The EU Framework Programme 6 Nanotechnology Innovation Network

A Preliminary Analysis

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Abstract

Research networks are regarded as the 'catalyst' of innovation in a knowledge-based society. With several instruments the European Union (EU) is funding research under the Framework Program (FP), aiming at creating innovation networks. This paper examines the shape of the EU FP6 research networks in Nanotechnology. It finds that different funding instruments create different shapes of research networks. It turns out that Social Network Analysis is helpful in analysing the effects of different policy measures, but fails to understand the underlying processes and to predict the outcomes of instrumental changes. The aim of this work is therefore to be understood as preliminary to an Agent Based Simulation of research networks, where it will help to calibrate the Simulation Model.

1. EU FP 6 Innovation Networks in Nanotechnology

1.1. Innovation Networks and knowledge generation

Innovation and thus knowledge is created by variation or recombination of codified, tacit or systemic knowledge. The new knowledge is tested e.g. through discussion, and passed on e.g. by imitation and publication. Individual researchers are connected to each other in a formal (e.g. by co-publication) or informal (e.g. on conferences) way, whereas companies are connected by virtual links, enabling them to open up new markets or giving the access to new technologies. Network structures can therefore be recognized as a 'catalyst' for the creation and dissemination of new knowledge, and thus innovation. Interaction and exchange of knowledge thereby make networks worth more than the sum of its parts (C. S. Wagner et al., 2004).

Universities, spin-offs, small and medium enterprises, research institutions, governmental organizations as well as financing intermediaries are forming these complex and evolving research networks in knowledge-based societies (Powell, White, Koput, & Owen-Smith, 2005). The instruments of EU Framework programs are intended to set up efficient innovation networks by combining organisations interdisciplinary, internationally, and intersectorally (Verspagen, 2001), thus helping the participating organisations to develop their absorptive capacity (Cohen & Levinthal, 1990). This 'Triple Helix of University-industry-government relations' (Etzkowitz, 2002) is at the centre of interest of the Framework Programmes. Networking itself is important for successful R&D, whereas the shape of networks is influenced by policy measures. The extend to which a region like the EU will profit from the innovations generated within a network fostered by the region's policy makers depends among others on factors such as market access and property rights. This in turn influences how research policy should be developed (C. S. Wagner et al., 2004). FP innovation networks in many cases do not only exist for the contract period but often persist beyond the end of the financial support provided by the EU (M. Barber, A. Krueger, T. Krueger, & Roediger-Schluga, 2005) making this funding instruments even more efficient.

1.2. Nanotechnology in Framework Programme 6

Materials at molecular and atomic level have significantly different properties than at larger scale. Nanotechnology as a new and emerging technology is trying to understand, to control and to make use of these properties. To reach these goals, scientists from diverse and traditionally separate science and technology areas work together. Therefore, Nanotechnology is believed to have the power to radically change numerous industrial sectors (Bozeman, Laredo, & Mangematin, 2007) such as ICT, Life sciences, manufacturing and materials (Forfás, 2010). Due to its applicability to many sectors, Nanotechnology is regarded as a general-purpose technology (Bresnahan & Trajtenberg, 1995), making it stand out from many other emerging technology sectors of the last decades. Nanotechnology innovation networks bring together different institutions, such as Universities, Research Institutions, large companies, SMEs and financial institutions from different countries. To understand the collaborative processes it is therefore crucial to know the different "national and institutional configurations" of network participants.

With FP4, nanotechnology was funded for the first time with approx 120 million Euros, rising to €220 million in FP5 and €347 million in FP6. It was also in FP6 that Nanotechnology became a thematic priority of Thematic Area 3: Nanotechnology and Nanoscience, knowledge-based multifunctional materials, new production processes and devices (NMP). Additionally, nanotechnology was funded under other strategic priorities (e.g. Health, Infrastructure), with a total funding amounting to €1.4 billion.

There is no database yet which would make it possible to measure the success of the innovation network funding by the EU in terms of publications or patents. However, SNA is a central method for the assessment of network structures and processes in order to evaluate the achievement of implementation goals. It can also help to examine the spread of knowledge in networks, the role of central players as well as the attachment processes of new participants. Efficiency and effectiveness of EU FP6 funding for innovation networks can thus be evaluated (C. S. Wagner et al., 2004).

There are five main funding instruments within the FP, each one of them with different objectives, thus attracting different sets of partners. It is also evident that the requirements for getting a project accepted influence the partners' research agenda (Wagner et al 2004).

- Specific Targeted Research Projects (STREPS) are aimed at generating and validating new knowledge by tackling a single issue. Small numbers of Universities, Research Institutions, Companies and SMEs are participating in these projects. The funding usually is for three years.
- Integrated Projects (IP) attract the same set of participants but in larger numbers. Also, there is a wet of issues being under investigation in IPs. Funding is given for up to five years
- Networks of Excellence are integrating research capacities from all participants to bring together fragmented research from all over the EU. NoEs are aimed at Research Institutions and Universities. Industrial partners are integrated only indirectly e.g. on the advisory board.
- Coordination action (CA) and specific support action (SSA): CA supports the coordination of research activities from different contexts. SSA are supporting preparational actions which arise from already existing research (M. J. Barber, Faria, Streit, & Strogan, 2008) (C. S. Wagner et al., 2004).

The introduction of FP6 was motivated by the goals of fostering industrial innovation, introducing an integrated European Research Area (ERA) and creating growth, cohesion and employment. On top of the already existing funding instruments such as Specific Targeted Research Projects, two new funding instruments (Integrated Projects and Networks of Excellence) were introduced and with these instruments the ERA was to be set up. Further emphasis was laid on the, in comparison to FP4 and FP5 even stronger, integration of SMEs into projects (Roediger-Schluga & M. J. Barber, 2007).

2. Social Network Analysis of the EU FP6 Nanotechnology network

2.1. Dataset and data handling

Consisting of 1.135 project participations, the dataset includes 706 partners and 7,014 edges in the network. The data was generated from the CORDIS database and cleaned manually as the CORDIS database e.g. does not contain unique names for universities. Each participant was given one distinct name, making it possible to identify units participating in several networks but having been assigned different names in CORDIS.

The dataset contains 108 FP6 NMP projects, thus all projects in FP6 on the thematic area of Nanotechnology, i.e. all projects and participating partners, funding volume and funding instrument, research type (Fundamental Research, NanoBiotechnology, Nanometre-scale Engineering, Applications, Emerging Needs), nationality of partner, partner type and a binary variable, indicating whether the partner comes from a new EU-member state or not.

Project networks where assumed to form fully connected subnetworks or cliques. This representation is an idealized type of graph which might not correspond to reality in all aspects of collaboration (Wagner-Luptacik, Heller-Schuh, Paier, & Müller, 2007) but which should hold sufficiently for our purposes, as none of the subnetworks contains a very large number of participants (Roediger-Schluga & M. J. Barber, 2007)(Verspagen, 2001).

2.2. Social Network Analysis of the FP6 Nanotechnology Network

The network analysis was carried out using the Gephi software package. For small networks, a visualization and identification of sub-networks by eye is a popular approach. (M. J. Barber, Faria, Streit, & Strogan, 2008). But even in larger networks with more than a dozen nodes it can be possible to identify community groups by visual inspection.

We first draw the network, adjusting the size of the nodes by their degree, i.e. number of edges. The first striking fact is, that there exists only one giant component, connecting 100% of all nodes, which means that none of the projects is carried out in isolation from the rest of the knowledge network. By colouring the edges according to the funding instrument, certain properties of different funding instruments become obvious. Networks of Excellence seem to be inside the network, almost exclusively connecting Research Institutions and Universities. Integrated projects seem to be on the edges of the whole structure, with a large number of projects that are funded under this instrument still clearly visible as sub-networks (see Fig. 1). In total, only around 60 sub-networks are still identifiable visually, whereas 48 'resolved' in the giant component, thus creating it.

Colouring the nodes by nationality reveals the spreading of participants from all parts of the world (Fig. 3) – especially interesting is the allocation of institutions from new EU member states (Fig. 2). In more than 50 sub-networks two or more new member organisations appear simultaneously, in at least six project networks more than three participants are located in a new member country. One possible explanation could be the geographical proximity of these organizations as all new member states are eastern European countries. Graphic proximity has already been an explanatory factor for co-occurrence in earlier network analysis studies (Powell, White, Koput, & Owen-Smith, 2005).

2.3. Scale free networks in Nanotechnology

Real world networks usually are characterised by a power law degree distribution. This means that there is a small number of actors having a large number of connections (high degree) and a high number of participants with only a few connections, i.e. a low degree. (Boccaletti, Latora, Moreno, Chavez, & Hwang, 2006). As Barabási and Albert (Barabási & Albert, 1999) have already shown, this also holds for knowledge intensive industry network. These so called 'scale free' networks are characterized by preferential attachment which can explain the existence of network hubs, i.e. actors with a high degree (hubs), and a large number of actors with a low degree (Powell, White, Koput, & Owen-Smith, 2005).

Hubs are seen as important partners with high status because of their position in the network and knowledge resources. Often large organisations with many resources and capabilities become network hubs (Malerba, Vonortas, Breschi, & Cassi, 2006). This attractiveness of hubs leads to a 'rich-get-richer' effect, thus reinforcing preferential attachment (Powell, White, Koput, & Owen-Smith, 2005). Reputation, personal contacts and recommendations can be seen as one explanation for the phenomenon of preferential attachment, but also experience made by earlier FP participation or being a former project coordinator is playing a role. This is regarded as especially important in FP projects as these come with a big amount of bureaucracy (Nokkala, 2009).

Hubs play a very important role in innovation networks, enabling effective knowledge flows to all parts of the network (Malerba, Vonortas, Cassi, Corrocher, et al., 2006). In the EU FP6 Nanotechnology network, the large majority of hubs (here the top 20% of participants by degree) are either Universities or Research Institutions (Fig. 5).

Fig. 1: EU FP6 Nanotech Network -

Node size adjusted by degree, node colour by organisational type, edge color by funding instrument.

<u>Nodes:</u> yellow: Research Institution, red: University; light blue: SME; puple: Industry; blue: Consultancy; green: Other

<u>Edges:</u> green: IP; :STRP; red: STRP; blue: NoE, purple: CA; dark blue: SSA.

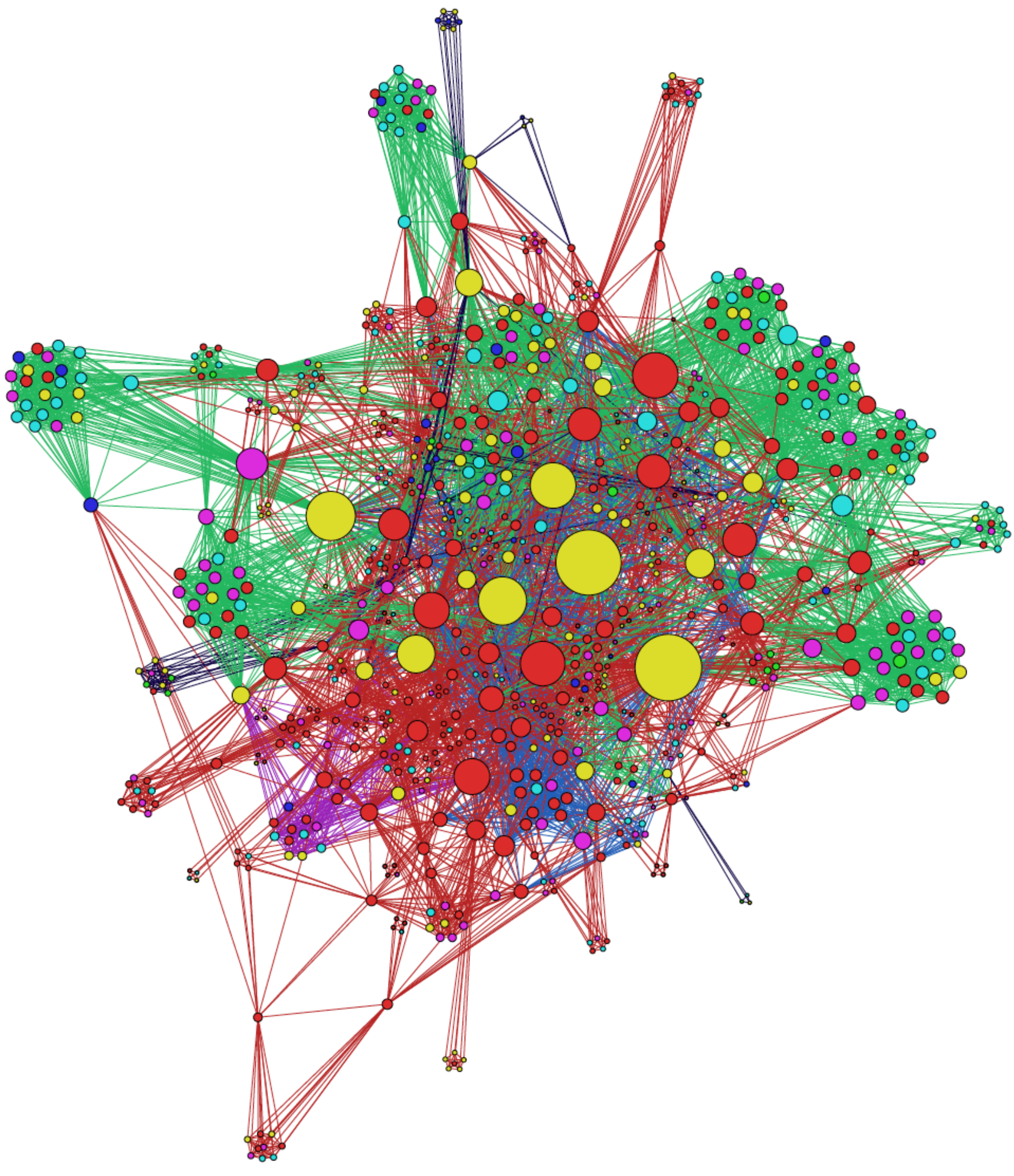


Fig. 2: EU FP6 Nanotech network -

Node size adjusted by degree; node color: red: New EU member nation.

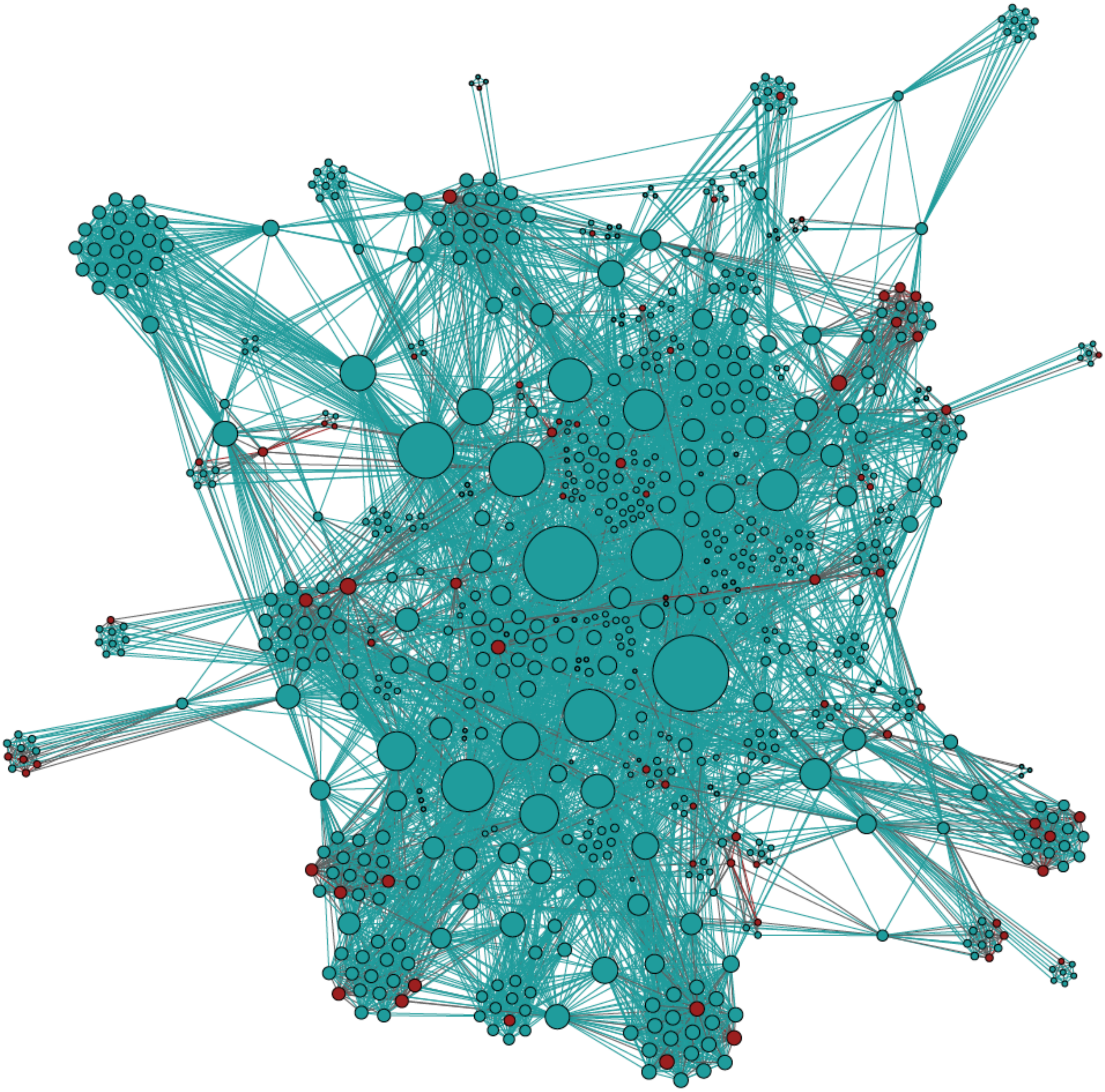


Fig. 3: EU FP6 Nanotech network -

Node size adjusted by degree; node color by nation.

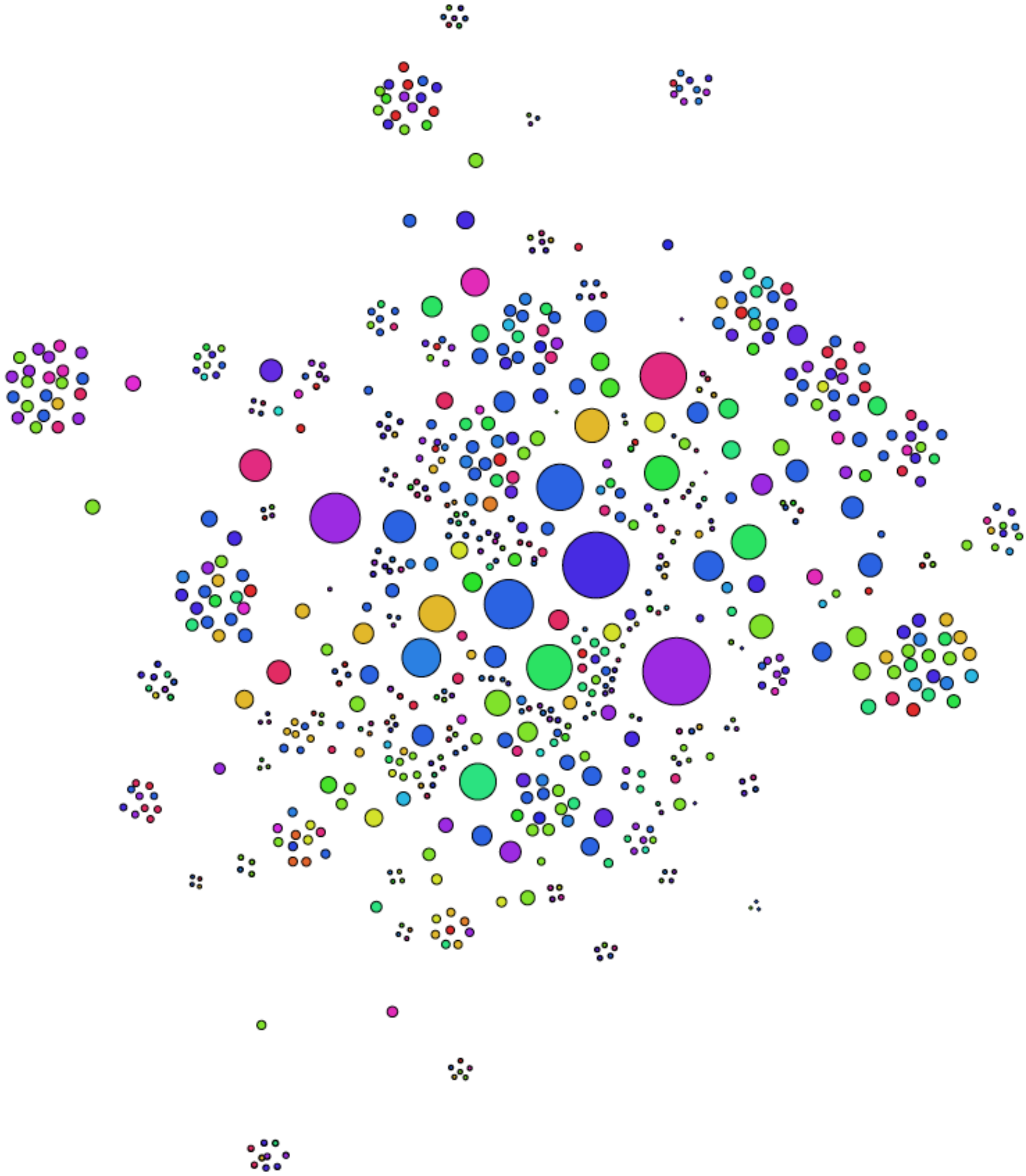


Fig. 4: EU FP6 Nanotech network -

Node size adjusted by degree. Node colors by organisational type (similar to Fig. 2), edges: NoE.

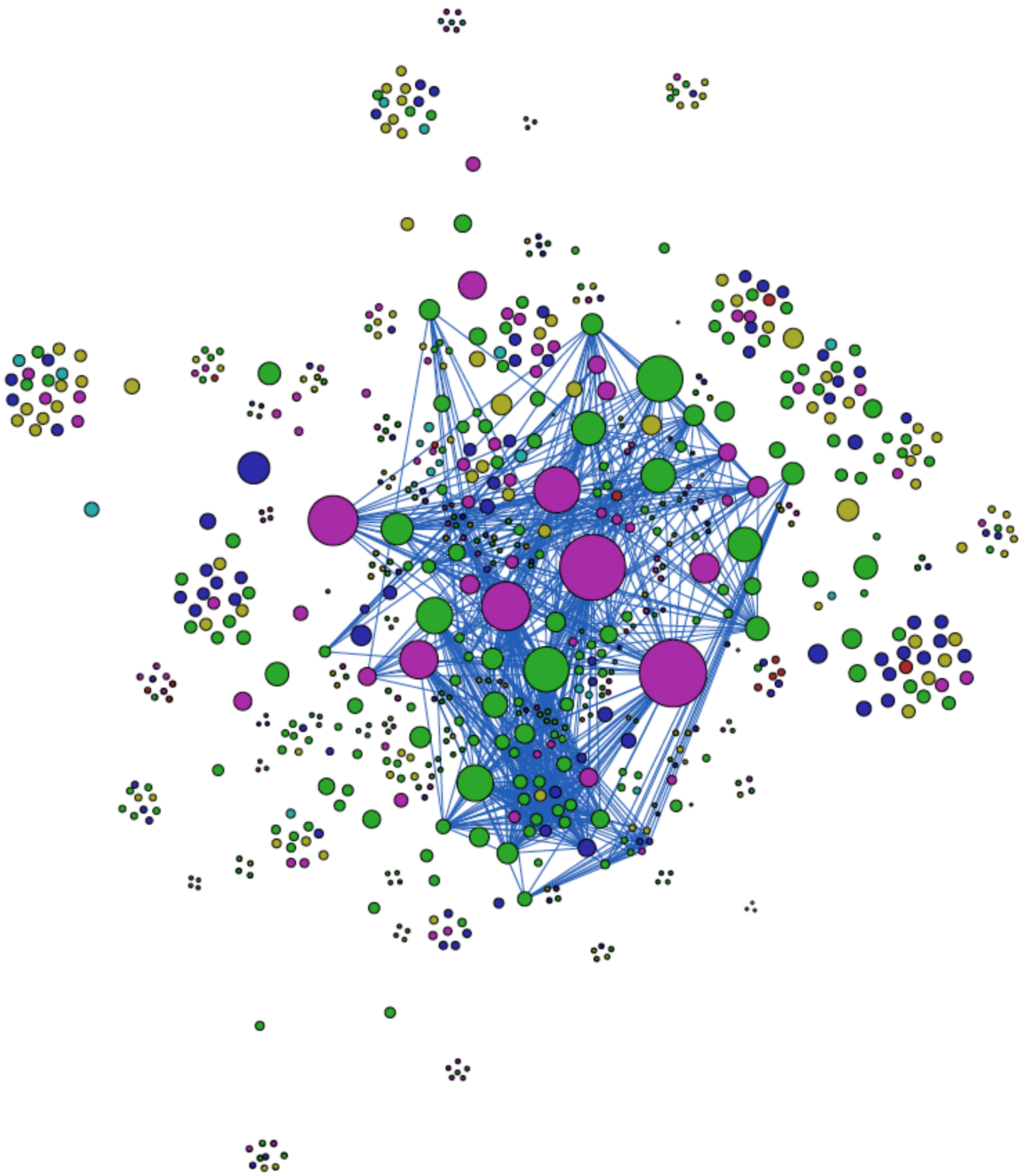


Fig 5: EU FP6 Nanotech network -

Node size adjusted by degree. Node color: dark nodes show upper 20% of degree distribution (here defined as network hubs)

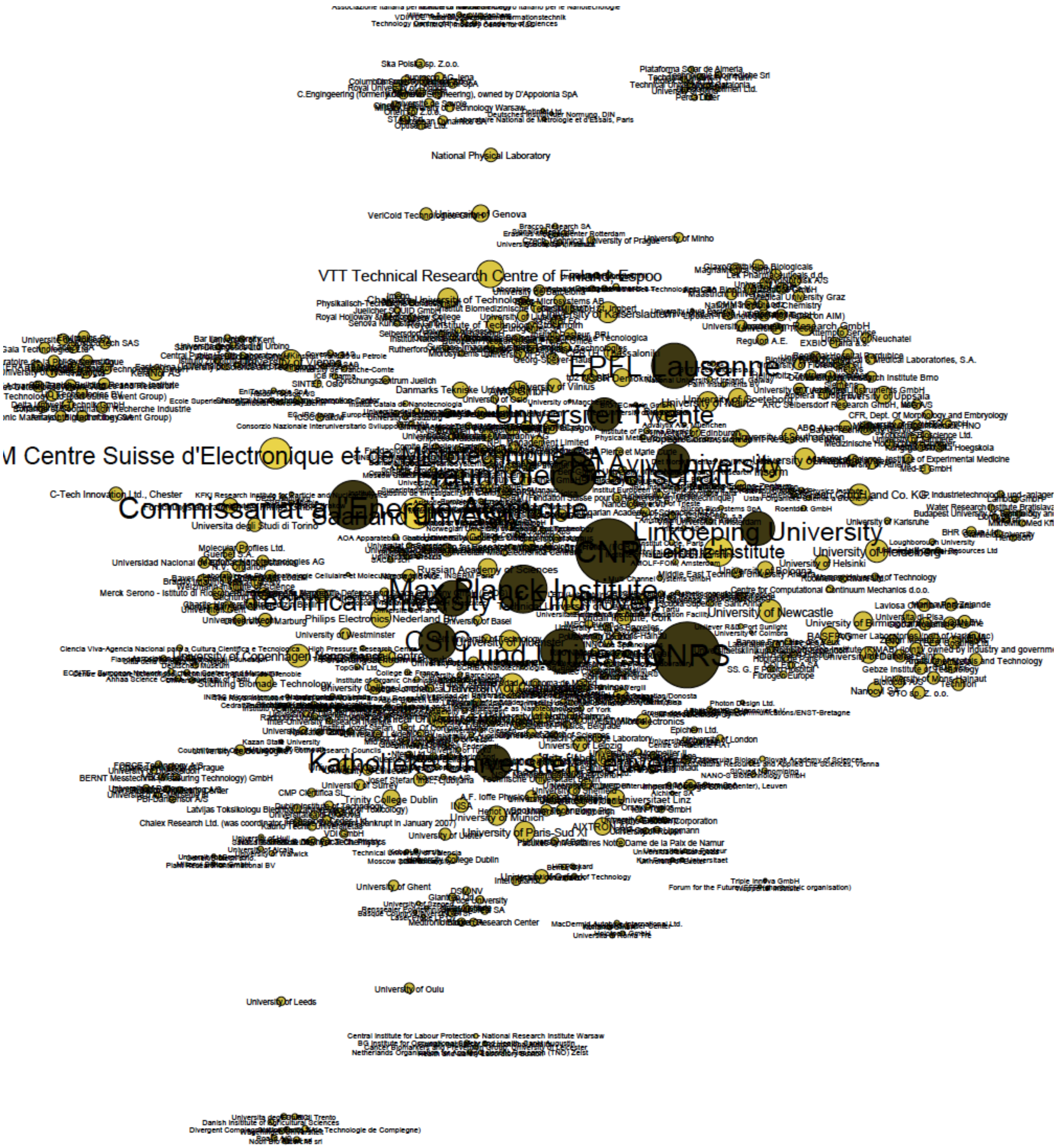
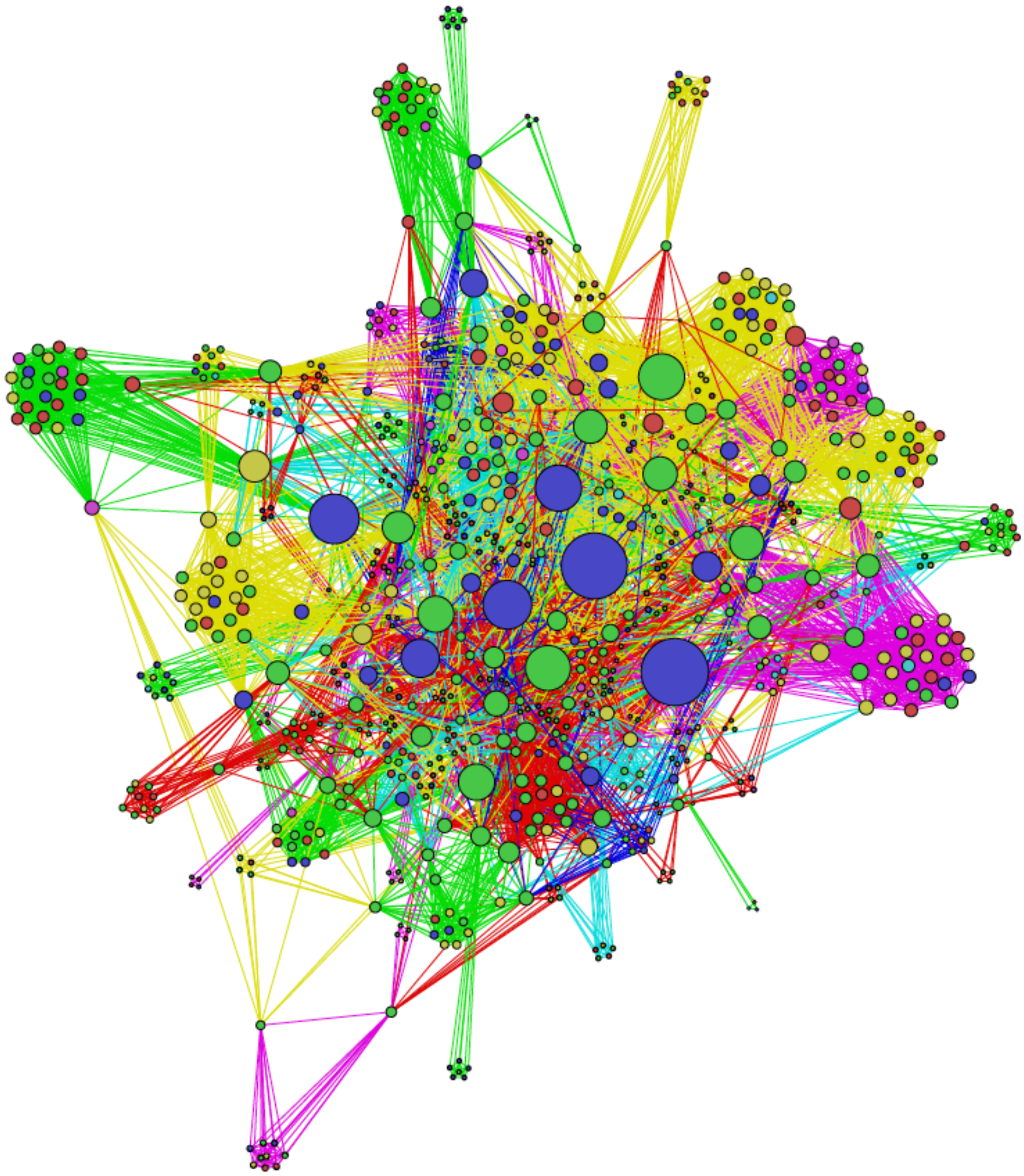


Fig 6: EU FP6 Nanotech network -

Node size adjusted by degree. Node colour by organisational type (similar to Fig. 2); Edges colour by research area.

<u>Edges:</u> yellow: Nanobiotechnologies, green: Emerging needs, red: fundamentals, pink: Nano applications, light blue: Nanometre-scale engineering, blue: Handling and control devices and instruments.



This is in contrast to Information Technology Society networks funded under FP6, where these two types of organisations are also overrepresented but large industrial organisations are in a hub position as well (Malerba, Vonortas, Cassi, Corrocher, et al., 2006). This could be a sign of nanotechnology still being a relatively new emerging technology, not yet attracting large industrial partners to take over an important role.

Calculating the power law coefficient for the network gives the value of 4.76. This is quite high and unusual as empirical findings show an exponent between 2 and 3 as to be most common (Boccaletti, Latora, Moreno, Chavez, & Hwang, 2006). This exceptional high power law exponent requires further research.

2.4. Small worlds properties of the Nanotechnology network

The spread of knowledge in networks works trough direct and indirect linkages between network participants. Characteristic path length and clustering are two of the most common indicators for assessing the efficiency of network structures for spreading knowledge. Small worlds enable knowledge at a high rate and at a high speed (Pyka, Gibkert, & Ahrweiler, 2009). For random graphs, long characteristic path lengths and high clustering coefficients go hand in hand. So-called ‘small world’ networks have relatively high clustering coefficients and small characteristic path lengths. This means that participants are mainly connected to the neighbours within their cluster but are connected to every other node of the network by only a short path length. A small world graph is defined by larger clustering coefficient of the actual network compared to the clustering coefficient of a random Moore graph with the same number of nodes and average degree.

With a clustering coefficient of 0.879 and a characteristic path length of 2.667 the FP 6 Nanotechnology network has small world properties according to the definition of Watts and Strogatz (Watts & Strogatz, 1998). A comparison to a random Moore graph will provide more precision. Nerverthless, knowledge dissemination within the EU FP6 network can therefore be considered as efficient. (Verspagen, 2001).

3. Conclusion and remarks

Research networks as an efficient way to bring together participants from different sectors and countries, of different size and organizational type and researchers from different disciplines (C. S. Wagner et al., 2004).

The examination of the EU FP6 Nanotechnology research network with Social Network Analysis methods shows some interesting facts about the networks evolving under the EU FP. The network is dominated by Research Institutions and Universities, which are positioned as hubs in the network. This is contrary to the IST FP6 network, where industrial partners also act as hubs. This difference might result from nanotechnology still being a relatively new emerging technology. Furthermore, the graph shows that some funding instruments are clearly identifiable as such in the giant (above all Integrated Projects), whereas others 'resolve' in the network (NoEs). It can also be seen that partners' nationalities span the entire world and that participants from new EU member nations quite frequently appear in larger numbers in a project.

There is no clear sign of scale free properties of the network as the exponent of the degree distribution function is rather large. Small world properties can also be found in the network, showing a high clustering coefficient and a low characteristic path length. However, a comparison to a random Moore graph is needs to be carried out for clarification.

The analysis carried out for this paper will be one of several more comparative studies to come. To gain deeper insights into the underlying processes which are shaping the networks, e.g. partner choice, influence of policy changes or collaboration rules between network participants, further studies will be carried out. SNA is an important tool in analysing structures and changes in innovation networks. This will become more evident when data from precedent as well as subsequent Framework Programs are included. These will also include studies on different emerging technology sectors not only by analysing project participation but also by examining project results such as patents or co-publications. However, neither is SNA capable of revealing the formative processes, nor will we be able to predict consequences of policy changes on network structures. Therefore a qualitative analysis is necessary to shed light on the processes mentioned above. The results of these qualitative and quantitative studies will then be used to construct and to calibrate an Agent Based Simulation of emerging technology sectors (Schwarz & Ernst, 2009), which in turn will enable us not only to simulate innovation networks, but also to estimate their future shape.

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