparison with the previous one. The success rate has decreased from 26% to 18%[10], implying fewer projects awarded and participations.

Figure 1: Number of nodes (N) in network organisations in FP1-FP6



10 Final evaluation of FP 6 Report by Rietschel, Arnold et al. (2009).

Figure 2: Number of edges (M) in organisation networks in FP1-FP6



The evolution of the degree of collaboration in the FPs can be given by the number of edges or ties between the organisations that are linked by their participation in collaborative project (M). The number of links in FPs increased significantly from FP1 to FP5 from 9,489 to 385,740, and has stabilised around 392,879 in FP6 (Figure 2).

Increasing in cohesiveness

The networks have increased in size and have became more cohesive as collaboration has evolved with time, with the positive learning processes on how to overcome barriers for collaboration, like the differences in culture, languages and other involved in multi-national collaboration in Europe. Measures of fragmentation/cohesiveness of networks are the number of sub-networks that compose the network (number of components), the size of the largest component (N for the largest component) their shares in terms of vertices and edges in relation to the total, and the size of the second largest component and its shares. According to data, there is a giant network in every FP. Its presence indicates that two arbitrary vertices are connected either directly or indirectly through a path of connected vertices (Table 1). These giant-components ensure that information flows easily between the participants in FPs, allowing coordination and alignment of networks, and promoting a common language and shared culture between them.

Table 1 also presents other measures, like the number of sub-networks (No of components). These sub-networks that have increased until FP5 have drastically reduced in FP6, showing that the objective for cohesion is being attained with a concentration of the previous sub-networks. The second largest component remains constant around more or less nine nodes.

High clustering effects with characteristics of "small world"

The evolution of cluster coefficient reflects how the intensity of collaborative links is evolving over time from FP1 to FP6. The cluster coefficient quantifies how close organisations (the nodes or vertices in the social network theory) are from each other through direct links or can be considered associated of their neighbouring organisations through indirect linkages. It measures the local density of a network by the mean clustering coefficient of all

Table 1: *Measures of fragmentation of the organisation networks FP1-FP6*

	FP1	FP2	FP3	FP4	FP5	FP6
No. of components	53	45	123	364	630	26
N for largest component	1,969	5,631	8,669	20,753	24,364	17,542
Share of total N (%)	93.1	97.8	95.9	96.1	94.2	99.5
M for largest component	9,327	62,044	108,388	237,632	384,316	392,705
Share of total M (%)	98.3	99.8	99.6	99.6	99.6	99.9
N for 2nd largest component	8	6	9	10	12	9
M for 2nd largest component	44	30	72	90	132	72

Table 2: *Cluster coefficient of organisations in FP1-FP6*

FP1	FP2	FP3	FP4	FP5	FP6
0.65	0.74	0.74	0.78	0.76	0.80

Table 3: *Structural characteristics of organisation networks in FP1-FP6*

	FP1	FP2	FP3	FP4	FP5	FP6
Diameter of largest component	9	7	8	11	10	7
ℓ for largest component	3.6	3.2	3.3	3.4	3.3	3.0
Mean degree	9.0	21.6	24.1	22.1	29.9	44.6
Fraction of N above the mean (%)	29.4	28.0	23.6	22.4	23.5	26.1
Mean vertex size P	3.0	3.1	3.3	3.0	2.8	2.7
Standard deviation of P	5.0	6.1	7.7	7.9	6.8	5.4

vertices (Watts and Strogatz 1998). The higher the value of the coefficient, the more connected is the network, closer to what sociologists call a “clique”, meaning a cohesive group with shared values, behaviour and norms. If the FP cluster coefficient increases over time it means that intra-European collaboration is developing and there is a move towards a more integrated ERA. From the calculations done, the cluster coefficient increases slightly from FP1 (0.65) to FP5 (0.76) (Table 2). The increasing trend continues up to FP6 reaching the value of 0.80. However, this last value could be a reflection of the effect of the new FP6 instruments aiming at the integration of teams, which foresaw an increase of the size of funded projects.

A high coefficient degree in the networks formed by FP means that a knitted fabric for the European research is taking place, promoting knowledge creation and diffusion and facilitating learning processes. This indication is compatible with the move towards the ERA, with the FP being a crucial instrument in this process through the creation of a well-connected European research community.

Combining a high clustering coefficient with a small diameter of the largest component (Table 3), FP networks can be characterised as belonging to the small-world type (Watts and Strogatz, 1998). In terms of what we presently know about knowledge creation and knowledge diffusion in social networks (Cowan 2006), this is a positive result. When path lengths are short, new knowledge can spread rapidly and widely through the population and thus fuel local knowledge creation.

The mean degree in the R&D collaboration networks is roughly constant until FP5, with a value around 23, but it shows a sharp jump for FP6 to 44.6 indicating that organisations have increased their number of ties and diversified their connections.

Overall, in their twenty-odd year period of implementation, the FPs have created a new layer in the European research systems based on transnational collaborative research. Over time, European collaborative networks were able to create a highly dense and integrated structure. From the analysis, it can also be argued that framework programmes have been promoting actively the move towards the ERA, through the construction of a European research community where knowledge is created jointly and that information flows fast through network channels.

3.2 Top 100 organisations in FP networks by centrality and participation

The embedding within networks is a basic condition for successful research, technological development and innovation. Networks offer access to new knowledge and other resources through every new partnership and therefore help to create new knowledge. Furthermore, networks between reliable partners may be utilised to jointly exploit and deepen existing knowledge in specific areas. The position of an actor within the network determines the likelihood that knowledge flows have an economically successful impact. In this process, direct relations are as relevant for the innovation process as indirect second- or third-degree relations, which can develop a variety of knowledge sources or partnerships.

One way for ranking organisations in the European landscape is to count the number of projects they participate in. However, participating in many projects is not sufficient for being a decisive player. We also take into account centrality, a measure of how well actors are connected (Wassermann and Faust 1994). We select four different centrality measures (accounting for local and global connectedness, the ability to control information flow in the network and the connectedness to other central nodes), and combine them to a *composite centrality ranking* (see Section 2.2).

Degree centrality shows to what extent an actor is integrated into a network by the number of direct links to other actors. The stronger the integration of an actor within a network through direct connections, the higher is his experience in co-operations and his ability to extract information from these direct contacts (local reach) and consequently is ability of exert power over the network.

Having many connections surely affords influence and power, but not all connections are the same. Typically, connections to actors who are themselves well connected (high degree) will provide actors with more influence than connections to poorly connected (low degree) actors. *Eigenvector centrality* thus accords each vertex a centrality that depends both on the number and quality of its connections by examining all vertices in parallel and assigning centrality weights that correspond to the average centrality of all neighbours.

Another way to define centrality is based on network paths. Assuming that information takes the shortest paths when spreading in a network, vertices that are at a short distance from any other are likely to receive them more quickly than more distant vertices. This idea is quantified by the *closeness centrality*. Actors, which are connected by shortest paths to all other actors, have the possibility to quickly spread information within the network (global reach).

Based on the same logic, the *betweenness centrality* measures the frequency of one actor positioned on the shortest path between other groups of actors arranged in pairs. If an actor is located at many links between other actors, he/she can more easily access information within the network, manipulate this information and distribute it. Those actors who are located on the shortest paths between many actors therefore hold a key position for controlling the flow of information within the network (gate keeper function).

In R&D networks, a small number of well-connected organisations can be expected to yield a substantial amount of control over the flow of information. By virtue of their position, such organisations could be called 'core'. Using the number of connections as a criterion, we can identify as 'core' those organisations that had a much higher centrality than the average. Actors with a high number of direct links hold strong collaborative experience and dispose of direct access to different information stocks (local reach).

Drawing data from the EUPRO database, we firstly identify the top 100 core network nodes (organisations with much larger degree centrality than the average) for FP1 to FP6; secondly we identify the top 100 key players, as the organisations that have the highest level of participation in FP1 to FP6, and thirdly we rank the top 100 central organisations (organisations with highest centrality values measured by the composite indicator.

Top 100 core organisations

Core organisations by organisation type

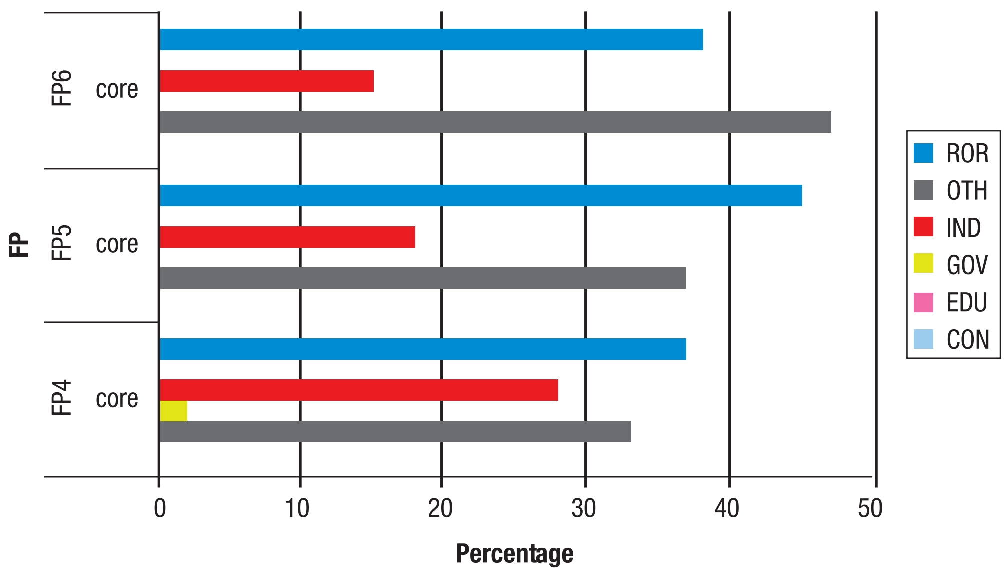
Table 4 and Figure 3 present a distribution of the top 100 core nodes by organisation type. We observe that from FP1 to FP6 educational

Table 4: Distribution of top 100 core organisations by organisation type, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	core	all	core	all	core	all	core	all	core	all	core	all
CON	1	1.1	1	1.8	0	2.2	0	2.3	0	2.8	0	1.7
EDU	35	27.6	28	27	49	26.8	33	16.9	37	16.8	47	22.3
GOV	1	3	7	3.9	0	4.4	2	4.7	0	4.3	0	3.9
IND	32	42.8	26	40.7	24	41.7	28	53.1	18	43.2	15	34.6
OTH	0	2.2	1	2.8	0	3.2	0	6	0	15.7	0	17.3
ROR	31	23.1	37	23.2	27	20.7	37	16.4	45	16.5	38	19.6

Note: Explanation of abbreviations, see in Annex

Figure 3: Percentages of type of core organisations by organisation type and FP programme



institutions and research organisations accounted for the greatest proportion of core organisations. Contrarily, industrial and government organisations have a comparatively lower percentage of core organisations. The percentage of core organisations from industry has decreased over time. Consultancy and organisations of type 'other' had no or only negligible representation among core organisations. Educational organisations were dominant among core organisations in FP6 with 48 per cent of participations, followed closely by research organisations with 38 per cent. Taken together these two types of organisations accounted for 85 per cent of core organisations.

Core organisations by countries

Table 5 and Figure 4 present a distribution of the top 100 core nodes (core organisations) by countries. Whereas France, Germany, the United Kingdom and Italy accounted for the bulk of core organisations in FP1, their relative position declined over time. It is interesting to note that while France was the dominant country among core organisations in FP1, from FP2 onwards the United Kingdom took the lead. New member states are particularly underrepresented among core organisations, with organisation from only Poland, Hungary and Cyprus making it to the top 100. Among associated states, the presence of Swiss organisations in the core group is notable (3 per cent in FP6), with only minimal representation from Norway and Turkey.

Core organisations by returning actors and new entrants

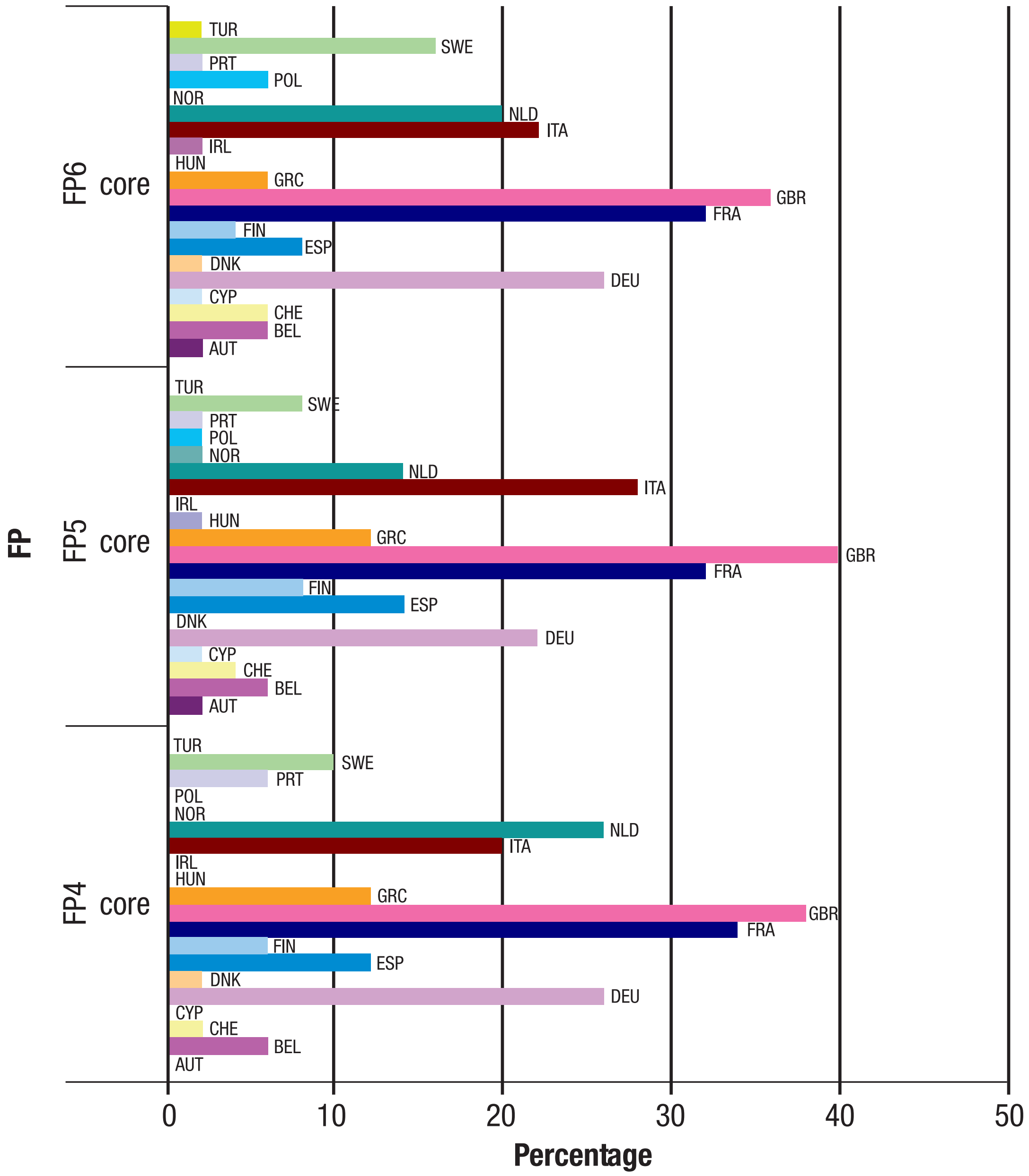
The percentage of organisations belonging to the group of returning actors (i.e. which have taken part in previous FPs) and the percentage of organisations belonging to the group of new entrants were calculated. Of those they reported

Table 5: Distribution of top 100 core organisations by countries, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	core	all	core	all	core	all	core	all	core	all	core	all
AUT	0	0.1	0	0.8	0	1.2	0	2.6	1	2.8	1	3
BEL	10	5.8	10	5.2	6	4.7	3	4.4	3	3.7	3	3.9
CHE	0	0.2	0	1.5	0	1.4	1	1.5	2	1.9	3	2.4
CYP	0	0	0	0	0	0	0	0.1	1	0.3	1	0.3
DEU	16	17.7	16	16.8	12	16.9	13	15.2	11	14.6	13	13.7
DNK	4	5.1	2	4.2	2	3.7	1	2.7	0	2.6	1	2.5
ESP	1	6.4	6	8.2	3	8.4	6	7.6	7	8.3	4	7.4
FIN	0	0.5	1	1.1	1	1.2	3	2.3	4	2.2	2	2
FRA	27	19	18	16.9	18	14.7	17	11.5	16	10.4	16	9.6
GBR	15	16.7	18	13.8	20	12.8	19	13.3	20	11.4	18	9.4
GRC	3	3.2	2	3.8	7	4.3	6	3.5	6	3.3	3	2.6
HUN	0	0	0	0	0	0.1	0	0.6	1	1.2	0	1.7
IRL	1	2.9	3	2.3	2	2.4	0	1.9	0	1.4	1	1.4
ITA	12	12.6	8	11.7	11	11.2	10	9.1	14	9.7	11	8.7
NLD	8	5.5	11	5.7	12	5.4	13	5.8	7	5	10	4.3
NOR	0	0.3	0	1	0	1.3	0	1.5	1	1.7	0	2
POL	0	0	0	0	0	0.1	0	0.7	1	1.6	3	2.7
PRT	3	2.4	3	3.1	4	3.1	3	2.9	1	2.3	1	1.8
SWE	0	0.8	2	2	2	2.2	5	3.7	4	3.1	8	2.9
TUR	0	0	0	0	0	0	0	0.1	0	0.2	1	0.7

Note: For an explanation of abbreviations see Annex.

Figure 4: Percentages of type of core organisations by countries and FP programme



for FP2 to FP6, the percentage of the 100 core organisations belonging to the group of returning actors and percentage of top 100 core organisations belonging to the group of new entrants.

In Table 6, the 100 core organisations are classified as 'old boys'/or 'new entrants'. An organisation is classified as an old boy when it has taken part in any earlier Framework Programme and as a new entrant otherwise. In almost all cases, the core organisations have taken part in earlier FPs (see core column). The exceptions are FP1, where all organisations are new entrants, and FP2, where the great majority of core organisations are already 'old boys'. For comparison purposes, the numbers and percentages of all returning organisations and new entrants are presented (all columns). Each column corresponds to a different FP, with the columns summing up to 100 percent.

As one would expect from such a wide ranging programme as the FP and a limited pool of potential entrants, the overall tendency

Table 6: *Distribution of returning actors and new entrants within the 100 core organisations (%)*

	FP1		FP2		FP3		FP4		FP5		FP6	
	core	all	core	all	core	all	core	all	core	all	core	all
Old Boys	0	0	87	23.3	100	36.9	100	26.5	100	34.6	100	49.4
New Entrants	100	100	13	76.7	0	63.1	0	73.5	0	65.4	0	50.6

(among all organisations) is for progressively fewer new entrants over time. However, we observe that, after FP3, 100 per cent of core organisations have been classified as 'old boys': the pool of core nodes appears to exhibit remarkable stability and has not been renewed in almost two decades.

Further interesting work can be envisaged on this topic. A larger core, perhaps defined as a fraction of the total number of organisations instead of as a fixed number, could be investigated. The stability of the core could be explored by seeing what fraction of organisations remains in the core between FPs, corresponding to a different idea of old boy. This approach has been applied in this study to identify core organisations in themes and instruments in Chapter 5.

Top 100 key player organisations

To identify the key players for ERA is important to qualify the ties in the networks that were built by FP, in order to obtain a strategic perspective on the role that some of the organisations might play in the consolidation and integration of the European Research Area. In fact, the position of an actor within the network might determine his ability to successfully participate in knowledge flows, either through direct or indirect relationships.

Table 7 presents the top 10 key player organisations in the FP in terms of their number of participations. The French CNRS department, Mathematics, Physics, Planet and Universe (MPPU), has been the most active participant, ranking first in every FP, followed by other CNRS departments for the life sciences that rank second since FP4. In fact, academic oriented organisations like CNRS centres and universities are predominant in this ranking. On the contrary, business companies are not so active with the exception of 8 large companies that are part of the rankings, however changing their position from one FP to the other.

Key players by country

The key players are mainly from France, the United Kingdom and Germany. These three countries on average have more than a half of the top 100 key player organisations participating in FP. But smaller countries are also represented in the top 10 as it is the case of Greece, Portugal, Finland and Austria, for example. Two associated countries are also part of the top 10, Switzerland and Turkey (Table 8).

Key players by organisation type

The distribution by organisation type for the top 100 key players confirms the dominance of higher education and research organisations, with a share of 80%. Although industry has an overall higher number of participations in projects, its share in the top 100 is lower, because of its dispersion into many organisations (Table 9).

Table 10 identifies the top 10 organisations in the FPs based on the composite centrality indicator (see Methodology), and shows that CNRS Mathématiques, Physique, Planète et Univers (MPPU) is not only the most active participant but also the most central since FP3, substituting TNO and Siemens which were the most central in FP1 and in FP2. Centrality rankings indicates a decreasing prominence of applied research organisations over time in favour of more basic research organisations.

Table 7: Names of the top 10 key players (organisations by number of participations), FP1-FP6

Rank		Ranking FP1		Ranking FP2		Ranking FP3		Ranking FP4		Ranking FP5		Ranking FP6
1	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)
2	2	BAE Systems PLC	2	Siemens AG (DEU)	2	Biotechnology and Biological Sciences Research Council (BBSRC)	2	CNRS/Sciences du vivant (SDV)	2	CNRS/Sciences du vivant (SDV)	2	CNRS/Sciences du vivant (SDV)
3	3	United Kingdom Atomic Energy Authority (UKAEA)	3	Philips NV (NLD)	3	CNRS/Sciences du vivant (SDV)	3	Thales Group (FRA)	3	FIAT Gruppo	3	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)
4	4	Université Catholique de Louvain	4	BAE Systems PLC	4	Siemens AG (DEU)	4	Biotechnology and Biological Sciences Research Council (BBSRC)	4	Thales Group (FRA)	4	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
5	4	TNO - Netherlands Organisation for Applied Scientific Research	5	CNRS/Sciences du vivant (SDV)	5	Thales Group (FRA)	5	FIAT Gruppo	5	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	5	Thales Group (FRA)
6	6	Biotechnology and Biological Sciences Research Council (BBSRC)	6	United Kingdom Atomic Energy Authority (UKAEA)	6	CNRS/Scientifique Chimie (SC)	6	Natural Environment Research Council (NERC)	6	Biotechnology and Biological Sciences Research Council (BBSRC)	6	FIAT Gruppo
7	7	Imperial College London (ImperialCL)	7	Biotechnology and Biological Sciences Research Council (BBSRC)	7	Natural Environment Research Council (NERC)	7	EADS European Aeronautic Defence and Space Company (FRA)	7	KUL/Faculty of Engineering	7	CEA/Direction de la recherche technologique
8	8	Natural Environment Research Council (NERC)	8	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	8	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	8	Siemens AG (DEU)	8	Siemens AG (DEU)	8	Siemens AG (DEU)
9	9	CNRS/Scientifique Chimie (SC)	9	Natural Environment Research Council (NERC)	9	EADS European Aeronautic Defence and Space Company (FRA)	9	Finmeccanica SPA (ITA)	9	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	9	INSERM/ADR Paris V
10	10	Université Libre de Bruxelles (ULB)	10	Thales Group (FRA)	10	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	10	CU/School of Physical Sciences	9	Natural Environment Research Council (NERC)	10	EADS European Aeronautic Defence and Space Company (DEU)

Table 8: Distribution of top 100 key players (nr participations) by country, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	Top 100	all	Top 100	all	Top 100	all	Top 100	all	Top 100	All	Top 100	all
AUT	0	0.1	0	0.8	0	1.2	0	2.6	0	2.8	1.9	3
BEL	9.4	5.8	7.9	5.2	6	4.7	3	4.4	3	3.7	2.8	3.9
CHE	0	0.2	0	1.5	0	1.4	0	1.5	2	1.9	2.8	2.4
CZE	0	0	0	0	0	0	0	0.5	0	1.2	0.9	1.5
DEU	13.2	17.7	12.9	16.8	12	16.9	13.9	15.2	10.9	14.6	15.1	13.7
DNK	1.9	5.1	2	4.2	2	3.7	2	2.7	2	2.6	0.9	2.5
ESP	1.9	6.4	5.9	8.2	6	8.4	4	7.6	5	8.3	5.7	7.4
FIN	0	0.5	0	1.1	0	1.2	2	2.3	4	2.2	0.9	2
FRA	23.6	19	20.8	16.9	16	14.7	16.8	11.5	18.8	10.4	17	9.6
GBR	19.8	16.7	20.8	13.8	19	12.8	20.8	13.3	19.8	11.4	17.9	9.4
GRC	3.8	3.2	2	3.8	8	4.3	5	3.5	5.9	3.3	2.8	2.6
IRL	3.8	2.9	2	2.3	2	2.4	1	1.9	1	1.4	0	1.4
ITA	11.3	12.6	8.9	11.7	12	11.2	7.9	9.1	8.9	9.7	10.4	8.7
NLD	8.5	5.5	12.9	5.7	12	5.4	15.8	5.8	10.9	5	11.3	4.3
NOR	0	0.3	0	1	4	1.3	1	1.5	2	1.7	0	2
POL	0	0	0	0	1	0.1	0	0.7	0	1.6	2.8	2.7
PRT	2.8	2.4	3	3.1	0	3.1	2	2.9	1	2.3	0.9	1.8
SWE	0	0.8	1	2	0	2.2	5	3.7	5	3.1	4.7	2.9
TUR	0	0	0	0	0	0	0	0.1	0	0.2	0.9	0.7

Table 9: Distribution of top 100 key players (nr participations) by organisation type, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	Top100	all	Top100	all	Top100	all	Top100	all	Top100	all	Top100	all
Higher Education	43.4	27.6	31.7	27.0	44.0	26.8	34.7	16.9	38.6	16.8	37.7	22.3
Research Organisations	34.0	23.1	38.6	23.2	36.0	20.7	41.6	16.4	42.6	16.5	44.3	19
Industry	20.8	42.8	25.7	40.7	20.0	41.7	23.8	53.1	18.8	43.2	17.9	34.6
Government	1.9	3.0	2.0	3.9	0.0	4.4	0.0	4.7	0.0	4.3	0.0	3.9
Consultants	1.0	1.1	1.0	1.8	0.0	2.2	0.0	2.3	0.0	2.8	0.0	1.7
Other	0.0	2.2	1.0	2.8	0.0	3.2	0.0	6.0	0.0	15.7	0.0	17.3

Table 10: *Names of top 10 central organisations (composite indicator), FP1-FP6*

Rank	Ranking FP1		Ranking FP2		Ranking FP3		Ranking FP4		Ranking FP5		Ranking FP6	
1	1	TNO - Netherlands Organisation for Applied Scientific Research	1	Siemens AG (DEU)	1	CNRS/Mathématiques, Physique, Planète et univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et univers (MPPU)	1	CNRS/Mathématiques, Physique, Planète et univers (MPPU)
2	2	Imperial College London (ImperialCL)	2	BAE Systems PLC	2	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	2	Thales Group (FRA)	2	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	2	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)
3	3	Université Catholique de Louvain	3	Philips NV (NLD)	3	Siemens AG (DEU)	3	FIAT Gruppo	3	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	3	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
4	3	Risø National Laboratory	4	CNRS/Mathématiques, Physique, Planète et univers (MPPU)	4	Philips NV (NLD)	4	EADS European Aeronautic Defence and Space Company (FRA)	4	FIAT Gruppo	4	CNRS/Sciences du vivant (SDV)
5	5	CNRS/Mathématiques, Physique, Planète et univers (MPPU)	5	Bull SA (FRA)	5	OU/Mathematical, Physical, & Life Sciences Division	4	Siemens AG (DEU)	5	CNRS/Sciences du vivant (SDV)	5	CEA/Direction de la recherche technologique
6	6	United Kingdom Atomic Energy Authority (UKAEA)	6	Alcatel-Lucent (FRA)	6	CNRS/Sciences du vivant (SDV)	6	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	6	Thales Group (FRA)	6	FIAT Gruppo
7	7	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	7	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	7	SotonU/Faculty of Engineering, Science and Mathematics	7	Finmeccanica SPA (ITA)	7	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	7	Siemens AG (DEU)
8	8	HHG/Forschungszentrum Jülich (FZJ)	8	EADS European Aeronautic Defence and Space Company (FRA)	8	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	8	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	8	Siemens AG (DEU)	8	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)
9	9	Universiteit Twente	9	INESC ID Lisboa	9	BAE Systems PLC	9	BAE Systems PLC	9	KUL/Faculty of Engineering	9	Consiglio Nazionale delle Ricerche (CNR)
10	10	Natural Environment Research Council (NERC)	10	Thales Group (FRA)	9	ImperialCL/Faculty of Engineering	10	DaimlerChrysler AG (DEU)	10	DaimlerChrysler AG (DEU)	9	Thales Group (FRA)

Table 11: Distribution of top 100 central organisations (centrality) by country, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	Top 100	all	Top 100	all	Top 100	all	Top 100	all	Top 100	all	Top 100	all
AUT	0.0	0.1	0.0	0.8	0.0	1.2	0.0	2.6	1.0	2.8	2.0	3.0
BEL	9.0	5.8	7.0	5.2	8.0	4.7	5.0	4.4	3.0	3.7	2.0	3.9
CHE	0.0	0.2	0.0	1.5	0.0	1.4	1.0	1.5	2.0	1.9	3.0	2.4
CZE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	0.3	1.0	0.3
DEU	15.0	17.7	18.0	16.8	13.0	16.9	13.0	15.2	11.0	14.6	14.0	13.7
DNK	3.0	5.1	2.0	4.2	2.0	3.7	0.0	2.7	0.0	2.6	1.0	2.5
ESP	2.0	6.4	3.0	8.2	3.0	8.4	6.0	7.6	4.0	8.3	6.0	7.4
FIN	0.0	0.5	1.0	1.1	1.0	1.2	2.0	2.3	4.0	2.2	2.0	2.0
FRA	26.0	19.0	20.0	16.9	18.0	14.7	19.0	11.5	17.0	10.4	16.0	9.6
GBR	17.0	16.7	22.0	13.8	19.0	12.8	21.0	13.3	20.0	11.4	19.0	9.4
GRC	4.0	3.2	5.0	3.8	7.0	4.3	6.0	3.5	7.0	3.3	4.0	2.6
IRL	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.6	1.0	1.2	0.0	1.7
ITA	3.0	2.9	2.0	2.3	2.0	2.4	0.0	1.9	1.0	1.4	0.0	1.4
NLD	11.0	12.6	6.0	11.7	11.0	11.2	11.0	9.1	15.0	9.7	11.0	8.7
NOR	7.0	5.5	10.0	5.7	11.0	5.4	9.0	5.8	7.0	5.0	6.0	4.3
POL	0.0	0.3	0.0	1.0	0.0	1.3	0.0	1.5	1.0	1.7	0.0	2.0
PRT	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.7	1.0	1.6	3.0	2.7
SWE	3.0	2.4	3.0	3.1	4.0	3.1	3.0	2.9	1.0	2.3	1.0	1.8
TUR	0.0	0.8	1.0	2.0	1.0	2.2	4.0	3.7	4.0	3.1	8.0	2.9

Table 12: Distribution of top 100 central organisations (centrality) by organisation type, FP1-FP6 (%)

	FP1		FP2		FP3		FP4		FP5		FP6	
	Top 100	all	Top 100	all	Top 100	all	Top 100	all	Top 100	all	Top 100	all
Higher Education	42.0	27.6	34.0	27.0	50.0	26.8	31.0	16.9	39.0	16.8	50.0	22.3
Research organisations	29.0	23.1	35.0	23.2	26.0	20.7	37.0	16.4	45.0	16.5	35.0	19.6
Industry	27.0	42.8	27.0	40.7	23.0	41.7	30.0	53.1	17.0	43.2	15.0	34.6
Government	1.0	3.0	2.0	3.9	1.0	4.4	2.0	4.7	0.0	4.3	0.0	3.9
Consultants	1.0	1.1	1.0	1.8	0.0	2.2	0.0	2.3	0.0	2.8	0.0	1.7

Top 100 central organisations

Central organisations by country

Like in the key players organisations, France, the United Kingdom and Germany have on average around 50% of the most central organisations, but their share has decreased from around 58% in FP 1 to 49% in FP 6, having had lower shares in FP3 and FP5. Norway and the Netherlands are relevant countries too with high shares of central organisations (Table 11).

Central organisations by organisation type

Contrary to organisation ranks by participation, it is evident from Table 12 that the three major sectors higher education, research institutes and industry have important shares in the top 100. This result might indicate that these three poles are almost equally important in the collaborative networks of research built by the FPs - at least until FP5. Nevertheless, the higher education remains the sector with more central organisations in almost all FPs, with the exception of FP4 and FP 5.

Chapter 4: Thematic networks and their functions

4.1 Network metrics for selected themes and instruments

In view of knowledge-related exchange processes within inter-organisational networks, there are theoretically and empirically grounded assumptions that thematic areas of the Framework Programmes differ systematically with respect to their collaboration network structures. An indication as to the type of activity involved can often be deduced from a project's thematic area and instrument or a combination of both. In this section, we therefore focus on the thematically more coherent sub-programme level and select various sub-networks to explore such differences in global network structure.

This section presents the properties of the organisation networks in different thematic priorities and different instruments (CSC/STREP, IP and NoE). The definitions of the various network metrics discussed here and the rationale for the selection of themes and instruments are provided in the section 2.3.

We employ two types of metrics here: first, we present the evolution of network properties of CSC/STREP from FP4 to FP6 programmes and in the four thematic priorities. Second, we compare the properties of networks in the new instruments introduced in FP6 (IP and NoE) across the four thematic priorities.

Networks properties of CSC/STREP

In Table 13 the network structures of the thematic sub-programme AEROSPACE are summarised. Only the sub-networks in Aerospace differ in some respects and show, especially for FP4 and FP5, even highly intensified clustering: The number of participating organisations compared to other thematic priorities is smaller (number of vertices), but the mean number of partners in FP4 (27) and FP5 (58) as well as the clustering coefficient

Table 13: Structural features of the Aerospace theme networks for the CSC/STREP instrument across FP4, FP5 and FP6.

Graph Characteristic	AERO_4_CSC	AERO_5_CSC	AERO_6_STREP
No. of vertices N	321	801	620
No. of edges M	4,354	23,463	5,993
No. of components	1	1	3
N for largest component	321	801	607
Share of total N (%)	100.0	100.0	97.90
M for largest component	4,354	23,463	5,995
Share of total M (%)	100.0	100.0	99.37
N for 2nd largest component	0	0	8
M for 2nd largest component	0	0	56
Mean clustering coefficient	0.85	0.89	0.87
Diameter of largest component	3	4	6
Characteristic path length of largest component	2.10	2.16	2.63
Mean degree	27.13	35.33	23.87
Fraction of N above the mean (%)	27.73	35.33	23.87
Mean vertex size	3.06	2.34	1.86
Standard deviation	5.57	4.71	2.84

Table 14: Structural features of the Energy and Environment theme networks for the CSC/STREP instrument across FP4, FP5 and FP6.

Graph Characteristic	AERO_4_CSC	AERO_5_CSC	AERO_6_STREP
No. of vertices N	321	801	620
No. of edges M	4,354	23,463	5,993
No. of components	1	1	3
N for largest component	321	801	607
Share of total N (%)	100.0	100.0	97.90
M for largest component	4,354	23,463	5,995
Share of total M (%)	100.0	100.0	99.37
N for 2nd largest component	0	0	8
M for 2nd largest component	0	0	56
Mean clustering coefficient	0.85	0.89	0.87
Diameter of largest component	3	4	6
Characteristic path length of largest component	2.10	2.16	2.63
Mean degree	27.13	35.33	23.87
Fraction of N above the mean (%)	27.73	35.33	23.87
Mean vertex size	3.06	2.34	1.86
Standard deviation	5.57	4.71	2.84

Table 15 Structural features of the Information and Communication Technologies theme networks for the CSC/STREP instrument across FP4, FP5 and FP6.

Graph Characteristic	ICT_4_CSC	ICT_5_CSC	ICT_6_STREP
No. of vertices N	2,622	5,462	2,393
No. of edges M	12,035	40,299	15,952
No. of components	34	29	3
N for largest component	2,489	5,304	2,376
Share of total N (%)	94.93	97.11	99.29
M for largest component	11,772	39,903	15,888
Share of total M (%)	97.81	99.02	99.60
N for 2nd largest component	12	16	9
M for 2nd largest component	132	72	72
Mean clustering coefficient	0.82	0.82	0.84
Diameter of largest component	11	8	9
Characteristic path length of largest component	3.77	3.44	3.39
Mean degree	9.18	14.76	13.33
Fraction of N above the mean (%)	25.97	25.94	27.12
Mean vertex size	1.91	2.07	1.67
Standard deviation	3.14	3.68	2.09

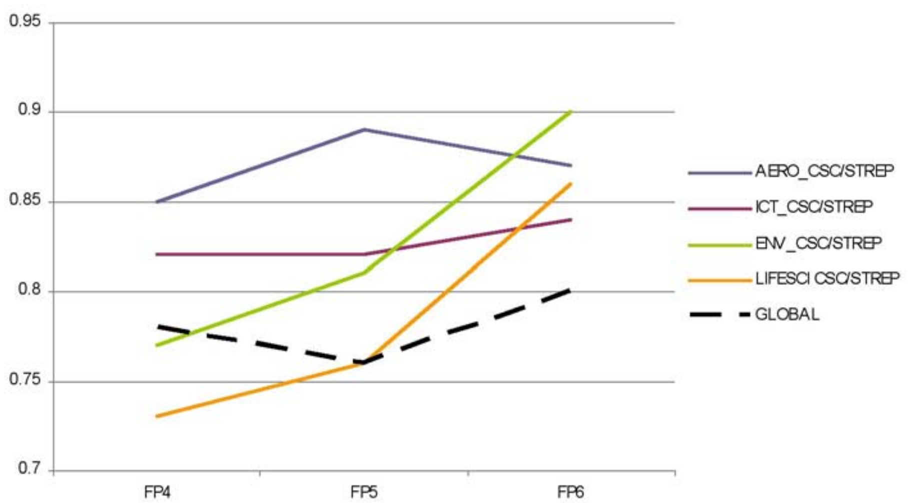
in each FP is significantly higher. Additionally, the network consists of one single component comprising all participants in Aerospace projects.

Table 14 to Table 16 present the structural properties of thematic sub-programmes ENV (Energy and Environment), ICT (Information and Communication Technologies) and LIFESCI (Life sciences). These networks show quite similar properties compared to the FP organisation networks in general. In each sub-network a giant component consists of the majority of

Table 16: Structural features of the Life Sciences theme networks for the CSC/STREP instrument across FP4, FP5 and FP6.

Graph Characteristic	LIFESCI_4_CSC	LIFESCI _5_CSC	LIFESCI _6_STREP
No. of vertices N	1,473	2,335	746
No. of edges M	13,407	23,243	4,685
No. of components	7	3	2
N for largest component	1,458	2,311	743
Share of total N (%)	98.98	98.97	99.60
M for largest component	13,395	23,150	4,682
Share of total M (%)	99.91	99.60	99.94
N for 2nd largest component	3	17	3
M for 2nd largest component	6	144	6
Mean clustering coefficient	0.73	0.76	0.86
Diameter of largest component	7	7	6
Characteristic path length of largest component	2.89	2.92	3.05
Mean degree	18.20	19.91	12.56
Fraction of N above the mean (%)	25.93	27.62	31.23
Mean vertex size	3.14	2.59	1.54
Standard deviation	5.77	4.39	1.67

Figure 5: Mean clustering coefficient across themes in the CSC/STREP instrument over time



nodes (94-100%) and each of the sub-networks shows small world network characteristics: high clustering coefficient (between 0.65 and 0.80) and a small characteristic path length (~3). Again, the clustering coefficient indicates increased clustering from FP4 to FP6 in most of the thematic priorities and the decreasing mean vertex size *P* shows that organisations tend to participate in FP6 in a smaller number of projects than in previous projects.

Looking at the evolution of the clustering coefficient across themes for the CSC/STREP instrument (Figure 5), we observe that organisations

Table 17: Characteristics of the organisation projection of FP four thematic priorities in Integrated Projects (IP)

Graph Characteristic	AERO_6_IP	ENV_6_IP	ICT_6_IP	LIFESCI_6_IP
No. of vertices N	595	1953	2119	917
No. of edges M	16,630	47,658	41,885	15,370
No. of components	1	2	1	2
N for largest component	595	1,936	2,119	909
Share of total N (%)	100.00	99.13	100.00	99.13
M for largest component	16,630	47,522	41,885	15,342
Share of total M (%)	100.00	99.71	100.00	99.82
N for 2nd largest component	0	17	0	8
M for 2nd largest component	0	272	0	56
Mean clustering coefficient	0.89	0.88	0.87	0.83
Diameter of largest component	4	5	4	4
Characteristic path length of largest component	2.05	2.61	2.56	2.33
Mean degree	55.90	48.80	39.53	33.52
Fraction of N above the mean (%)	38.32	28.67	29.87	30.75
Mean vertex size	1.56	1.47	1.69	1.75
Standard deviation	1.59	1.26	2.17	1.98

Table 18: Characteristics of the organisation projection of FP four thematic priorities in Networks of Excellence (NoE)

Graph Characteristic	AERO_6_NOE	ENV_6_ NOE	ICT_6_ NOE	LIFESCI_6_ NOE
No. of vertices N	43	449	914	568
No. of edges M	394	10,905	24,231	17,158
No. of components	1	1	1	1
N for largest component	43	449	914	568
Share of total N (%)	100	100	100	100
M for largest component	394	10,905	24,231	17,158
Share of total M (%)	100	100	100	100
N for 2nd largest component	0	0	0	0
M for 2nd largest component	0	0	0	0
Mean clustering coefficient	0.95	0.94	0.86	0.88
Diameter of largest component	2	5	4	3
Characteristic path length of largest component	1.53	2.41	2.24	2.03
Mean degree	18.33	48.57	53.02	60.42
Fraction of N above the mean (%)	53.49	43.88	37.64	29.93
Mean vertex size	1.14	1.18	1.58	1.50
Standard deviation	0.46	0.51	1.33	1.13

in Environment and Life Sciences have consistently moved towards higher values, an indication of more tightly knit networks and perhaps of closer collaboration. For ICT this tendency only applies to the move from FP5 to FP6 and is less pronounced.

As observed earlier, the evolution of clustering in Aerospace differs considerably though. After a notable increase from FP4 to FP5, unlike the other themes (as well as the FP as a whole), the move to FP6 was marked by a decrease.

Figure 6: *Number of vertices N, FP6*

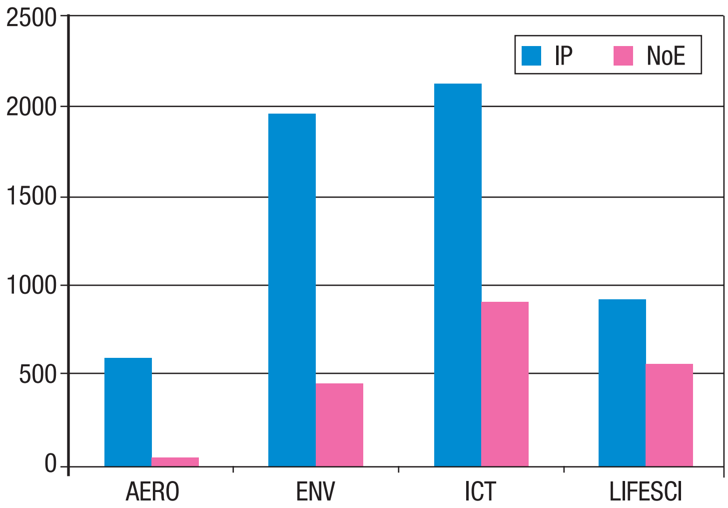
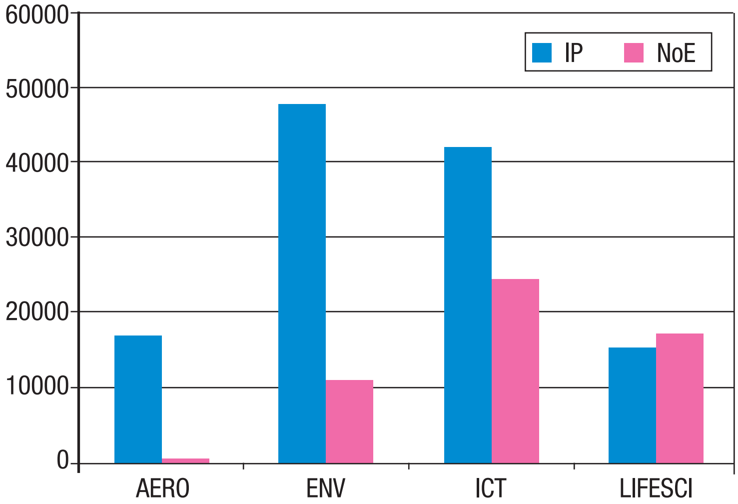


Figure 7: *Number of edges M, FP6*



As a general observation, it is apparent that for CSC/STREP, a principally industry-oriented instrument, the tendencies have not always coincided with those prevalent across the FP, demonstrating that the customisation of instruments can have an observable effect on the dynamics of emerging networks.

Network properties of IP and NoE in FP 6

Table 17 and Table 18 summarise the network features for the instruments IP and NoE in FP6. Such comparison is limited to FP6 because the above mentioned instruments were first introduced in it and therefore data are not available for previous FPs.

The differences between instruments showed in Table 17 and Table 18 correspond to different project sizes. Integrated Projects and Networks of Excellence involve large projects with many participants; therefore the mean number of partners per organisation (mean degree) as well as the clustering coefficient in these networks is higher than in networks based on projects of instrument Cost Shared Contracts (CSC and STREP).

After a closer examination of the differences across themes in terms of the number of vertices and number of edges, the behaviour of organisations in Life Sciences clearly stands out (Figure 6 and Figure 7). The theme exhibits a high edges/vertices ratio regardless of instrument. The greater number of edges in NoE than IP in this theme is probably a reflection of the intense participation of non-industrial actors.

As a general observation, the various differences highlighted support the view that both themes and instruments exert some influence on collaboration structures.

4.2 Instrumental functions of themes

Each project in the FP runs under certain contractual provisions referred to as instruments. The EURPO database contains 16 different instruments, e.g. Shared-Cost Actions or Thematic Networks. With respect to the instrumental functions of thematic sub-programmes, we use the following analytical framework. Instruments are taken to be manifestations of a function of the project intended by R&D policy. Thus, the 'instrumental function' of a project is defined as its instrument and – using policy documents – an exploratory and an exploitative component is assigned to its activities (European Commission 2003).

In the case of FP5, we select three prominent instruments – according to their expected ability to differentiate the programmes with respect to exploration-exploitation, the ease of attribution of a network-related function, and last but not least due to limited resources. It has to be emphasised that this somewhat arbitrary choice is merely made in order to show the applicability of the method, and that an exhaustive analysis should include all instruments. The selected instruments are Cost Shared Contracts (CSC), Thematic Networks (THN), and Cooperative Research Contracts (CRC):

Under CSC, we consider the Shared-Cost Actions, collaborative RTD projects with the aim of obtaining new knowledge, demonstration projects with the aim of showing the viability of new technologies, and support measures for access to research infrastructures. They require a minimum of two partners.

Thematic Networks (THN) aim at co-ordinating a group ('cluster') of projects funded at the community, national or private level, or at establishing and developing general networking activities which can contribute significantly to achieving the objectives of the FP (European Commission 2000b).

The group of instruments subsumed under CRC comprises specific actions for SMEs, namely Cooperative research projects (CRAFT), that enable small and medium-sized enterprises (SME) unable to do research work themselves to either entrust the resolution of their common technological problems to third legal entities with appropriate research capacities or to jointly try to resolve them. A minimum of three SMEs is required.

For FP6, the attributions of instrumental functions to the instruments are taken from the Instrument description issued by the European Commission and from related communication documents (European Commission, 2003). For similar reasons as argued above, we pick Integrated Projects (IP), Specific Targeted Research Projects (STREP), Networks of Excellence (NoE), and Co-operative Research and Collective Research activities (CRC) in FP6:

Integrated Projects (IP) are a new instrument in FP6 devoted to basic as well as applied objective-driven research with a 'programme approach.' IP are expected to assemble the necessary critical mass of activities, expertise and resources to achieve ambitious objectives. In practice, organisations with skills in management, dissemination and knowledge transfer, as well as potential users and other stakeholders, are recommended, as well as a project size of 10-20 participants.

Specific Targeted Research Projects (STREP) represent the former Shared-Cost Actions and comprise objective driven research of limited scope, focused on a single issue. Projects are to be smaller than IP (6-15 participants; monodisciplinary). SMEs usually state a clear preference for this instrument.

Networks of Excellence (NoE) are also a new instrument in FP6 and are designed to strengthen scientific and technological excellence on a focused research topic. NoE are therefore an instrument aimed at tackling fragmentation of existing research capacities and aim at gathering research centres, universities, research and technology organisations, and to a lesser extent enterprises. 6-12 participants are recommended.

CRC subsumes the horizontal research activities for SMEs in FP6, including Cooperative Research and Collective Research activities. RTD performers (e.g. research centres, universities, etc.) conduct research on behalf of industrial associations or groupings to expand the knowledge base of large communities of SMEs, improving their general standard of competitiveness. Participation of two independent industrial associations/groupings, or one European industrial association/grouping is required, as well as a core group of at least two eligible SMEs, and at least two RTD performers.

These instruments have been categorised in a simple way using a two-dimensional scheme referring to the extent of exploration-orientation on the one hand, and exploitation-orientation on the other hand. In doing this, we combine two well-known notions from literature: First, Stokes (1997) introduced a categorisation of R&D activities with respect to the quest for fundamental understanding and the degree of usability. Second, in organisation science, March (1991) distinguishes the twin notions exploration and exploitation as options for firms and individuals to strengthen their competitive position. In the context of performing R&D, the relation between the exploration of new possibilities and the exploitation of old certainties can be applied to complementary strategies for generating innovations. Following the instrument descriptions above, we assign a high degree of exploration orientation to the Thematic Networks and the Networks of Excellence and a low degree of exploitation-orientation. The Cost-Shared Contracts and Integrated Projects are assumed to entail both high exploration and high exploitation-orientation, while the SME-oriented instruments (CRC) are expected to show high exploitation- and low exploration-orientations (Table 19).

Using this categorisation of the instruments, it is possible to assign an instrumental function to a thematic programme by simply aggregating the instrumental function of the projects running under this programme. The composition of the FP5 sub-programmes in terms of instruments (based on the number of projects) is shown in Table 20. In this case, all sub-programmes with the exception of the Direct Action (JRC) – these projects are labelled with a special instrument

Table 19: Exploration- vs. exploitation-orientation of instrument types in FP5 and FP6

		Exploitation-orientation	
		low	**high**
Exploration-orientation	**high**	THN (FP5) NoE (FP6)	CSC (FP5) STREP (FP6) IP (FP6)
	low		CRC (FP5) CRC (FP6)

Notes: CSC=cost shared contracts, THN=thematic network contracts, CRC=cooperative research contracts, STREP=specific targeted research project, IP=integrated project, NoE=Network of excellence; CRC=cooperative research contracts.

Table 20: Set-up of FP5 sub-programmes in terms of project types

	Share of instruments types		
FP5 sub-programme	**CSC**	**THN**	**CRC**
IST	very high	high	low
EESD	high	low	Low
GROWTH	high	very high	very high
LIFE	high	high	low
HUMAN	very low	-	very low
INCO	medium	-	very low
SME	very low	-	low

Note: Explanation of abbreviations see Annex

Table 21: Set-up of FP6 sub-programmes in terms of project types

	Share of instrument types			
FP6 sub-programme	**STREP**	**IP**	**NoE**	**CRC**
IST	medium	high	medium	-
AEROSPACE	high	high	low	-
NMP	medium	very high	medium	-
LIFESCIHEALTH	medium	very high	high	-
CITIZENS	medium	low	very high	-
SME	-	-	-	very high
NEST	very high	-	-	-

Note: Explanation of abbreviations see Annex

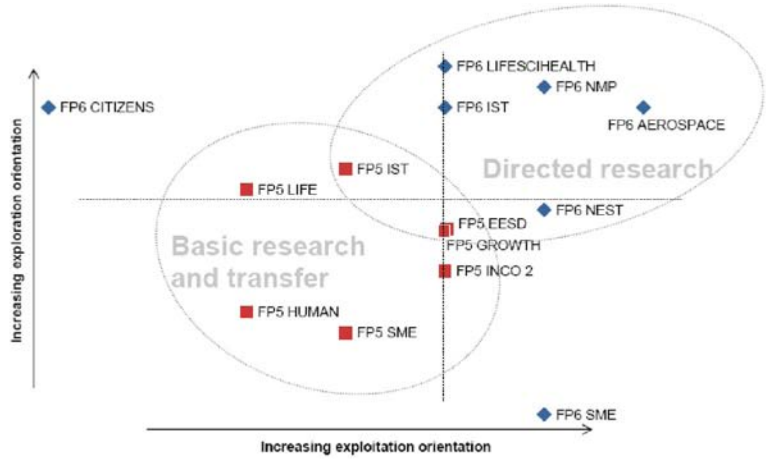
that refers only to the JRC - are included. Based on the number of funded projects that use a certain instrument, we calculated characteristic profiles of the sub-programmes. In order to keep the exploratory analysis simple, the resulting shares were grouped in five categories referring to 'very high', 'high', 'medium', 'low', and 'very low' share of this instrument in the sub-programme.

Likewise, the profiles of FP6 sub-programmes are calculated in terms of instruments. Seven Sub-programmes are included either for reasons of comparability with corresponding sub-programmes in FP5 (e.g. IST, LIFESCIHEALTH), or because they were specific new programmes in FP6 and relevant for the structure/function issue addressed here. The exact shares of instruments are again categorised as shown in Table 21.

By combining the functions (exploration vs. exploitation) assigned to the instruments (Table 19) with the set-up of the thematic sub-programmes (Table 20 and Table 21), we are able to assign an instrumental function to entire sub-programmes. The orientation of an instrument towards a certain function, e.g. exploration, is valued with -1 (low) and +1 (high) respectively. Henceforth, the shares of the different instruments within a sub-programme is valued from 0 (zero share), 1 (low share), up to 5 (very high share). By simple linear combination of these parameters, we obtain a classification of the sub-programmes with respect to their instrumental functions. Figure 5 shows the result of this quantitative analysis of selected FP5 and FP6 sub-programmes.

At first glance, the sub-programmes in FP5 are mutually more similar in terms of their exploration versus exploitation orientation (see Figure 8), as their 'follow-up programmes' in FP6. There are no outliers in FP5, in contrast to FP6. This observation may partly result from the broader thematic orientation of the sub-programmes in FP5, as

Figure 8: Exploration- vs. exploitation-orientation of FP5 and FP6 sub-programmes



Note: The dotted lines represent the median values.

a closer look at the programme descriptions suggests.

The strategic goals are formulated quite broadly. So we group these sub-programmes under one instrumental function and call it 'Basic research and Transfer'. For example, in IST – which in our analysis appears to be the sub-programme with the highest exploration-orientation in FP5 and medium exploitation-orientation – the major strategic goals are to confirm Europe as a leading force in enabling technologies and to meet the need and expectation of high-quality services of general interest. Similarly, the sub-programme LIFE, which scores high in exploration-orientation and relatively low in exploitation-orientation, is targeted at basic research needs and the build-up of a knowledge base within identifiable socio-economic and market needs, like the quality and safety of food, control of infectious diseases, cell research, as well as health and environment. The high scoring programmes in exploitation-orientation are GROWTH and EESD, both with only medium orientation towards exploration. This is also in accordance with the policy goals that stress the problem-solving character of the research. The focus is both on a sustainable innovation effort within European industry, and directly on a number of pressing environmental and energy concerns. The sub-programmes with lowest exploration orientation are HUMAN and SME, while they are also low and medium in exploitation-orientation. This is due to the focus on training and mobility of researchers, access to infrastructures and on strengthening the socio-economic knowledge base on the one hand, and on the transfer and dissemination of technologies on the other. It seems plausible, that this orientation in our categorisation scheme is at the expense of exploratory activities and cutting-edge research.

What we find for the FP6 sub-programmes is more discriminatory in terms of orientation towards exploration or exploitation than for FP5. For example, the programmes CITIZENS and SME are very different from the rest of the selected sub-programmes: CITIZENS (very high exploration orientation, very low exploitation-orientation) is intended to mobilise European research capacities in economic, political, social sciences and humanities, and is – as one would expect – not predestined for exploitative activities. SME, on the other hand, supports European competitiveness, enterprise and innovation policies and funds activities boosting the technological capacities of European SMEs, and is thus quite naturally high in exploitation-orientation and very low in exploration-orientation. The other five sub-programmes selected from FP6 appear rather similar in our scheme, all showing high exploration-orientation and relatively high exploitation orientation.

Among the five remaining FP6 sub-programmes, AEROSPACE obtains the highest degree of exploitation-orientation, which is in accordance with its strong reliance on the European Aeronautics industry and the space technology sector. The highest exploration-orientation together with high exploitation-orientation is attributed to LIFESCIHEALTH, which aims at exploiting breakthroughs achieved in genomics and supporting the European biotechnology industry. Neither IST nor NMP appear in surprising positions: Both programmes are dedicated to the development of leading-edge technologies for the competitiveness of European industry, and thus are both high in exploration- and exploitation-orientation. Somewhat surprising is the horizontal basic research programme NEST, but considering its focused nature with only small research projects (STREP) and the lack of NoE explains that its exploration-orientation is only medium. Hence we attribute the instrumental function 'Directed research'. As Figure 8 suggests, this category mostly entails strong governance by industry, thus it is plausible that this function also applies to the FP5 sub programmes IST, EESD, and GROWTH.

Summing up, the instrumental function of FP sub-programmes is revealed from the orientation of the different instruments towards the knowledge exploration and knowledge exploitation activities, and the relative importance of these instruments within the sub-programmes. We find roughly two discernable instrumental functions, namely 'Basic research and Transfer', and Directed research'. Another important finding of this analysis is the increasing specialisation of the sub-programmes in terms of exploration-vs.exploitation-orientation from FP5 to FP6.

4.3 Structural functions of themes

In this section the focus is on the structure of the collaboration networks that have emerged within these sub-programmes and provide some arguments for the suitability of these structures for certain knowledge-related functions. We construct the organisation projection of the collaboration networks associated with the thematic sub-programmes of FP5 and FP6 and present a set of structural parameters that characterise their global structural features (Table 22 and Table 23).

Table 22: Structural parameters of R&D collaboration organisation networks in the European Framework Programmes (FP5) by theme

Graph Characteristic	IST	EESD	GROWTH	LIFE	HUMAN	INCO2	SME
No. of vertices N	8,296	6,181	8,829	5,392	2,514	1,974	496
No. of edges M	90,906	77,330	130,335	59,838	19,503	12,118	3,236
No. of components	150	105	280	243	14	46	23
N for largest component	7,844	5,894	8,119	4,874	2,466	1,751	358
Share of total N (%)	94.6	95.4	92	90.4	98.1	88.7	72.2
M for largest component	90,159	76,959	129,482	59,438	19,388	11,597	2,701
Share of total M (%)	99.2	99.5	99.3	99.3	99.4	95.7	83.5
N for 2nd largest component	12	8	12	9	10	12	20
M for 2nd largest component	132	44	112	72	90	72	380
Mean clustering coefficient	0.8	0.8	0.8	0.7	0.8	0.9	0.9
Diameter of largest component	10	8	8	8	8	13	9
Characteristic path length of largest component	3.4	3.2	3.2	3.2	3.5	4.3	3.3
Mean degree	21.9	25	29.5	22.2	15.5	12.3	13
Fraction of N above the mean (%)	22.6	27.8	25.9	25.7	31.1	27.2	29
Mean vertex size P	2.2	2.3	2	2.5	2.1	1.5	1.4
Standard deviation of P	4	4	3.8	4.8	3	1.2	1.3

Table 23: Structural parameters of R&D collaboration organisation networks in the European Framework Programmes (FP6) by theme

Graph Characteristic	IST	AERO SPACE	NMP	LIFESCI HEALTH	CITIZENS	SME	NEST
No. of vertices N	4,745	1,135	2,678	1,838	979	2,463	400
No. of edges M	88,511	22,682	41,614	38,554	14,427	18,113	1,470
No. of components	5	5	3	13	4	50	19
N for largest component	4,718	1,116	2,667	1,813	965	1,955	289
Share of total N (%)	99.4	98.3	99.6	98.6	98.6	79.4	72.3
M for largest component	88,429	22,637	41,589	38,533	14,397	15,715	1,184
Share of total M (%)	99.9	99.8	99.9	99.9	99.8	86.8	80.5
N for 2nd largest component	9	8	6	5	7	30	13
M for 2nd largest component	72	56	30	12	42	258	84
Mean clustering coefficient	0.82	0.88	0.87	0.81	0.87	0.96	0.93
Diameter of largest component	6	4	6	5	6	12	10
Characteristic path length of largest component	2.8	2.37	2.84	2.45	2.63	4.6	4.19
Mean degree	37.31	39.97	31.08	41.95	29.47	14.71	7.35
Fraction of N above the mean (%)	27.8	35.1	35.5	27.9	36.2	32.5	22.3
Mean vertex size P	2.24	2.02	1.61	2.27	1.59	1.15	1.21
Standard deviation of P	3.97	3.68	1.75	3.66	1.38	1.07	0.62

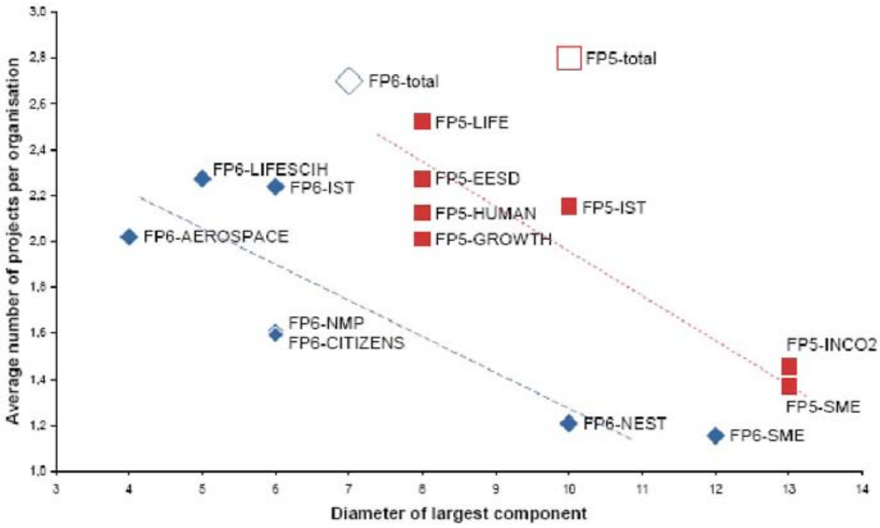
A first comparison of FP5 and FP6 networks reveals several differences on the programme as well as on the sub-programme level. The time-lag in data capture on the programme level leads to considerably fewer projects and organisations in our FP6 networks, which we have to take into account when we interpret size-dependent structural parameters. Moving to the sub-programme level, we also observe large differences in network size due to the different budgets devoted to the thematic programmes. For example, in the field of Information Society Technologies (FP6-IST) a total budget of 3,984 million Euros was available, while in the programme for New and Emerging Technologies (FP6-NEST) 215 million Euro were foreseen. Thus, the network in FP6-NEST comprises only 400 organisations while the FP6-IST network involves 4,745 organisations, and in FP5, the GROWTH programme comprises no less than 8,829 organisations.

While the number of projects per organisation remains virtually the same in FP5 and FP6, the diameter of the network is significantly smaller in FP6. This is, of course related with network size, but also due to the fact that projects in FP6 are on average larger in terms of participants, so that network connectivity is higher than in FP5. Moreover, Figure 9 shows that the sub-programmes differ greatly in the degree of involvement of organisations in EU research: the number of projects that a single organisation participates in (see also 'Mean vertex size P' in Table 22 and Table 23) is much lower in SME-oriented programmes than, e.g. in IST programmes. This explains the lower connectivity in the SME programmes and the larger diameter of these sub-programme networks. SMEs, INCO partners or basic research actors in the NEST programme are more likely one-time participants, which leads to low global connectivity.

In the context of information and knowledge flows, is highly important that multiple project participation and large projects reduce the average distance in the network, and increase the potential of information exchange between these organisations.

As a next step, we focus on the potential of different network structures for knowledge

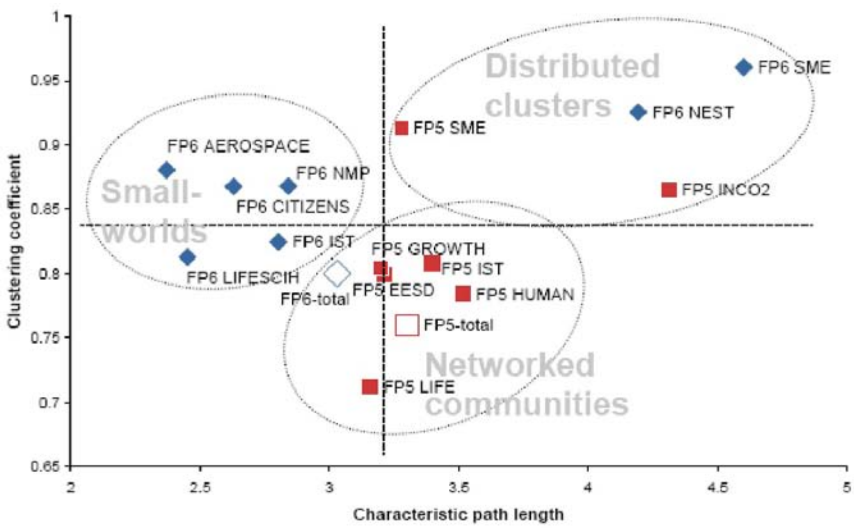
Figure 9: Individual involvement and network connectivity in FP5 and FP6 sub-networks (organisation projection)



diffusion, and use the clustering coefficient and the average distance of the networks as dimensions of analysis. We find three different groups of network structures, 'small-worlds', 'distributed clusters', and 'networked communities', and we try to associate them with different knowledge related functions (structural functions). First, we follow Cowan and Jonard (2004), who test different network structures with respect to their suitability for the diffusion of knowledge. They use the Watts-Strogatz (1998) model and simulate knowledge diffusion on the network as a barter process of knowledge exchange among the network partners. The result of their analysis is that the so-called small-world structures allow for a faster diffusion process than regular lattices or random networks. Small world networks are networks with high clustering and low characteristic path lengths.

Small-worlds: We calculate these two parameters and find the FP6 network slightly more small-world-like than the FP5 network. Its characteristic path length is smaller and

Figure 10: A structural classification of FP5 and FP6 sub-networks (organisation projection)



its clustering coefficient is larger. On the sub programme level, this difference is even more distinctive: Especially, the sub-networks FP6-AEROSPACE, FP6-CITIZENS, and FP6-NMP explicitly show the small-world feature: They have an above-median clustering coefficient and a characteristic path length that is well below the median value of all sub-programmes. But also FP6-IST and FP6-LIFESCIHEALTH may be categorised as small-world networks. In the context of our structural functions analysis, we are led to call this group of networks 'small-worlds' (Figure 10). According to the high clustering, we can attribute to these small-worlds a high potential to jointly perform exploitation-oriented, thematically focused R&D activities, and also the ability to diffuse knowledge efficiently all over the network.

Distributed clusters: In contrast, FP6-NEST and FP6-SME show much higher characteristic path lengths, although their clustering coefficient is substantially high. The same is true for FP5-SME and FP5-INCO2. These networks exhibit local clusters weakly interlinked. Thus we categorise these four sub-programmes as 'distributed clusters' (Figure 10). Diffusion is well supported in these network structures, but with a limited reach. The focus of activity is laid on scientific advancement or efficient transfer of knowledge within the own clique while long-range relations play a minor role.

Networked communities: Data analysis reveals a third group of sub-networks, all emerging from FP5 sub-programmes that are medium in characteristic path-length but considerably lower (below-median) in clustering. Within this group, we find the more industry-oriented programmes FP5-GROWTH, FP5-IST, but also FP5-EESD, and the socio-economic programme FP5-HUMAN. FP5-LIFE exhibits a surprisingly low clustering coefficient, but nevertheless can be categorised as a 'networked community' (Figure 10). As the low clustering stems to a large extent from the smaller size of the projects (in terms of participants), these structures may support focused cutting-edge research, but the general ability to diffuse knowledge may be lower than in the small-worlds.

Summing up, in this section we categorise selected sub-programmes of FP5 and FP6 according to their clustering and connectivity structure, and from this, we attribute a 'structural function' to them. We find three groups of networks, namely the 'small-worlds', the 'distributed clusters', and the 'networked communities'. The small-worlds, with high clustering and low average distances, can be associated with the function of thematically focused, exploitation-oriented R&D, and also the ability to diffuse knowledge efficiently. The distributed clusters, with high clustering and high average distances, can be interpreted as structures supporting the advancement of knowledge and efficient transfer within relatively closed cliques. The networked communities, showing weak internal clustering and medium distances, seem to be best suited for cutting-edge research, but may be less suited for the diffusion and exploitation of knowledge.

4.4 Crossing instruments with themes and typology of networks

Finally, we compare instrumental and structural function of the sub-networks and valuate the degree to which these two characterisations of the sub-programmes conform. It must, however, be emphasised that matching the instrumental and structural functions is closely related with the problem of finding optimal project structures for certain functions – an area of ongoing research. This part of our approach is thus to be seen as exploratory.

Summing up, we observe small world networks (with high clustering and short global distances) in sub-programmes with a strong emphasis on directed research, mostly with industrial character. Distributed cluster

Table 24: Comparison of instrumental and structural functions (FP5 and FP6 sub programmes)

Acronym	Instrumental function	Structural function
FP5 (1998-2002)		
IST	Basic research and transfer, Directed research	Networked community
EESD	Basic research and transfer, Directed research	Networked community
GROWTH	Basic research and transfer, Directed research	Networked community
LIFE QUALITY	Basic research and transfer	Networked community
HUMAN POTENTIAL	Basic research and transfer	Networked community
INCO 2	Basic research and transfer	Distributed clusters
INNOVATION-SME	Basic research and transfer	Distributed clusters
FP6 (2002-2006)		
IST	Directed research	Small world
AEROSPACE	Directed research	Small world
NMP	Directed research	Small world
LIFESCIHEALTH	Directed research	Small world
CITIZENS	Outlier (Exploratory research)	Small world
SME	Outlier (Exploitation of results)	Distributed clusters
NEST	Directed research	Distributed clusters

networks are found in programmes with a strong exploitative component and knowledge transfer functions. More evenly distributed network structures with lower clustering are associated with basic research and broader orientations entailing also transfer activities.

Comparing FP5 to FP6 (Table 24), we observe extensive instrumental and structural change. Specifically, the thematic priorities IST, EESD, GROWTH (FP5) / AEROSPACE (FP6), LIFEQUALITY (FP5) / LIFESCIHEALTH (FP6) changed their instrumental function from basic research and transfer to directed research. The same thematic priorities changed their structural function from networked community to small world type networks. GROWTH/AEROSPACE too exhibits the same instrumental and structural functions.

Chapter 5: Core organisations by themes and instruments in FP4 to FP6

Using the number of connections as a criterion, we can identify 'core' organisations as those that had a much higher degree than the average. These organisations form centrally located and highly interlinked nodes in FP networks that dramatically affect the way a network is connected. To define the core in thematic networks we used in this chapter a fraction (square root) of the total number of organisations in each sub-network.

5.1 Core organisations by countries in themes and instruments

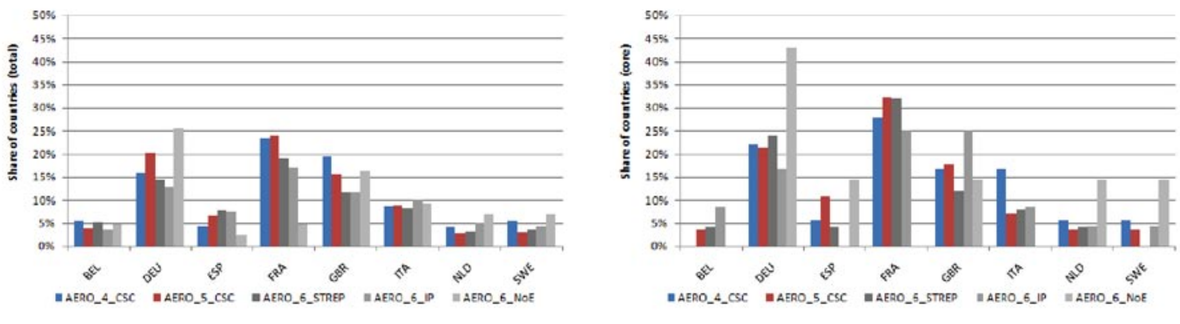
In this section, a more detailed view of core organisations across countries is offered, considering the selected thematic areas and the relevant FP programmes. Table 63 to Table 66 in the Annex show the distribution of core organisations with largest degree (compared to the total number of organisations) in projects of instrument CSC and STREP, in the four selected thematic priorities from FP4 to FP6 (see Methodology). Such step allows the identification of the involvement of different countries in specific topics across FPs.

Additionally, the distribution of core organisations in different instruments in FP6 (STREP, IP, NoE) in the thematic priorities is presented in Table 67 to Table 70 in Annex, which enables to compare the extent of participation of each country in different types of instruments in FP6 that represents the strengthening, integration and structuring of the European Research Area (ERA). Figure 11 to Figure 14 include the most active countries (share above 5% in any of the instruments) in each theme and compares share of organisations in total with the share of core organisations in each theme.

Aerospace

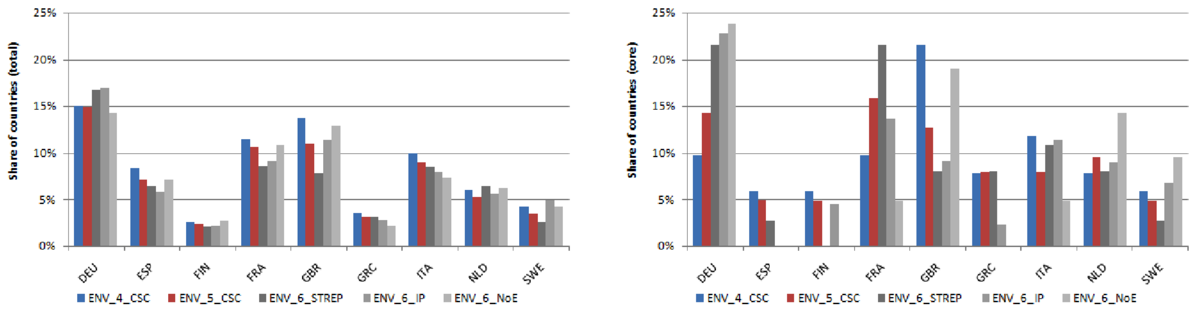
Aerospace shows a strong and stable participation of organisations from France, Germany, and United Kingdom in smaller research projects (CSC, STREP), for FP4 to FP6 (Figure 11). Organisations from Italy represent a high share of core organisations in FP4, but this share decreases in the following FP. With respect to the different instruments in FP6, organisations from France (25%) and United Kingdom (25%) represent one half of the core organisations in Integrated Projects, while core organisations in STREP originate mainly from France (32%) and Germany (24%). Nearly one half of the core organisations in NoE come from Germany (42%). This is in contrast to

Figure 11: Distribution of organisations and core organisations by countries in FP4 to FP6 by countries and theme (AERO)



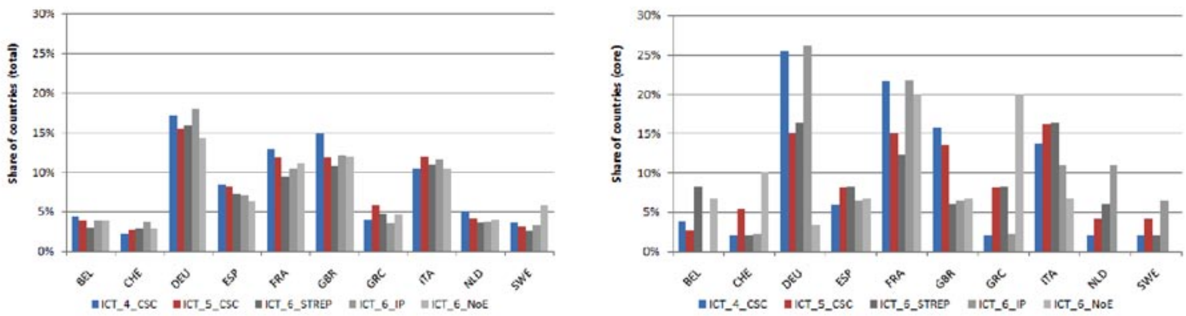
Note: Explanation of abbreviations see Annex

Figure 12: Distribution of organisations and core organisations by countries in FP4 to FP6 by countries and theme (ENV)



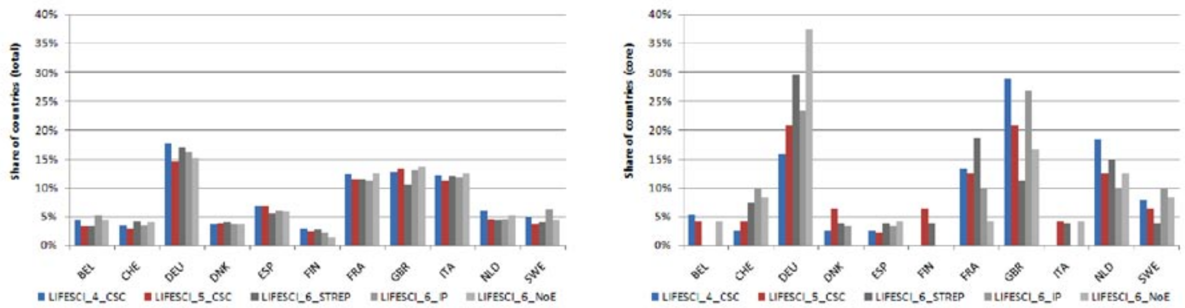
Note: Explanation of abbreviations see Table 62 Annex

Figure 13: Distribution of core organisations in FP4 to FP6 by countries and theme (ICT)



Note: Explanation of abbreviations see Annex

Figure 14: Distribution of core organisations in FP4 to FP6 by countries and theme (LIFESCI)



Note: Explanation of abbreviations see Annex

the general trend where the United Kingdom is dominant among core organisations.

Energy and Environment

In FP4, Energy/Environment is characterised by a strong attendance of core organisations from United Kingdom (21.6%), which declines significantly in the following FPs (Figure 12). Only in FP6 NoE projects organisations from the United Kingdom hold a high share. On the contrary, an increasing importance of organisations from Germany and France can be observed in this topic in the later FPs, especially as core organisations in STREP. Increased interest in this topic can be observed for organisations from Netherlands and

Sweden (share of organisations above average). This is consistent with the overall representation of core organisations from these two countries: they were among a small group of older member states (together with Germany) whose overall share increased in FP6.

ICT

In ICT, German (25.5%) and French organisations (21.6%) represent a high share of core organisations in FP4, but their share decreases in the following FPs in CSC and STREP (Figure 13). Instead of attending small research projects, French organisations concentrate on large IP (21.7% of core organisations) and NoE (20% of core organisations). The declining share of organisations from Germany and France is complemented by an increasing share of Italian (core) organisations (16%). Organisations from Greece show increased activities in ICT (share of core organisations above average in NoE and STREP).

Life Sciences

Finally, Life Sciences can be characterised by a growing number of core organisations from Germany (esp. in NoE) (Figure 14). Organisations from the United Kingdom show a strong but decreasing participation in small research projects, but a high share of core organisations in IP and NoE - comparable to France in ICT. Life Sciences appear as research topic of increased interest for organisations from Netherlands, Sweden and Switzerland, that represent a significant share of core organisations; Italy participates in Life Science projects frequently, but only few organisations collaborate with many different partners (i.e. only few core organisations).

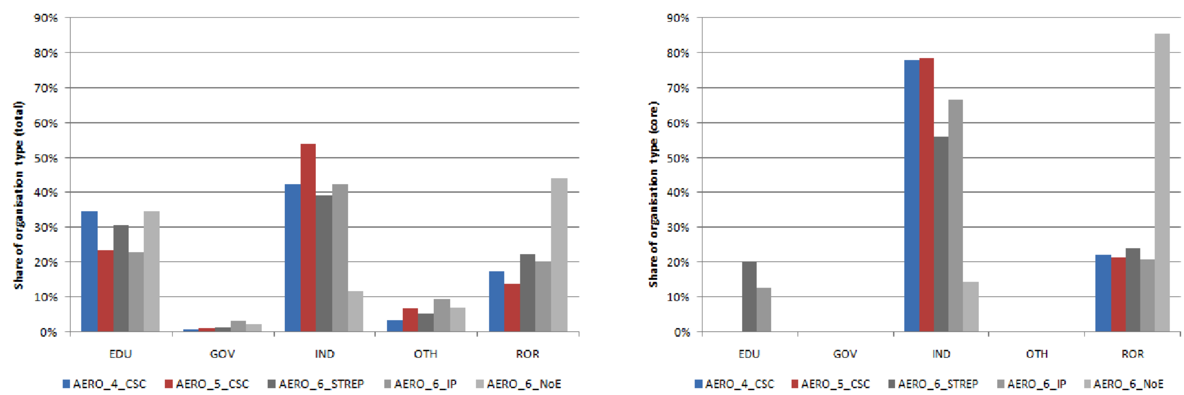
5.2 Core organisations by organisation type in themes and instruments

Tables 75 to 78 in the Annex present the distribution of core organisations, in terms of organisation type, in projects of instrument CSC/STREP in four selected thematic priorities from FP4 to FP6. The extent to which (core) organisations from science and industry participate in different topics corresponds to underlying technological regimes and allows for the characterisation of thematic sub networks. The following figures compare the share of organisations in total with the share of core organisations in each theme and instrument.

Aerospace

Aerospace in general can be described as an industry-university topic, which is lead by companies (Figure 15). It shows a strong involvement of industry partners in CSC, STREP and

Figure 15: Distribution of core organisations in FP4 to FP6 by organisation type and theme (AERO)



Note: Explanation of abbreviations see Annex

IP, but not in NoE, which are designed to strengthen scientific and technological excellence on a focused research topic, and show in all thematic priorities a strong participation of universities and research organisations. Companies constitute the highest share of core organisations in Aerospace (nearly 80% in FP4 and FP5) with a significant decrease in FP6 (56%). Universities participate significantly above average in Aerospace, but none of the core organisations in FP4 and FP5 is a university. Research organisations participate in this topic to a lesser extent, but represent a quarter of the core organisations. The visualisation of the collaboration structure of the core organisations in Aerospace (Figures 22 to 26 in the Annex) shows that the same research organisations are centrally positioned in each of the networks. They form the connection between two separate communities dominated by companies.

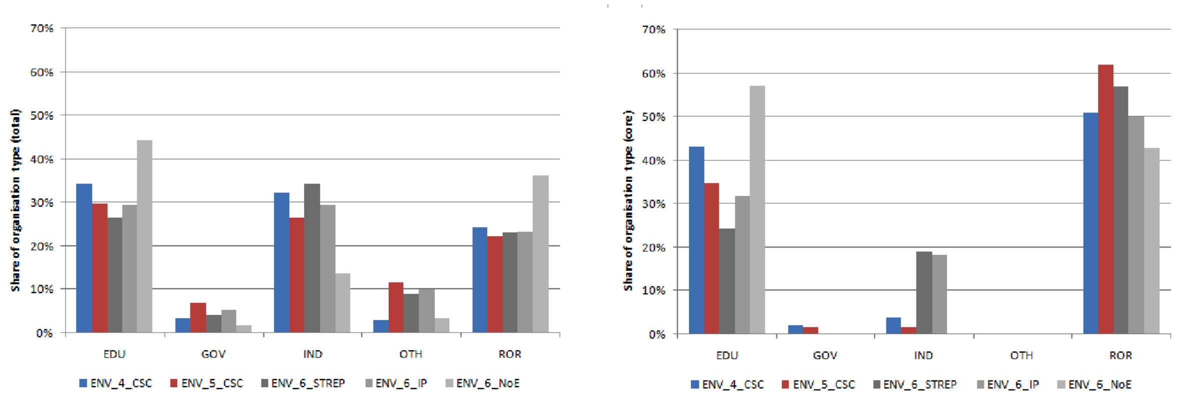
Energy and Environment

In Energy/Environment (Figure 16) research organisations hold the highest and constant share of core organisations. More than half of all organisations with a high number of different collaboration partners turn out to be research organisations. Because of the strong involvement of universities (especially in NoE), this topic can be characterised as a science based topic (research-university topic), lead by research organisations. This topic shows a smaller share of participating core organisations from industry, but these are increasingly connected directly with many other organisations in FP6 instruments. The visualisation of the network of core organisations in this topic (Figures 27 to 31 in the Annex) demonstrates a rather balanced collaboration between research organisations and universities in CSC/STREP projects. The British Ministry of Defence plays a central role in FP4 and FP5, but is not a member of the core organisations in any of the instruments in FP6. In contrast, companies are tightly connected in the FP6 IP networks and form a separate community, the NoE networks are constituted by two communities: one dominated by universities and the other by research organisations.

ICT

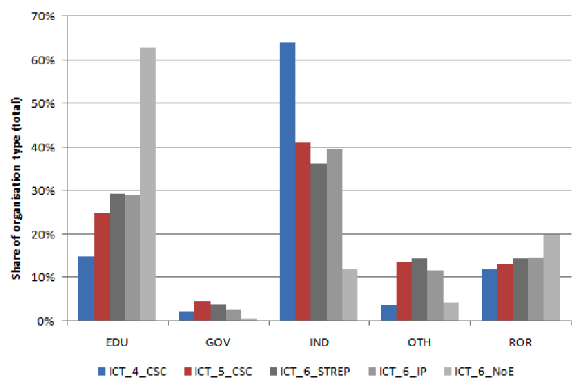
In ICT (Figure 17), especially in FP4, companies are in general strongly involved in projects. As compared to Aerospace, this topic presents a strong participation of industry (especially in IP), of universities (especially in NoE) and an increased share of research organisations in the group of core organisations. Governmental organisations and due to the increasing importance of universities in the group of core organisations, this topic can be characterised as industry-university topic with university lead. The network visualisation (Figures 32 to 36 in the Annex) indicates that companies are centrally positioned in CSC projects in FP4 and FP5 as well as in FP6 IP projects, whereas

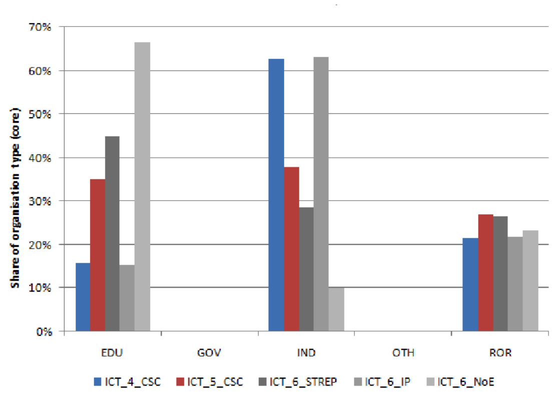
Figure 16: Distribution of core organisations in FP4 to FP6 by organisation type and theme (ENV)



Note: Explanation of abbreviations see Annex

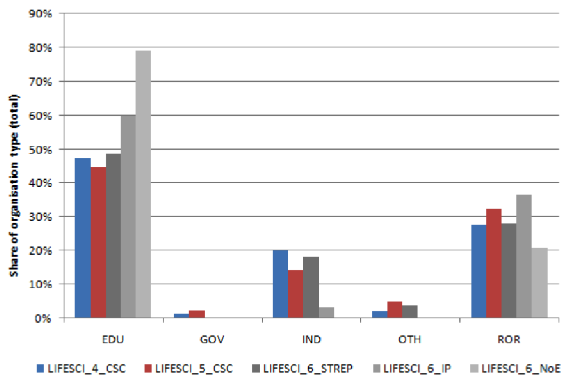
Figure 17: Distribution of core organisations in FP4 to FP6 by organisation type and theme (ICT)

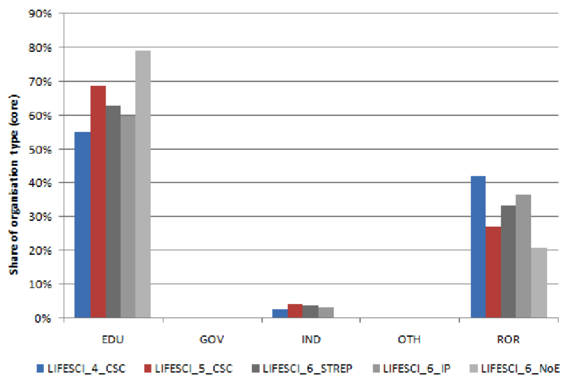




Note: Explanation of abbreviations see Annex

Figure 18: Distribution of core organisations in FP4 to FP6 by organisation type and theme (LIFESCI)





Note: Explanation of abbreviations see Annex

collaboration between core organisations from science and industry seem to be more balanced in FP6 STREP projects.

Life Sciences

Finally, Life Science is the topic with the highest participation of universities and research organisations (Figure 18). Compared to other topics, Life Science exhibits the smallest share of core organisations from industry. The visualisation of the network of core organisations in this topic (Figures 37 to 41 in the Annex) shed light on the role of research organisations in Life Science. Their share is lower in all instruments and FPs than the share of universities; nevertheless research organisations constitute the centre of nearly all collaboration networks. The FP6 NoE networks are an exception. In this case all core organisations are evenly strongly connected with each other.

Chapter 6: Key player organisations and universities by themes and instruments in FP5 and FP6

In this section we calculate the ranks of key organisations based on their level of participation in the four selected priorities - Aerospace, Energy & Environment, ICT and Life Sciences - crossed with the three selected instruments, the two new ones, IP and NoE, and the typical instrument of FPs, the STREP for FP5 and FP6. Then the ranks are specifically calculated for the universities in FP 6 in the same selected areas and instruments.

Ideally, an analysis of the position of key organisations and universities in networks should be based on measures of centrality rather than participation. However this information could not be produced given the resource limitations of the study. Nevertheless, there are good reasons to expect that such rankings can provide relevant information. Many research organisations, particularly large and important ones, participate in several projects. The frequency of their participation can be expected to be related to their thematic specialisation. Therefore for a given thematic priority and/or a combination of thematic priorities and instruments, the number of participations may provide valuable information as to the specialisation and strategic orientation (basic/applied – exploratory-/exploitation-oriented).

However the precise position of individual organisations should not be overemphasised. First, the participation to the FP is not necessarily a reflection of specialisation or strategic orientation – lack of national sources of funding and other factors could be strong motivators. Second, the ranks are used here as a summary device (intended to reduce the amount of information extracted and assist in its analysis), not as some sort of contest, and should not therefore be used for direct comparisons. The intention is rather to find out more about the general characteristics of organisations involved in each subprogramme and infer broad patterns about the recent evolution of the ERA.

Organisations and universities were ranked in each thematic priority crossed by type of instrument, in terms of their number of participations in projects. Even without a rank by centrality, it is possible to position the most active organisations and universities in the four thematic priorities and understand their preferences in terms of instruments. With this approach it is also possible to know the choices taken by each actor in terms of their positioning in the coordination of research and technology development through the take up of the two new instruments or in collaborative research with the STREP instrument in the four thematic priorities.

6.1 Key player organisations by themes and instruments

Aerospace

In the thematic priority Aerospace, due to its highly specialised nature, one would expect a relatively small number of actors and relatively little change over time. Indeed, some industrial (Airbus, EADS), public (DLR, CNR, CNRS) and academic actors are present in the top positions in both FP5 and FP6 (Table 25 and Table 26). The various parts of Airbus and EADS dominate the top positions. With the exception of small differences in ranks, the pool of participants remained relatively stable over the two FPs examined here. The pool of industrial actors is relatively small and is constrained to a handful of relatively large manufacturers who can afford the high capital costs associated with the sector. No universities appear in the top ranks for FP5, whereas only two universities (University of Patras and University of Cranfield) make it to the top 20 in FP6.

Table 25: Top 20 key player organisations in FP5 in the thematic priority of Aerospace

Rank	Organisation	Number of participations in FP5 GROWTH/ Aeronautics
1	National Aerospace Laboratory (NLR)	64
2	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	60
3	AIRBUS SAS (FRA)	47
4	Airbus SAS (DEU)	46
5	Defence Evaluation and Research Agency (DERA)	41
5	EADS European Aeronautic Defence and Space Company (DEU)	41
7	EADS European Aeronautic Defence and Space Company (FRA)	36
8	MTU Aero Engines GmbH	34
9	Airbus SAS (GBR)	32
9	Thales Group (FRA)	32
11	BAE Systems plc	31
12	Finmeccanica SPA (ITA)	30
13	Centro Italiano Ricerche Aerospaziale, Italian Aerospace Research (CIRA)	29
14	Rolls-Royce plc (GBR)	26
15	Airbus SAS (ESP)	20
15	Rolls-Royce plc (DEU)	20
17	Avio SPA	17
17	Turbomeca SA	17
19	CNRS/Sciences et technologies de l'information et de l'ingénierie (ST2I)	16
19	Dassault Aviation SA	16

Table 26: Top 20 key player organisations in FP6 in the thematic priority of Aerospace

Rank	Organisation	Number of participations in FP6-AEROSPACE
1	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	63
2	EADS European Aeronautic Defence and Space Company (DEU)	60
3	National Aerospace Laboratory (NLR)	41
4	EADS European Aeronautic Defence and Space Company (FRA)	39
5	Thales Group (FRA)	34
6	Airbus SAS (DEU)	33
6	Dassault Aviation SA	33
8	Finmeccanica SPA (ITA)	32
9	AIRBUS SAS (FRA)	29
10	Société Nationale d'Etudes et de Construction de Moteurs d'Aviation (SNECMA)	26
11	Airbus SAS (GBR)	22
12	University of Patras/School of Engineering	19
13	MTU Aero Engines GmbH	18
13	ONERA/Aérodynamique Appliquée	18
13	Rolls-Royce plc (GBR)	18
16	Avio SPA	17
16	BAE Systems plc	17
18	Rolls-Royce plc (DEU)	16
19	Swedish Defence Research Agency (FOI)	15
20	Cranfield University/School of Engineering	14
20	Centro Italiano Ricerche Aerospaziale, Italian Aerospace Research (CIRA)	14
20	Centre de Recherche en Aéronautique, ASBL	14

Table 27: *Top 20 key player organisations in FP5 in the thematic priority Aerospace crossed by the CSC instrument*

Rank	Organisation	Nr of participations in FP5 GROWTH/ Aeronautics and CSC
1	National Aerospace Laboratory (NLR)	54
2	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	51
3	Airbus SAS (DEU)	42
4	AIRBUS SAS (FRA)	37
5	Defence Evaluation and Research Agency (DERA)	34
6	MTU Aero Engines GmbH	31
7	Airbus SAS (GBR)	30
7	EADS European Aeronautic Defence and Space Company (DEU)	30
9	EADS European Aeronautic Defence and Space Company (FRA)	29
10	Centro Italiano Ricerche Aerospaziale, Italian Aerospace Research (CIRA)	26
11	BAE Systems Plc	24
12	Rolls-Royce plc (GBR)	23
13	Finmeccanica SPA (ITA)	22
14	Airbus SAS (ESP)	19
14	Thales Group (FRA)	19
16	Rolls-Royce plc (DEU)	17
16	Avio SPA	17
18	Turbomeca SA	16
19	Société Nationale d études et de Construction de Moteurs d Aviation (SNECMA)	13
19	Dassault Aviation SA	13

Table 28: *Top 20 key player organisations in FP6 in the thematic priority of Aerospace crossed by instrument IP*

Rank	Organisation	Number of participations in FP6-AEROSPACE and IP
1	National Aerospace Laboratory (NLR)	16
2	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	15
3	AIRBUS SAS (FRA)	13
4	EADS European Aeronautic Defence and Space Company (DEU)	12
5	EADS European Aeronautic Defence and Space Company (FRA)	11
6	Thales Group (FRA)	10
6	Finmeccanica SPA (ITA)	10
6	Airbus SAS (DEU)	10
9	BAE Systems Plc	8
9	Dassault Aviation SA	8
11	Cranfield University/School of Engineering	7
12	Snecma Group	6
12	EUROCOPTER	6
12	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	6
15	Airbus SAS (GBR)	5
15	Univ. Patras/School of Engineering	5
15	Rolls-Royce plc (GBR)	5
15	MTU Aero Engines GmbH	5
15	ONERA/Aérodynamique Appliquée	5
15	JRC/IES (Institute for Environment and Sustainability)	5

Table 29: Top 20 Key player organisations in FP6 in the thematic priority of Aerospace crossed by instrument NoE

Rank	Organisation	Number of participations in FP6-AEROSPACE and NoE
1	Swedish Defence Research Agency (FOI)	3
1	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	3
3	Defence Evaluation and Research Agency (DERA)	2
3	National Aerospace Laboratory (NLR)	2

Table 30: Top 20 key player organisations in FP6 in the thematic priority of Aerospace crossed by instrument STREP

Rank	Organisation	Number of participations in FP6-AEROSPACE and STREP
1	EADS European Aeronautic Defence and Space Company (DEU)	34
1	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	34
3	Dassault Aviation SA	19
4	Finmeccanica SPA (ITA)	18
4	Airbus SAS (DEU)	18
6	EADS European Aeronautic Defence and Space Company (FRA)	17
7	National Aerospace Laboratory (NLR)	16
8	Airbus SAS (GBR)	12
8	Avio SPA	12
8	Thales Group (FRA)	12
11	Univ. Patras/School of Engineering	11
11	Rolls-Royce plc (GBR)	11
13	Société Nationale d'Études et de Construction de Moteurs d Aviation (SNECMA)	10
13	Rolls-Royce plc (DEU)	10
13	AIRBUS SAS (FRA)	10
16	Centre de Recherche en Aéronautique, ASBL	9
16	CU/School of Technology	9
16	MTU Aero Engines GmbH	9
19	ONERA/ Aérodynamique appliquée	8
19	Centro Italiano Ricerche Aerospaziale, Italian Aerospace Research (CIRA)	8
19	Israel Aircraft Industries Ltd (IAI)	8

When one narrows down FP5 participation to the CSC instrument and comparing against IP and STREP in FP6 a similar picture arises. Comparing the ranks of top organisations across instruments in FP6 shows no obvious differences in the participation profile of different organisation types or countries (Tables 27 to 30).

Energy & Environment

In the thematic priority of Energy and the Environment there appears to be stability in the top 20 between the two FPs. The overall number of participations in FP6 was smaller than FP5. When one considers that FP6 devoted substantially more resources, the small number of participations can be seen as an indication of larger projects. Large public and semi-public research organisations (CNRS, TNO, CNR, CSIC, Fraunhofer, JRC) participate most prominently followed by universities (Stuttgart, UTL). Three UK universities (Imperial, Southampton, Newcastle) are new entrants in the top 20 group for FP6 (Table 31 and Table 32).

Comparing overall FP5 ranks to those for the instrument CSC, the pool of actors does not change much but relative positions do, with large

Table 31: Top 20 key player organisations in FP5 in the thematic priority of Energy and Environment

Rank	Organisation	Number of participations in FP5 EESD
1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	133
2	Natural Environment Research Council (NERC)	100
3	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	56
4	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	53
4	TNO/Built Environment and Geosciences	53
6	Center For Renewable Energy Sources (CRES)	51
7	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	49
8	Uni Stuttgart/Fakultät für Maschinenbau	47
9	ENVIRA/NILU - Norwegian Institute for Air Research (Norsk Institutt for Luftforskning)	46
10	JRC/IES (Institute for Environment and Sustainability)	45
10	FHG/Fraunhofer-Institut für Solare Energiesysteme (ISE)	45
12	CNRS/Sciences du vivant (SDV)	43
13	CSIC/Recursos Naturales	39
14	CNRS/Environnement et Développement Durable	37
15	CEA/Direction des Sciences de la Matière	36
16	CU/School of Physical Sciences	35
17	CNRS/Sciences et technologies de l'information et de l'ingénierie (ST2I)	32
17	HHG/Forschungszentrum Jülich (FZJ)	32
19	Electricité de France (EDF)	31
20	Danish Meteorological Institute (DMI)	30

Table 32: Top 20 key player organisations in FP6 in the thematic priority of Energy and Environment

Rank	Organisation	Number of participations in FP6-SUSTDEV
1	FIAT Gruppo	35
2	Natural Environment Research Council (NERC)	32
3	UTL/Instituto Superior Técnico (IST) (Higher Technical Institute)	29
4	Siemens AG (DEU)	26
5	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	25
6	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	23
7	Alstom (FRA)	21
8	Uni Stuttgart/Fakultät für Maschinenbau	19
8	JRC/IES (Institute for Environment and Sustainability)	19
10	DaimlerChrysler AG (DEU)	18
10	Institut Français du Pétrole (IFP)	18
10	NCL/Faculty of Science, Agriculture and Engineering	18
10	CEA/Direction de la recherche technologique	18
10	Det Norske Veritas A/S (NOR)	18
15	Volvo Group (SWE)	17
15	CNRS/Sciences du Vivant (SDV)	17
17	HHG/Umweltforschungszentrum Leipzig-Halle (UFZ)	16
17	RWTH/Fakultät für Maschinenwesen	16
19	TNO/Built Environment and Geosciences	15
19	ASCZE/Section of Bio-Ecological Sciences	15
19	WGL/Potsdam-Institut für Klimafolgenforschung, Potsdam	15
19	VUA/Faculty of Earth and Life Sciences	15
19	PAS/Division IV Technical Sciences	15
19	HHG/Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)	15

Table 33: Top 20 key player organisations in FP5 in the thematic priority Energy and Environment crossed by the CSC instrument

Rank	Organisation	Number of participations in FP5 EESD and CSC
1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	92
2	Natural Environment Research Council (NERC)	74
3	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	45
4	ENVIRA/NILU - Norwegian Institute for Air Research (Norsk Institutt for Luftforskning)	40
5	Uni Stuttgart/Fakultät für Maschinenbau	35
5	JRC/IES (Institute for Environment and Sustainability)	35
5	CNRS/Environnement et Développement Durable	35
8	TNO/Built Environment and Geosciences	34
9	CEA/Direction des Sciences de la Matière	33
10	CU/School of Physical Sciences	31
11	CNRS/Sciences du vivant (SDV)	30
12	Danish Meteorological Institute (DMI)	29
12	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	29
14	CSIC/Recursos Naturales	28
15	Center For Renewable Energy Sources (CRES)	27
16	CNRS/Sciences et technologies de l'information et de l'ingénierie (ST2I)	26
17	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	25
17	SU/Faculty of Natural Sciences	25
17	Ministry of Defence (UK)/Met Office	25
20	FHG/Fraunhofer-Institut für Solare Energiesysteme (ISE)	24

public organisations faring marginally better in CSC (Table 33). With regard to the ranking of organisations by instrument, there is again a clear distinction between the profile of participation in NoE and IP and STREP. In that respect, the relative ranking of organisations can be seen as indicative of the position of their research (basic vs. more close to the market). In NoE in particular organisations from new member states (Poland and the Czech Republic) are in the top 20. In agreement with the instrument's political expectations, in FP6 IP (Table 34) a number of industrial actors make it to the top 20 (Daimler-Chrysler, Fiat, Volvo, Alstom and Siemens). The picture with regard to industrial participation is similar in FP6 STREP (Table 36), but also with some representation of smaller companies (Cybernetix, BMT).

Table 34: Top 20 key player organisations in FP6 in the thematic priority of Energy and Environment crossed by instrument IP

Rank	Organisation	Number of participations in FP6-SUSTDEV and IP
1	DaimlerChrysler AG (DEU)	13
2	LU/Institute of Technology (LTH)	12
2	RWTH/Fakultät für Maschinenwesen	12
2	FIAT Gruppo	12
2	Natural Environment Research Council (NERC)	12
6	Institut Français du Pétrole (IFP)	11
6	Volvo Group (SWE)	11
6	Alstom (FRA)	11
6	Siemens AG (DEU)	11
10	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	10
10	Uni Stuttgart/Fakultät für Maschinenbau	10
12	JRC/IES (Institute for Environment and Sustainability)	9
12	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	9
12	WUR-ROR/Alterra - Research Institute for the Green World	9
15	VUA/Faculty of Earth and Life Sciences	8
15	HHG/Umweltforschungszentrum Leipzig-Halle (UFZ)	8
17	ImperialCL/Faculty of Natural Sciences	7
17	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	7
17	Air Liquide SA (FRA)	7
17	Electricité de France (EDF)	7
17	Volkswagen AG (DEU)	7
17	CEA/Direction de la recherche technologique	7
17	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente	7
17	Institut National de Recherche sur les Transports et leur Sécurité (INRETS)	7
17	HHG/Forschungszentrum Jülich (FZJ)	7
17	NCL/Faculty of Science, Agriculture and Engineering	7
17	PSI/Research Department General Energy (ENE)	7

Table 35: Top 20 key player organisations in FP6 in the thematic priority of Energy and Environment crossed by instrument NoE

Rank	Organisation	Number of participations in FP6-SUSTDEV and NoE
1	Natural Environment Research Council (NERC)	6
2	UTL/Instituto Superior Técnico (IST) (Higher Technical Institute)	4
3	PAS/Division VII Earth and Mining Sciences	3
3	Chalmers/Department of Applied Mechanics	3
3	Danish Institute for Fisheries Research (DFU)	3
3	KNAW/Science	3
3	Imperial College London (ImperialCL)	3
3	UUpp/Faculty of Science and Technology	3
3	University of Amsterdam/Faculty of Science	3
3	rug.nl/Faculty of Mathematics and Natural Sciences	3
3	HHG/Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)	3
3	Marine Biological Association of the United Kingdom (MBA)	3
3	SZN - Stazione Zoologica 'Anton Dohrn'	3
3	TNO/Defence, Security, Safety	3
3	WUT/Faculty of Power and Aeronautical Engineering	3

Table 36: Top 20 key player organisations in FP6 in the thematic priority of Energy and Environment crossed by instrument STREP

Rank	Organisation	Number of participations in FP6-SUSTDEV and STREP
1	FIAT Gruppo	11
1	HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)	11
3	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	9
4	Siemens AG (DEU)	8
5	CERTH/Chemical Process Engineering Research Institute	7
5	Alstom (FRA)	7
5	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	7
5	CEA/Direction de la recherche technologique	7
5	NTUA/Faculty of Naval Architecture and Marine Engineering	7
10	Uni Stuttgart/Fakultät für Maschinenbau	6
10	CYBERNETIX S.A.	6
10	Det Norske Veritas A/S (NOR)	6
13	British Maritime Technology (BMT) Ltd	5
13	Bureau Veritas S A (FRA)	5
13	Swedish National Road and Transport Research Institut - Statens Väg- och Transportforskningsinstitut (VTI)	5
13	University of Strathclyde /Faculty of Engineering	5
13	HHG/Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)	5
13	NCL/Faculty of Science, Agriculture and Engineering	5

ICT

In the thematic priority ICT there appears to be remarkable stability between FP5 and FP6 (Tables 37 and Table 38). Large public and semi-public research organisations (e.g. Fraunhofer, CNRS) occupy the very top positions, followed by an assortment of highly specialised universities (NTUA, Southampton) and large private companies (Siemens, France Telecom, BT, Intracom, Deutsch.

There are no major differences between overall FP5 participation and participation in the CSC instrument (Table 39). In FP6 the three instruments clearly delineate the participation of industrial and academic actors with, as expected, the first ranking more highly in IP and STREP and the latter in NoE (Table 40, Table 41 and Table 42).

The systematic absence of participants from the new member states in the top rankings is important to note. The situation does not change much when one increases the threshold to the top 100: organisations from new member states are relatively underrepresented and in lower positions to organisations from countries with research systems of comparable size.

Table 37: Top 20 key player organisations in FP5 in the thematic priority of ICT

Rank	Organisation	Number of participations in FP5 IST
1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	147
2	Thales Group (FRA)	97
3	Siemens AG (DEU)	78
4	INRIA/Unité de Recherche Rocquencourt	62
5	France Telecom (FRA)	60
6	Intracom SA	59
7	Philips NV (NLD)	58
8	CEA/Direction de la recherche technologique	57
9	NTUA/Faculty of Electrical and Computer Engineering	55
10	Telecom Italia SPA (ITA)	53
10	FIAT Gruppo	53
12	Infineon Technologies AG (DEU)	47
13	EADS European Aeronautic Defence and Space Company (FRA)	44
13	Soton University/Faculty of Engineering, Science and Mathematics	44
15	British Telecom PLC (BT) (GBR)	43
16	Telefonica de Espana SA	42
17	KUL/Faculty of Engineering	40
18	DaimlerChrysler AG (DEU)	39
18	Deutsche Telekom AG	39
20	Atos Origin (ESP)	38
20	CSIC/Ciencias Y Tecnologia Fisicas	38

Table 38: Top 20 key player organisations in FP6 in the thematic priority of ICT

Rank	Organisation	Number of participations in FP6-IST
1	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	100
2	Thales Group (FRA)	75
3	Telefonica de Espana SA	68
4	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	64
5	Siemens AG (DEU)	61
6	FRANCE TELECOM (FRA)	60
7	CEA/Direction de la recherche technologique	52
8	INRIA/Unite de Recherche Rocquencourt	49
9	NTUA/Faculty of Electrical and Computer Engineering	46
10	Philips NV (NLD)	43
11	FIAT Gruppo	41
12	Telecom Italia SPA (ITA)	37
13	Consiglio Nazionale delle Ricerche (CNR)	36
14	Alcatel-Lucent (FRA)	35
15	Atos Origin (ESP)	33
16	SAP AG	32
17	CNRS/Sciences du vivant (SDV)	30
17	EPFL/School of Engineering (STI)	30
19	IMEC/Microsystems, Components & Packaging (MCP)	29
20	Royal Institute of Technology - Kungliga Tekniska Högskolan(KTH)	26

Table 39: Top 20 key player organisations in FP5 in the thematic priority ICT crossed by the CSC instrument

Rank	Organisation	Number of participations in FP5 IST and CSC
1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	105
2	Thales Group (FRA)	73
3	Siemens AG (DEU)	56
4	France Telecom (FRA)	53
5	Intracom SA	49
6	INRIA/Unité de Recherche Rocquencourt	44
7	NTUA/Faculty of Electrical and Computer Engineering	43
7	Telecom Italia SPA (ITA)	43
9	CEA/Direction de la recherche technologique	40
9	Philips NV (NLD)	40
11	FIAT Gruppo	38
12	SotonU/Faculty of Engineering, Science and Mathematics	35
12	Deutsche Telekom AG	35
14	Atos Origin (ESP)	32
15	Telefonica de Espana SA	31
15	EADS European Aeronautic Defence and Space Company (FRA)	31
15	Nokia Corporation (FIN)	31
18	British Telecom PLC (BT) (GBR)	29
19	EPFL/School of Engineering (STI)	28
19	DaimlerChrysler AG (DEU)	28

Table 40: Top 20 key player organisations in FP6 in the thematic priority of ICT crossed by instrument IP

Rank	Organisation	Number of participations in FP6-IST and IP
1	Telefonica de Espana SA	33
2	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	31
3	Siemens AG (DEU)	29
4	Thales Group (FRA)	27
5	France Telecom (FRA)	26
6	Telecom Italia SPA (ITA)	20
7	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	18
7	Philips NV (NLD)	18
9	SAP AG	17
9	FIAT Gruppo	17
9	NTUA/Faculty of Electrical and Computer Engineering	17
12	INRIA/Unité de Recherche Rocquencourt	16
12	British Telecom PLC (BT) (GBR)	16
14	Alcatel-Lucent (FRA)	15
15	CEA/Direction de la recherche technologique	13
16	Deutsches Forschungszentrum für Künstliche Intelligenz GmbH	12
16	Nokia Corporation (FIN)	12
16	DaimlerChrysler AG (DEU)	12
19	Microsoft Corporation (DEU)	11
19	Consiglio Nazionale delle Ricerche (CNR)	11
19	Deutsche Telekom AG	11
19	EPFL/School of Engineering (STI)	11
19	Motorola INC (FRA)	11

Table 41: *Top 20 key player organisations in FP6 in the thematic priority of ICT crossed by instrument NoE*

Rank	Organisation	Number of participations in FP6-IST and NoE
1	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	21
2	France Telecom (FRA)	12
3	EPFL/School of Engineering (STI)	8
3	KUL/Faculty of Engineering	8
3	INRIA/Unite de Recherche Rocquencourt	8
6	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	7
6	UPC/Departamento de Teoria del Senyal i Comunicacions (TSC) (Signal Theory and Communications Department)	7
6	UNIGE.ch/Faculty of Sciences	7
6	AUTH/Faculty of Engineering	7
10	CEA/Direction de la recherche technologique	6
10	Telefonica de Espana SA	6
10	BME/Faculty of Electrical Engineering and Informatics	6
10	EPFL/School of Computer and Communication Sciences (I&C)	6
10	INSTITUT EURECOM	6
10	Thales Group (FRA)	6
10	SotonU/Faculty of Engineering, Science and Mathematics	6
10	NTUA/Faculty of Electrical and Computer Engineering	6
10	UCL/Ecole Polytechnique de Louvain	6
10	UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)	6

Table 42: *Top 20 key player organisations in FP6 in the thematic priority of ICT crossed by instrument STREP*

Rank	Organisation	Number of participations in FP6-IST and STREP
1	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	50
2	Thales Group (FRA)	27
3	CEA/Direction de la recherche technologique	22
4	Telefonica de España SA	21
5	INRIA/Unite de Recherche Rocquencourt	20
6	Siemens AG (DEU)	19
6	FIAT Gruppo	19
8	NTUA/Faculty of Electrical and Computer Engineering	18
9	Consiglio Nazionale delle Ricerche (CNR)	17
9	IMEC/Microsystems, Components & Packaging (MCP)	17
9	France Telecom (FRA)	17
9	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	17
13	CNRS/Sciences du vivant (SDV)	16
14	Atos Origin (ESP)	14
14	T.X.T. E-Solutions Spa	14
16	University of Southampton (SotonU)	13
16	Philips NV (NLD)	13
18	Katholieke Universiteit Leuven	11
18	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	11
20	UK TH/Forschungszentrum Informatik (FZI)	10
20	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)	10
20	TU Wien/Fakultät für Elektrotechnik und Informationstechnik	10
20	SAP AG	10
20	Universität Stuttgart/University of Stuttgart	10

Life Sciences

In the thematic priority of Life Sciences a group of highly specialised public laboratories and medical schools dominate the top ranks (Table 43 and Table 44). In FP5 France, the Netherlands, Sweden, Spain, Germany and the UK are the countries with most organisations in the top ranks – a profile that does not seem to change appreciably in FP6. It is striking that no industrial actors are to be found in the top ranks, though the reasons for this are not clear. One possible explanation is that the long lead times associated with R&D the industrial sectors concerned (drugs, medical instruments etc.) and the need to closely guard research results make the relatively short-term and collaborative projects of the FP unattractive for such companies. More research will be needed to clarify this.

It is also striking that with one exception (Genome Research Ltd.) no industrial actors make it to the top 20 key player organisations even in the industry-oriented instruments (FP5 CSC, FP6 IP and STREP) (Table 45, Table 46 and Table 48).

Table 43: Top 20 key player organisations in FP5 in the thematic priority of Life Sciences

Rank	Organisation	Number of participations in FP5 LIFE QUALITY
1	CNRS/Sciences du vivant (SDV)	217
2	Biotechnology and Biological Sciences Research Council (BBSRC)	146
3	Medical Research Council (MRC), UK	88
4	INSERM/ADR Paris V	69
4	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	69
6	KUL/Faculty of Engineering	56
7	UCL/Faculty of Biomedical Sciences	51
8	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	50
9	INRA/Centre de Recherche de Paris	45
10	OU/Medical Sciences Division	44
11	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research	42
12	EKUT/Medizinische Fakultät	41
12	EUR/University Medical Centre Rotterdam	41
14	WUR-ROR/Plant Research International	37
15	RUN/University Medical Centre Nijmegen	36
16	LU/Faculty of Medicine	35
16	Institut Francais de Recherche pour l Exploitation de la Mer (IFREMER)	35
16	WUR-EDU/Social Sciences	35
19	WUR-ROR/Animal Sciences Group	34
20	unimi/Facoltà di Medicina e Chirurgia	33
20	UNIMAAS/Faculty of Health, Medicine and Life sciences	33

Table 44: Top 20 key player organisations in FP6 in the thematic priority of Life Sciences

Rank	Organisation	Number of participations in FP6-LIFESCIHEALTH
1	CNRS/Sciences du vivant (SDV)	67
2	INSERM/ADR Paris V	59
3	EMBL Heidelberg	40
4	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	36
5	Medical Research Council (MRC), UK	34
6	OU/Medical Sciences Division	33
7	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	32
8	HHG/Deutsches Krebsforschungszentrum, Heidelberg (DKFZ)	26
9	EUR/University Medical Centre Rotterdam	24
9	UCL/Faculty of Biomedical Sciences	24
11	UUpp/Faculty of Medicine	22
12	RKUH/Medizinische Fakultät Heidelberg	21
13	UZ/Medical Faculty	20
13	INSERM	20
15	HHG/Forschungszentrum für Umwelt und Gesundheit (GSF)	18
15	ImperialCL/Faculty of Medicine	18
15	CU/School of Biological Sciences	18
15	ASCZE/Section of Biological and Medical Sciences	18
19	Charite/Campus Mitte	15
19	KUL/Faculty of Medecine	15
19	UvA/Faculty of Medicine	15
19	HEL/Faculty of Medicine	15
19	RUN/University Medical Centre Nijmegen	15
19	DTU/BioCentrum	15

Table 45: Top 20 key player organisations in FP5 in the thematic priority Life Sciences crossed by the CSC instrument

Rank	Organisation	Number of participations in FP5 LIFE QUALITY and CSC
1	CNRS/Sciences du vivant (SDV)	118
2	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	53
3	INSERM/ADR Paris V	48
4	Medical Research Council (MRC), UK	47
5	Biotechnology and Biological Sciences Research Council (BBSRC)	45
6	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	34
7	KUL/Faculty of Engineering	30
8	UCL/Faculty of Biomedical Sciences	27
9	OU/Medical Sciences Division	26
9	EKUT/Medizinische Fakultät	26
11	UZ/Medical Faculty	25
12	RUN/University Medical Centre Nijmegen	23
12	Karolinska Institutet	23
12	LU/Faculty of Medicine	23
12	EUR/University Medical Centre Rotterdam	23
16	UTU/Faculty of Medicine	22
17	KI/Department of Neuroscience	21
17	CU/School of Biological Sciences	21
19	HEL/Faculty of Medicine	20
19	rug.nl/Faculty of Mathematics and Natural Sciences	20
19	CNRS/Mathématiques, Physique, Planète et Univers (MPPU)	20
19	ImperialCL/Faculty of Medicine	20
19	LMU/Medizinische Fakultät	20
19	HHG/Forschungszentrum für Umwelt und Gesundheit (GSF)	20

Table 46: Top 20 key player organisations in FP6 in the thematic priority of Life Sciences crossed by instrument IP

Rank	Organisation	Number of participations in FP6-LIFESCIHEALTH and IP
1	INSERM/ADR Paris V	27
2	CNRS/Sciences du vivant (SDV)	26
3	Medical Research Council (MRC), UK	17
4	EMBL Heidelberg	16
5	OU/Medical Sciences Division	15
6	HHG/Deutsches Krebsforschungszentrum, Heidelberg (DKFZ)	11
6	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	11
8	UCL/Faculty of Biomedical Sciences	10
8	UZ/Medical Faculty	10
8	UUpp/Faculty of Medicine	10
8	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	10
12	ASCZE/Section of Biological and Medical Sciences	9
12	Genome Research Ltd	9
14	Charite/Campus Mitte	8
14	HHG/Forschungszentrum für Umwelt und Gesundheit (GSF)	8
14	HHG/Max-Delbrück-Centrum für Molekulare Medizin (MDC)	8
17	ImperialCL/Faculty of Medicine	7
17	The Netherlands Cancer Institute - Antoni van Leeuwenhoek Ziekenhuis (NKI-AvL)	7
17	EUR/University Medical Centre Rotterdam	7
17	RUN/University Medical Centre Nijmegen	7

Table 47: Top 20 key player organisations in FP6 in the thematic priority of Life Sciences crossed by instrument NoE

Rank	Organisation	Number of participations in FP6 LIFESCIHEALTH and NoE
1	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	9
1	Medical Research Council (MRC), UK	9
1	EMBL Heidelberg	9
4	CNRS/Sciences du vivant (SDV)	8
5	ImperialCL/Faculty of Medicine	7
5	OU/Medical Sciences Division	7
5	INSERM/ADR Paris V	7
5	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	7
9	EUR/University Medical Centre Rotterdam	6
9	Fondazione Centro San Raffaele del Monte Tabor	6
11	INSERM	5
11	Karolinska Institutet	5
11	LMU/Medizinische Fakultät	5
11	KUL/Faculty of Medecine	5
11	CU/School of Biological Sciences	5
16	LU/Faculty of Medicine	4
16	UNIGE.ch/Faculty of Sciences	4
16	UniBe/Medizinische Fakultät - Faculty of Medicine	4
16	ASCZE/Section of Biological and Medical Sciences	4
16	UCL/Faculty of Biomedical Sciences	4
16	DTU/BioCentrum	4
16	RUN/Faculty of Science	4
16	RKUH/Medizinische Fakultät Heidelberg	4
16	GAG/Medizinische Fakultät	4
16	UHH/Fachbereich Medizin	4
16	UUpp/Faculty of Medicine	4
16	Charite/Campus Mitte	4
16	WWUM/Medizinische Fakultät	4

Table 48: Top 20 key player organisations in FP6 in the thematic priority of Life Sciences crossed by instrument STREP

Rank	Organisation	Number of participations in FP6-LIFESCIHEALTH and STREP
1	CNRS/Sciences du vivant (SDV)	25
2	INSERM/ADR Paris V	20
3	EMBL Heidelberg	14
4	RUL/Leiden University Medical Centre (LUMC)/Faculty of Medicine of RUL	12
5	CSIC/Biologia Y Biomedicina (Biology and Biomedicine)	11
6	INSERM	10
6	HHG/Deutsches Krebsforschungszentrum, Heidelberg (DKFZ)	10
8	HEL/Faculty of Medicine	9
9	OU/Medical Sciences Division	7
9	HHG/Forschungszentrum für Umwelt und Gesundheit (GSF)	7
9	rug.nl/Faculty of Medical Sciences	7
9	RKUH/Medizinische Fakultät Heidelberg	7
13	UZ/Medical Faculty	6
13	INSERM/ADR Paris VI	6
13	EUR/University Medical Centre Rotterdam	6
13	DTU/BioCentrum	6
13	UCL/Faculty of Biomedical Sciences	6
18	ALUF/Fakultät für Medizin	5
18	RUN/Faculty of Science	5
18	Federation Nationale des Centres de Lutte Contre le Cancer (FNLCC)	5
18	Fondazione Telethon	5
18	UUpp/Faculty of Medicine	5

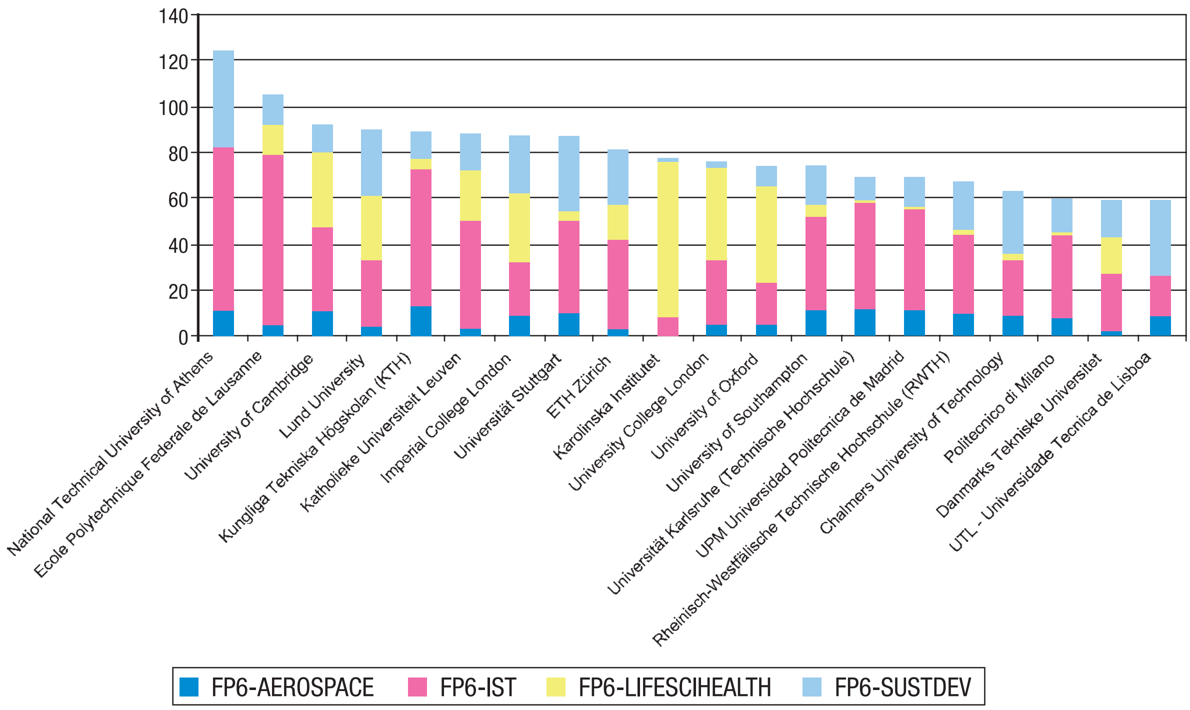
From these analyses, we can draw some general conclusions. First, in the theme of Aerospace, firms from a small group of countries are dominant players. Universities from several countries participate in the theme, presumably ones possessing sector-specific capabilities. Second, the theme of Energy and Environment is in direct contrast to Aerospace dominated by public organisations, with industrial actors only represented in the top 20 for the IP instrument. This is the only theme where organisations from the new member states are represented in the top 20. Third, in the field of ICT industrial and academic actors are equally represented in the top 20, coming mainly from older member states. Fourth, in the theme of Life sciences, we observe the complete absence of industrial actors in the top 20, with public organisations and universities being the only participants.

6.2 Key universities by themes and instruments in FP6

Universities are recognised as major players in the development of the European Research Area, because of their mission that comprises nowadays three main roles: training the new generations, producing codified and embodied knowledge, and diffusing knowledge throughout the economy and society. As demonstrated before, universities are at the core of the networks built by the FPs through time, increasing their centrality and share of participation. Large and small, generic and specialised universities are all involved in the FPs.

Figure 19 provides a summative view of the 'top of the top': that is the top 20 universities in terms of their overall frequency of participation, restricted for universities appearing in the top ranks in the four themes in the FP6. These universities are from ten European countries with diverse size and research intensity. The United Kingdom

Figure 19: *'Top of the top': top 20 universities according to their frequency of participation (restricted for universities appearing in the top ranks in the four themes) FP6*



has five universities in the top 20, followed by Sweden with four and Germany with three, while Switzerland has two. Belgium, Italy, Greece, Portugal, Denmark, and Spain have one university each in the top.

The top 20 universities are in general active in the four themes. All of them participate in two of the four themes, ICT and Energy and Environment. In average the focus of these universities in terms of relative participation in the four themes is in ICT (46% on average), achieving seven of these top 20 universities a share above 55 per cent. Only three universities are not present in one of the themes, Karolinska Institute is not in Aerospace, and the Technical Universities of Lisbon and Athens are not participating in Life Sciences. The participation of some universities in the FPs tends to be rather selective in terms of the topic, like it is the case for the participation of École Polytechnique Fédéral de Lausanne (70%), University of Karlsruhe (67%), Kungliga Tekniska Hogskolan (66%) in ICT. In Life Sciences Karolinska Institutet has the highest concentration of all, with 88% of its participations centred in this thematic.

Only four of the top 20 universities are part of the Top 10 key player organisations (number of participation) (Table 7) and Top 10 central organisations (Table 10), previously listed: the Imperial College of London[11], the Technical University of Lisbon/Instituto Superior Técnico[12] and Katholieke University of Leuven[13], and Technical University of Denmark[14].

Aerospace

The following tables (Table 49 to Table 51) present the rankings of the universities in the priority Aerospace for IP, NoE and STREP. Aerospace, has demonstrated earlier, is a small-world network with fewer nodes and heavily

11 Imperial College of London ranked seventh in FP1 in top key player list, and in the top central organisations it ranked second in FP1 and nineth in FP3.

12 Universidade Técnica de Lisboa ranked eighth in the top key player list in FP2 and in FP3 and ninth in FP5. In the top ranks of central organisations, it was seventh in FP2, second in FP3, fifth in FP4, second in FP5 and eighth in FP6.

13 Katholieke University of Leuven ranked seventh in FP 5.

14 Technical University of Denmark ranked seventh in the top central organisations in FP 1

Table 49: *Top universities in FP6 in Aerospace priority crossed by IP instrument*

Rank	University	Number of participations in FP6-AEROSPACE and IP
1	Cranfield University (CranfieldU)	8
2	National Technical University of Athens (NTUA)	6
3	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	5
3	Universität Stuttgart/University of Stuttgart	5
3	University of Patras	5
6	University of Dublin - Trinity College (TCD)	4
6	University of Southampton (SotonU)	4
8	Technische Universität München/Technical University of Munich	3
8	Universität Karlsruhe (Technische Hochschule) /Karlsruhe University of Technology	3
8	University of Malta (MaltaU)	3
8	Imperial College London (ImperialCL)	3
8	Universitá degli Studi di Firenze, University of Florence	3
8	Technische Universität Darmstadt/Darmstadt University of Technology	3
8	Universität Bremen/University of Bremen	3
8	Delft University of Technology	3
8	Technische Universität Dresden/Dresden University of Technology	3
8	Chalmers University of Technology	3

Table 50: *Top universities in FP6 in Aerospace priority crossed by NoE instrument*

Rank	University	Number of participations in FP6-AEROSPACE and NoE
1	University of Sheffield (SheffU)	1
1	University of Patras	1
1	University of Oslo - Universitetet I Oslo	1
1	Universität Salzburg/University of Salzburg	1
1	Universität Karlsruhe (Technische Hochschule) /Karlsruhe University of Technology	1
1	Universitá di Roma “La Sapienza”, University of Rome “La Sapienza”	1
1	Universitá degli Studi della Basilicata, University of Basilicata	1
1	Technische Universität Bergakademie Freiberg/Freiberg University of Mining and Technology	1
1	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	1
1	National Technical University of Athens (NTUA)	1
1	National and Kapodistrian University of Athens (UOA)	1
1	Manchester Metropolitan University (MMU)	1
1	Linköping University (LIU)	1
1	King’s College London (KCL), (UOL)	1
1	Bergische Universität - Gesamthochschule Wuppertal	1

connected between them, with stronger emphasis in IP and STREP instruments. From the analysis of actor’s position in the three rankings for each instrument, some preliminary observations might be made which need to be explored further. Universities tend to participate heavily in one of the three instruments. This is the case for the University of Cambridge that participates mostly in STREP ranked second, and both Universidad Politécnica de Madrid (ranked 3rd in STREPs) and RWTH Aachen University (ranked 4th in IP). If there is a participation in two instruments that will be a combination of IP and STREP. An example of this is the Cranfield Institute, which ranks first in IP and fourth in STREP. It is rare to have a university participating in all three instruments, in fact only

Table 51: *Top universities in FP6 in Aerospace priority crossed by STREP instrument*

Rank	University	Number of participations in FP6-AEROSPACE and STREP
1	University of Patras	13
2	University of Cambridge (CU)	10
3	UPM Universidad Politécnica de Madrid/Madrid Polytechnical University	9
4	Cranfield University (CranfieldU)	8
4	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University	8
6	UTL - Universidade Tecnica de Lisboa, Technical University of Lisbon	7
6	University of Southampton (SotonU)	7
6	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	7
9	Universitá degli studi di Napoli Federico II, University of Napels	6
9	Universität Karlsruhe (Technische Hochschule) /Karlsruhe University of Technology	6
9	Imperial College London (ImperialCL)	6
9	Technische Universität Berlin/Berlin University of Technology	6
13	Politecnico di Milano	5
13	Universite catholique de Louvain	5
13	Universität Stuttgart/University of Stuttgart	5
13	Universitá di Roma “La Sapienza”, University of Rome “La Sapienza”	5
13	Technische Universität München/Technical University of Munich	5
13	Chalmers University of Technology	5
13	University of Sheffield (SheffU)	5
13	Eindhoven University of Technology	5

Table 52: *Top universities in FP6 in Energy and Environment priorities crossed by IP*

Rank	University	Number of participations in FP6-SUSTDEV and IP
1	Lund University	23
2	National Technical University of Athens (NTUA)	18
3	Universität Stuttgart/University of Stuttgart	16
4	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University	15
5	UTL - Universidade Tecnica de Lisboa, Technical University of Lisbon	14
6	Chalmers University of Technology	13
6	Imperial College London (ImperialCL)	13
8	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology	12
9	Wageningen UR (EDU)	11
10	Vrije Universiteit Amsterdam - Vereniging Voor Christelijk Wetenschappelijk Onderwijs	10
10	Politecnico di Torino	10
12	Universiteit Utrecht	9
12	University of Cambridge (CU)	9
14	Aristoteles University Of Thessaloniki	8
14	UB Universitat de Barcelona - University of Barcelona	8
14	University of Newcastle upon Tyne (NCL)	8
17	University of Stockholm (Stockholms Universitet)	7
17	Delft University of Technology	7
17	Universite catholique de Louvain	7

Table 53: Top universities in FP6 in Energy and Environment priorities crossed by NoE

Rank	University	Number of participations in FP6-SUSTDEV and NoE
1	University of Southampton (SotonU)	5
1	Imperial College London (ImperialCL)	5
3	UTL - Universidade Tecnica de Lisboa, Technical University of Lisbon	4
3	Warsaw University of Technology / Politechnika Warszawska	4
3	Chalmers University of Technology	4
6	Royal Netherlands Academy of Arts & Sciences - Koninklijke Nederlandse Akademie van Wetenschappen - KNAW	3
6	Universiteit van Amsterdam	3
6	Rijksuniversiteit Groningen	3
6	National Technical University of Athens (NTUA)	3
6	Universitá di Roma “La Sapienza”, University of Rome “La Sapienza”	3
6	Politecnico di Milano	3
6	University of Birmingham (BirmU)	3
6	UPM Universidad Politécnica de Madrid/Madrid Polytechnical University	3
6	University of Göteborg	3
6	University of Uppsala	3

Table 54: Top universities in FP6 in Energy and Environment priorities crossed by STREP instrument

Rank	University	Number of participations in FP6-SUSTDEV and STREP
1	National Technical University of Athens (NTUA)	15
2	Universität Stuttgart/University of Stuttgart	12
3	UTL - Universidade Tecnica de Lisboa, Technical University of Lisbon	9
4	Chalmers University of Technology	8
5	Aristoteles University Of Thessaloniki	7
5	Technische Universität Berlin/Berlin University of Technology	7
5	Politecnico di Milano	7
8	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	6
8	Katholieke Universiteit Leuven	6
8	Norwegian University of Science and Technology - Norges Teknisk-Naturvitenskapelige Universitet (NTNU)	6
8	Delft University of Technology	6
8	University of Strathclyde (StrathU)	6
13	Technische Universität Wien/ Technical University Vienna (TU Wien)	5
13	University of Newcastle upon Tyne (NCL)	5
13	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne	5
13	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)	5
13	Imperial College London (ImperialCL)	5
13	Alborg Universitet	5
13	Warsaw University of Technology / Politechnika Warszawska	5

Table 55: *Top universities in FP6 in Information Communications Technologies priorities crossed by IP instrument*

Rank	University	Number of participations in FP6-IST and IP
1	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne	28
2	National Technical University of Athens (NTUA)	25
3	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	21
4	Universität Karlsruhe (Technische Hochschule) /Karlsruhe University of Technology	20
5	UPM Universidad Politecnica de Madrid/Madrid Polytechnical University	17
6	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology	16
6	Universität Stuttgart/University of Stuttgart	16
8	Katholieke Universiteit Leuven	14
8	Universitat Politecnica de Catalunya (UPC)	14
10	University of Cambridge (CU)	13
10	Politecnico di Milano	13
12	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University	12
12	Technische Universität Dresden/Dresden University of Technology	12
12	University College London (UCL), (UOL)	12
15	University of Sheffield (SheffU)	11
15	University of Surrey (SurreyU)	11
17	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)	10
18	Lund University	9
18	University of Southampton (SotonU)	9

Table 56: *Top universities in FP6 in Information Communications Technologies priorities crossed by NoE instrument*

Rank	University	Number of participations in FP6-IST and NoE
1	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne	20
2	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	18
3	Universitat Politecnica de Catalunya (UPC)	14
4	National Technical University of Athens (NTUA)	13
5	Groupe Des Ecoles Des Telecommunications	11
6	Katholieke Universiteit Leuven	10
6	UPM Universidad Politecnica de Madrid/Madrid Polytechnical University	10
6	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology	10
9	Universiteit Twente	9
9	Technische Universität Wien/ Technical University Vienna (TU Wien)	9
9	Universitá degli Studi di Pisa, University of Pisa	9
9	University of Cambridge (CU)	9
9	Universite de Geneve - University of Geneva (UNIGE)	9
9	National and Kapodistrian University of Athens (UOA)	9
9	Eindhoven University of Technology	9
16	Technische Universität Darmstadt/Darmstadt University of Technology	8
16	Delft University of Technology	8
16	University of Uppsala	8
16	Chalmers University of Technology	8
16	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	8
16	Aristoteles University Of Thessaloniki	8
16	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University	8
16	Politecnico di Torino	8
16	Universite catholique de Louvain	8

Table 57: Top universities in FP6 in Information Communications Technologies priorities crossed by STREP instrument

Rank	University	Number of participations in FP6-IST and STREP
1	National Technical University of Athens (NTUA)	26
2	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne	23
3	Universität Karlsruhe (Technische Hochschule) /Karlsruhe University of Technology	22
4	University of Southampton (SotonU)	20
5	Katholieke Universiteit Leuven	19
6	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)	17
6	Universitat Politecnica de Catalunya (UPC)	17
8	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)	16
8	Politecnico di Milano	16
10	Technische Universität Wien/ Technical University Vienna (TU Wien)	15
11	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University	13
11	Universität Stuttgart/University of Stuttgart	13
13	Eindhoven University of Technology	12
14	University of Ljubljana / Univerza v Ljubljani	11
14	University of Sheffield (SheffU)	11
14	Universiteit Twente	11
14	UPV Universidad Politecnica de Valencia - Politechnical University of Valencia	11
14	Technische Universität Berlin/Berlin University of Technology	11
19	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	10
19	University of Manchester (ManU)	10
19	UPM Universidad Politécnica de Madrid/Madrid Polytechnical University	10
19	Imperial College London (ImperialCL)	10
19	University Of Patras	10
19	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology	10

two of them do: University of Patras (ranking 1st in STREP and 3rd in IP) and Universitat Karlsruhe (ranking 8th in IP and 9th in STREP).

Another observation is that highly involved universities in IP are in general not participating in NoE. The explanation for this choice and the identification of the characteristics of these universities might be an interesting avenue for further study.

Energy & Environment

In Energy and Environment, 64 per cent of the ranked universities by number of participations only participate in one instrument (Table 52, Table 53, Table 54) . Only 4 universities out of the 39 ranked in this topic are heavily involved in all instruments - National Technical University of Athens, Technical University of Lisbon, Chalmers University of Technology and Imperial College of London.

In IP and STREPs there are 3 universities that rank in the first positions of these instruments Lund University is first in IP, but is not ranked in any other instrument, the National Technical University of Athens ranks first in STREP and second in the IP, and the University of Stuttgart is second in STREP and third in IP.

The patterns observed here may indicate a 'division of labour' between universities in terms of their participation in IPs and/or NoEs. 60 per

Table 58: *Top universities in FP6 in Life Sciences priorities crossed by IP instrument*

Rank	University	Number of participations in FP6-LIFESCIHEALTH and IP
1	Karolinska Institutet	28
2	University College London (UCL), (UOL)	19
3	University of Oxford (OU)	18
4	University of Cambridge (CU)	14
5	Universitá degli Studi di Milano, University of Milan	12
5	Imperial College London (ImperialCL)	12
5	University of Uppsala	12
8	Universität Zürich - University of Zürich (UZ)	11
8	Universiteit Leiden /Leiden University	11
8	King's College London (KCL), (UOL)	11
11	Katholieke Universiteit Leuven	10
11	Ludwig-Maximilians-Universität München	10
11	Lund University	10
11	Radboud Universiteit Nijmegen	10
15	Johann Wolfgang Goethe-Universität Frankfurt am Main	9
15	Ruprecht-Karls-Universität Heidelberg	9
17	Eberhard Karls Universität Tübingen/Eberhard Karls University of Tübingen	8
17	University of Manchester (ManU)	8
17	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne	8
17	University of Arhus - Arhus Universitet (AU)	8
17	Universiteit van Amsterdam	8
17	Charite - Universitätsmedizin Berlin	8
17	St George's Hospital Medical School (SGHMS), (UOL)	8
17	Erasmus Universiteit Rotterdam	8

cent of the ranked universities in the NoE are not involved in any of the other two instruments.

ICT

ICT was the first theme for which a collaborative research funding mode was developed at the European level (ESPRIT I). Probably because of this long standing collaborative effort key players are more involved in the three instruments compared to the other themes, some of which have done so successively over time as previously demonstrated. Moreover in this theme, universities that are highly involved in IP tend to be highly involved in NoE as well, in contrast to Aeronautics and Energy and Environment themes.

In Energy and Environment there are four universities participating in the three instruments, in ICT this level of participation is achieved by eight universities (Table 55, Table 56, Table 57). The universities highly ranked in the three instruments are Ecole Polytechnique Fédéral de Lausanne, ranked first in IP and in NoE, and second in STREP, National Technical University of Athens first in STREP and second in IP and fourth in NoE, and Kungliga Tekmiska Hogskolan second in the NoE and third in IP and sixth in STREP.

To summarise, the following general observations can be made. The ranks of the top universities differ by themes. In Life Sciences and ICT, maybe because of a large basic research base, the same universities are represented equally in the top ranks of the three instruments. On the contrary, Aerospace and Energy and Environment, more applied research fields, universities that participate in NoE tend not to be involved in IP and STREP.

Table 59: Top universities in FP6 in Life Sciences priorities crossed by NoE instrument

Rank	University	Number of participations in FP6-LIFESCIHEALTH and NoE
1	Karolinska Institutet	15
2	Imperial College London (ImperialCL)	11
3	Universiteit Leiden /Leiden University	10
3	University of Oxford (OU)	10
5	University of Cambridge (CU)	9
6	University College London (UCL), (UOL)	8
7	Radboud Universiteit Nijmegen	7
7	Universite de Geneve - University of Geneva (UNIGE)	7
7	Lund University	7
7	Ludwig-Maximilians-Universität München	7
11	University of Helsinki, Helsingin Yliopisto	6
11	Ruprecht-Karls-Universität Heidelberg	6
11	Hebrew University of Jerusalem (HUJ)	6
11	Erasmus Universiteit Rotterdam	6
15	Universität zu Köln	5
15	UniBe Universität Bern - University of Bern	5
15	Katholieke Universiteit Leuven	5
15	King's College London (KCL), (UOL)	5
15	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	5
15	Charite - Universitätsmedizin Berlin	5
15	Universität Zürich - University of Zürich (UZ)	5
15	Technische Universität München/Technical University of Munich	5
15	Charles University in Prague / Univerzita Karlova v Praze	5
15	Universitá degli Studi di Torino, University of Turin	5
15	Universitá degli Studi di Padova, University of Padova	5

Table 60: Top universities in FP6 in Life Sciences priorities crossed by STREP instrument

Rank	University	Number of participations in FP6-LIFESCIHEALTH and STREP
1	Karolinska Institutet	16
2	Universiteit Leiden /Leiden University	15
3	University of Helsinki, Helsingin Yliopisto	13
4	Medizinische Universität Wien/Medical University of Vienna (MUW)	9
4	Universität Zürich - University of Zürich (UZ)	9
4	Rijksuniversiteit Groningen	9
4	Hebrew University of Jerusalem (HUJ)	9
4	University of Oxford (OU)	9
4	Radboud Universiteit Nijmegen	9
10	University College London (UCL), (UOL)	8
10	Lund University	8
10	Ruprecht-Karls-Universität Heidelberg	8
10	Albert-Ludwigs-Universität Freiburg	8
14	King's College London (KCL), (UOL)	7
14	Imperial College London (ImperialCL)	7
14	Erasmus Universiteit Rotterdam	7
14	Universität Basel - University of Basel	7
18	University of Cambridge (CU)	6
18	Universiteit Utrecht	6
18	University of Liege (ULg)	6
18	Universite Libre de Bruxelles (ULB)	6
18	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)	6
18	Eberhard Karls Universität Tübingen/Eberhard Karls University of Tübingen	6

Chapter 7: Future research directions

7.1 Introduction

The focus of the current study has been the analysis of networks emerging within the European Research Area (ERA) as captured by joint R&D projects funded within the FPs. The objective was to produce various kinds of network analyses focussed on FP network properties (network metrics), on participating institutions (actor metrics), disaggregated by different thematic priorities and types of instruments.

However, there remains much space for further empirical analyses and theoretical explorations. In light of the analyses in this project as well as of the relevant empirical and theoretical literature, we focus on four main blocks of potential future research directions:

- The investigation of the progress towards ERA is an important research area, both from a scientific as well as from a European policy perspective. Various kinds of empirical analyses of European R&D networks could yield valuable insights for policy.

- The exploration of the impact of R&D networks on the economic performance and innovative behaviour of organisations, regions and countries will be one of the key challenges of the empirical research on innovation and networks in the near future.

- The empirical literature that investigates the relationship between function, structure and governance of R&D networks is still in an unsatisfactory stage of development and some extensions could be envisaged.

- Further investigation and modelling of the dynamic evolution of R&D networks are strongly needed to improve our understanding of the processes and mechanisms on such networks.

7.2 ERA monitoring using the spatial dimension of R&D networks

The ERA has become a key reference for research policy in Europe. Endorsed at the European Council in Lisbon 2000, ERA is intended to implement an integrated European market for research, where researchers, technology and knowledge can diffuse freely. This requires an effective European-level coordination of national and regional research activities, programmes and policies, as well as the implementation of initiatives funded at the European level. The EU FPs are explicitly designed to support the creation of ERA and its funding has been substantially increased with the current 7th Framework Programme.

However, as noted in the ERA Green Paper 2007, there is still much further to go to build ERA, particularly to overcome the fragmentation of research activities, programmes and policies across Europe. In this context, it is essential to constantly monitor progress towards the ERA. Thus, one of the potential future research directions may focus on enriching and complementing on-going work on the monitoring progress towards ERA by using indicators of networking at various levels of aggregation and analysing them using a variety of methodological tools.

Analysing European integration in research

Autant-Bernard et al. (2007) argue that the geographical analysis of European R&D networks may provide important insight into the progress towards an integrated European research area. Scherngell and Barber (2009) follow this approach and focus on cross-region R&D collaborations as captured by joint FP5 projects by modelling the influence of geographical space – while controlling for economic, technological and cultural effects – on the variation of cross-region R&D collaborations within a spatial interaction modelling framework. The approach of Scherngell and Barber (2009) may be used for a deeper analysis of various R&D networks at different points in time and in different thematic fields, and provide important additional empirical insight into the progress towards ERA.

In addition, European integration in research could be assessed using statistical measures of spatial dependence for R&D variables (for some preliminary results see Pontikakis and Azagra-Caro, 2009), including those derived from the analysis of networks in the FPs.

Analysing science-industry collaborations in ERA

As noted in the ERA Green Paper 2007, bringing together the scientific communities and companies is one of the key challenges. Thus, research on (spatial) patterns of science industry interactions is crucial, for instance concerning the question of how far different companies/universities look for collaborators in R&D. Empirical analyses that put emphasis on science-industry interaction may widen our understanding on these issues. Various descriptive analyses of science-industry relations in Europe by using different indicators, such as joint FP projects, disaggregated by different thematic fields and at different points in time (for a preliminary analysis see Azagra-Caro et al., 2009) can be envisaged. On the other hand, various social network analysis techniques and different econometric approaches, such as discrete choice models or, again, spatial interactions models, can be used to characterize such science-industry interactions.

Analysing R&D specialisation of actors, regions and countries

The identification and distribution of thematic priorities is another important issue regarding the monitoring of ERA. There are various studies that investigate R&D specialisation in Europe using different indicators. However, thematic specialisation using data on FP projects have not been used for this purpose before now. The *sysres EUPRO* database provides detailed information on the thematic orientation of funded FP projects, for instance by the assignment of subject indices. Using these subject indices, we are able to provide a rich picture of R&D specialisation across actors, regions and countries in Europe (e.g. differentiation of participation profiles of member states – across FP instruments and thematic priorities – reflecting national research strategies). Economic Geography provides a rich toolset of spatial concentration indices that may be used (see Combes, Mayer and Thisse 2008 for an overview), including concentration measures such as the Isard Index, the Herfindahl Index or the Theil index, as well as measures for spatial clustering such Moran`s I or Geary`s C (see Anselin, 1995).

Analysing the transnational dimension of R&D policy

More coherent implementation of national and European research activities and closer relations between the various organisations of scientific and technological cooperation in Europe is, as indicated by the ERA Green Paper 2007, a further step towards the key objectives in ERA. The trans-national dimension of European R&D activities can be analysed by expanding the spatial interaction framework with variables accounting for country borders between organisations. Furthermore, variables that account for the probability of cooperation between border regions may be added to the model. Additional qualitative (e.g. identification of thematic priorities of joint projects) and quantitative analysis of selected border regions can be useful to identify networking behaviour between border regions.

Analysing the mobility of researchers within ERA

Policies for human resources within ERA focus to a large extent on the mobility of researchers. Possible lines of analysis in this context involve the investigation of Marie Curie Fellowships in the *sysres EUPRO* database. However, additional efforts in primary data collection, for instance in the form of a representative survey that addresses issues like incentives for researchers to move, individual history of researchers' mobility, etc., may be needed.

Identifying the main actors and institutional backdrop of ERA

This issue has already been addressed at the level of FP1-FP6 in this study. However, this line of research can be expanded by identifying main players in different thematic sub-programmes or communities. The identification of main players is based on a ranking of central players in the European research landscape. One way is to count the number of projects they participate in. However, participating in many projects is not sufficient for being a decisive player. Thus, centrality should also be taken into account, a measure of how well actors are connected.

Four different centrality measures come to mind, accounting for local [Degree Centrality] and global connectedness [Closeness Centrality], the ability to control information flow in the network [Betweenness Centrality] and the connectedness to other central nodes [Eigenvector Centrality], and combined into a composite centrality ranking or a weighted centrality index. The latter merges normalised values of different metric indicators (i.e. centrality measures) to an aggregated index by a linear-additive combination. Additionally, connections may be made between funding programmes and structurally determined sub-networks.

Building on recent research into identification of communities within networks, sub-networks reflective of the interactions realised within European R&D networks can be identified, and their similarities and differences from policy-based groupings can be investigated (see Fortunato and Castellano, 2008).

Positioning of top research universities in different thematic fields

Rankings of universities, though controversial, have become increasingly popular (e.g. Academic Ranking of World Universities, Leiden, Die Zeit, Times) – and influential. Most of them are focusing on accomplishments within the scientific community, and comprise indicators of established reputation and contemporaneous academic performance. Policy makers are paying increasing attention to the international standing of European universities, but an appraisal of the role of the FP in that regard is lacking. For instance, the analysis of top research university participation to FP6 by Henriques et al. (2009) could be extended to previous FPs.

As regards industrial relevance of university research, however, established rankings are often less relevant. This problem could be tackled by comparing some of the common university rankings to rankings developed by analysing FP networks (Nokkala et al., 2009). In an econometric framework university rankings are validated against the developed ranking of network embeddedness in different thematic fields. Thus, we are able to identify those sub-indicators of university rankings delivering results that are more closely related with centrality measures in the EU FPs. These results would be relevant for the strategic orientation of universities in the context of an increasing need for third-party funding.

7.3 Impact of R&D networks

One of the fundamental questions raised by the theoretical and empirical research concerns the impact of R&D networks. This is an issue taken up in the strategic management literature

(Gilsing et al. 2008; Ahuja 2000; Shan et al. 1994). Much of the work is relatively ad hoc vis-à-vis the underlying theory of performance and network position, and refers explicitly to firms. On the theoretical side the existing literature could be improved by providing better underpinnings; on the empirical side different types of actors (universities, research labs etc.) could be introduced, for whom innovation is a primary rather than an instrumental goal.

Up to now, there are only very few empirical studies that have investigated the link between R&D networks and economic output, innovative performance and organisational behaviour. Thus, this research direction aims to explore the impact of R&D networks from both a micro- and macroeconomic perspective, i.e. at the level of organisations as well as regions and countries. When talking about impact, we shift attention to understanding the relationship of R&D networks and innovative and economic performance. This requires the definition of a suitable conceptual and theoretical framework. The impact of R&D networks may be captured by employing different quantitative methods, in particular coming from (spatial) econometrics and network analysis techniques.

In this block of potential future research directions we distinguish three levels of analysis:

The link between R&D networks and European integration

Using an appropriate econometric modeling framework, indicators derived from the analysis of FP networks could be used to appreciate the contribution of the FP to an integrated ERA. Work that explicitly compares the forces of geography to those of networks by, for instance, substituting measures of geographic distance for network distance could also help assess the contribution of FP to European integration.

The link between R&D networks and innovative output

The first level of analysis is intended to disclose the relationship between R&D networks –as, for instance, networks of organisations participating in joint projects funded by the European Framework Programmes– and innovative output of participating organisations. Innovative output will be measured by proxy indicators widely used in empirical innovation studies, such as patents or publications. From a methodological point of view, the relationship between knowledge inputs –such as human resources, R&D expenditures and (as an intermediary form) R&D networks– and knowledge outputs may be characterised by a class of (spatial) panel data models used in previous studies of similar spirit (see, for instance, Fischer, Scherngell and Reismann, 2009) or spatially-aware knowledge production functions with network effects (see, for instance, Varga and Pontikakis, 2009).

The link between R&D networks and economic performance

The second level of analysis goes a step further and investigates how R&D networks influence the economic performance of organisations, regions and countries. A key concept that could be used to investigate the outcome/impact of R&D networks is the concept of Total Factor Productivity (TFP) referring to the component of output growth not attributable to the accumulation of conventional inputs, such as labour and physical capital. It is not only a question whether or not a relationship between TFP and R&D networks exists, but also whether or not quantitative, especially (spatial) econometric studies, can –in spite of all measurement difficulties– characterise such a relationship in a satisfactory manner, in particular at the regional level of observation.

Dynamics of R&D networks

A better understanding of the dynamic evolution of European R&D networks is strongly needed in order to get a deeper insight into the processes and mechanisms of such networks. In particular the question of how scientific communities evolve over time is of crucial interest in this context. These questions can be addressed by using data of the *sysres EUPRO* database. It provides rich material allowing for not only cross-sectional, but also detailed longitudinal investigation.

Methodologically, this may include the description of the global and local characteristics of the networks over time, a study of network formation mechanisms (attachment rules), the identification of stable actor configurations and homogeneous subgroups, as well as the presumably shifting thematic priorities of the collaborative research we are able to observe.

Another aspect that can be studied within the scope of this research direction is the geographical evolution of the research networks in the European Framework Programmes. However, to get a deeper understanding of the evolution of communities in European R&D networks, further methodological advances are required, for instance regarding the identification of communities within networks. A community of a network is a portion of the network whose members are more tightly linked to one another than to other members of the network. Further, understanding the dynamic evolution of networks is an area of active research; the construction of meaningful time series of R&D networks thus can draw on cutting edge research, but also presents significant challenges.

A specific opportunity lies with the closer examination of the New Member States. As their participation in FPs is both relatively recent and growing, their accession provides a natural experiment with which to examine the effects of FP networking activity. In addition, recent FPs have, in their calls, emphasised the value of including partners from New Member States. Until very recently, FP participants in EU-15 countries have had little contact with and know little about institutions and potential partners in New Member States. One interesting question is how old participants get information about new and comparatively unknown participants. It seems likely that there is some information network other than the FP network on which information about potential partners travels. Seeing how this works is a way of asking how new information enters a network generally, but also how new participants join the FP, ERA network specifically. If this is addressed quickly, there may be an opportunity to gather relevant data (perhaps through adding questions to the CIS) as the participation from the New Member States grows rapidly.

One of the key issues from a systemic point of view is how networks combine with other governance forms, such as markets and hierarchies (both corporate and political); moreover, there is growing interest in, but to date only limited analysis of, the interrelationships among the networks themselves. Most individuals and organisations who constitute the present database are also members of other networks (disciplinary, topic oriented, policy-oriented, etc.). This potential profusion of networking gives scope for possibilities of 'network failure' (akin to 'market failure', 'government failure', etc.), at the level of both the specific network and of the systems of networks ('networks of networks'). Such issues are examined in the still underdeveloped literature on 'network alignment' (von Tunzelmann, 2007). A key issue is how the structure of projects (e.g. in a FP – the objects of the network) aligns with the structure of subjects (e.g. the technologies) and with the structure of the agents themselves.

Function and structure of R&D networks

In chapter 4 we stress issues concerning the link between the specific knowledge functions (exploration-exploitation) and the structural properties of R&D networks (see, for instance, March, 1991; Stokes, 1997; Cowan and Jonard, 2004; Cowan, 2006). The results provide some preliminary and basic insights into this topic and present an analytical framework that may be developed further. Further research efforts in this direction are strongly needed from a European policy perspective: on the one hand, to identify ways to create and appraise desirable network structures for realising key functions of R&D collaboration networks, and, on the other hand, to analyse the impact of governance rules on the realisation of network functions.

From this perspective, this research direction could produce quantitative statements about desirable network structures and suitable governance rules shaping the emergence of different types of collaboration networks. To advance in this direction one would have to investigate which typologies of networks exist with respect to network function and governance rules.

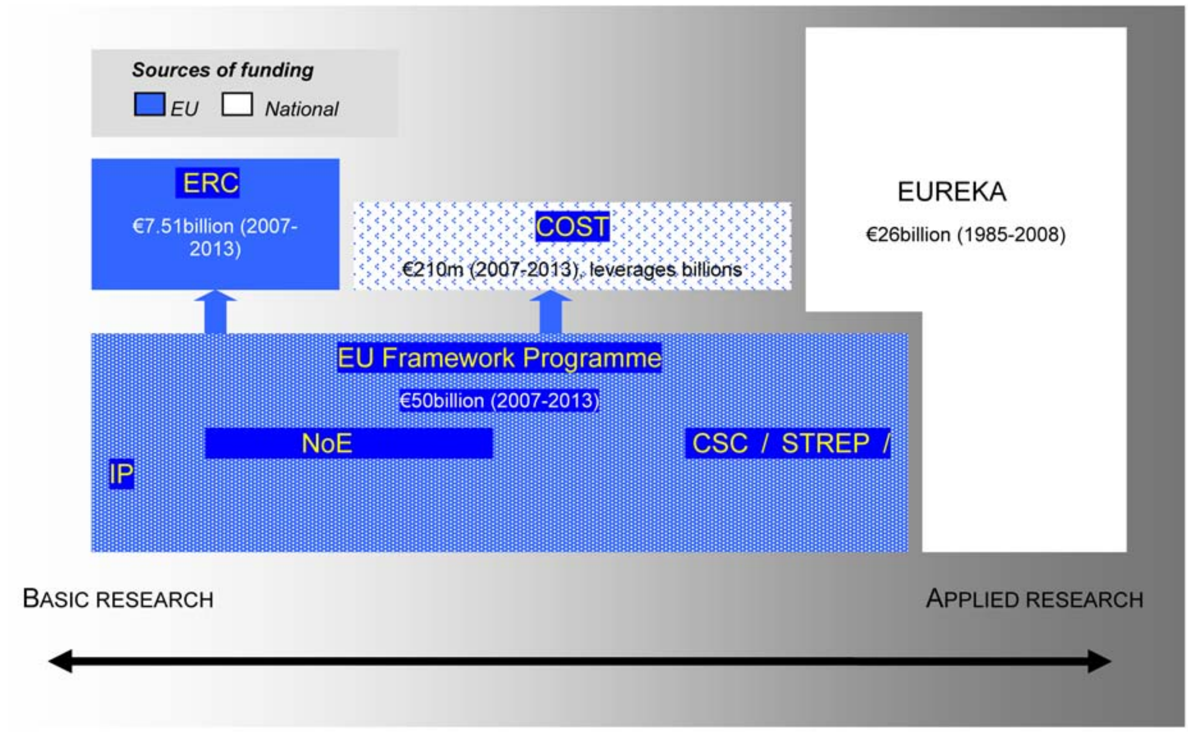
There has been a small amount previous work along these lines, but none having to do with ERA. In addition, previous work has focussed almost exclusively on small world properties of networks (with a limited amount of attention to scale free networks). It should be possible to move beyond these two characterisations. Social network analysis has developed a battery of statistics for network description, and the challenge is to understand which of these is relevant for different aspects of network performance.

7.4 Feasibility of extending network analysis to alternative data sources (COST, ERC, EUREKA)

European R&D policy instruments in perspective

European RTD policy is formulated at multiple levels of governance, with EU competences overlapping with those of national and regional authorities. The current landscape is conditioned by a long history of common research policies and the coordination of national research policies. Historically, the benefits of common policies for basic research, in terms of knowledge diffusion, capability development and critical mass effects, have been obvious. Hence, the development of a common budget for pre-competitive collaborative research in the form of ESPRIT and later the FP has been a largely uncontentious matter.

Figure 20: Position of European collaborative R&D instruments



However, national authorities have been less eager to relinquish control over funds for research that is close to the market. The emergence of a transnational initiative for applied research in the form of EUREKA in the mid-1980s came as a response to the Commission's efforts to facilitate greater coherence in applied R&D (Georghiou, 2001). To this day, funding for such research comes from national sources.

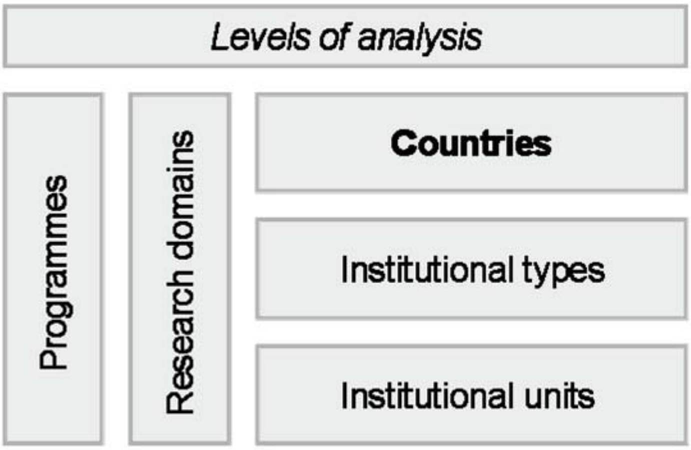
Figure 20 positions the various instruments along a basic/applied research axis. At the 'basic' end of the spectrum, the ERC and the FP's Networks of Excellence (NoE) target more science oriented, blue-sky type research. EUREKA caters for the 'applied' end of the spectrum, followed by the FP's Shared Cost Actions (CSC), Specific Targeted Research Projects (STREP) and Integrated Projects (IP), with COST in-between.

The various instruments are called to fulfil different but ultimately inter-complementary missions. Collectively they can be seen as the result of efforts to form a coherent 'research and innovation' policy spanning the whole of the continent.

Table 61: Feature comparison of databases of European collaborative R&D instruments

	FP	COST	ERC	EUREKA
Actors potentially defined as (number of nodes in parenthesis, ballpark figures)	Countries (>120), Themes (8), Organisations (varies from 2216 in FP1 up to 25840 in FP5)	Countries (> 36) Themes (9) Organisations (huge number) Researchers (25,000)	Countries (38), Research Domain (4), Researchers (300), Home institutions (of the applicant), Host Institutions	Countries (43), Themes (10), Organisations (>13,000)
Links potentially defined as	Common projects, Themes	Common actions = projects Themes	Changes of state of researchers, common institution (origin/ destination)	Common projects, Themes
Lowest level of aggregation	Organisations, Individual researchers (in FP7)	Organisations, researchers	Individual researchers	Organisations
Instruments available	IP, NoE, STREPs, etc.	COST Grants, Meetings, STSM missions, Training Schools, GASG, etc.	only Actions (+ funding instruments: Starting Grants, Advanced Grants, CSAs etc)	Individual projects, Clusters, Umbrella
Unique participant identifier	Yes (inconsistent)	Yes for projects, No for organisations	Yes (project number)	No
Participant geographic Identifier	NUTS3, further detail potentially inferred from participant's address field	Potentially inferred from organisational affiliation	NUTS0, further detail potentially inferred from organisational affiliation	NUTS0
Budget breakdown by participant	Yes (available only to Commission services)	No	Yes	Only at the country level
Data publicly available	Yes (with exceptions)	Yes, but with a high collection cost	Yes, partially	Yes (with exceptions)

Figure 21: Common elements of analysis



Data availability and potential for analysis

There is a sprawling literature examining specific forms of R&D collaboration, such as those recorded in scientific publications and patenting, but relatively little is known about R&D collaborations facilitated by policy. Comparing the analysis of the FP with those of alternative data sources could help towards ascertaining its individual characteristics and this way better understand its role in the European research system.

This section presents a feasibility assessment of extending network analysis performed thusfar on the FP to other European instruments for collaborative R&D. Table 61 presents a feature comparison of the respective databases of the aforementioned instruments and the FPTable 61. In terms of data quantity and public availability, the FP and the EUREKA databases are the most voluminous and most easily accessible data sources. COST too has potentially voluminous data of very high value for policy-relevant analysis, but it is currently in a form that is costly to collect, process and analyse (the current lack of studies is probably a testament to this). ERC could also evolve into a valuable resource, but it is simply too new to produce meaningful insights at the European level. Its value instead may lie in shedding light on the dynamics of human resource mobility within specific disciplines, offering a snapshot of the upper-tail of the quality distribution.

The type and amount of information available indicate that all three data sources are receptive to some form of network analysis, though the precise scope will vary in each case. A conceptualisation of common elements of analysis is presented in Figure 21. It is obvious from this figure and our discussion so far that variation in data availability, in the types of programmes and research themes/domains renders the possibility of cross-instrument analysis remote. Crucially, the differences in rationales between instruments may mean that even when cross-instrument analysis is possible, it may not be meaningful. A holistic analysis of European R&D instruments may be better served by an approach that treats them as separate but inter-complementary components.

The processing of COST, ERC and EUREKA data in a form that is suitable for network analysis, would form a valuable asset on its own right and could pave the way to additional policy-relevant studies. One could for instance, investigate the possibility to link COST, ERC and EUREKA with research output data (publications, patents, copyrights), along the lines of on-going work in the FP, and thus get a feel for the impact of each instrument in terms of R&D outputs.

A particularly fascinating possibility arising from the availability of a complete dataset on all four instruments (FP, COST, ERC, EUREKA) is the joint examination of the participation of the same actors across the various instruments. For example, network analysis that treats the instruments as nodes could identify those instruments that are central in framing research in particular disciplines and chart the evolution of such centrality over time. It would highlight the key organisations facilitating the flow of knowledge from the basic-research end of the spectrum to the applied one (and vice versa). In doing so, it would unravel the structure and properties of the emerging 'system of instruments' and thus contribute to a better understanding of the breadth of European RTD policy levers.

Chapter 8: Policy Implications for ERA

The application of network analysis on data from the FPs contributes to the emerging evidence base for the design of ERA-related policies. The present analysis highlights the following implications for the 'ERA Vision 2020[15]'.

In the first part we highlight the general structural features emerged in the analysis of FPs and we discuss their policy implications. In the second part we examine insights derived from the analysis of instruments.

8.1 Structural features

A network analysis of the FPs is an important analytical tool for the overall evaluation of results and impact of R&D policies in the EU. The above analysis of structural features of FP5 and FP6 networks suggests several implications for ERA. The distinction between three kinds of networks – small world networks, distributed clusters networks and networked communities- as the outcome of different sub programmes has repercussions for the implementation of ERA.

In the context of ERA, small world networks might favour knowledge diffusion and building up expertise across time but might be less effective to foster wider integration because of the difficulties that new players have in joining in. In general, different kinds of networks represent different answers to ERA priorities, between the two main aims of building up expertise and of knowledge diffusion, there are irreducible trade-offs in opting for sub-programmes in future FPs.

15 Council of the European Union (2009), "The first steps towards the realisation of European Research Area (Vision 2020)", Brussels, May 18

Comparing the evolution of the FPs over time, we observe extensive instrumental and structural change. Over time, for the same type of instruments and for the same themes, the networks emerging are more integrated and more tightly knitted. This could be interpreted as a signal of self-reinforcing pan-European thematic communities built on trust and a common operational framework that has evolved in its present state alongside the FP.

According to FP data for FP5 and FP6, small world networks (with high clustering) in sub-programmes emerge for sub programmes strongly oriented on direct research. Such kind of networks are known for their resilience over time and their resistance to change due to the filtering apparatus of using highly connected nodes (or 'hubs'), and its better effectiveness in relaying information while keeping the number of links required to connect a network to a minimum. In other words, in the context of ERA, such networks might favour knowledge and building up expertise across time but might be less effective to foster wider integration because of the difficulties that new players have in joining in.

Distributed cluster networks are found in programmes with a strong exploitative component and knowledge transfer functions. Such networks are less clustered than small world networks and represent a balance of expertise accumulation and integration, with less high obstacle in joining in. Favouring the advancement of knowledge and efficient transfer within relatively closed cliques, they represent an interesting tool for ERA.

Finally, there are more evenly distributed network structures, the so called 'networked communities' that with a lower clustering are associated with basic research. Such networks are better suited for cutting-edge research and allow a wider integration since links are easily formed (due to the small nature of the projects involved). However, they might be less suited for an efficient diffusion and exploitation of knowledge.

In general, different kinds of networks represent different answers to ERA priorities, between the two main aims of building up expertise and of knowledge diffusion, there are irreducible trade-offs in opting for sub-programmes in future FPs. We identify the following main dimensions along which different network types are relevant:

- *Building strengths*. The identified distinction between three kinds of networks as the outcome of different sub programmes has repercussions for the implementation of ERA. In the context of ERA, small world networks might favour knowledge and building up expertise across time but might be less effective to foster wider integration because of the difficulties that new players have in joining in. In general, different kinds of networks represent different answers to ERA priorities, between the two main aims of building up expertise and of knowledge diffusion, there are irreducible trade-offs in opting for sub-programmes in future FPs. Comparing the evolution of the FPs over time, we observe extensive instrumental and structural change. Over time, for the same type of instruments and for the same themes, the networks emerging are more integrated and more tightly knitted. This could be interpreted as a signal of self-reinforcing pan-European thematic communities built on trust and a common operational framework that has evolved in its present state alongside the FP.

- *Cohesion of the European Research Area*. Distributed cluster networks are found in programmes with a strong exploitative component and knowledge transfer functions. Such networks are less clustered than small world networks and represent a balance of expertise accumulation and integration, with less high obstacle in joining in. Favouring the advancement of knowledge and efficient transfer within relatively closed cliques, they represent an interesting cohesion tool for ERA. The overall success of the FP in involving research teams from new member states and integrating smaller peripheral communities into wider European networks shows that it is contributing to the construction of the 'backbone' of the ERA. Core organisations have played the role of integrator and coordinator in the building a European-level research agenda for a given topic. However, the rankings of top organisations provide some indications of high entry costs. Aerospace in particular, is dominated by industry, exhibiting relative stability in the ranks of universities and research organisations, with some mobility in the ranks of industrial actors over time. High entry costs are also reflected in more inclusive thematic priorities (such as ICT), with the top ranks dominated by organisations from older member states. Discussions on the future evolution of the ERA should take into account the high entry costs for new participants and take the necessary steps to facilitate entry.

The actors that can achieve in both dimensions are universities that are at the core of the networks built by the FPs through time, increasing their centrality and share of participation. Because of stability in the top positions and, as observed previously, the wide representation of some of universities in different thematic networks, they play a double role of capacity building and cohesion. Stability over time also suggests that policy interventions will need to take into account the specificities of these top actors and the networks in which they participate. Of all organisation types, universities are the ones that form the building blocks of the ERA, acting as harbours of stability. It is therefore important that their central role is recognised in any discussion on the future evolution of the ERA.

8.2 Instruments

The analysis by instrument is of particular interest from an ERA perspective, given that two of the instruments examined (IP, NoE) were tasked with strengthening the ERA: IP and NoE aimed at the facilitation of common research agendas, at the integration of smaller research communities and new Member States (NMS), and at the promotion of virtual centres of excellence that are visible at the global level.

In accordance with the expectations attached to IP and NoE, we found that they favoured large projects with many participants.

The top 20 positions of universities are spread across different countries, in contrast to the typical concentration found in academic ranking tables. Large and small, generic and specialised universities are all involved in the FPs. This image is consistent with the ERA vision that sees coordination and cooperation (as promoted by the FP, but also other instruments such as COST and EUREKA) as contributing on existing strengths and integrating the knowledge periphery.

Analysis suggests that Energy and Environment has allowed a better integration of new organisations. This can be seen as a reflection of a topic dealing with the production and diffusion of public good-type knowledge, which requires more inclusive networks. As such, this priority might represent an exemplar of how the FP could contribute to the tackling of 'Grand Challenges'.

In real-world networks, this likelihood tends to be greater than the average probability of a tie randomly established between two nodes (Holland and Leinhardt, 1971; Watts and Strogatz, 1998) is higher than in networks based on Cost Shared Contracts (CSC and STREP). The above can be taken as an indication that the two ERA instruments shaped the structure of research collaboration networks across Europe.

The overall success of the FP in involving research teams from new member states and integrating smaller peripheral communities into wider European networks is compatible with the view that it is contributing to the construction of the 'backbone' of the ERA. Core organisations have played the role of integrator and coordinator in the building a European-level research agenda for a given topic.

Our analysis points to significant differences in the resulting networks across thematic priorities. We also observe that the exact shape (distribution) of the knowledge triangle is thematically conditioned: the composition of resulting networks varies in terms of leading organisation type with Aerospace in one extreme (where industry is dominant) and Life Sciences in the other (where universities dominate). The above observations suggest that the role of the FP in structuring the ERA could be enhanced by the suitable design of instruments that are tailored to the needs of thematic communities.

The even mix of organisation types represented in the top ranks of ICT is indicative of a priority that is conducive to knowledge sharing between different organisation types. The above observations suggest that the role of the FP in structuring the ERA could be enhanced by the suitable design of instruments that are tailored to the needs of thematic communities.

Organisation rankings indicate wide variation across themes but, within a given theme, relative homogeneity across instruments. In other words, representation in the top ranks is primarily thematically conditioned. Within each theme, we can distinguish between a core of stable presences in the top ranks and others that are rather volatile. We observe a different mix of organisations across the various thematic priorities.

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Annex

1. Abbreviations

ORGANISATION TYPE

Org Type Code	Organisation Type
IND	Industry
EDU	Education (Universities, Schools, ...)
ROR	Research Organisations
GOV	Government
OTH	Others
CON	Consultants
NCL	Non-Commercial

COUNTRY CODES

Country Code	Country name
AUT	Austria
BEL	Belgium
CHE	Switzerland
CYP	Cyprus
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HUN	Hungary
IRL	Ireland
ITA	Italy
NLD	Netherlands
NOR	Norway
POL	Poland
PRT	Portugal
SWE	Sweden
TUR	Turkey

Table 62: Thematic sub-programmes of the RTD Framework Programmes

Acronym	Title	Number of collaborative projects in the database
FP5 (1998-2002)		
IST	User-friendly information society	2,424
EESD	Energy, environment and sustainable development	1,714
GROWTH	Competitive and sustainable growth	2,019
LIFE QUALITY	Quality of life and management of living resources	2,076
HUMAN POTENTIAL	Improving the human research potential and the socio-economic knowledge base	738
INCO 2	Confirming the international role of Community research	429
INNOVATION-SME	Promotion of innovation and encouragement of participation of SMEs	84
FP6 (2002-2006)		
IST	Information society technologies	874
AEROSPACE	Aeronautics and space	147
NMP	Nanotechnologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices	305
LIFESCIHEALTH	Life sciences, genomics and biotechnology for health	324
CITIZENS	Citizens and governance in a knowledge-based society	120
SME	Specific SME activities	256
NEST	New and Emerging Science and Technology	85

Source: sysres EUPRO database.

2. Tables

Table 63: Distribution of core organisations by countries and theme (AERO) for CSC/STREP (%)

	AERO_4_CSC		AERO_5_CSC		AERO_6_STREP	
	core	all	core	all	core	all
AUT	0.0	0.3	0.0	1.4	0.0	3.1
BEL	0.0	5.3	3.6	3.9	4.0	5.2
BGR	0.0	0.0	0.0	0.0	0.0	0.0
CHE	0.0	1.6	0.0	1.4	0.0	2.1
CYP	0.0	0.0	0.0	0.0	0.0	0.3
CZE	0.0	0.0	0.0	0.9	0.0	1.9
DEU	22.2	15.9	21.4	20.1	24.0	14.5
DNK	0.0	1.9	0.0	0.7	0.0	1.1
ESP	5.6	4.4	10.7	6.7	4.0	7.7
FIN	0.0	0.3	0.0	0.7	0.0	0.5
FRA	27.8	23.4	32.1	24	32.0	19.2
GBR	16.7	19.6	17.9	15.6	12.0	11.9
GRC	0.0	3.1	0.0	1.7	4.0	5.0
HUN	0.0	0.0	0.0	0.0	0.0	0.8
IRL	0.0	2.8	0.0	1.7	0.0	0.8
ISR	0.0	0.9	0.0	0.6	4.0	2.1
ITA	16.7	8.7	7.1	8.9	8.0	8.2
NLD	5.6	4.0	3.6	2.9	4.0	3.2
NOR	0.0	0.3	0.0	0.9	0.0	1.1
POL	0.0	0.0	0.0	0.7	0.0	1.5
PRT	0.0	1.9	0.0	0.6	4.0	1.3
ROU	0.0	0.0	0.0	0.6	0.0	1.0
RUS	0.0	0.3	0.0	0.4	0.0	1.1
SVK	0.0	0.0	0.0	0.0	0.0	0.2
SVN	0.0	0.0	0.0	0.1	0.0	1.1
SWE	5.6	5.3	3.6	3.1	0.0	3.7
USA	0.0	0.0	0.0	1.1	0.0	0.0

Table 64: Distribution of core organisations by countries and theme (ENV) for CSC/STREP (%)

	ENV_4_CSC		ENV_5_CSC		ENV_6_STREP	
	core	all	core	all	core	all
AUT	0.0	3.1	0.0	3.3	0.0	3.2
BEL	0.0	3.6	0.0	2.9	2.7	3.4
BGR	0.0	0.2	1.6	0.6	0.0	0.2
CHE	3.9	2.8	4.8	2.6	2.7	1.7
CYP	0.0	0.1	0.0	0.4	0.0	0.2
CZE	0.0	0.3	0.0	1.9	2.7	3.4
DEU	9.8	15.0	14.3	14.9	21.6	16.8
DNK	3.9	4.1	4.8	3.6	0.0	3.1
ESP	5.9	8.4	4.87	7.1	2.7	6.5
FIN	5.9	2.6	4.8	2.4	0.0	2.1
FRA	9.8	11.5	15.9	10.6	21.6	8.6
GBR	21.6	13.8	12.7	11.0	8.1	7.9
GRC	7.8	3.6	7.9	3.1	8.1	3.1
HUN	0.0	0.4	0.0	1.5	0.0	1.7
IRL	0.0	1.4	0.0	0.6	0.0	0.8
ISR	0.0	0.8	0.0	0.9	0.0	1.3
ITA	11.8	10.0	7.9	9.0	10.8	8.5
NLD	7.8	6.0	9.5	5.3	8.1	6.4
NOR	3.9	2.1	3.2	2.6	2.7	2.7
POL	0.0	0.5	1.6	2.5	2.7	3.8
PRT	2.0	2.7	1.6	2.2	2.7	2.5
ROU	0.0	0.3	0.0	1.0	0.0	0.6
RUS	0.0	0.7	0.0	0.8	0.0	0.8
SVK	0.0	0.0	0.0	0.7	0.0	0.4
SVN	0.0	0.4	0.0	1.1	0.0	0.8
SWE	5.9	4.2	4.8	3.5	2.7	2.6
USA	0.0	0.0	0.0	0.7	0.0	0.4

Table 65: *Distribution of core organisations by countries and theme (ICT) for CSC/STREP (%)*

	ICT_4_CSC		ICT_5_CSC		ICT_6_STREP	
	core	**all**	**core**	**all**	**core**	**all**
AUT	2.0	2.8	1.4	2.7	4.1	2.8
BEL	3.9	4.4	2.7	3.9	8.2	3.0
BGR	0.0	0.0	0.0	0.4	0.0	0.8
CHE	2.0	2.2	5.4	2.7	2.0	2.8
CYP	0.0	0.1	0.0	0.4	0.0	0.2
CZE	0.0	0.1	0.0	0.9	0.0	1.0
DEU	25.5	17.1	14.9	15.5	16.3	15.9
DNK	0.0	2.5	0.0	1.7	0.0	1.6
ESP	5.9	8.4	8.1	8.1	8.2	7.2
FIN	2.0	2.1	1.4	2.4	2.0	2.3
FRA	21.6	12.9	14.9	11.8	12.2	9.4
GBR	15.7	14.8	13.5	11.8	6.1	10.7
GRC	2.0	4.0	8.1	5.8	8.2	4.8
HUN	0.0	0.3	0.0	0.8	2.0	2.7
IRL	0.0	2.5	0.0	1.4	0.0	2.0
ISR	0.0	1.0	0.0	1.8	0.0	2.0
ITA	13.7	10.5	16.2	12.0	16.3	10.9
NLD	2.0	5.0	4.1	4.2	6.1	3.6
NOR	2.0	1.7	2.7	1.5	0.0	1.8
POL	0.0	0.2	0.0	1.2	0.0	3.3
PRT	0.0	2.3	1.4	1.8	0.0	1.3
ROU	0.0	0.1	0.0	0.3	0.0	1.2
RUS	0.0	0.0	0.0	0.1	0.0	0.4
SVK	0.0	0.1	0.0	0.9	2.0	1.3
SVN	0.0	0.1	0.0	0.4	2.0	0.8
SWE	2.0	3.6	4.1	3.1	2.0	2.6
USA	0.0	0.2	0.0	0.7	0.0	0.2

Table 66: Distribution of core organisations by countries and theme (LIFESCI) for CSC/STREP (%)

	LIFESCI_4_CSC		LIFESCI _5_CSC		LIFESCI_6_STREP	
	core	all	core	all	core	all
AUT	0.0	3.3	0.0	3.0	0.0	4.3
BEL	5.3	4.3	4.2	3.3	0.0	3.2
BGR	0.0	0.1	0.0	0.3	0.0	0.4
CHE	2.6	3.5	4.2	2.9	7.4	4.2
CYP	0.0	0.0	0.0	0.1	0.0	0.0
CZE	0.0	0.3	0.0	1.0	0.0	1.1
DEU	15.8	17.7	20.8	14.6	29.6	17.0
DNK	2.6	3.7	6.3	3.8	3.7	4.0
ESP	2.6	6.7	2.1	6.8	3.7	5.6
FIN	0.0	3.0	6.3	2.5	3.7	2.7
FRA	13.2	12.4	12.5	11.3	18.5	11.3
GBR	28.9	12.8	20.8	13.3	11.1	10.5
GRC	2.6	2.0	0.0	3.1	0.0	0.8
HUN	0.0	0.3	0.0	1.2	0.0	1.7
IRL	0.0	1.8	0.0	1.4	0.0	0.7
ISR	0.0	1.0	0.0	1.7	0.0	2.3
ITA	0.0	12.2	4.2	11.1	3.7	12.1
NLD	18.4	6.0	12.5	4.5	14.8	4.4
NOR	0.0	1.4	0.0	1.7	0.0	1.3
POL	0.0	0.1	0.0	1.7	0.0	2.0
PRT	0.0	1.5	0.0	1.8	0.0	0.9
ROU	0.0	0.0	0.0	0.2	0.0	0.3
RUS	0.0	0.0	0.0	0.2	0.0	0.3
SVK	0.0	0.1	0.0	0.5	0.0	0.4
SVN	0.0	0.1	0.0	0.4	0.0	0.9
SWE	7.9	4.8	6.3	3.6	3.7	4.0
USA	0.0	0.1	0.0	0.8	0.0	0.4

Table 67: *Distribution of core organisation by countries and by theme (AERO), FP6 instruments (IP, NoE, STREP) (%)*

	AERO_6_IP		AERO_6_NOE		AERO_6_STREP	
	core	all	core	all	core	all
AUT	0.0	2.4	0.0	4.7	0.0	3.1
BEL	8.3	3.7	0.0	4.7	4.0	5.2
CHE	0.0	2.0	0.0	4.7	0.0	2.1
CYP	0.0	0.7	0.0	0.0	0.0	0.3
CZE	0.0	2.9	0.0	2.3	0.0	1.9
DEU	16.7	12.9	42.9	25.6	24.0	14.5
DNK	0.0	1.0	0.0	2.3	0.0	1.1
ESP	0.0	7.6	14.3	2.3	4.0	7.7
FIN	0.0	0.8	0.0	0.0	0.0	0.5
FRA	25.0	17.0	0.0	4.7	32.0	19.2
GBR	25.0	11.8	14.3	16.3	12.0	11.9
GRC	8.3	4.4	0.0	7.0	4.0	5.0
HUN	0.0	0.2	0.0	0.0	0.0	0.8
IRL	0.0	2.0	0.0	0.0	0.0	0.8
ISR	0.0	1.3	0.0	0.0	4.0	2.1
ITA	8.3	10.1	0.0	9.3	8.0	8.2
NLD	4.2	4.9	14.3	7.0	4.0	3.2
NOR	0.0	1.5	0.0	2.3	0.0	1.1
POL	0.0	2.0	0.0	0.0	0.0	1.5
PRT	0.0	1.7	0.0	0.0	4.0	1.3
RUS	0.0	1.3	0.0	0.0	0.0	1.1
SVK	0.0	0.0	0.0	0.0	0.0	0.2
SWE	4.2	4.4	14.3	7.0	0.0	3.7
TUR	0.0	0.7	0.0	0.0	0.0	0.0

Table 68: Distribution of core organisation by countries and by theme (ENV), FP6 instruments (IP, NoE, STREP) (%)

	ENV_6_IP		ENV_6_NOE		ENV_6_STREP	
	core	all	core	all	core	all
AUT	2.3	2.9	0.0	2.2	0.0	3.2
BEL	2.3	4.0	0.0	4.5	2.7	3.4
CHE	6.8	2.8	0.0	1.1	2.7	3.4
CYP	0.0	0.2	0.0	0.0	0.0	0.2
CZE	2.3	2.2	4.8	1.1	2.7	1.7
DEU	22.7	17.0	23.8	14.3	21.6	16.8
DNK	0.0	3.3	4.8	2.9	0.0	3.1
ESP	0.0	5.8	0.0	7.1	2.7	6.5
FIN	4.5	2.2	0.0	2.7	0.0	2.1
FRA	13.6	9.1	4.8	10.9	21.6	8.6
GBR	9.1	11.4	19.0	12.9	8.1	7.9
GRC	2.3	2.8	0.0	2.2	8.1	3.1
HUN	0.0	1.3	0.0	1.3	0.0	1.7
IRL	0.0	0.6	0.0	1.1	0.0	0.8
ISR	0.0	0.4	0.0	0.7	0.0	1.3
ITA	11.4	8.0	4.8	7.3	10.8	8.5
NLD	9.0	5.6	14.3	6.2	8.1	6.4
NOR	4.5	3.2	0.0	4.2	2.7	2.7
POL	0.0	2.3	4.8	3.3	2.7	3.8
PRT	2.3	1.2	4.8	2.2	2.7	2.5
RUS	0.0	0.8	0.0	0.9	0.0	0.8
SVK	0.0	0.0	4.8	0.9	0.0	0.4
SWE	6.8	5.0	9.5	4.2	2.7	2.6
TUR	0.0	0.5	0.0	0.7	0.0	0.7

Table 69: Distribution of core organisation by countries and by theme (ICT), FP6 instruments (IP, NoE, STREP) (%)

	ICT_6_IP		ICT_6_NOE		ICT_6_STREP	
	core	all	core	all	core	all
AUT	0.0	3.4	3.3	2.6	4.1	2.8
BEL	0.0	3.9	6.7	3.9	8.2	3.0
CHE	2.2	3.8	10.0	2.8	2.0	2.8
CYP	0.0	0.4	3.3	0.1	2.0	0.4
CZE	0.0	1.1	0.0	1.0	0.0	1.0
DEU	26.1	17.9	3.3	14.3	16.3	15.9
DNK	0.0	1.9	0.0	2.8	0.0	1.6
ESP	6.5	7.1	6.7	6.3	8.2	7.2
FIN	4.3	2.2	3.3	2.3	2.0	2.3
FRA	21.7	10.4	20.0	11.1	12.2	9.4
GBR	6.5	12.1	6.7	12.0	6.1	10.7
GRC	2.2	3.5	20.0	4.6	8.2	4.8
HUN	0.0	0.7	3.3	0.8	2.0	2.7
IRL	0.0	1.4	0.0	1.5	0.0	1.3
ISR	0.0	1.7	0.0	1.1	0.0	2.0
ITA	10.9	11.6	6.7	10.5	16.3	10.9
NLD	10.9	3.7	0.0	4.0	6.1	3.6
NOR	0.0	1.1	0.0	1.9	0.0	1.8
POL	0.0	1.7	0.0	1.9	0.0	3.3
PRT	0.0	1.3	3.3	2.0	0.0	1.3
RUS	0.0	0.4	0.0	0.4	0.0	0.4
SVK	0.0	0.2	0.0	0.3	2.0	0.6
SWE	6.5	3.3	0.0	5.8	2.0	2.6
TUR	0.0	0.3	3.3	1.0	0.0	0.6

Table 70: Distribution of core organisation by countries and by theme (LIFESCI), FP6 instruments (IP, NoE, STREP) (%)

	LIFESCI_6_IP		LIFESCI_6_NOE		LIFESCI_6_STREP	
	core	all	core	all	core	all
AUT	0.0	2.5	0.0	2.5	0.0	4.3
BEL	0.0	5.1	4.2	4.4	0.0	3.2
CHE	10.0	3.5	8.3	3.9	7.4	4.2
CYP	0.0	0.0	0.0	0.0	0.4	0.0
CZE	3.3	0.8	0.0	1.1	0.0	1.1
DEU	23.3	16.2	37.5	15.1	29.6	17.0
DNK	3.3	3.6	0.0	3.7	3.7	4.0
ESP	3.3	6.0	4.2	5.8	3.7	5.6
FIN	0.0	2.1	0.0	1.4	3.7	2.7
FRA	10.0	11.1	4.2	12.5	18.5	11.3
GBR	26.7	13.1.	16.7	13.6	11.1	10.5
GRC	0.0	1.5	0.0	0.7	0.0	0.8
HUN	0.0	0.9	0.0	1.8	0.0	1.7
IRL	0.0	0.0	0.0	0.7	0.0	0.7
ISR	0.0	1.1	0.0	2.3	0.0	2.3
ITA	0.0	11.9	4.2	12.5	3.7	12.1
NLD	10.0	4.5	12.5	5.1	14.8	4.4
NOR	0.0	0.7	0.0	0.4	0.0	1.3
POL	0.0	1.4	0.0	2.1	0.0	2.0
PRT	0.0	0.7	0.0	1.4	0.0	0.9
RUS	0.0	0.4	0.0	0.4	0.0	0.3
SVK	0.0	0.3	0.0	0.2	0.0	0.4
SWE	10.0	6.2	8.3	4.4	3.7	4.0
TUR	0.0	0.1	0.0	0.4	0.0	0.0

Table 71: Distribution of core organisations in FP4 to FP6 by organisation type and theme (AERO) of CSC/STREP instrument

	AERO_4_CSC		AERO_5_CSC		AERO_6_STREP	
	core	all	core	all	core	all
CON	0.0	0.9	0.0	0.9	0.0	1.3
EDU	0.0	34.9	0.0	23.5	20.0	30.5
GOV	0.0	0.9	0.0	1.0	0.0	1.3
IND	77.8	42.4	78.6	54.1	56.0	39.2
OTH	0.0	3.4	0.0	6.7	0.0	5.3
ROR	22.2	17.4	21.4	13.7	24.0	22.3

Table 72: Distribution of core organisations in FP4 to FP6 by organisation type and theme (ENV) of CSC/STREP instrument

	ENV_4_CSC		ENV_5_CSC		ENV_6_STREP	
	core	all	core	all	core	all
CON	0.0	2.0	0.0	2.3	0.0	2.3
EDU	43.1	34.5	34.9	29.8	24.3	26.5
GOV	2.0	3.4	1.6	6.8	0.0	4.0
IND	3.9	32.3	1.6	26.6	18.9	34.5
OTH	0.0	2.9	0.0	11.6	0.0	8.9
ROR	51.0	24.3	61.9	22.3	56.8	23.2

Table 73: Distribution of core organisations in FP4 to FP6 by organisation type and theme (ICT) of CSC/STREP instrument

	ICT_4_CSC		ICT_5_CSC		ICT_6_STREP	
	core	all	core	all	core	all
CON	0.0	2.8	0.0	2.3	0.0	1.5
EDU	15.7	15.0	35.1	25.0	44.9	29.3
GOV	0.0	2.2	0.0	4.6	0.0	3.8
IND	62.7	64.1	37.8	41.1	28.6	36.2
OTH	0.0	3.7	0.0	13.6	0.0	14.4
ROR	21.6	11.9	27.0	13.0	26.5	14.5

Table 74: Distribution of core organisations in FP4 to FP6 by organisation type and theme (LIFESCI) of CSC/STREP instrument

	LIFESCI_4_CSC		LIFESCI_5_CSC		LIFESCI_6_STREP	
	core	all	core	all	core	all
CON	0.0	0.3	0.0	0.3	0.0	0.4
EDU	55.3	47.5	68.8	45.0	63.0	48.7
GOV	0.0	1.4	0.0	2.5	0.0	0.4
IND	2.6	20.2	4.2	14.3	3.7	18.2
OTH	0.0	2.1	0.0	5.0	0.0	3.9
ROR	42.1	27.8	27.1	32.5	33.3	28.0

Table 75: Distribution of core organisations by organisation type and theme (AERO) of FP6 instruments

	AERO_6_IP		AERO_6_NoE		AERO_6_STREP	
	core	all	core	all	core	all
CON	0.0	1.0	0.0	0.0	0.0	1.3
EDU	12.5	23.0	0.0	34.9	20.0	30.5
GOV	0.0	3.2	0.0	2.3	0.0	1.3
IND	66.7	42.5	14.3	11.6	56.0	39.2
OTH	0.0	9.4	0.0	7.0	0.0	5.3
ROR	20.8	20.3	85.7	44.2	24.0	22.3

Table 76: *Distribution of core organisations by organisation type and theme (ENV) of FP6 instruments*

	ENV_6_IP		ENV_6_NoE		ENV_6_STREP	
	core	all	core	all	core	all
CON	0.0	1.6	0.0	0.7	0.0	2.3
EDU	31.8	29.5	57.1	44.3	24.3	26.5
GOV	0.0	5.1	0.0	1.8	0.0	4.0
IND	18.2	29.6	0.0	13.6	18.9	34.5
OTH	0.0	10.1	0.0	3.3	0.0	8.9
ROR	50.0	23.3	42.9	36.3	56.8	23.2

Table 77: *Distribution of core organisations by organisation type and theme (ICT) of FP6 instruments*

	ICT_6_IP		ICT_6_NoE		ICT_6_STREP	
	core	all	core	all	core	all
CON	0.0	1.6	0.0	0.0	0.0	1.5
EDU	15.2	29.1	66.7	62.9	44.9	29.3
GOV	0.0	2.8	0.0	0.8	0.0	3.8
IND	63.0	39.6	10.0	12.0	28.6	36.2
OTH	0.0	11.7	0.0	4.4	0.0	14.4
ROR	21.7	14.8	23.3	19.9	26.5	14.5

Table 78: *Distribution of core organisations by organisation type and theme (LIFESCI) of FP6 instruments*

	LIFESCI_6_IP		LIFESCI_6_NoE		LIFESCI_6_STREP	
	core	all	core	all	core	all
CON	0.0	0.5	0.0	0.2	0.0	0.4
EDU	60.0	46.5	79.2	53.0	63.0	48.7
GOV	0.0	0.4	0.0	0.2	0.0	0.4
IND	3.3	20.0	0.0	11.1	3.7	18.2
OTH	0.0	4.1	0.0	7.0	0.0	3.9
ROR	36.7	28.2	20.8	28.0	33.3	28.0

3. Figures

Figure 22: Network of core organisations (AERO_4_CSC)

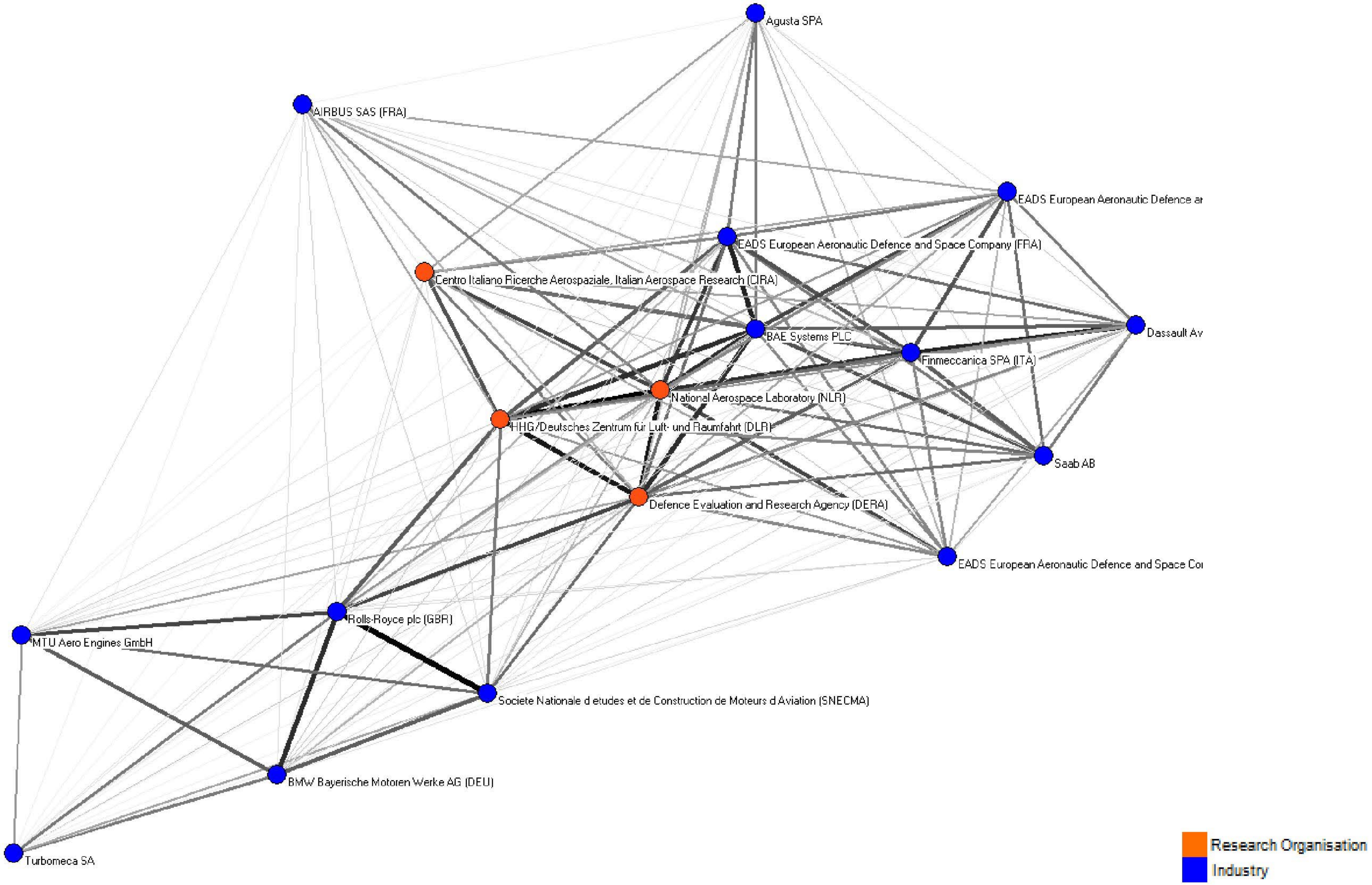


Figure 23: *Network of core organisations (AERO_5_CSC)*

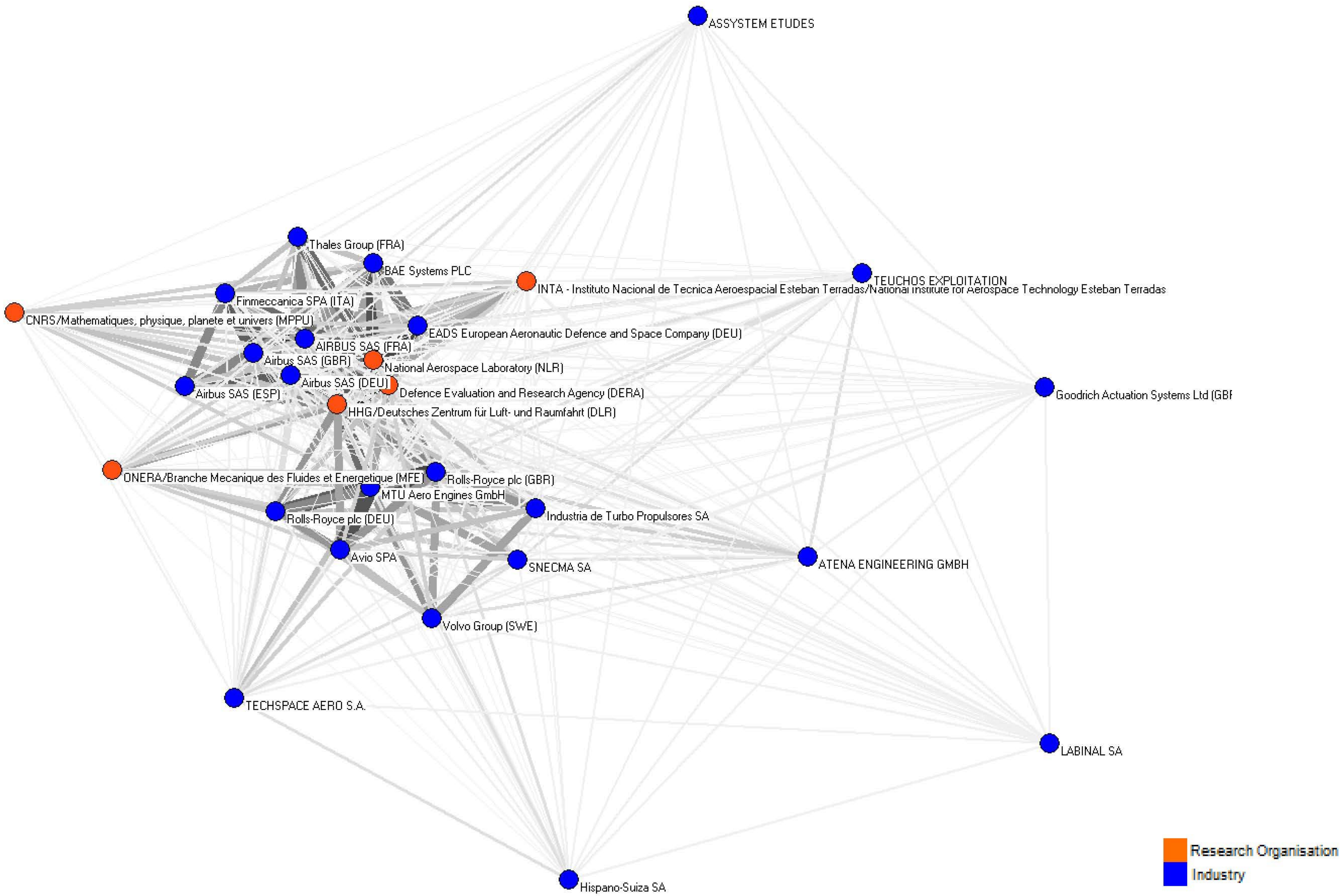


Figure 24: Network of core organisations (AERO_6_STREP)

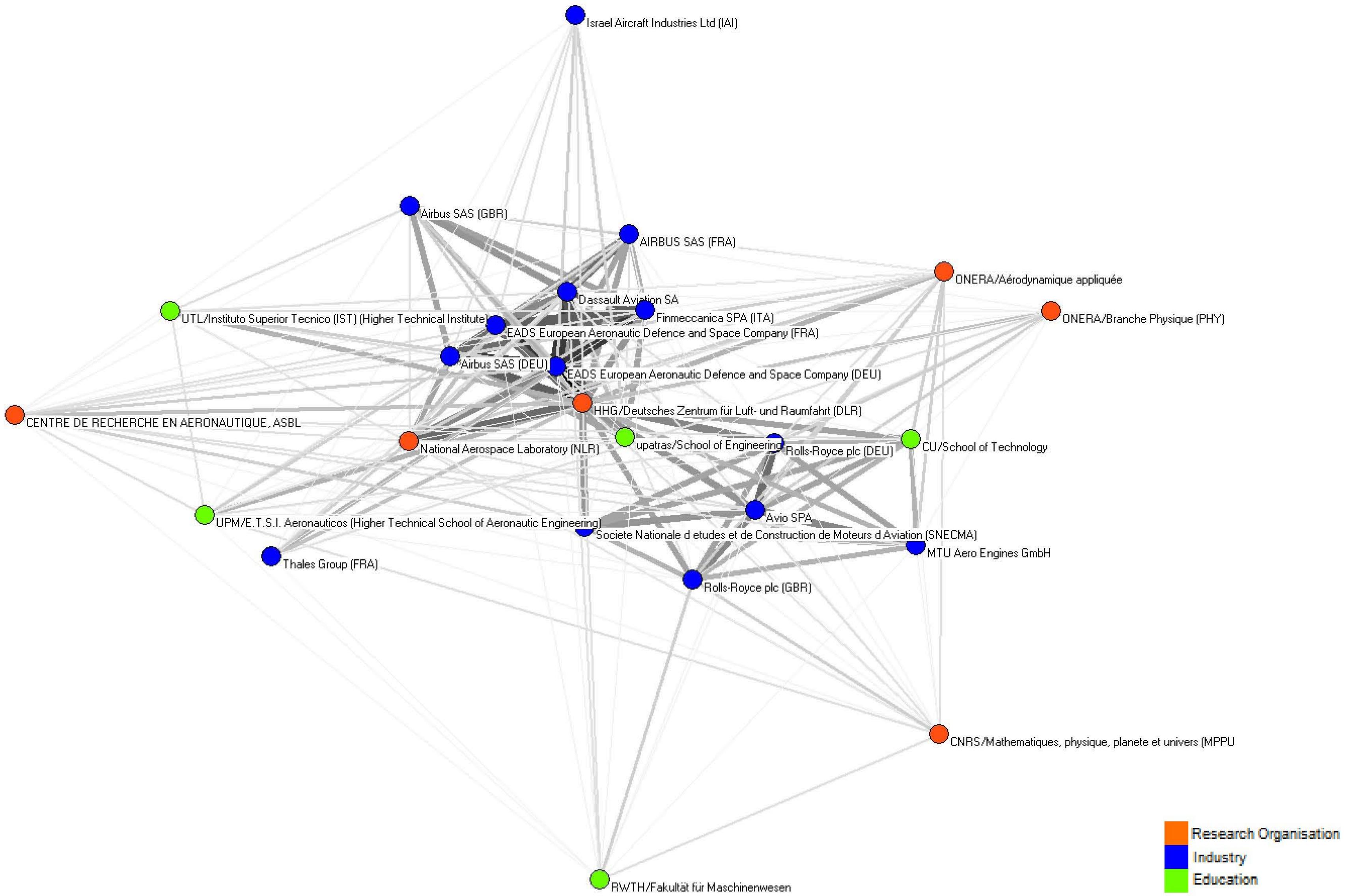


Figure 25: Network of core organisations (AERO_6_IP)

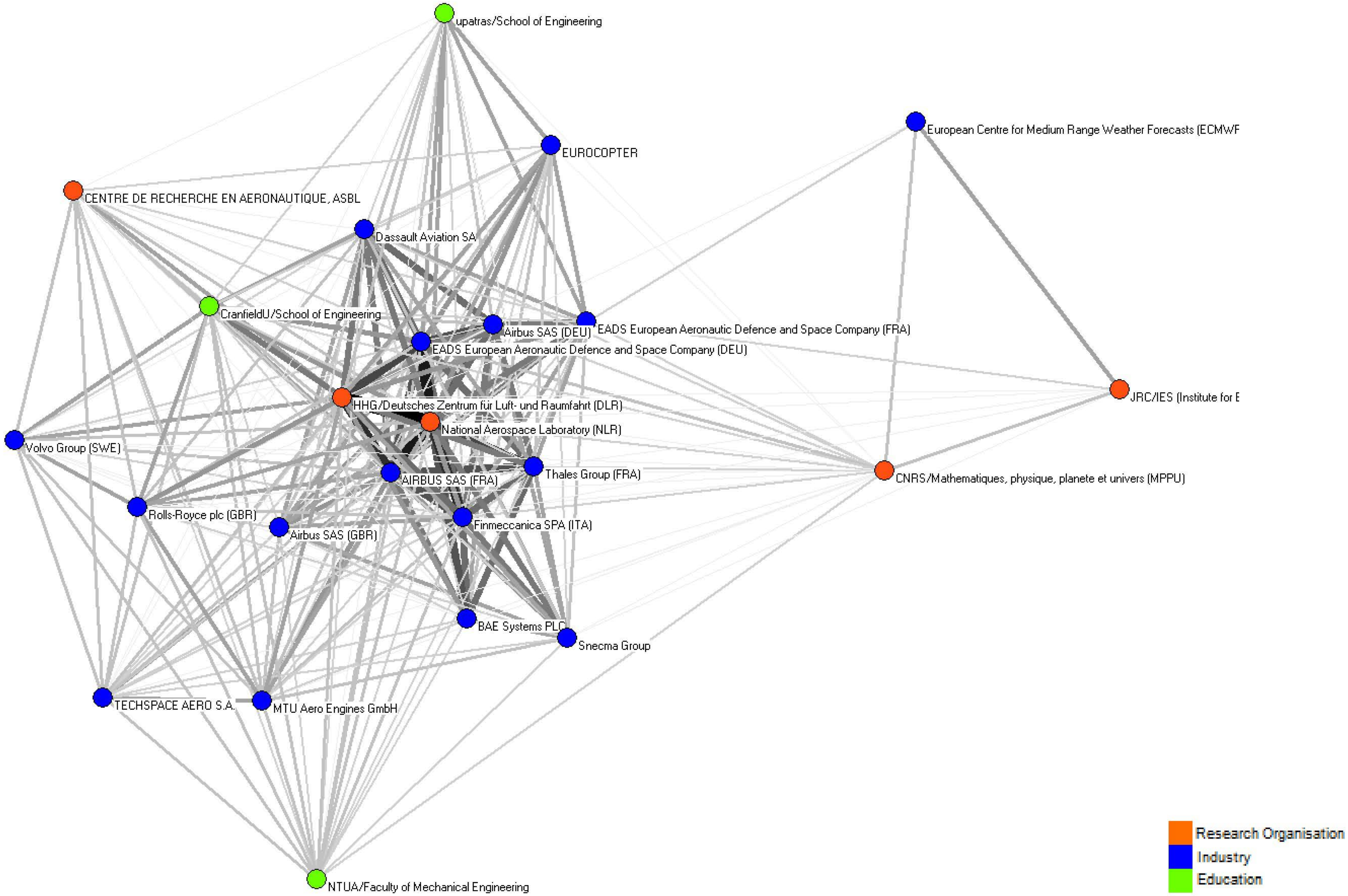


Figure 26: *Network of core organisations (AERO_6_NoE)*

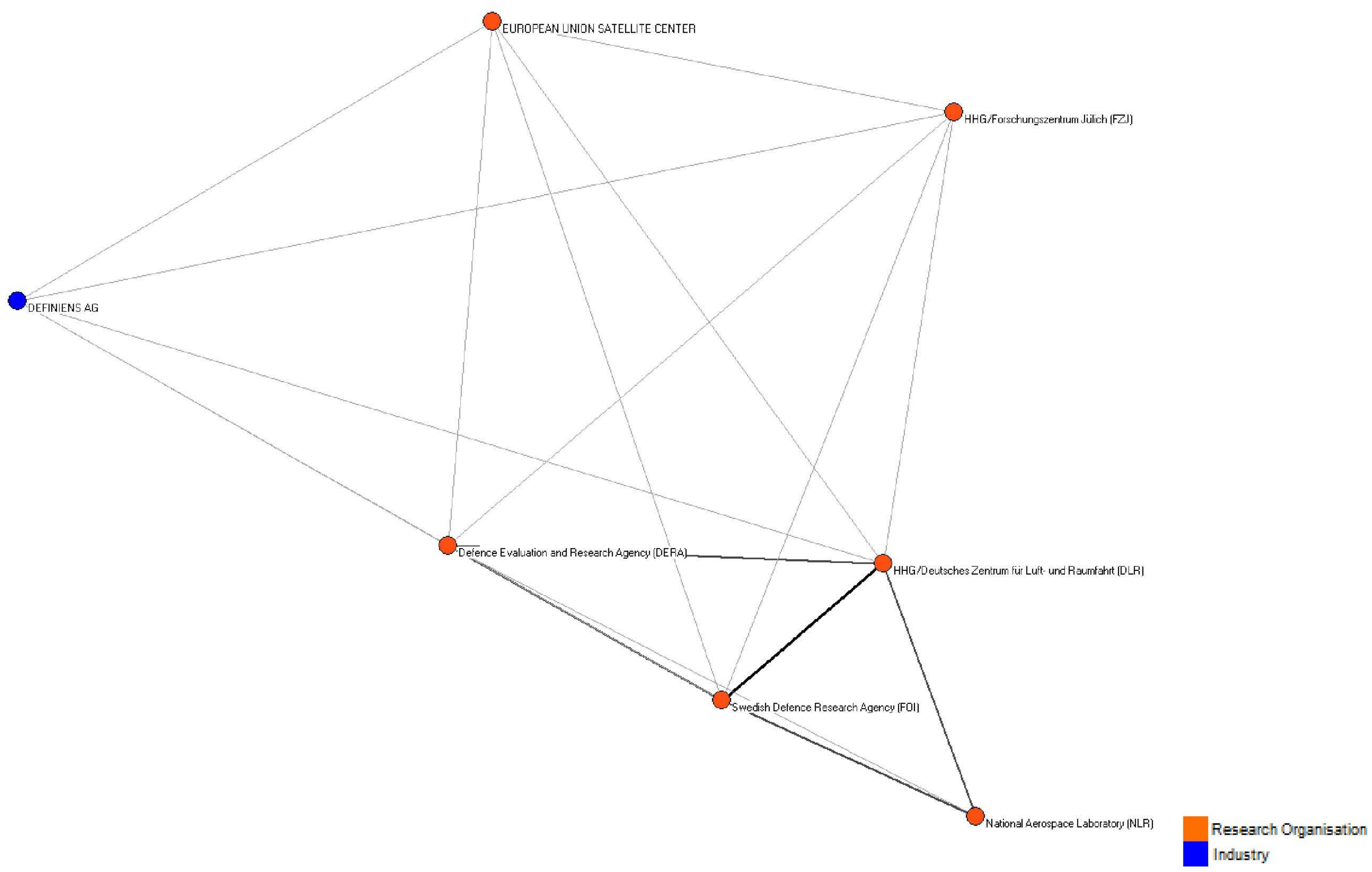
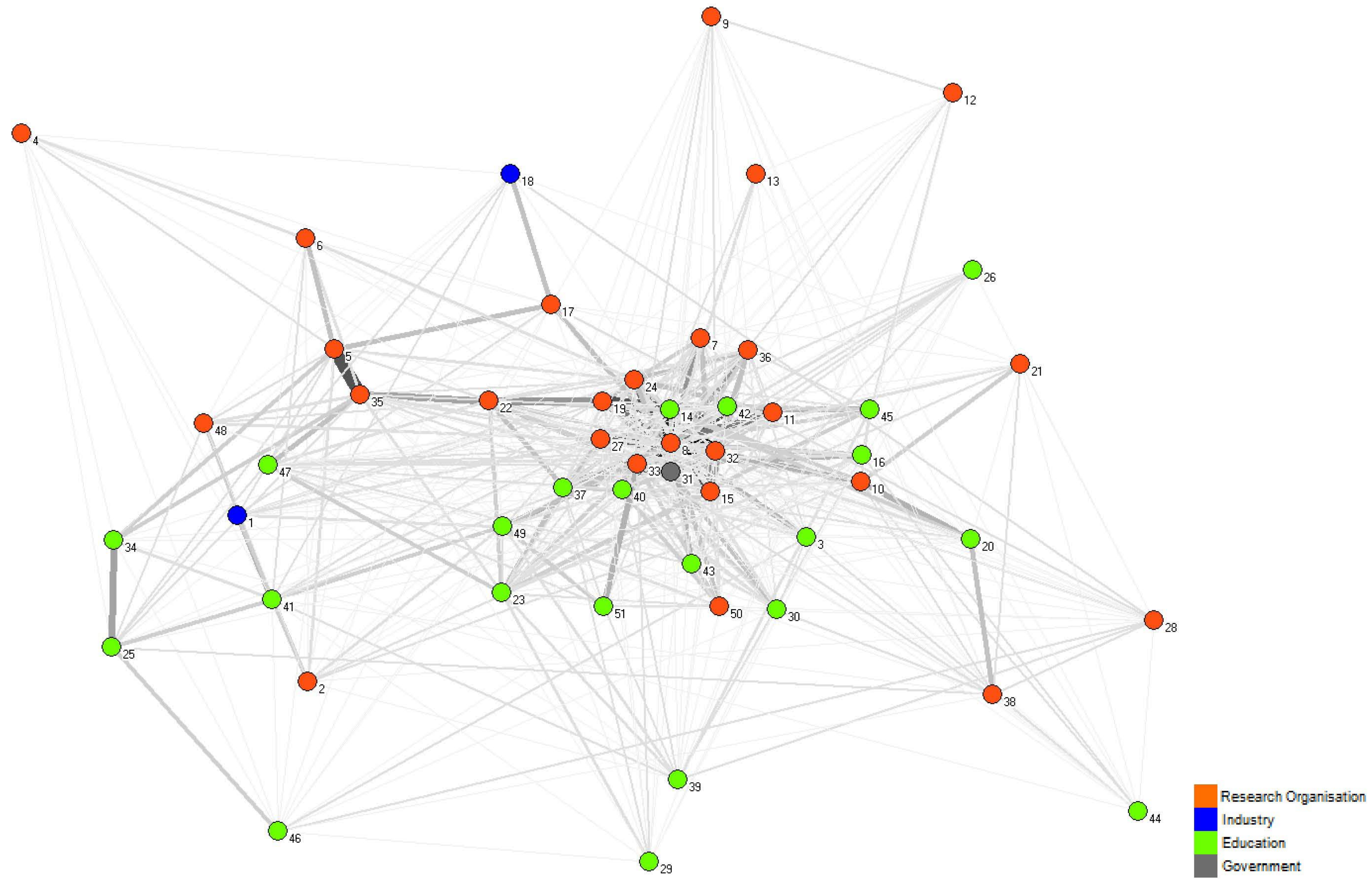


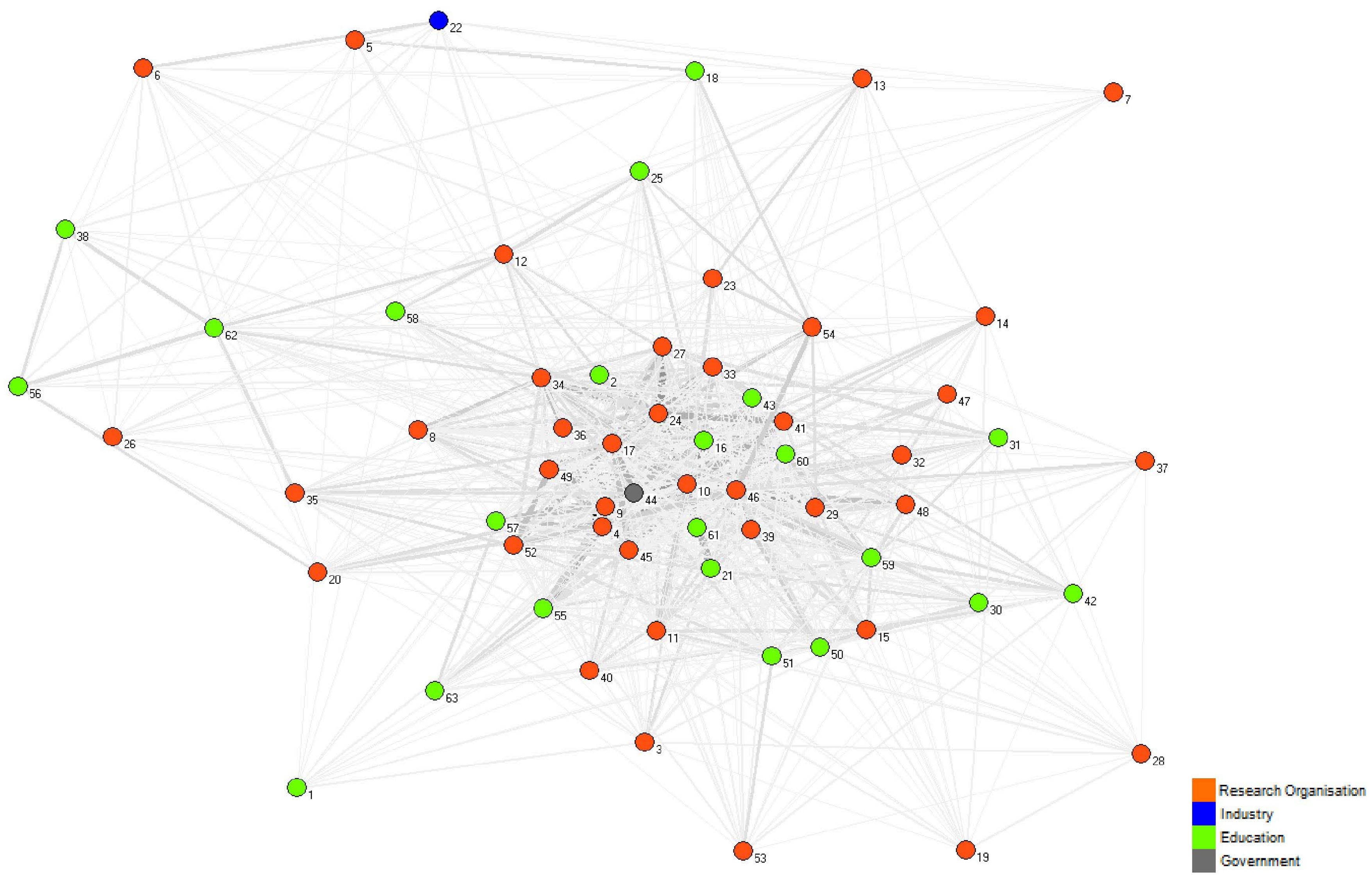
Figure 27: *Network of core organisations (ENV_4_CSC)*



Names of core organisations (ENV_4_CSC)

1 AEA Technology Plc
2 ARMINES/Domaine Energétique et Environnement
3 AUTH/Faculty of Sciences
4 CEA/Direction de la recherche technologique
5 CENTER FOR RENEWABLE ENERGY SOURCES (CRES)
6 CIEMAT/Departamento de Energias Renovables (Department of Renewable Energies)
7 CNR/Institute of atmospheric sciences and climate (ISAC)
8 CNRS/Mathématiques, Physique, Planète et Univers (MPPU)
9 CNRS/Sciences du vivant (SDV)
10 CNRS/Sciences et technologies de l'information et de l'ingénierie (ST2I)
11 Council for the Central Laboratory of the Research Councils (CCLRC)
12 CSIC/BIOLOGIA Y BIOMEDICINA (Biology and Biomedicine)
13 CSIC/RECURSOS NATURALES
14 CU/School of Physical Sciences
15 Danish Meteorological Institute (DMI)
16 EdinburghU/College of Science & Engineering
17 ENEA - Ente per le Nuove tecnologie, Energia e Ambiente
18 ENEL - Ente Nationale Energia Elettrica SPA
19 ENVIRA/NILU - Norwegian Institute for Air Research (Norsk Institutt for Luftforskning)
20 EPFL/School of Architecture, Civil and Environmental Engineering (ENAC)
21 FHG/Fraunhofer-Institut für Solare Energiesysteme (ISE)
22 Finnish Meteorological Institute, FMI, Ilmatieteen Laitos
23 HEL/Faculty of Science
24 HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)
25 ImperialCL/Faculty of Engineering
26 ImperialCL/Faculty of Natural Sciences
27 JRC/IES (Institute for Environment and Sustainability)
28 JRC/IPSC (Institute for the Protection and Security of the Citizen)
29 LU/Institute of Technology (LTH)
30 ManU/Faculty of Engineering and Physical Sciences
31 Ministry of Defence (UK)/Met Office
32 MPG/MPI für Meteorologie
33 Natural Environment Research Council (NERC)
34 NTUA/Faculty of Mechanical Engineering
35 Risoe/Wind Energy Department
36 Royal Netherlands Meteorological Institute/Koninklijk Nederlands Meteorologisch Instituut (KNMI)
37 SU/Faculty of Natural Sciences
38 TNO/Built Environment and Geosciences
39 UCL/Faculty of Social and Historical Sciences
40 UEA/Faculty of Science
41 Uni Stuttgart/Fakultät für Maschinenbau
42 UniBe/Philosophisch-naturwissenschaftliche Fakultät - Faculty of Science
43 unibo/Facolta di Scienze Matematiche, Fisiche e Naturali
44 UOA/School of Sciences
45 UoB/Faculty of Mathematics and Natural Science
46 UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)
47 UUpp/Faculty of Science and Technology
48 VTT Processes
49 VUA/Faculty of Earth and Life Sciences
50 WGL/Potsdam-Institut für Klimafolgenforschung, Potsdam
51 WUR-EDU/Environmental Sciences

Figure 28: *Network of core organisations (ENV_5_CSC)*



Names of core organisations (ENV_5_CSC)

1 AUTH/Faculty of Engineering
2 AUTH/Faculty of Sciences
3 BAS/Department of Earth Sciences
4 CEA/Direction des Sciences de la Matiere
5 Center For Renewable Energy Sources (Cres)
6 Centro Elettronico Sperimentale Italiano (CESI) Giacinto Motta SPA
7 CIEMAT/Departamento de Energias Renovables (Department of Renewable Energies)
8 CNR/Institute of atmospheric sciences and climate (ISAC)
9 CNRS/Environnement et Développement Durable
10 CNRS/Mathématiques, Physique, Planète et Univers (MPPU)
11 CNRS/Sciences du vivant (SDV)
12 CNRS/Sciences et technologies de l'information et de l'ingénierie (ST2I)
13 CNRS/Scientifique Chimie (SC)
14 Csic/Ciencias Y Tecnologia Quimicas
15 Csic/Recursos Naturales
16 CU/School of Physical Sciences
17 Danish Meteorological Institute (DMI)
18 DUT/Faculty of Civil Engineering and Geosciences
19 EAWAG Eidgenössische Anstalt für Wasserversorgung - Swiss Federal Institute Of Environmental S&T
20 ECN/Hydrogen and Clean Fossil Fuels
21 EdinburghU/College of Science & Engineering
22 electricite de France (EDF)
23 ENEA - Ente per le Nuove tecnologie, Energia e Ambiente
24 ENVIRA/NILU - Norwegian Institute for Air Research (Norsk Institutt for Luftforskning)
25 EPFL/School of Architecture, Civil and Environmental Engineering (ENAC)
26 FHG/Fraunhofer-Institut für Solare Energiesysteme (ISE)
27 Finnish Meteorological Institute, FMI, Ilmatieteen Laitos
28 FV Berlin/Institut für Gewässerökologie und Binnenfischerei
29 Geological Survey of Denmark and Greenland (GEUS)
30 GU/Faculty of Natural Science
31 HEL/Faculty of Science
32 Hellenic Centre For Marine Research
33 HHG/Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)
34 HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)
35 HHG/Forschungszentrum Geesthacht (GKSS)
36 HHG/Forschungszentrum Jülich (FZJ)
37 HHG/Umweltforschungszentrum Leipzig-Halle (UFZ)
38 ImperialCL/Faculty of Engineering
39 Institut Français de Recherche pour l Exploitation de la Mer (IFREMER)
40 Istituto Nazionale di Geofisica e Vulcanologia (INGV)
41 JRC/IES (Institute for Environment and Sustainability)
42 KU/Faculty of Sciences
43 LeedsU/Faculty of Environment
44 Ministry of Defence (UK)/Met Office
45 MPG/MPI für Meteorologie
46 Natural Environment Research Council (NERC)
47 PAS/Division VII Earth and Mining Sciences
48 Royal Netherlands Institute for Sea Research (NIOZ)
49 Royal Netherlands Meteorological Institute/Koninklijk Nederlands Meteorologisch Instituut (KNMI)
50 SotonU/Faculty of Engineering, Science and Mathematics
51 SU/Faculty of Natural Sciences
52 Swedish Meteorological and Hydrological Institute - Sveriges meteorologiska och hydrologiska institut (SMHI)
53 SYKE/Research Department
54 TNO/Built Environment and Geosciences
55 UEA/Faculty of Science
56 Uni Stuttgart/Fakultät für Maschinenbau
57 UniBe/Philosophisch-naturwissenschaftliche Fakultät - Faculty of Science
58 UOA/School of Sciences
59 UoB/Faculty of Mathematics and Natural Science
60 UP VI/Pôle Espace Environnement ecologie
61 UPS/UFR Sciences de la Vie et de la Terre (SVT)
62 UTL/Instituto Superior Tecnico (IST) (Higher Technical Institute)
63 UU/Faculty of Geosciences

Figure 29: Network of core organisations (ENV_6_STREP)

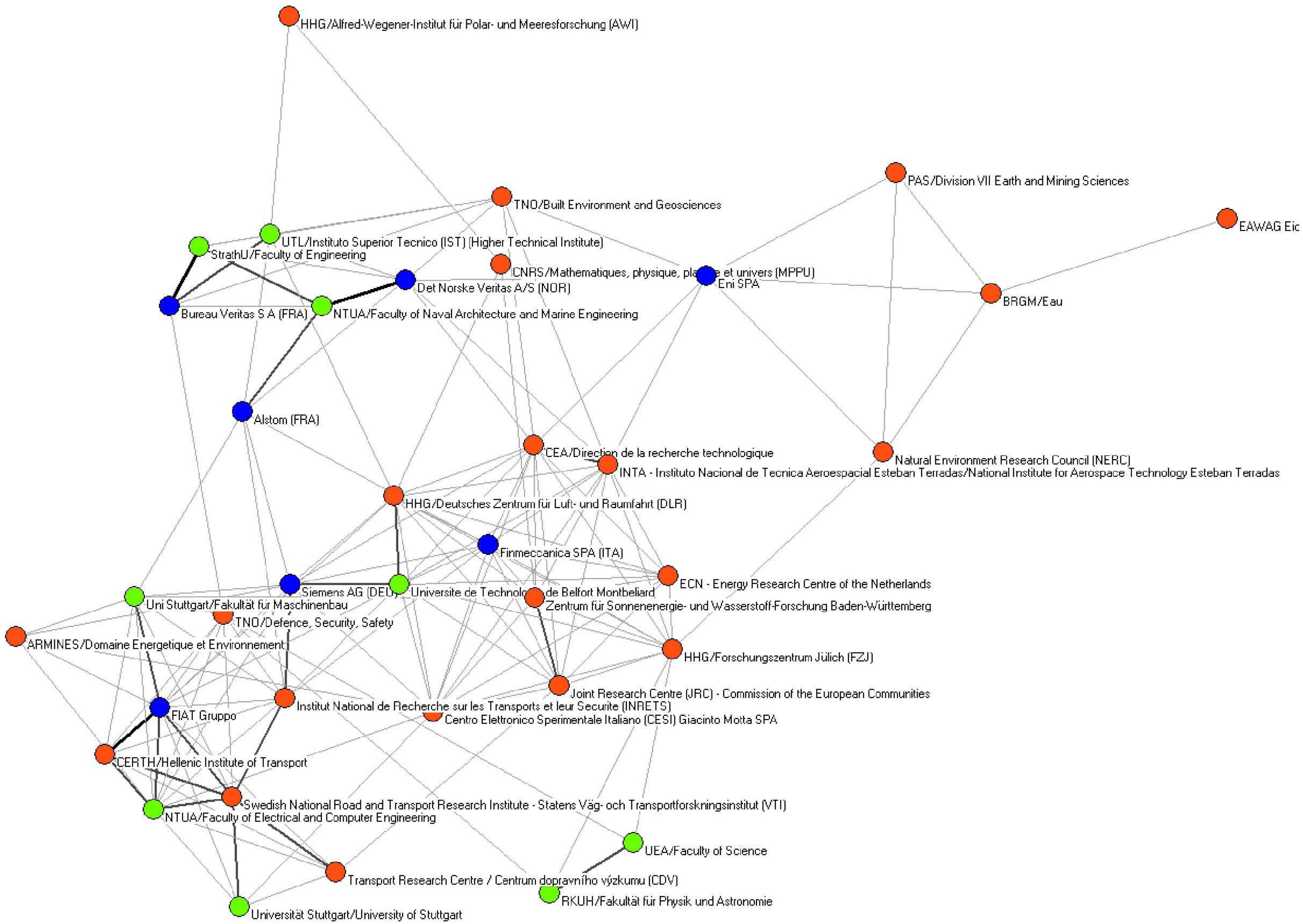


Figure 30: Network of core organisations (ENV_6_IP)

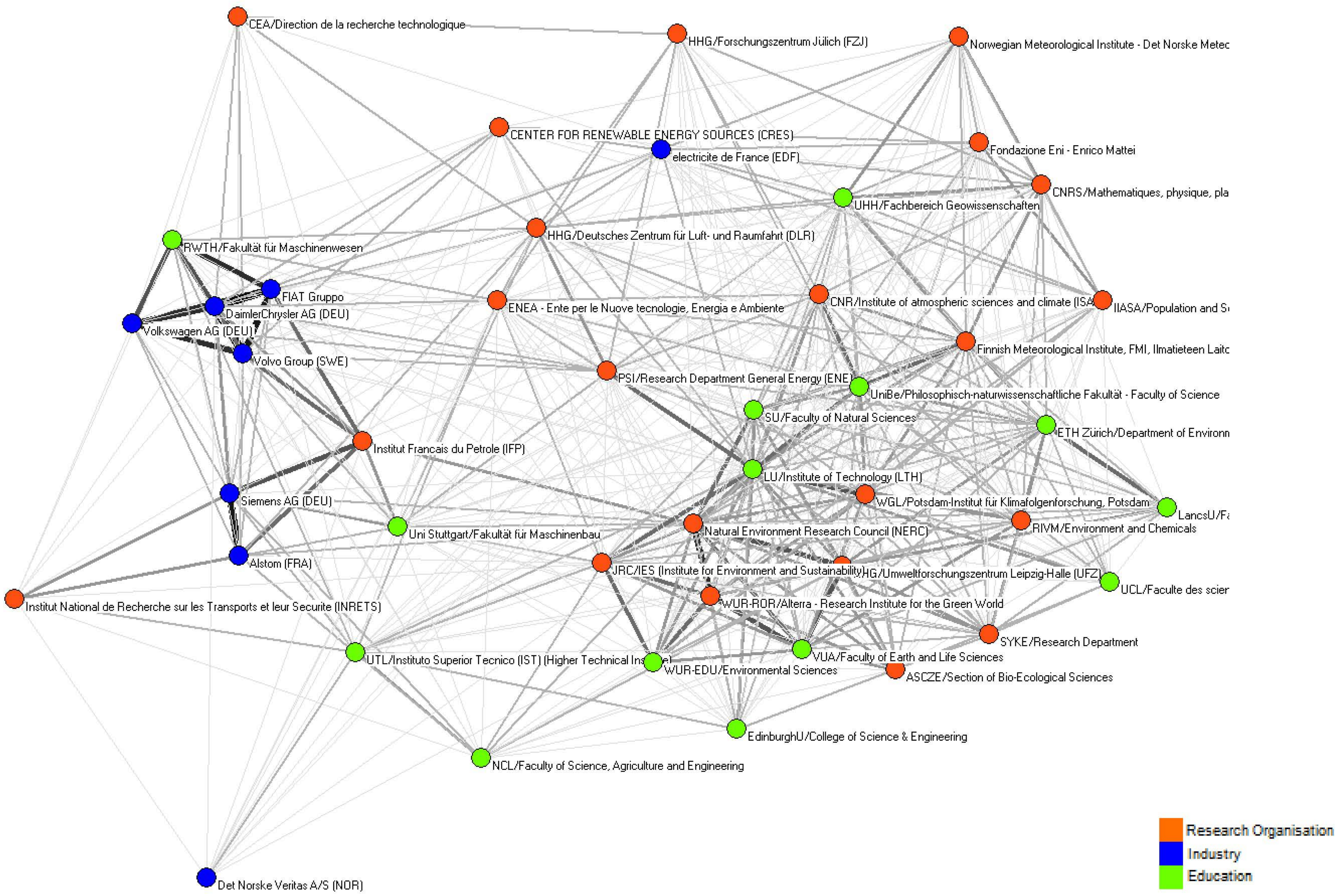


Figure 31: Network of core organisations (ENV_6_NoE)

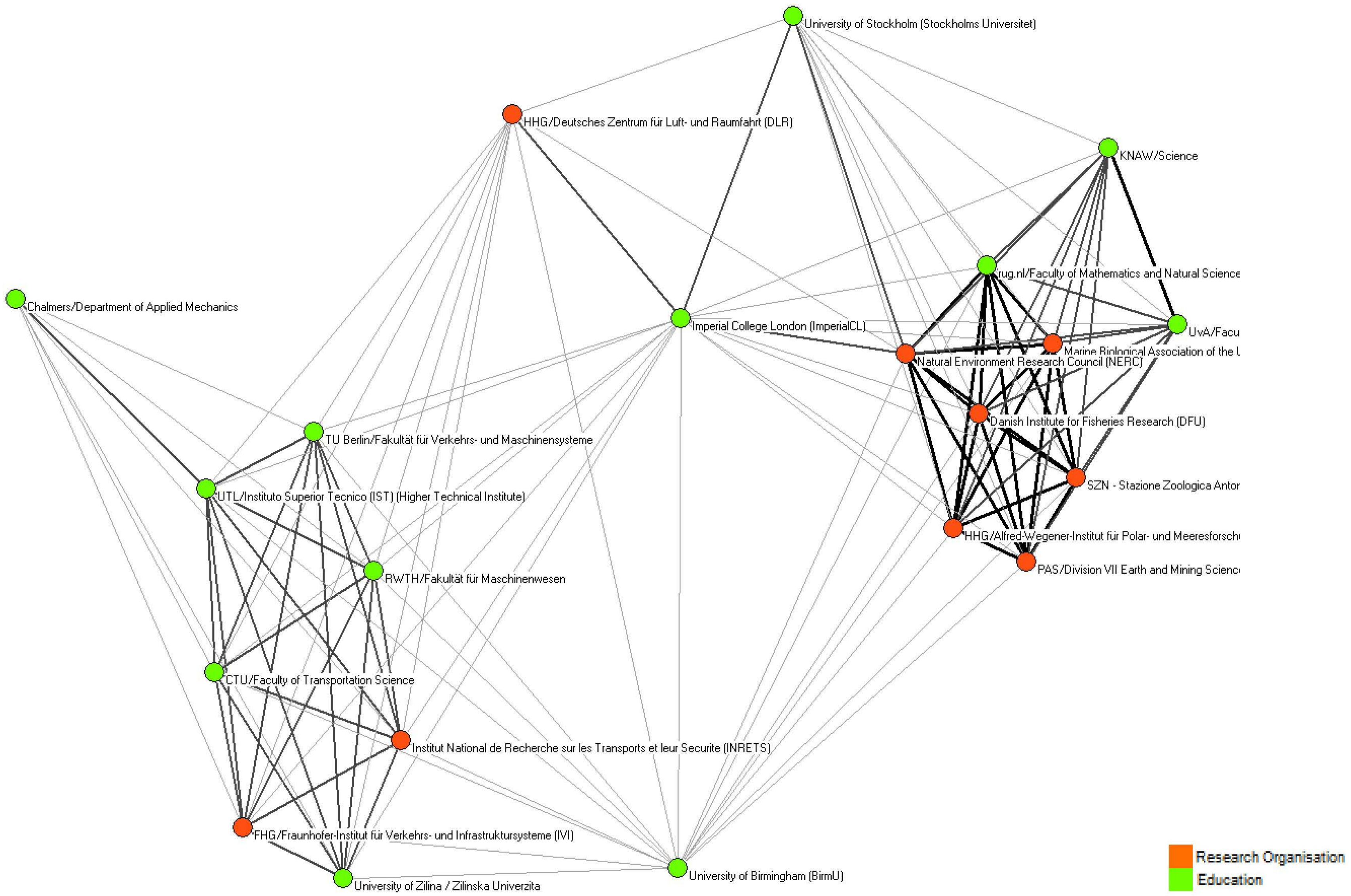


Figure 32: Network of core organisations (ICT_4_CSC)

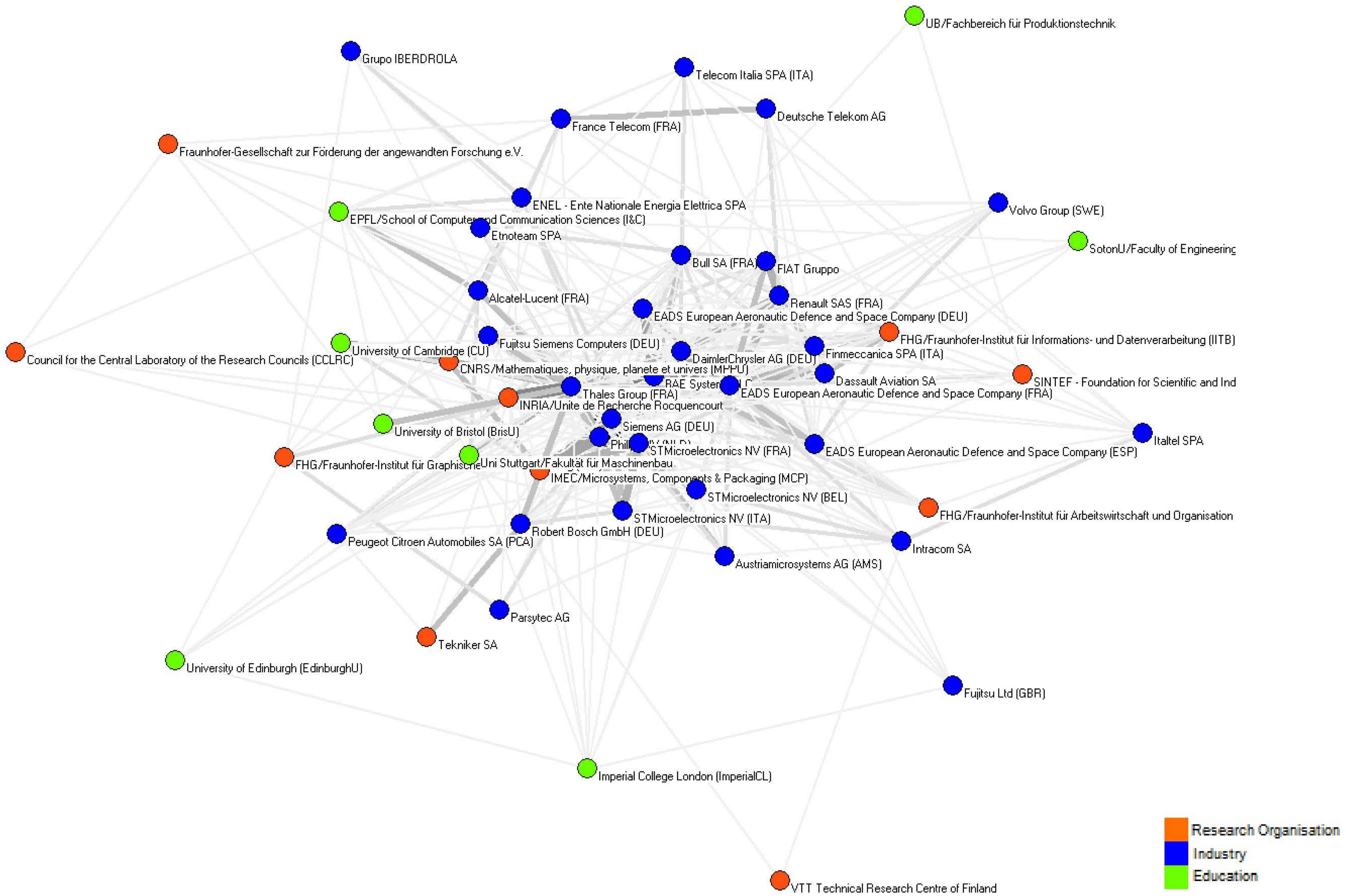
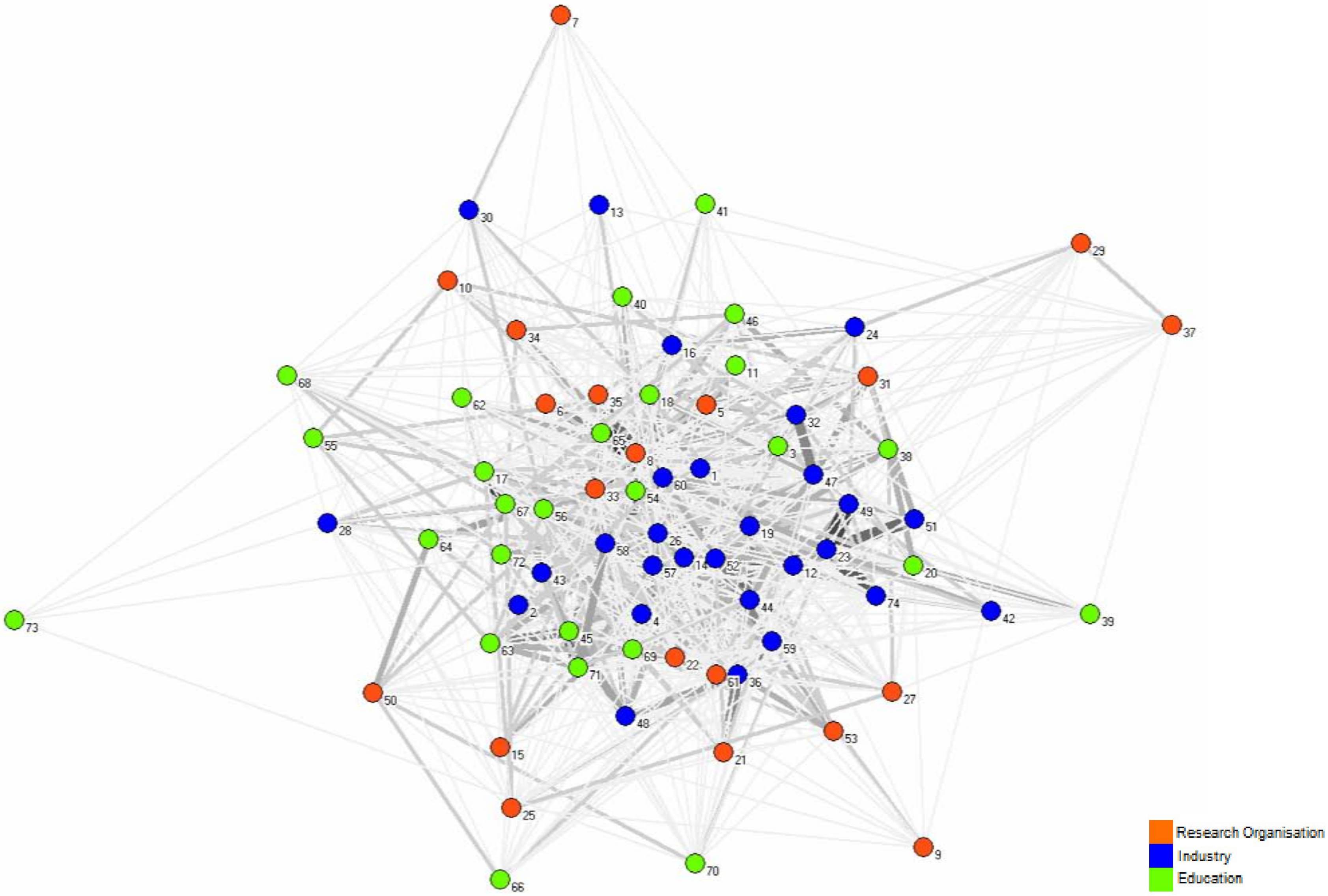


Figure 33: Network of core organisations (ICT_5_CSC)



Names of core organisations (ICT_5_CSC)

1 Alcatel-Lucent (FRA)
2 Atos Origin (ESP)
3 BrisU/Faculty of Engineering
4 British Telecom PLC (BT) (GBR)
5 CEA/Direction de la recherche technologique
6 CEA/Direction des Sciences de la Matière
7 CERTH/Informatics and Telematics Institute (I.T.I.)
8 CNRS/Mathématiques, Physique, Planète et Univers (MPPU)
9 Council for the Central Laboratory of the Research Councils (CCLRC)
10 Csic/Ciencias Y Tecnología Físicas
11 CU/School of Technology
12 DaimlerChrysler AG (DEU)
13 Datamat Ingegneria die Sistemi SPA
14 Deutsche Telekom AG
15 Deutsches Forschungszentrum für Künstliche Intelligenz GmbH
16 EADS European Aeronautic Defence and Space Company (FRA)
17 EPFL/School of Computer and Communication Sciences (I&C)
18 EPFL/School of Engineering (STI)
19 Ericsson AB (Telefonaktiebolaget LM Ericsson) (SWE)
20 ETH Zürich/Department of Information Technology and Electrical Engineering (D-ITET)
21 FHG/Fraunhofer-Institut für Graphische Datenverarbeitung (IGD)
22 FHG/Fraunhofer-Institut für Offene Kommunikationssysteme (FOKUS)
23 FIAT Gruppo
24 Finmeccanica SPA (ITA)
25 FORTH/Institute Of Computer Science (ICS)
26 France Telecom (FRA)
27 Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
28 Giunti Multimedia SRL
29 HHG/Deutsches Zentrum für Luft- und Raumfahrt (DLR)
30 Ibermatica SA
31 IMEC/Microsystems, Components & Packaging (MCP)
32 Infineon Technologies AG (DEU)
33 INRIA/Unité de Recherche Rocquencourt
34 Instituto Nazionale per la Fisica della Materia (INFM)
35 Instituto Trentino di Cultura
36 Intracom SA
37 JRC/IES (Institute for Environment and Sustainability)
38 KUL/Faculty of Engineering
39 LancsU/Faculty of Science and Technology
40 LIU/Institute of Technology
41 ManU/Faculty of Engineering and Physical Sciences
42 Mizar Automazione SPA
43 Motorola INC (FRA)
44 Nokia Corporation (FIN)
45 NTUA/Faculty of Electrical and Computer Engineering
46 OU/Mathematical, Physical, & Life Sciences Division
47 Philips NV (NLD)
48 Portugal Telecom SA
49 Renault SAS (FRA)
50 Research Academic Computer Technology Institute
51 Robert Bosch GmbH (DEU)
52 Siemens AG (DEU)
53 SINTEF Information and Communication Technology (ICT)
54 SotonU/Faculty of Engineering, Science and Mathematics
55 SSSUP/DIVISIONE RICERCHE
56 SurreyU/Faculty of Engineering and Physical Sciences
57 Telecom Italia SPA (ITA)
58 Telefonica de Espana SA
59 Telenor ASA
60 Thales Group (FRA)
61 TNO/Defence, Security, Safety
62 TU Wien/Fakultät für Informatik
63 UCL/Faculty of Engineering Sciences
64 UCY/Faculty of Pure and Applied Sciences
65 UJF/Direction Scientifique Mathématiques et Informatique (DS1)
66 Uni Stuttgart/Fakultät für Maschinenbau
67 UNIGE.ch/Faculty of Sciences
68 unige.it/Facolta Di Science Mathematiche Fisiche E Naturali
69 UniRoma1/Faculty Of Mathematics And Natural Sciences
70 Univ. Patras/School of Engineering
71 UPC/Departament de Teoria del Senyal i Comunicacions (TSC)
72 UPM/E.T.S.I. Telecomunicacion (Higher Technical School of Telecommunication Engineering)
73 UvA/Faculty of Social and Behavioural Sciences
74 Volvo Group (SWE)

Figure 34: Network of core organisations (ICT_6_STREP)

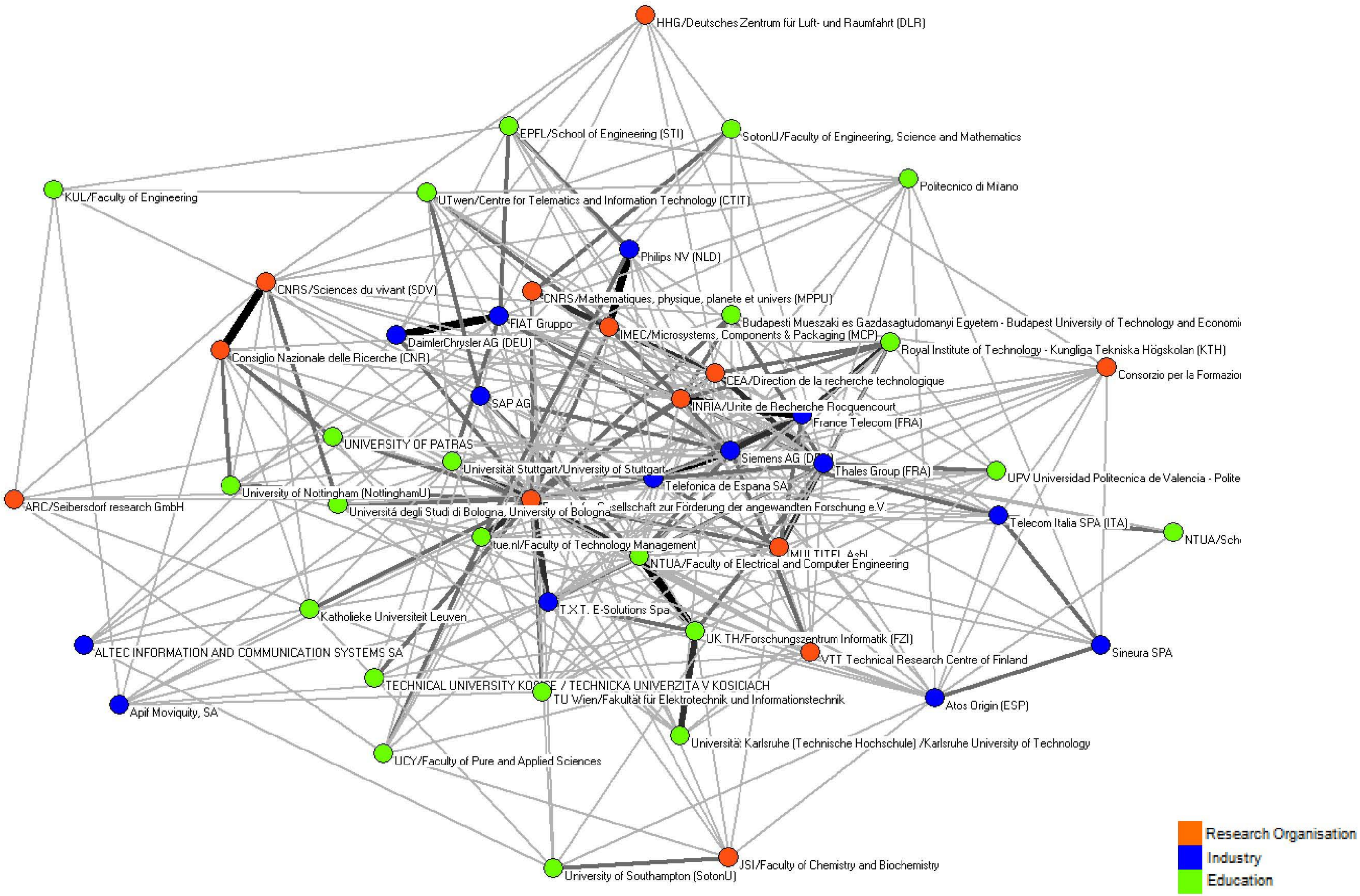


Figure 35: Network of core organisations (ICT_6_IP)

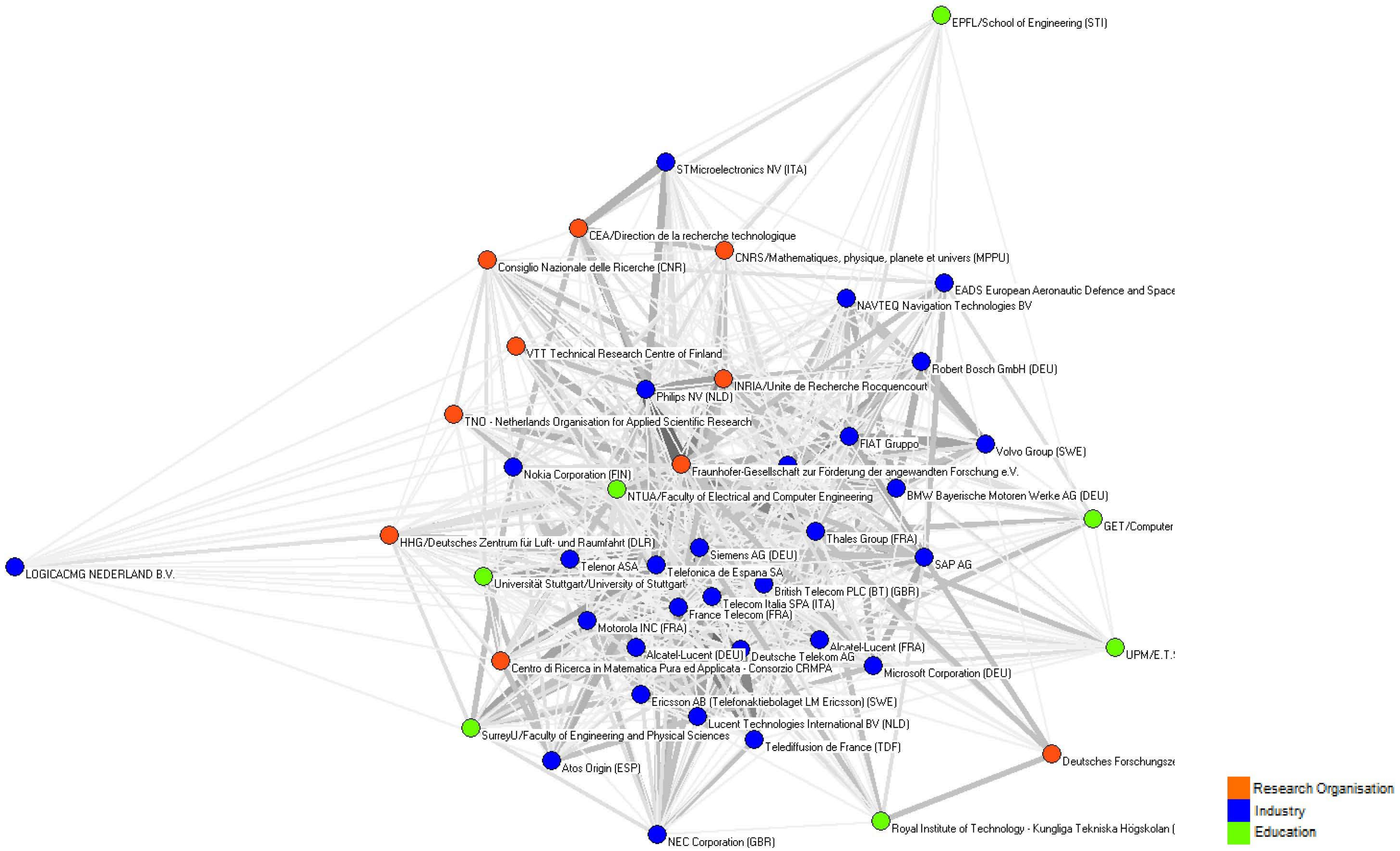


Figure 36: Network of core organisations (ICT_6_NoE)

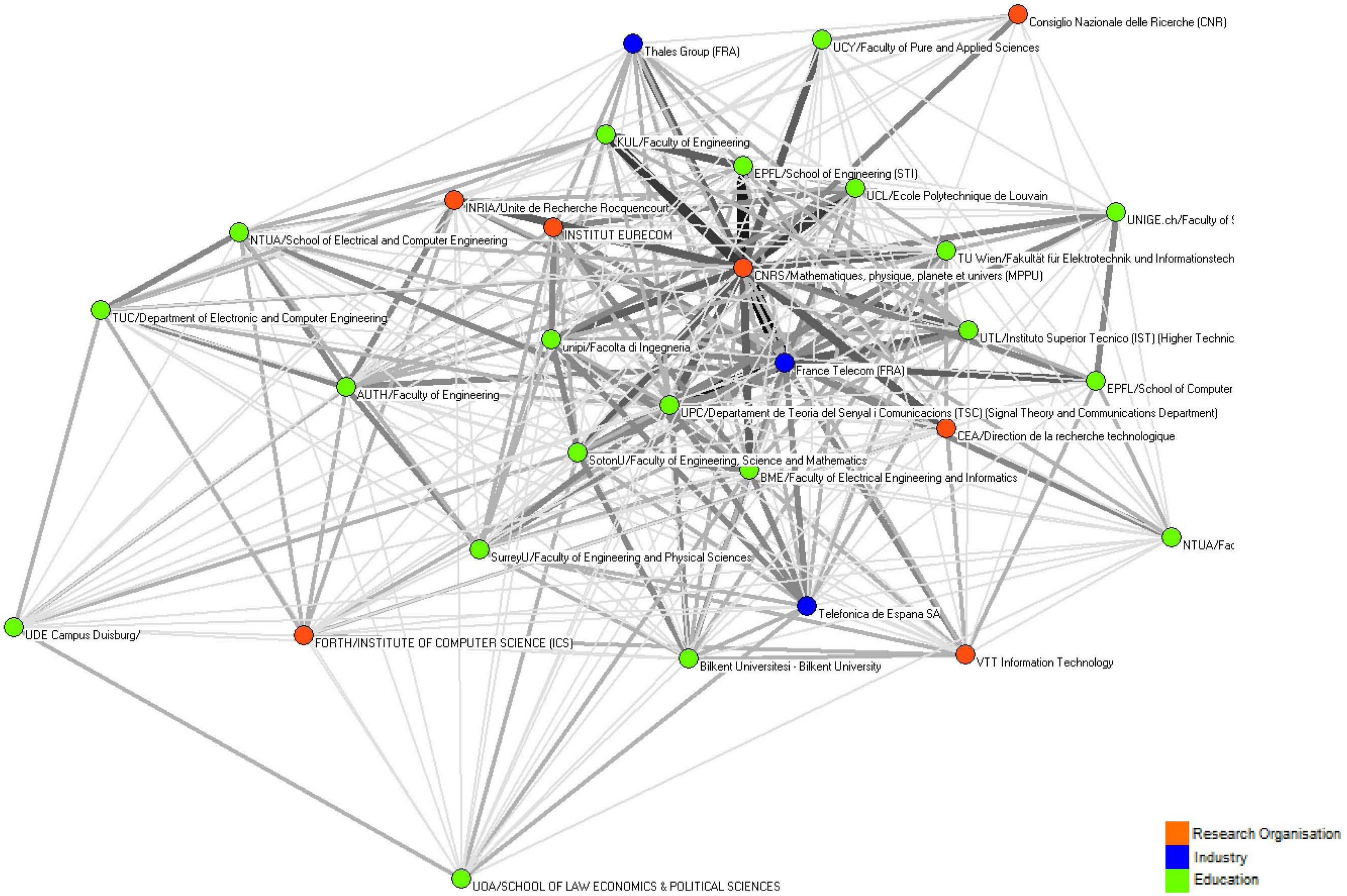


Figure 37: Network of core organisations (LIFESCI_4_CSC)

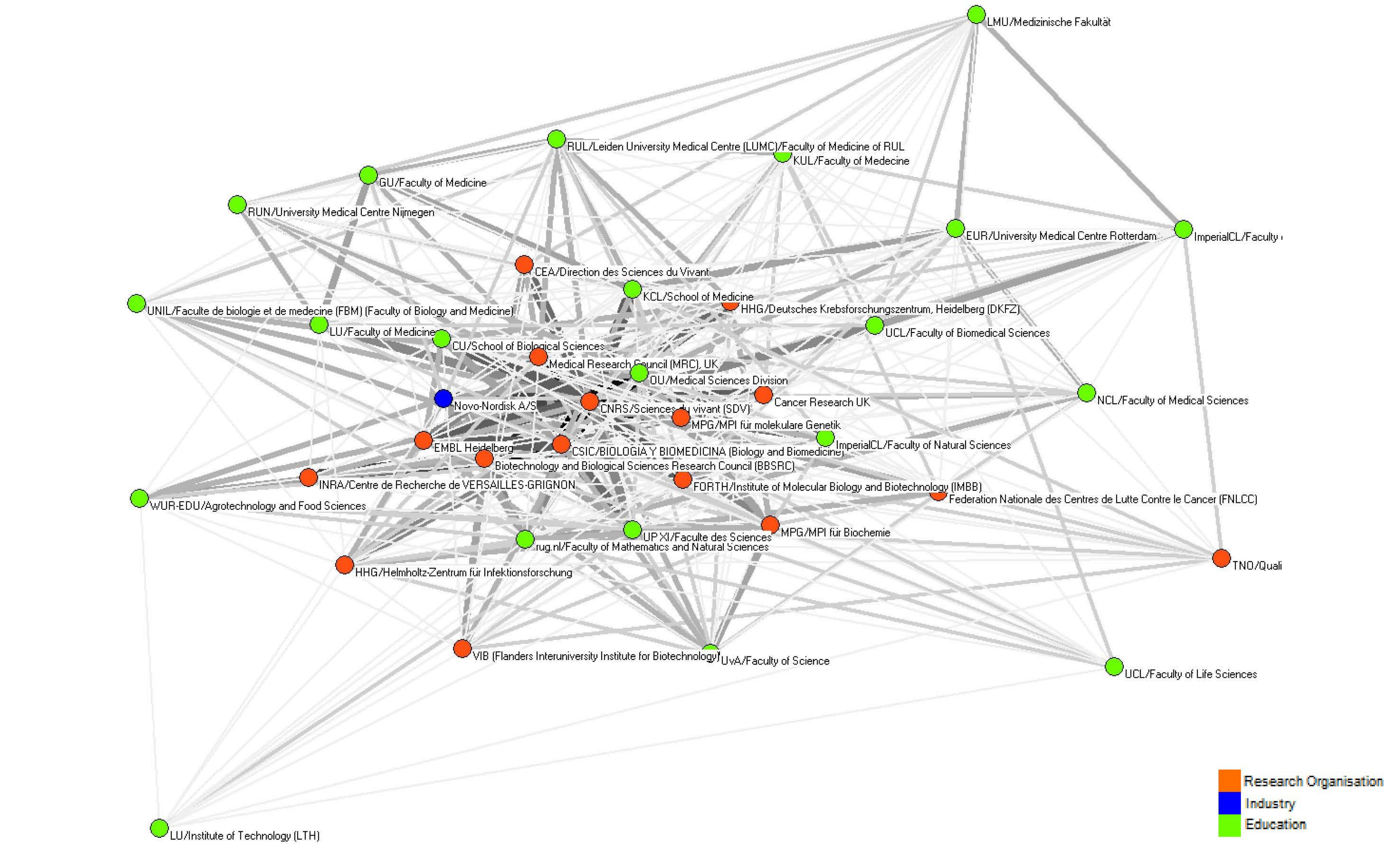


Figure 38: Network of core organisations (LIFESCI_5_CSC)

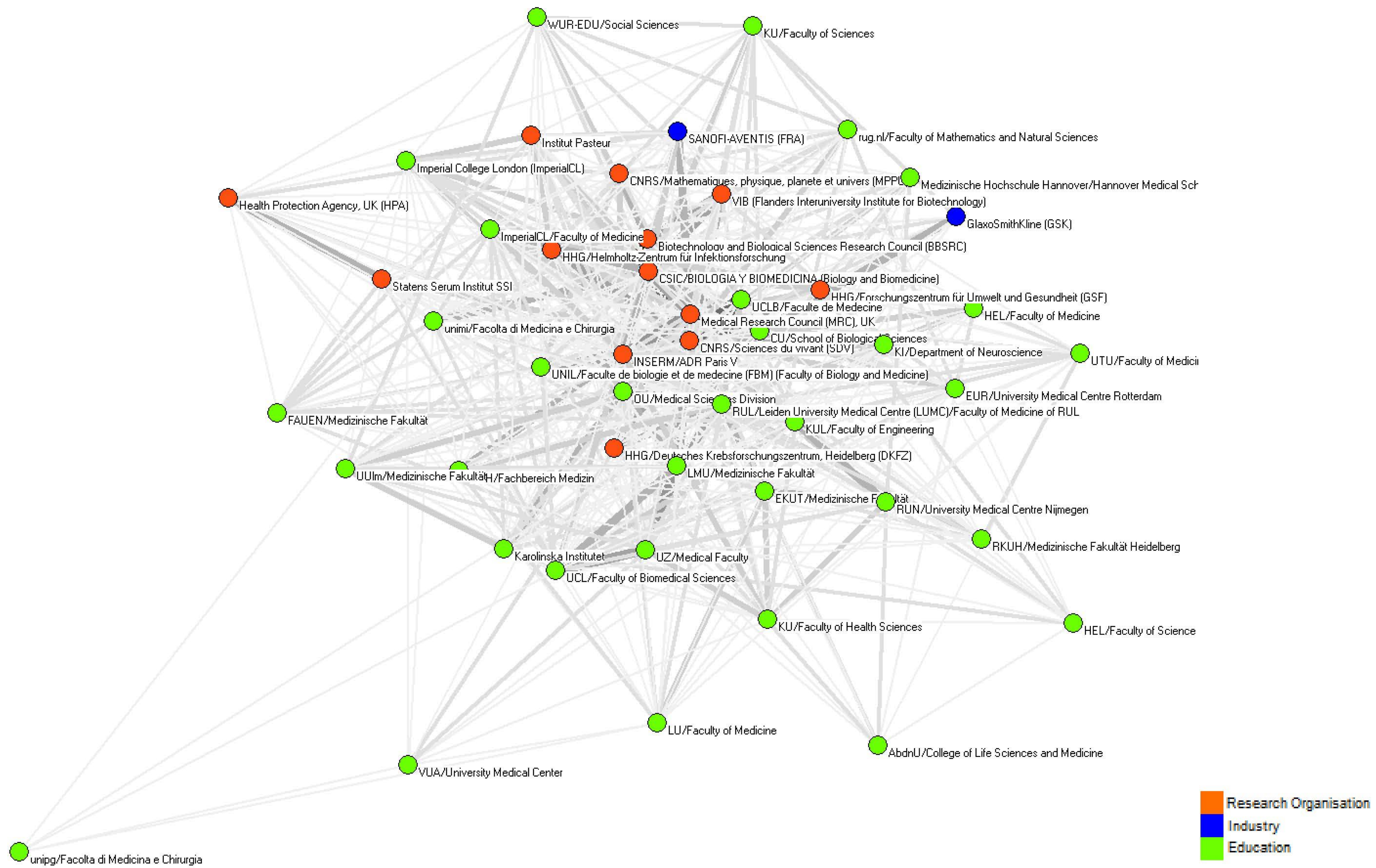


Figure 39: *Network of core organisations (LIFESCI_6_STREP)*

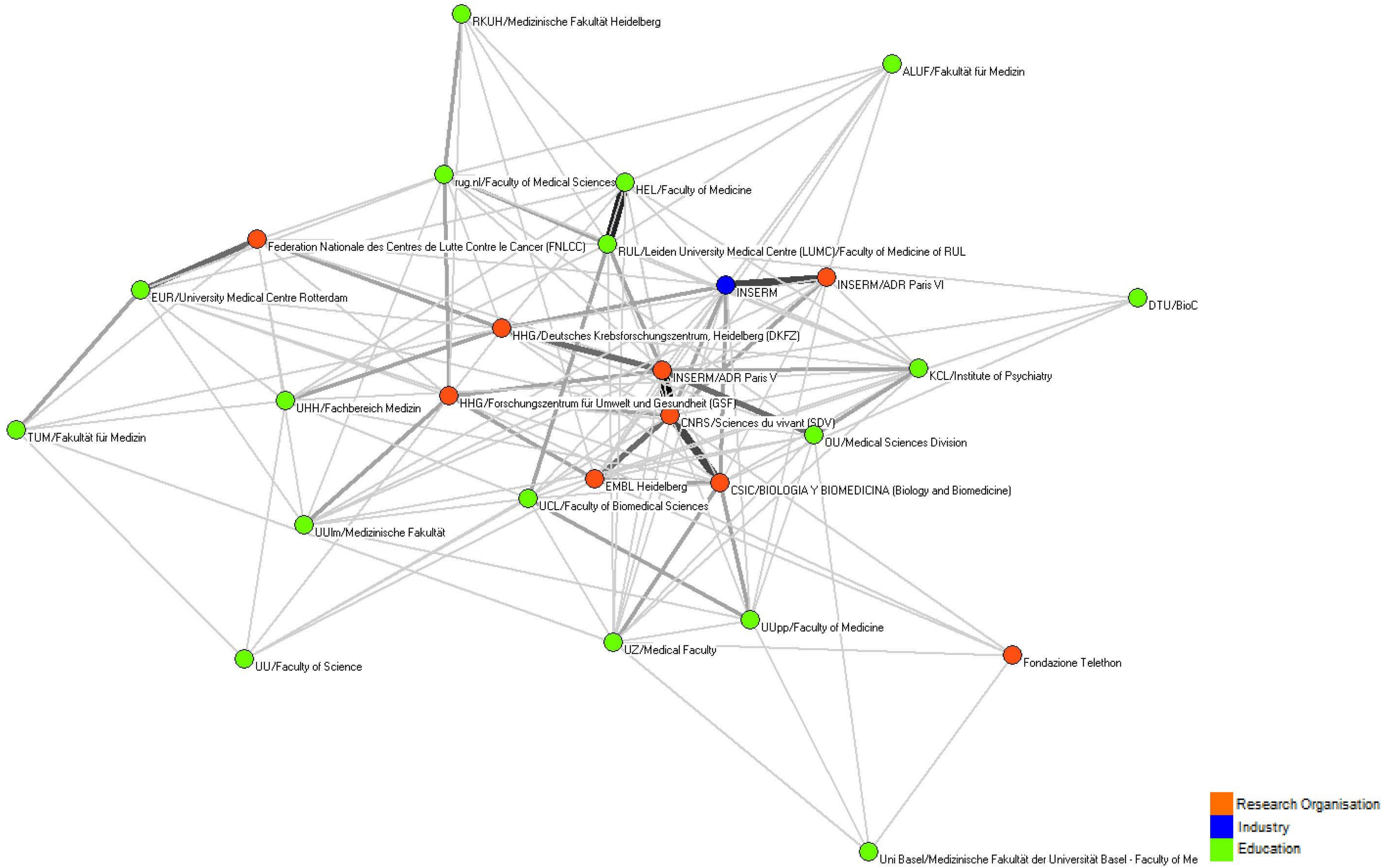
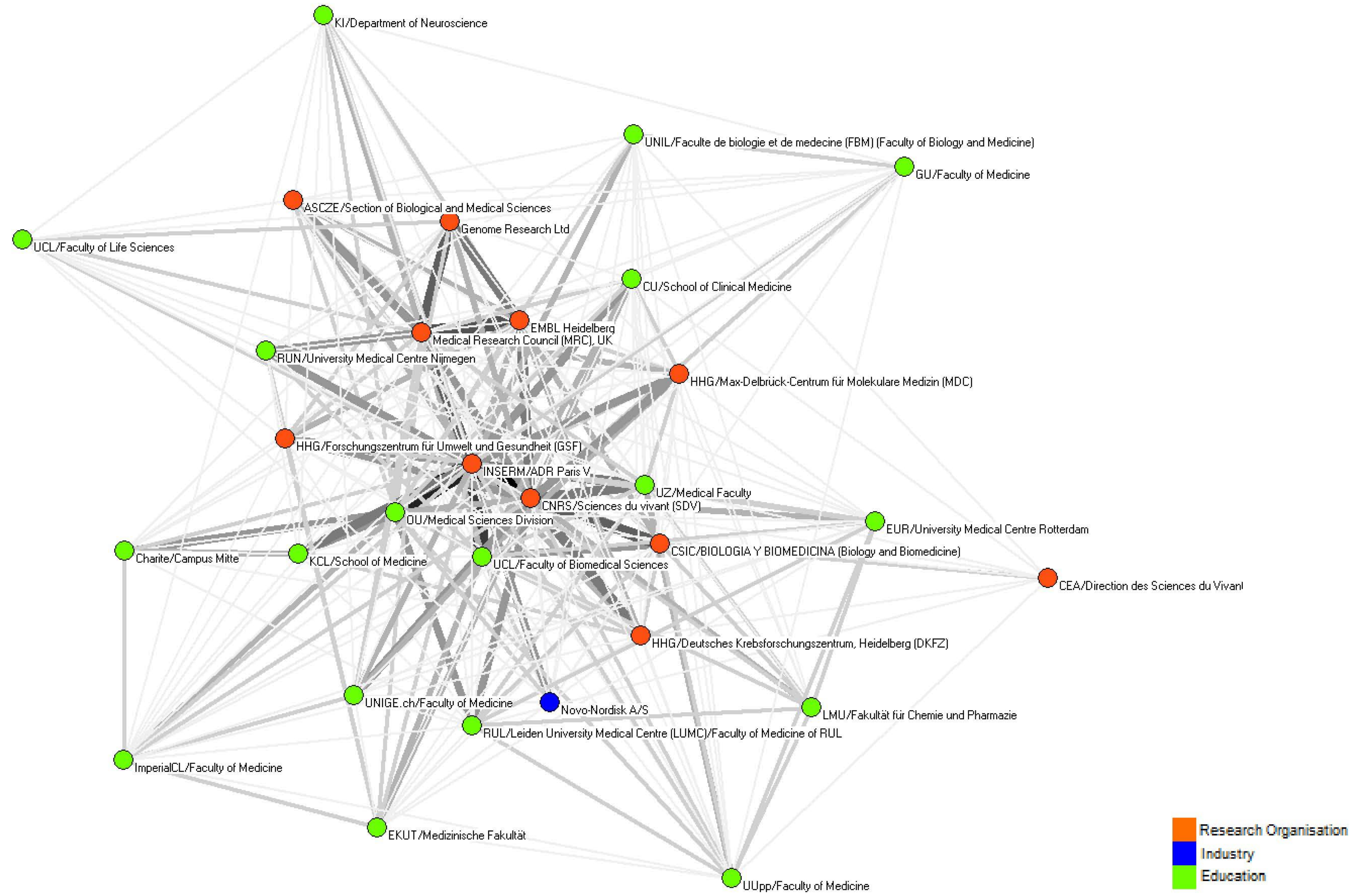
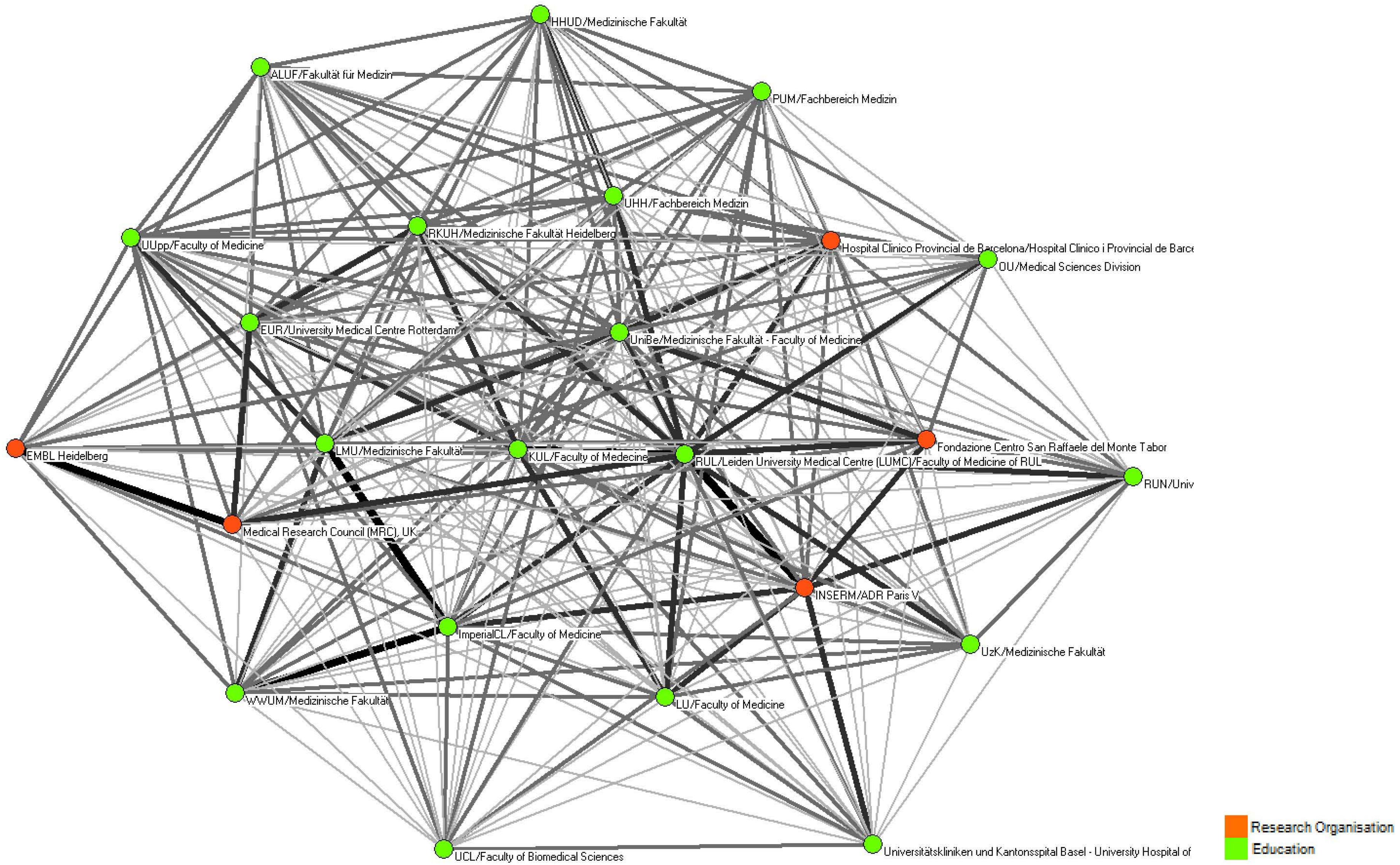


Figure 40: Network of core organisations (LIFESCI_6_IP)



■ *Figure 41: Network of core organisations (LIFESCI_6_NoE)*



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Title: Analysis of Networks in European Framework Programmes (1984-2006)

Authors: Barbara Heller-Schuh, Michael Barber, Luisa Henriques, Manfred Paier, Dimitrios Pontikakis, Thomas Scherngell, Giuseppe A. Veltri, Matthias Weber

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Abstract

In line with the Europe 2020 vision, there is an increasing need for adequate analytical tools to monitor progress towards the European Research Area (ERA). The Framework Programme (FP) is the main instrument of EU research policy. With 17.5 billion euros devoted to FP6 (rising to 51billion euros in FP7), it funds a substantial proportion of collaborative research activity in the EU and is, by far, the most prominent funding mechanism for transnational research globally. Therefore, the analysis of the structure of European networks of collaboration in the FPs, from FP1 to FP6, is a valuable tool in understanding the contribution of European policies in transforming the fabric of research within the ERA, as well as in identifying a possible backbone of research actors in the ERA. Within this context, the projects "Network analysis study on participations in Framework Programmes" conducted by ARC sys (now Austrian Institute of Technology) and "Centrality Analysis in Research Networks" carried out by the Knowledge for Growth Unit of the Institute for Prospective and Technological Studies (IPTS), Joint Research Centre (JRC), European Commission, respond to the on-going need for data and analysis on the characteristics and evolution of the ERA. This report presents findings of the above-mentioned studies and discusses them in a policy context. In addition, it applies novel methodological tools for analysing data on FP participations and improving our understanding of transnational networks of collaborative research.

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