Agentschap NL

Development of Policy Driven Innovation Networks

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Abstract

For years, the Dutch government stimulates collaboration networks with policy instruments like Innovation Orientated Research Programmes (IOPs). This research aims at providing more insight in the long term development of such policy driven innovation networks. Developments in the themes Paintings and Catalysis were analyzed as both themes experienced policy intervention for decades. From a descriptive analysis over 20 years, it appeared that the type of policy instrument used is of major influence at the composition of public funded research projects. IOP projects consist of more actors than projects executed in IOP sequels. Projects in the generic set of policy instruments are carried out with even smaller consortia. Ten interviews with key actors in the networks of Paintings and Catalysis were conducted which revealed that the government fosters network activities, but that industry-university and supplier-customer relations between key players already existed before the IOPs were started. The added value of the public funded research projects is the knowledge generated, the interaction between industry and universities for possible employees and research contracts, and the frequent contacts between participants of the consortia which enables further collaboration without any policy support. To gain more detailed information about dynamics in the participation and role of different types of organizations, a Multi Level Model was used in SPSS. The results of this model indicate that knowledge institutes and large companies are participating very actively compared to SMEs. SMEs are often only involved in projects financed by the generic set of innovation instruments. Over time, large companies play the most important role in terms of degree centrality. Knowledge institutes are central and connecting actors in terms of betweenness centrality, but this observation is case dependent.

Contents

1. Introduction

Innovation is a major driver of long term economic growth (Baumol, 2004; Rosenberg, 2004). Especially high-technology sectors contribute to this growth (European Commission, 2004: 110). Not surprisingly, the Dutch government has been formulating innovation policy for decades and currently still stresses the importance of innovation based on technological development (Jacobs, 2009). More specifically, innovation policy focuses on stimulating public-private interactions in high-tech sectors with instruments like e.g. Innovation Orientated Research Programmes and Technological Top Institutes (STW, 2004; AWT, 2006). Such measures are supported by scientific claims that collaboration is essential to innovate successfully in technological fields that develop rapidly (Edquist, 2001; Hagedoorn, 2002; Bekkers *et al*, 2002; Powell *et al*, 1996). In the Dutch governmental budget for 2011 the formation and development of innovation networks is mentioned as one of the targets of several policy measures (Government of the Netherlands, 2010). In the current Topsector policy of the Ministry of Economic Affairs, cooperation between knowledge institutes, industry and government is argued to be of crucial importance (EL&I, 2011). These arguments illustrate the ongoing consciousness of policy makers that networks foster innovation. Although separate policy instruments aiming at fostering collaborative activities have been evaluated themselves, their cumulative effect on long term innovation network development is not known yet.

Research on policy driven networks is often focussed at single policy instruments or is limited to a relative short period. For instance, networks forthcoming from the European Framework Programme are analyzed by several scholars which often focus on the determinants of participation and the choice of partners (see e.g. Barajas and Huergo, 2010; Malerba *et al*, 2006; Protegerou *et al*, 2010). Dynamics of these European networks are for instance studied by Breschi and Cusmano (2004) but this research only covers 1992 until 1996. On policy driven networks in the Netherlands, research by Van der Valk (2007) is focused at developments over five years of the BioPartner network. Existing innovation networks of former Innovation Programmes have been analyzed by the Dutch government as well but the report mentions the need for gaining insight into the way their composition has developed over time (NL Agency, 2010).

Accordingly, this longitudinal study investigates the development of policy driven networks over a period of 20 years and determines how the composition of the networks is influenced by innovation policy measures. In addition to existing studies, the focus is rather on themes instead of analyzing single policy instruments. More specifically, this research aims at studying the composition of networks in terms of participation and positions of different types of organizations over time. These arguments lead to the main research question:

> *"How do policy initiated innovation networks develop over time in terms of participation and positions of different actors?"*

To answer this question the development of Dutch networks within two technological fields are studied: Paintings and Catalysis, themes that have been experiencing policy intervention for years. First, a theoretical framework is developed in Chapter Two. The sources used to gather data on the two technologies and methods of analysis applied are treated in Chapter three. The Methodology Chapter will also operationalize the hypotheses formulated in the theoretical section. The results are presented in Chapter Four. Hereafter, conclusions are presented in Chapter five. A discussion chapter with suggestions for further research and other implications will be presented in Chapter six to complete this study.

2. Theory

In this study, the concept of 'innovation network' describes collaborations among firms and knowledge institutes in a particular technological or research field (Carlsson & Stankiewicz, 1991; Powell & Grodal, 2005). When such a network is supported by policy instruments is referred to as 'policy driven'. In this chapter, a theoretical framework will be developed to answer the research question. First, the rationales for governmental policy intervention and the Dutch situation in particular are described. Then the Resource Based approach is used to explain the need for cooperation between organizations in general. Before organization-specific motives to participate in policy driven collaborations are given for firms and knowledge institutes, the most important concepts of innovation networks are explained. Finally, the conceptual model will summarize the hypothesis that are formulated in this chapter.

2.1 Rationales for policy interventions

Organizations deploying innovative activities can face barriers in their exploration and exploitation of novelty. Therefore, innovation policy aims at lowering these barriers and "encourage and facilitate the generation, application, and diffusion of new ideas" (Nooteboom & Stam, 2008: 40). Roughly, we can distinguish two categories of barriers or failures that legitimate a government to intervene. The first rationale for innovation policy is to solve market failures or imperfections (Van der Horst *et al*, 2006). The second rationale for policy intervention is the existence of system failures (Metcalfe, 2003). While market failures are barriers in a particular market like for instance existence of a monopoly, failures in the entire innovation system are mismatches between interests of different stakeholders involved, or poor performances of institutions that facilitate innovation like standards, physical infrastructure, education and politics (Nooteboom & Stam, 2008). According to Carlsson and Jacobsson (1997) one of the most important types of system failures is network failure. This exists when activities of actors are poorly coordinated because of a lack of interaction among them (Autio *et al*, 2008). Policy measures aim at stimulating interactions among system members and to restructure innovation systems (Kuhlmann, 2004).

2.2 Policy interventions in the Netherlands

From the theoretical perspective above, it is interesting to take a look at the Dutch situation. In 1979, the Innovation Note identified the general challenge to bridge the gap between science and business and several technological fields were chosen to intervene (Innovatienota, 1979). After the Innovation Note, Innovation Orientated Research Programmes – hereafter abbreviated as IOPs – were started as an instrument to foster "fundamental strategic research at knowledge institutes in a direction that fits the innovation need of Dutch business" (SenterNovem, 2005: 6). IOPs are one of the oldest thematic instruments and they nowadays still exist. From 1983 until now, 26 IOPs were launched with a budget of 16 million euro on average, spread over a period of either four or eight years (SenterNovem, 2006; EZ, 1989). IOPs are evaluated during and afterwards their execution in order to determine in what way they have fulfilled earlier formulated expectations and intentions (EZ, 1989). Much of the IOPs had a sequel in the formation of institutes or execution of other instruments that ensure the results gained and to continue the thematic support (SenterNovem, 2005). The IOP as instrument has also been evaluated three times to determine the fulfilment of policy goals but not regarding the influence at the long term dynamics of innovation networks (see e.g. Bureau Bartels, 2010).

Besides the generation of knowledge in promising technological fields, another aim of IOPs is the creation of sustainable networks between commercial enterprises and the knowledge infrastructure in promising fields (SenterNovem, 2008). The execution of IOPs and subsequent policy measures can be seen as at least partially solving network failure due to a mismatch between knowledge centres and businesses. In practice, IOP and their sequels consist of PhD research projects, executed by universities and supervised by a couple of interested and related businesses. Systemic policy instruments like IOPs that focus on strengthening relationships and shaping framework conditions aim ultimately at behavioural additionality: creating a permanent solution by introducing new capabilities that lead to a self sustaining cycle of investment and innovations (Georghiou, 2002). Actors that participate in IOP networks should ultimately also cooperate without any policy instrument backup. There are several reasons for firms and knowledge institutes to be involved in collaborations, which are derived from the Resource Based and Resource Dependent View.

2.3 Resource Based and Resource Dependent View

The actors involved in policy driven networks have different motivations to participate. So, a theoretical framework at the organizational level is needed. From the Resource Based View (RBV) resources are conceived as "anything which could be thought of as a strength or weakness of a given firm" or "assets which are tied semi permanently to the firm" (Wernerfelt, 1984: 172). Then resources can be for instance land, labour skills, brand names, equipment or in-house knowledge of technology (Penrose, 1959; Wernerfelt, 1984). Organizations can achieve rents from their specific resources by transforming them into outputs but also by the competence of making better use of it compared to their competitors (Penrose, 1959; Teece, 2007). The RBV theory has been studied extensively; its key message related to this research is that innovation is related to the usage of a bundle of firm specific resources (Kor & Mahoney, 2004). Relying on the RBV, the Resource Dependence View (RDV) characterizes an organization as an open system, dependent on contingencies in the external environment (Pfeffer & Salancik, 1978; Coombs & Metcalfe, 2000). This means that in some cases firms *must gain access to* resources outside their organization, which cannot simply acquired but accessed by collaborative processes of learning and coordination (Grant & Baden-Fuller, 2004). This explains why organizations gain advantages by using and mobilizing valuable, non-substitutable, and non-imitable resources from the environment (Hillman *et al*, 2009).

2.4 Innovation networks

From an organizational perspective, networks provide access to resources like knowledge that are not available via market exchange (Gulati, 1999; Gulati *et al*, 2000). By participating in networks, organizations can therefore achieve competitive advantage in comparison with organizations that are not participating (Foss, 1999). When the network is analyzed as the sum of public funded collaboration projects on a certain theme, it exists of several actors that participate with different intensities. Insight in the composition of such networks is useful because then policy makers can distinguish how much and which organizations they reach with instruments (NL Agency, 2010). The importance and position of actors in such a network determines their ability to acquire knowledge and other resources in the network (Inkpen & Tsang, 2005). Central actors become better informed about the ongoing processes and flows of information in a network which enhances the possibility to create alliances with other network participants (Gilsing *et al*, 2007; Gnyawali & Madhavan, 2001).

A network of relations between firms and knowledge institutes is rather dynamic than static (Ozman, 2003). In the emergence and development of current networks history is a determinant: due to processes of experience accumulation, the state of a network affects the state of the network in the future (Garcia-Pont & Nohria, 2002). This evolution is the result of self-organization of the actors and systemic interaction between technological, social and institutional factors like policy interventions (Kogut, 2000). In their study on the composition of biotech organization networks, Powell *et al* (2005) found a set of organizations forming the core of a science based network over a long time. Ahuja (2000) draws the same conclusion in his longitudinal study of inter-firm alliances. Although these scholars investigated networks without any policy intervention, it could be expected that this also applies for policy driven networks.

2.5 Firms, resources and collaboration

Following the arguments above, commercial enterprises have several reasons to cooperate with other organizations. Firms need to acquire external resources to profit from innovation, but also by the "ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece *et al*, 1997: 516; Teece, 1986). Especially in high-tech industries – which IOP themes often are – firms can hardly have all knowhow and resources necessary to innovate successfully in-house (Powell *et alI, 1996).* Accordingly, the interest of firms lie in the exchange of pre-competitive knowledge, joint development of standards, and ultimately the commercialization of knowledge in the realisation of new products and processes (Kuhlmann, 2004). Collaborations can accelerate this process of commercialization by reducing costs, development time and risks (De Man, 2000: 198). Gaining entrance to new or unusual markets and gaining economies of scale are other motivations for firms to cooperate (Tidd *et al*, 2005: 285). Taking this to a more broader scope, the access of complementary competences or resources is a primary incentive for firms to cooperate (Lunnan & Haugland, 2008). At the firm level, participation in policy driven collaborations provides access to resources that finally lead to the creation of economic value.

However, there are several potential risks for firms when participating in collaborations, e.g. leakage of information, loss of control or ownership, and divergent objectives resulting in conflict (Littler, 1993). A lack of trust between partners can also be destructive to the sustainability of the collaboration (Nooteboom, 1999). Determinants for the continuity of joint research ventures are performance, network ties outside the collaboration, knowledge related involvement in the project, and the existence of strategic goals (Olk & Young, 1997; Lunnan & Haugland, 2008). In publicly funded PhD research like IOP projects there is often a stable duration of four years per consortium.

In general, large firms are more often involved in strategic alliances than SMEs – small and medium enterprises (Hagedoorn *et al*, 2000). From a resource based perspective this could be explained by the fact that SMEs have fewer resources to share and in particular less resources required to participate (Tödtling & Kaufmann, 2001). Sometimes this can be a financial contribution required to participate. SMEs have less resources that facilitate experimentation and innovation (like high-tech equipment) which will also negatively influence their network position (Meeus *et al*, 2008). About the effects of firm size and the participation in policy funded research collaborations, Breschi and Cusmano (2004) and Wagner *et* al (2005) have studied differences between SMEs and large companies in their studies on the European Framework Programme networks. According to these scholars SMEs play only a minor role in the FP networks and participate often by linking to larger organizations. Although some IOP sequels use instruments like conferences or newspapers to transfer the generated knowledge to SMEs, IOPs and their sequels do usually not especially aim at the participation of SMEs in formal R&D projects. Therefore the first two hypotheses of this research suggests that the participation and position of SMEs in policy driven networks like IOPs is less than of large companies.

H_{1A}: SMEs are participating less in policy driven networks than large firms.
H_{1B}: SMEs have less important positions in policy driven networks than large firms.

2.6 Knowledge institutes, resources and collaboration

Research or knowledge institutes are also participating in innovation networks. In the complex search for novelty, major technological opportunities are often offered by advances in scientific knowledge (Dosi, 1988). As Kaiser and Prange (2004: 396) state it: "In science-based industries, firms are intensively engaged in cooperation with universities and non-university research institutes as they rely heavily on the exchange of knowledge with the domestic or international science base". This trend is confirmed by the trend that organizations outsource an increasing part of their R&D activities (CBS, 2006). Universities play an important role in modern economies as sources of fundamental knowledge (Mowery & Sampat, 2005). Next to the execution of risky research universities also educate scholars (AWT, 2005). In an innovation system, knowledge is also supplied by other institutions than universities (Lundvall *et al*, 2002). Non-university research institutes[1] tend to focus more on applied research than on fundamental or basic research (Krupp, 1983). Besides the task of knowledge creation, research institutes or other intermediaries can also help firms and in particular SMEs to overcome barriers to innovate as these firms often do not have own facilities for research or lack individual lobby power to articulate their interests (Batterink *et al*, 2010).

At the micro level of individual research collaborations, there is a "cultural difference" between profit-driven industrial researchers and academic researchers, who are motivated by scientific contributions (Dasgupta & David, 1994; David *et al*, 1999). Typical interests of scientists to participate in networks are the development of their scientific reputation by publications and participating in conferences (Kuhlmann, 2004). Scientific career development is positively affected by resources available through networks (Van Rijnsoever *et al*, 2008). According to Nieminen and Kaukonen (2001) and Harman (2001), networks are also important resources for scientists to acquire contracts and funding. Especially policy driven networks can give entrance to these resources. As IOPs aim at the *creation of knowledge in a promising technology* it can be expected that knowledge institutes are participating actively and have a central role in innovation networks stimulated by thematic innovation policy instruments.

H_{2A}: Knowledge institutes are participating more in policy driven networks than firms.
H_{2B}: Knowledge institutes have a more prominent position in policy driven innovation networks than firms.

[1] In the Netherlands, the most common known non-university research institute is TNO, the Netherlands Organization for Applied Scientific Research - partially public funded (TNO, 2010).

2.7 Conceptual model

All arguments together result in the conceptual model below. An innovation network consists of several inter-organizational collaborations. With policy instruments, the governments provides resources for these networks. The participation and position of actors is related to the type of organization that is involved.

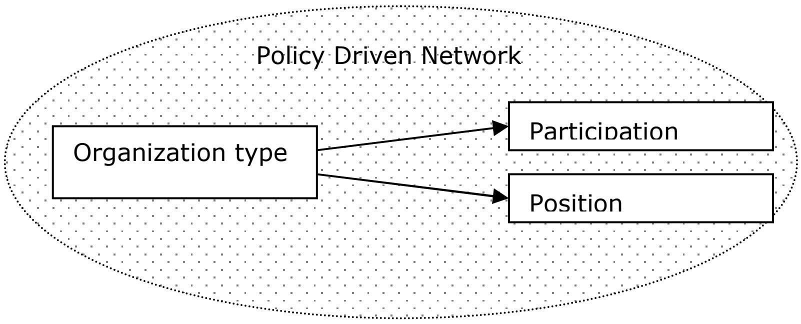

Figure 1: Conceptual model

The concepts must be translated into variables that can be measured in order to test the hypotheses formulated before. Therefore the next chapter will describe the methodology to be followed.

3. Methodology

In this research, a multiple case study design is chosen. An advantage of this design is that it allows direct replication: the possibility to compare analytic results over multiple cases which allows to draw stronger conclusions (Yin, 2009). Thus, conducting a multiple case study increases the robustness of the results (Bryman, 2008). In this chapter, the cases selected are described and the sources of data are discussed. Finally, the methods applied for testing the hypotheses are presented.

3.1 Case selection

To answer the research question, data must be gathered from innovation networks that have experienced governmental interventions. To describe and study the development of these networks, it is essentially to pick historical themes rather than recent topics. The two cases selected are Paintings and Catalysis, both with a different rate of governmental intervention. Paintings is about successjve developments in Paintings technologies and coatings. Catalysis is an enabling technology to instigate and accelerate chemical reactions. Figure 2 gives an overview of the thematic policy measures executed per theme with respect to time.

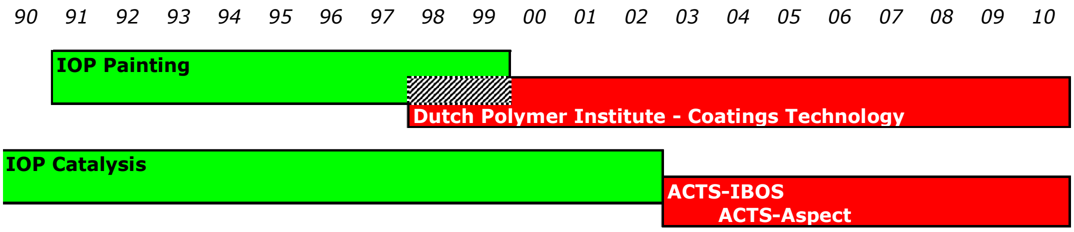

Figure 2: Overview cases 1990-2010

The Catalysis IOP is finished for a while and it had a sequel in the formation of an institute as the 'anchor' of the achieved knowledge and routines (SenterNovem, 2005). This sequel came a couple of years after the IOP was finished in the form of the NWO related ACTS[2] programme. The ACTS settlement consists of five research programmes (Van Dongen *et al*, 2007): Aspect is about catalysts for bulk processes; B-Basic focuses on the development of biofuels; IBOS stimulates environmental friendly production of chemicals by catalysts and biosynthetic approaches; Process-on-a-Chip (PoaC) stands for micro-chemistry; and the Sustainable Hydrogen programme investigates possibilities of a hydrogen economy. For this research, only projects from Aspect and IBOS are taken into account since these programmes reflect the 'original' catalysis theme as instigated by the IOP.

Like Catalysis, the Paintings IOP has finished but without tangible embedding afterwards. However, Paintings became one of the research lines in the Dutch Polymer Institute (DPI) with the Coatings Technology cluster in 1998. The DPI was one of the first Technological Top Institutes operating under the Ministry of Economic Affairs and a sequel of the Polymers IOP (SenterNovem, 2005). The general setup of DPI and ACTS research is the same as the IOPs with PhD projects done at universities with several firms in a supervising commission. However, the difference is that in DPI and ACTS projects firms must give a financial contribution to participate (Van Dongen *et al*, 2007; DPI, 2008).

[2] NWO: Netherlands Organization for Scientific Research; ACTS: Advanced Catalytic (nowadays: Chemical) Technologies for Sustainability

3.2 Data sources

This study contains both quantitative and qualitative data sources which increase the validity of the findings (Bryman, 2008). The usage of multiple data sources will prodive additional and supportive information. Quantitative data on the selected themes Paintings and Catalysis are obtained from various internal documents of the Ministry of Economic Affairs, Senter, SenterNovem, NWO, and DPI. These documents are used to gather information about thematic collaboration projects like duration and participants. Especially Senter (1999; 2000; 2001) had valuable sets of IOP project data. Beside participation in thematic policy instruments, actors can also cooperate in projects stimulated by generic measures. Generic measures are not aiming at one sector or technology in particular. Such generic policy instruments allowing cooperation are e.g. WBSO (Wet Bevordering Speur en Ontwikkeling), BTS (Bedrijfsgerichte Technologie Stimulering) and IS (Innovatie Samenwerkingen) projects. The NL Agency project database is searched for collaborations of IOP, DPI and ACTS participants in this generic set of policy instruments. In the sources mentioned, the composition and duration of public funded projects is documented. Some general facts of the cases are given below in table 1.

	Paintings 1991-2010	Catalysis 1990-2010
Number of actors involved	85	93
Number of IOP projects	17	87
Number of DPI / ACTS projects	39	53
Number of generic projects	23	57

Table 1: Actors and projects per case

Qualitative data is gathered by conducting ten interviews. A selection of highly involved organizations to be interviewed is made and listed in Appendix 6. The interviewees have been involved with multiple IOP projects, multiple DPI or ACTS projects, or with both IOP and sequel projects. For case study research, interviews are one of the most important data sources since they can reveal causal relations (Yin, 2009). Interviews are therefore used to reveal additional, supportive or contrasting data and to understand quantitative results. In this research, a focused interview is used (Merton *et al*, 1990). This procedure is derived from the ‘semi structured research’ method and involves a structured set of questions to reveal motivations of actors to participate in the network, but the possibility for the researcher and interviewee to deviate from the topic is always open (Baarda *et al*, 2005). When all data is gathered, three methods are applied. First, a descriptive analysis is done in order to describe network dynamics at the macro level. Second, a quantitative analysis is done based on the interviews. Third, a statistical model is used to test the hypotheses.

3.3 Descriptive analysis

The main topic of this research is the long term development of policy driven innovation networks. But existing text books on network analysis methods do not treat methods to study network development (Powell *et al*, 2005). Therefore, dynamics can only be analyzed by comparing characteristics of networks over time (Van der Valk, 2007). To study the development of the Paintings and Catalysis networks in a descriptive way, an event based process study is done (Van de Ven, 1990). This method describes the construction of a timeline based on quantitative measurement of key indicators or descriptives (Poole *et al*, 2000). Yearly key descriptives are the amount of active projects per type of policy instrument, the number of unique organizations per type of actor and the average size of a project in terms of participants (Hospes, 2009). Then, the social network analysis tool NETDRAW is used to visualize the Paintings and Catalysis networks and provide some general information about their structure and composition (Borgatti, 2002).

3.4 Qualitative analysis

After the quantitative analysis have been carried out, the interviews are conducted in order to gain more insight in the processes of the emergence and development of the policy driven networks of Paintings and Catalysis. After conducting the interviews, they were transcribed and their text fragments were coded. One interview was analyzed and a coding scheme for this text was created (Bryman, 2008). Then, another interview was analyzed and the first coding scheme was adapted if needed. By repeating this cycle to the remaining interviews, a coding scheme was created that finally fitted the information of all interviews. Interview topics are the emergence of the networks, the existence of other collaborations with or without public support, the role of the government compared to that of the industry and knowledge infrastructure, organization specific motivations to participate, and the added value of thematic policy instruments. The questions can be found in Appendix 5.

3.5 Statistical analysis

When a global description of the networks and qualitative findings are given, our next step is to analyze the hypotheses formulated in the theoretical section. In the conceptual model, the independent variable is organization type and supposed to influence to the dependent variables participation and position of actors in innovation networks.

- For **organization types** a distinction is made between Large Companies, SMEs with less than 250 employees, Knowledge Institutes and Other actors. The last category contains for instance sector or semi-government organizations.

- **Participation** of individual actors in a network can be measured by their degree centrality (Hospes, 2009). This basically means counting the number of projects an actors is involved in[3]. When a degree centrality for an actor is zero, it is in that specific year inactive.

- The **position** of actors in a network can be analyzed using a betweenness centrality index which counts the number of paths that pass through a certain node or organization (Freeman, 1979). Betweenness centrality thus measures whether participants connect clusters of the network (Malerba *et al*, 2006). If organizations connect parts of the network, they will have a high score on this centrality measure and these actors will play an important role as communicators and diffusers of knowledge (Borgatti, 2005). Actors can have equal degree centralities but different betweenness centralities, illustrating that there are differences in their relative importance in a network[4].

[3] Technically this is a 2-mode degree centrality index. A 1-mode degree centrality is defined as counting the number of relations an organization has (Malerba *et al*, 2006). Organizations that are in projects with a lot of other participants will then score high centralities (Hospes, 2009). As this research investigates the individual project participation of actors, the 2-mode degree centrality is chosen.

[4] Other measures to test the importance of actors in a network are eigenvector centrality and closeness centrality (Ruhnau, 2000). Eigenvector centrality is based on the organization's relations and the ties these relations have at their turn (Newman, 2007). An organization's closeness centrality is its average distance to other actors (Borgatti, 2005). As the networks investigated are relative small the betweenness centrality is used as this gives additional information about the position of actors in terms of knowledge collaboration.

For each actor, we calculate its degree centrality and betweenness centrality. The degree centralities can be derived with Excel using the Pivot Table function in the original datafile. To calculate the betweenness centrality per actor, the social network analysis tool UCINET is used. Now we have a yearly observation per actor of its participation and position in the network which is panel data. As the conceptual model suggests differences between groups in this dataset, a method must be applied that is able to compare groups over different years. In order to control for time and group related effects a Multi Level Model is used, i.e. a random effects model (Kwol *et* al, 2008). According to Kwok *et al* (2008), a Multi Level Model is a useful tool to analyze longitudinal observations of multiple cases. Such a model "can be conceptualized as a series of interrelated regression models that explain sources of variance at multiple levels of analysis" (Hoffman & Rovine, 2007: 102). Therefore the relations between the variables described above are analyzed in SPSS with the MIXED function in the advanced models menu (Peugh & Enders, 2005).

The independent variables supposed to influence the two centrality measures as dependent variables is organization type. As elaborated in the case description, both themes had a sequel that slightly differs from the original IOP setting. Therefore we will also control for this difference by include a dummy variable to separate the IOP and post-IOP period. This dummy variable is for every case in a certain year equal. Furthermore we control for the total number of active projects as the higher this number is, the higher the centrality measures become. To include a time dimension, the repeating variable is time measured since the starting year of the IOP. Table 2 gives a sample of three Paintings organizations and their scores in one particular year.

		Independent variable	Dependent variable		Control variables		
Actor	Year	Type	Degree centr.	Betweenness centr.	IOP active?	Active projects	Time, start IOP=0
X	1992	SME	2	0.002	1	7	2
Y	1992	Large Comp.	5	0.154	1	7	2
Z	1992	Know. Inst.	4	0.029	1	7	2

Table 2: Data preparation SPSS MIXED model, Paintings

The covariance structure used in the SPSS MIXED function is AR1 which means that the outcome of a certain year is influenced by the result of one year before. The hypotheses suggest a relation between the type of organization and the centrality measures, this is the first level of the model. As we will control for differences between the IOP and post-IOP period, the interaction term TYPE*IOP_active is used in the model. This will allow to compare between organization types and between the thematic policy instruments. Now, SPSS calculates the effects and significance levels of organizations types at participation and position in the policy driven innovation networks of Paintings and Catalysis.

A last step is to judge the validity of the statistical models. To do this, SPSS calculates per model several values known as the Information Criteria (Leyland, 2004). Per case and per dependent variable a model is tested without parameters and without random effects. Then, researchers must compare the values and select the model with the lowest values (Kwok *et al*, 2008). The difference among the -2 Restricted Log Likelihood information criterion values can be analyzed as a Chi-square distribution (Pleugh & Enders, 2005).

4. Results

This section will present the results obtained by the methods described above. First, the general descriptives of the networks are given. After that, the interviews that were conducted are discussed. Finally results of the statistical analyses are presented.

4.1 Macro results: network development descriptives

In order to get an impression of the activity of the innovation networks of Paintings and Catalysis, the yearly number of active projects is given. IOP projects are labelled green, DPI or ACTS projects are red and generic projects are blue. Another descriptive is the average size of a public funded project in terms of numbers of organizations that participate in it. Again, IOP, DPI/ACTS and generic projects are labelled green, red and blue. The third descriptive is the number of unique organizations that are participating. In these lowest graphs the colours blue, red, green and grey correspond respectively with large companies, SMEs, knowledge institutes and other organizations.

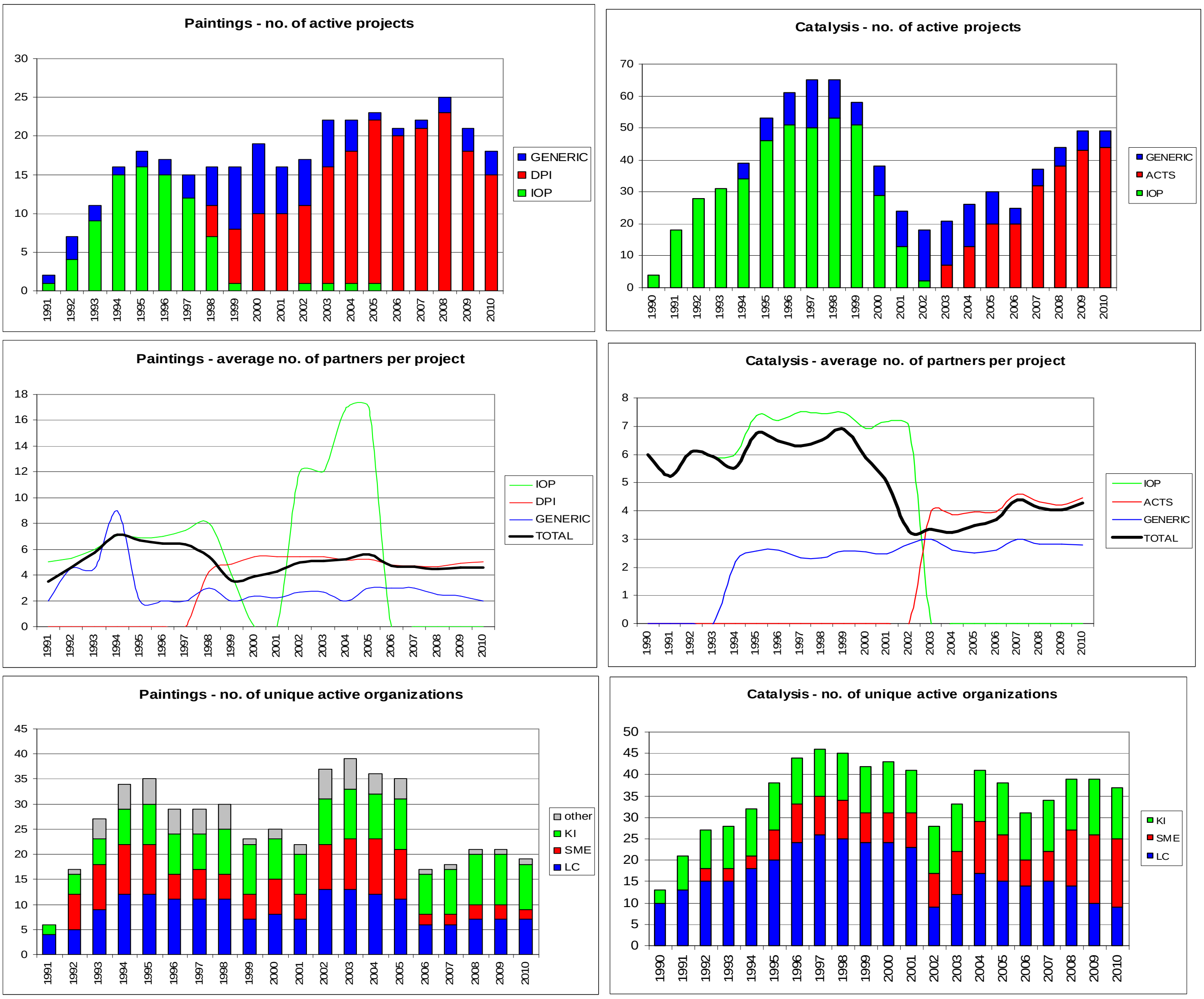

Figure 3: Descriptives of the Paintings and Catalysis networks

In general, Paintings and Catalysis show similar patterns of network activity in terms of active projects. The IOP and sequel phases are clearly visible; during and after the IOP projects end, its sequel gradually starts new projects. The Paintings network shows from 2002 until 2005 IOP activity again, this is the Decorad consortium that was partly financed by remaining IOP Paintings resources (SenterNovem, 2005; SHR, 2005). For both themes, there is activity of the network actors based on the generic set of policy instruments too. For Catalysis, during the first years of the IOP there was no collaboration in the generic instruments while for Paintings some generic projects were carried out during the entire period studied.

The two graphs with average number of partners per project show a clear difference in the size of the research consortia in policy funded projects: IOP projects have relative large groups with about 6 to 7 participants on average, DPI-CT and ACTS projects have on average 4 to 5 participants, and generic projects have on average 2 to 3 organizations. This could possibly be explained by the mentioned difference in the setting of the instruments: participating in IOP projects does not require financial resources while DPI and ACTS projects require a private contribution from firms. The peak of participants per project for the IOP Paintings in 2002-2005 is the single Decorad project with many different organizations involved.

The Decorad project is also responsible for a rise in the number of participants in the Paintings network from 2002 until 2005. Although the amount of active projects in the DPI phase is higher than in the IOP phase, the number of unique participants is quite lower. DPI Coatings Technology projects therefore consist on average of less organizations and often the same ones. In the Catalysis network, ACTS activity is in terms of active projects on average lower than the IOP phase but the amount of unique actors is almost equal. Even though ACTS projects are on average done with less partners than IOP projects, the composition of ACTS consortia differ strongly resulting in the high amount of unique organizations. In one of the ACTS research lines, IBOS, projects should be done with at least one SME. This explains the significant part of active SMEs in the ACTS phase. However, as this only implies that single projects are done with SMEs, section 4.3 will give more information about the actual participation of SMEs.

To get more insight in the participation of different types of actors in different types of policy instruments, network graphs are given for Paintings and Catalysis. These are networks with organizations (coloured circles, categorized as Knowledge Institute, Large Company, SME, Other) and links to the projects they are participating in (black objects, shapes correspond with IOP, DPI-CT or Generic projects). Such networks with two variables (actors and projects) are known as '2-mode' networks, graphs with for instance only connected organizations without any projects are known as '1-mode' networks.

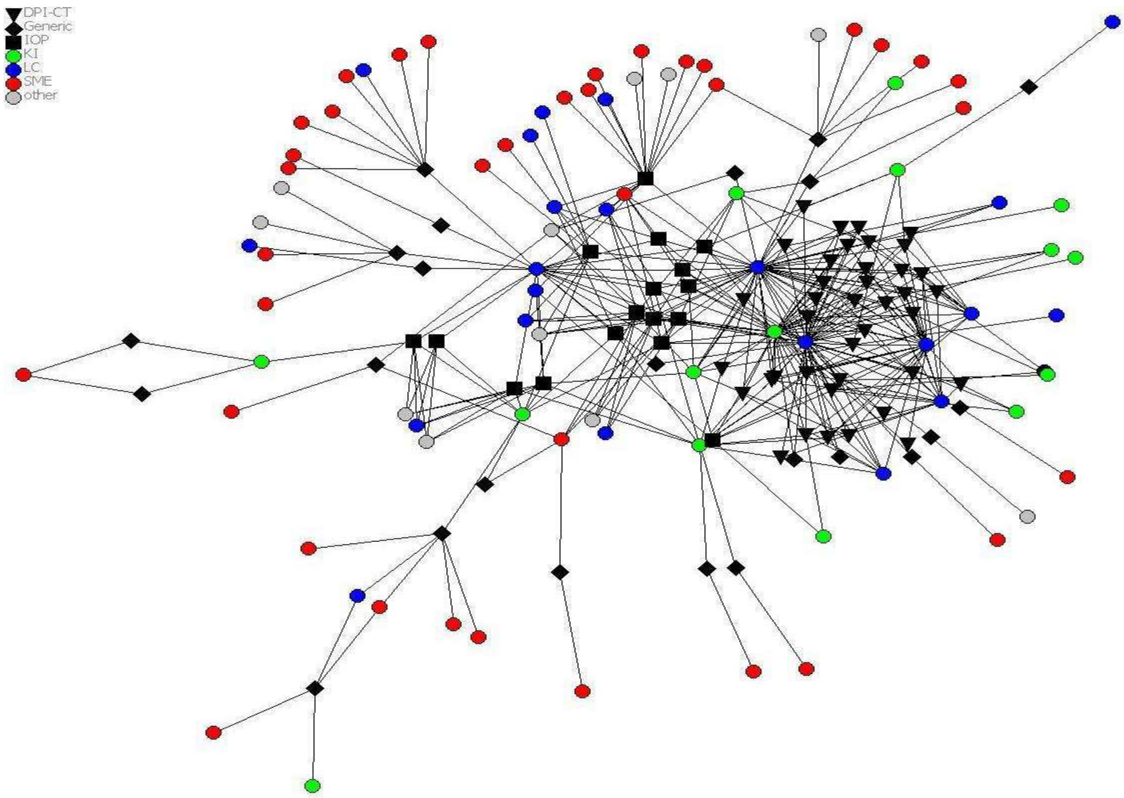

Figure 4: 2-mode network Paintings, 1991-2010

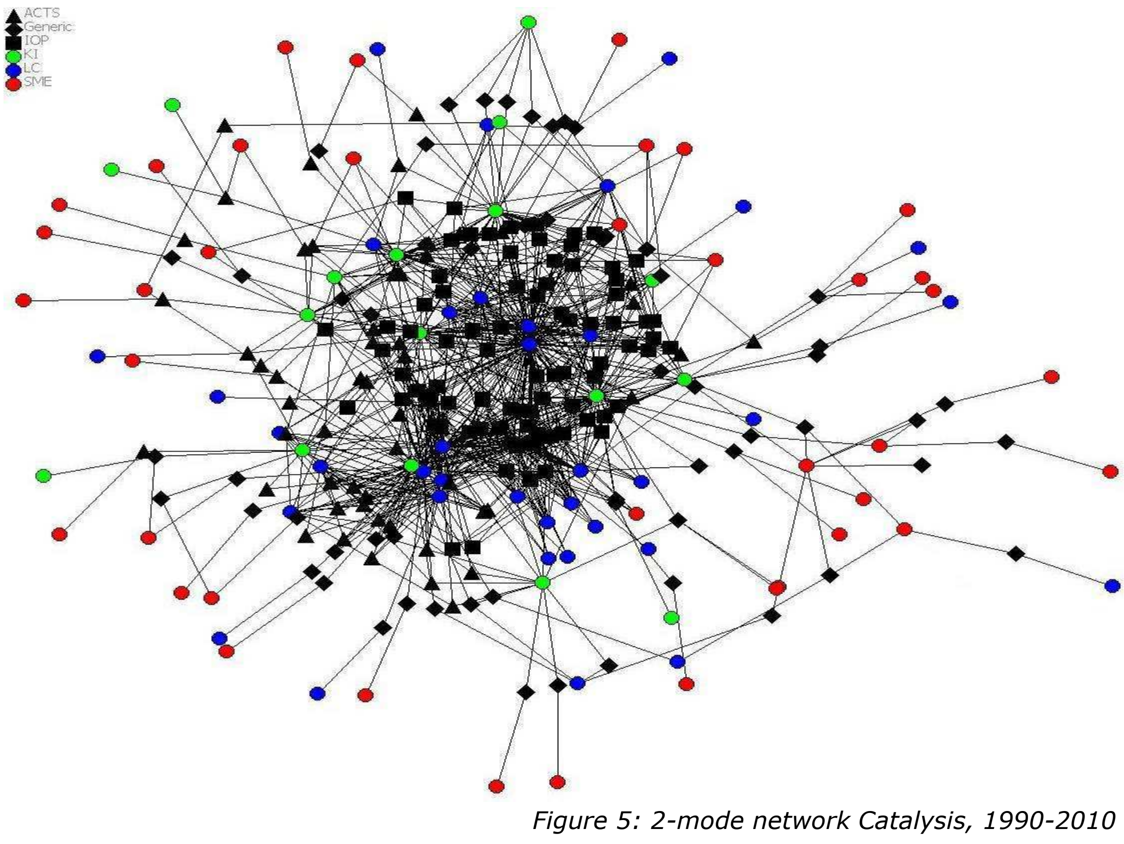

Figure 5: 2-mode network Catalysis, 1990-2010

These network images suggest the importance of knowledge institutions and large companies as these types are most present organizations in the dense part of the network. On the other hand, it seems that SMEs are often at the edges of the network and usually connected via a generic project with one or two knowledge institutes or large companies. The importance of knowledge institutes and large firms and the position of SMEs at the edges of a network was also observed in an analysis of the former Innovation Programme networks (NL Agency, 2010). In the Catalysis network, a couple of SMEs are connected participants in single ACTS-IBOS projects. These observations are in line with Section 2.4 about the underperformance of SMEs in research collaborations. The simplified network images in Appendix 1 and 2 illustrate that organizations that participate in all type of innovation policy instruments, i.e. IOP, its sequel and generic, are always large companies and knowledge institutes. Over the entire period, actors that participate the most are also knowledge institutes and large companies (Appendices 3 and 4). The next section will present the results of interviewing a selection of these core actors.

4.2 Qualitative results: interviews

In total ten interviews were conducted: six for Paintings and four for Catalysis. As discussed in the methodological chapter, the transcribed interviews were analyzed using a coding sheme. Table 3 displays the results, showing the codes and their frequencies.

Topic	Codes	Paintings (out of 6)	Catalysis (out of 4)	Total (out of 10)
Network development, collaborations	Bilateral industry-university interaction, with known partners	6	4	10
	Cooperation in other policy instruments	6	4	10
	"Crown jewels" are done individually or bilaterally	1	2	3
	Supplier-customer bilateral relations	2	1	3
Influence of policy instruments	Contacts existed before IOP: small world.	3	3	6
	New contacts from IOP, DPI, ACTS	2	1	3
	DPI or ACTS as consequence of IOP	2	3	5
	Lead for IOP sequence by industry and KIs	2	2	4
	"What if" scenario: much less research should have done	5	3	8
	Knowing each others expertise stimulates collaboration	5	1	6
	Government is facilitating and creating vision	5	2	7
Motivations and output of network activity	Funding of research	2	1	3
	Broadening knowledge base, precompetitive	4	3	7
	Contacts with industry and universities, PhDs	4	2	6
	IOP, DPI, ACTS (in)tangible results	4	2	6
	Generic projects lead more to commercial applications	1	2	3

Table 3: Coding scheme interview results

All interviewees indicated that their organizations are also involved in network activities without any policy interventions. Roughly two types other than policy driven interactions can be distinguished: industrial supplier-producer interactions and university-industry interactions. These interactions are often with the same partners as the ones in IOP and sequel instruments. Organizations cooperate also in other policy instruments than the ones searched for, mostly STW projects which are not included in the NL Agency project database. Like supplier-customer and university-industry relations these projects are mostly done with IOP, DPI or ACTS partners. According to the interviewees this is not directly caused by the participation in policy driven networks but rather a consequence of acting in a "*small world*" business with just a few key players. Especially in large scale businesses like Paintings and Catalysis, firms are dependent of each other and of the knowledge that is generated at knowledge institutes. For instance, a firm with catalyst preparation as core business has from itself good informal and formal relations with university departments that are specialized in these processes. A majority of the contacts suggested that the contacts between key actors in the technology fields of Paintings and Catalysis therefore already existed before their IOPs were started.

A couple of interviews revealed that if organizations think explorative research will be of major importance in their future, they prefer to develop this alone or bilaterally. Without the IOP, DPI and ACTS subsidies less research would have been done. The unique feature of public funded research projects is the size of the consortia as collaboration normally takes place bilaterally. Thematic projects like IOPs therefore allow to meet new contacts. An advantage of participating in IOP and sequel projects is that the partners get to know each others competences well or as one interviewee said *"separate the wheat from the chaff".* This enhances possible future collaborations. Firms indicate that they participate in policy driven networks to broaden their precompetitive knowledge base. Although it is difficult to assign commercial results to IOP, DPI or ACTS projects, the precompetitive knowledge that is generated is seen as valuable. Knowledge institutes gain access to necessary funding for their research. For both firms and knowledge institutes the industry-knowledge interactions are valuable. Firms can meet new employees while universities can acquire research contracts. In the emergence of the Paintings and Catalysis IOPs and their sequels DPI and ACTS as well, the industry plays a driving role while the government facilitates the creation of a long term vision.

With the generic macro developments of the Paintings and Catalysis networks and the qualitative findings above in mind, the next step is to analyse the networks by means of the statistical methods described in section 3.4.

4.3 Statistics

The aim of this paragraph is to test the hypotheses formulated in Chapter 2. Table 4 shows the results of the various models estimated by SPSS. In the parameter column the independent variable assumed to influence the degree centrality (participation) as well as the betweenness centrality (position) is shown. These are the organization types in the IOP and in the post-IOP period. The IOP_OFF variable reflects the DPI and ACTS as dominant thematic policy instrument. In the Catalysis network there are no other actors than firms and knowledge institutes. The estimate is the value which the dependent variable differs compared to the reference parameter. In the Paintings model, the reference case are Other organizations in the IOP phase. In the Catalysis model, Knowledge Institutes during the IOP are the reference case. Next to the estimate its significance is given. Significances from 0,05 till 0,1 are marked with yellow and levels below 0,05 are marked orange.

	PAINTINGS				CATALYSIS			
	Degree centrality		Betweenness centrality		Degree centrality		Betweenness centrality	
Parameter	Estimate	Sign.	Estimate	Sign.	Estimate	Sign.	Estimate	Sign.
Intercept	-1,104	0,221	0,010	0,681	-1,752	0,173	0,021	0,073
LC*IOP_OFF	2,017	0,044	0,032	0,179	-0,204	0,881	0,010	0,456
LC*IOP_ON	1,797	0,067	0,031	0,141	-0,168	0,897	-0,002	0,819
SME*IOP_OFF	-0,655	0,509	-0,002	0,964	-4,112	0,003	-0,024	0,096
SME*IOP_ON	-0,636	0,495	0,001	0,957	-3,990	0,006	-0,001	0,940
KI*IOP_OFF	0,502	0,633	0,012	0,613	-0,479	0,524	0,036	0,003
KI*IOP_ON	0,376	0,718	0,042	0,064	0	0	0	0
Other*IOP_OFF	-0,212	0,726	-0,004	0,924	*No other organizations in the Catalysis network*			
Other*IOP_ON	0	0	0	0				
Active Projects	0,187	0,000	-0,001	0,484	0,181	0,000	0,000	0,228
Time	-0,046	0,263	0,001	0,568	-0,015	0,824	0,001	0,373
Model performance: Information Criteria (smaller-is-better)								
-2 Restricted Log Likelihood MIXED model	1815,9		-1143,3		3479,7		-2351,8	
-2 Restricted Log Likelihood empty model	1893,4		-1184,7		3738,8		-2384,1	
Difference (=χ^2 value)	77,5		41,4		259,1		32,3	
Degrees of freedom	3		3		3		3	
Chi-square sign.	<0,0005		<0,0005		<0,0005		<0,0005	
Legend: LC= Large Company SME= Small Medium Enterprise KI= Knowledge Institute Other= Other organization IOP_OFF= Post-IOP phase, i.e. DPI or ACTS IOP_ON= IOP phase								

Table 4: Results Multi Level Models (SPSS MIXED)

Both Paintings and Catalysis models of degree centrality show a significant effect of control variable total active projects. As expected, the higher the amount of active project, the higher individual actors score at their participation rate. The amount of active projects does not influence the betweenness centrality scores.

For Paintings, it can be concluded that compared to Other organizations in the IOP phase, Large Companies have in both periods a higher degree centrality as their estimates are positive and significant. SMEs and Knowledge institutes have compared to Other organizations no significant differences in either the IOP or DPI period. This means in practice that on average, a large firm will be involved in more projects than a SME, knowledge institute, or other organization. Although in the DPI Coatings Technology research projects only knowledge institutes and large firms participate[5], there is no significant difference in participation between knowledge institutes and SMEs in the model of the entire network. This could be explained by the relative high amount of generic projects where SMEs participates in.

In the Catalysis case, Knowledge Institutes and Large Companies have no differences in their participation rates. Compared to these organization types, SMEs have in both IOP and post-IOP phase significant lower degree centralities. Despite the activity of SMEs in the ACTS-IBOS projects mentioned in section 4.1, in the overall network they participate on average in fewer projects than large firms and knowledge institutes. Hypothesis 1A is therefore confirmed – SMEs do participate less than large firms. Hypothesis 2A cannot be confirmed: knowledge institutes participate in the Catalysis case more than SMEs but at the same rate as large firms. In the Paintings network large firms participate even more despite there some highly involved knowledge institutes (see Appendix 3). Apparently, there are noteworthy differences between the several knowledge institutes.

Regarding the betweenness centrality index in the Paintings network is can be observed that knowledge institutes have during the IOP a significant positive estimate. This means that in this period, they have a significant higher betweenness centrality and therefore more central position in the network than other types of actors. The Catalysis case shows that knowledge institutes have a higher betweenness centrality in the post-IOP period. Hypothesis 2B can therefore be confirmed partially: in terms of betweenness centrality it depends on the case whether knowledge institutes are the connecting actors of the innovation network. About the differences in positions between SMEs and large firms, it can only be observed that SMEs have in the post-IOP a significant worse position than all other organizations, including large firms. However, this is not enough evidence to confirm hypothesis 1B.

From the lowest part of table 4 it can be concluded that the validity of the models is quite satisfying. All models have substantial smaller log likelihood values than the empty models without parameters and random effects. With three degrees of freedom (as the variables removed are TYPE, IOP_ON and Active_Projects) all Chi-square values are significant which means that the reduced models fit significantly worse than the full models.

[5] See either figure 4 or the simplified network image of the Paintings network in Appendix 2.

5. Conclusion

As discussed in the introduction, the dynamics of policy driven innovation networks have not been studied structurally over a long term. Therefore the main research question of this research is:

> *"How do policy initiated innovation networks develop over time in terms of participation and positions of different actors?"*

The type of policy instrument that is used to stimulate a certain theme strongly affects the characteristics of the collaboration projects and therefore the composition of the network. IOP projects attract much different organizations compared to their sequels which required private contributions to participate. Projects executed in the generic set of instruments are done in even smaller consortia, varying from two to three participants. A core of large companies and knowledge institutes dominates the thematic policy driven networks and sustain in their key positions over time. Network activity in the generic set of policy instruments can be observed after a couple of years the IOPs started. Often these projects are done with new actors, usually SMEs. Beside participation in policy driven networks, central network actors also collaborate bilaterally. Between universities and firms this is contract research. Between companies, bilateral user-producer innovation interaction takes place. Such relations already existed before an IOP started. The role of the government is facilitating: by offering the possibility of a policy instrument the network gets a boost and gets tied stronger. The unique feature of multilateral collaboration in thematic projects strengthens existing relations between the most important actors and fosters other partnerships that emerge without policy backup. By intensive interaction the partners get to know each other and their capabilities. Frequent contacts between industry and universities are for both of them valuable as it provides access to potential employees and additional funding. Research with the most future strategic value is always done by firms individually or bilaterally. In both IOP and post-IOP phases of the Catalysis network, large companies and knowledge institutes were found to have a significant higher degree centralities than SMEs. In the Paintings network, large firms had higher degree centralities than all other types of organizations. The statistical models thus show that firm size determinant is for the participation in policy driven networks: SMEs participate less in the networks of formal research projects. Although knowledge institutes play an important role as generators of knowledge, in general they do not participate in more projects than firms. In terms of betweenness centrality which reflects the position of an actor in a network, the importance of knowledge institutes is case dependent. Knowledge institutes are bridges between clusters of collaboration, but in the Paintings case this was found in the IOP phase while the Catalysis case showed this in the post-IOP period.

6. Discussion

To finish this research, this last chapter will first discuss the quality of the research design regarding construct validity, internal and external validity and reliability. Then theoretical, managerial and policy implications are presented. From these implications, suggestions for further research are derived.

5.1 Quality of research design

The construct validity of a research concerns the way indicators reflect the concepts under investigation. Development of innovation networks is difficult to measure but as argued, the only way to analyze network dynamics is to compare indicators over time. The indicators used are widely accepted measures in social network methodologies (Newman 2007).

Internal validity is defined as the validity of causal relations identified (Bryman, 2008). Regarding this quality criteria, the combination of quantitative and qualitative research designs proved to be valuable. The major share of the network activity is visible in the composition of the public funded projects. Conducting interviews was useful as they clarified more about informal aspects of the innovation networks of Paintings and Catalysis and collaborations that happen without any governmental support. A coding scheme was used as an instrument to analyze the interviews; this is increases construct validity and supports internal validity. Interviewees have indirect interests by participating in future policy instruments and as consequence, they could give social desirable answers. However, since they are asked about projects which are often already finished, this problem might be circumvented.

Another point of discussion is the external validity of the results: generalization of the results. The findings are derived from two cases that show similar patterns and both had a sequel – the question remains how their networks should have developed without any follow-up. However, most IOPs had a tangible embedding of the knowledge and network gained (SenterNovem, 2005). Consequently, for most policy driven networks the findings of this research are valuable. About the sequels of both themes, a remark must be made. As elaborated in the case description, in general is the setup of research executed under DPI and ACTS the same with PhD research and industrial supervisors. But ACTS is part of NWO (Ministry of Education, Culture & Science) and DPI is part of the Ministry of Economic Affairs, Agriculture and Innovation. This possibly could explain differences in the position of knowledge institutes in these networks. Another comment in the context of generalizablity is that Paintings and Catalysis are both themes regarding chemistry. On the one hand most policy driven networks are about such science based technologies which makes the results useful but on the other hand sectors innovation processes can be sector dependent (Malerba, 2002).

The extent to which a research can be replicated is its reliability. The methods followed in this study are easy to replicate on other themes that experienced policy intervention. With the sources of NL Agency, data is available on different broad array themes which means external reliability can be assessed. Internal reliability refers to the extend to which other researchers should have drawn the same conclusions from the data available. Therefore in the Results chapter the coding scheme shown to demonstrate intermediary steps to the final conclusions.

5.2 Implications

The central ideas forthcoming from the Resource Based and Dependent View have proven to be useful in this research. In the interviews, organization specific resources that motivate actors to participate in policy driven networks reflect these theories. The findings of the existence of a core of organizations in the networks is in line with e.g. Powell *et al* (2005) and Ahuja (2000). The added value of this research lies primarily in the notion that this core consists of large firms and knowledge institutes. As themes were studied for a period of at least 20 year, a contribution is made compared with existing studied about the effects of individual policy instruments. At the managerial level of individual firms, managers should be aware of the rich possibilities that public funded projects offer. The access to possible employees and precompetitive knowledge are big advantages.

For policy makers, this research provides more insight in the composition of networks that are shaped by the execution of policy instruments. A central message is that thematic policy instruments like IOP, ACTS and DPI in particular attract knowledge institutes and large firms to participate. The absence of SMEs can be a consequence of the private contribution of firms in IOP sequels. When the participation of SMEs is a goal too, policy makers should especially try to transfer the knowledge generated to them. IOPs, ACTS and DPI do practice such activities and policy makers should be aware that these initiatives are often the only possibilities for SMEs to reach the network. When the goal of a policy intervention is to generate knowledge and to foster network activities, IOPs and their sequels are quite satisfying. A network cannot only be made by such instruments: momentum from the industry and knowledge infrastructure is needed to succeed in the successful emergence and development of a policy driven network.

5.3 Future research

To enhance the external validity other policy driven domains like high tech or life sciences and health should be studied. Studying such themes will enhance the robustness of the findings. Explaining the observed differences in the central positions of knowledge institutes in DPI and ACTS could provide more insight in the effects of institutional factors. Another suggestion is to compare cases in other countries since factors at the national level can determine innovation processes as well (Edquist, 2005). The IOP instrument is quite unique for the Netherlands, although other counties practice thematic innovation instruments as well. Such cases can reveal whether the observed differences between small firms, large firms and knowledge institutes are always present in public funded research consortia. Further research could also study the spread of generated knowledge by thematic policy instruments through the network to gain more insight in indirect outcomes of innovation networks and their correlation with generic projects. In such a research, a selection of IOP or sequel projects could be followed in order to determine both the scientific impact of the PhD thesis and publications as commercial revenues. However, measuring commercial outputs of earlier generated precompetitive knowledge would be difficult to realize. A last suggestion is to follow the careers of former PhD students from IOPs and similar instruments to see whether the micro-networks between industrial scholars and professors sustain over time. Such human capital monitoring can reveal additional information about informal industry-university network activities and forthcoming formal collaborations.

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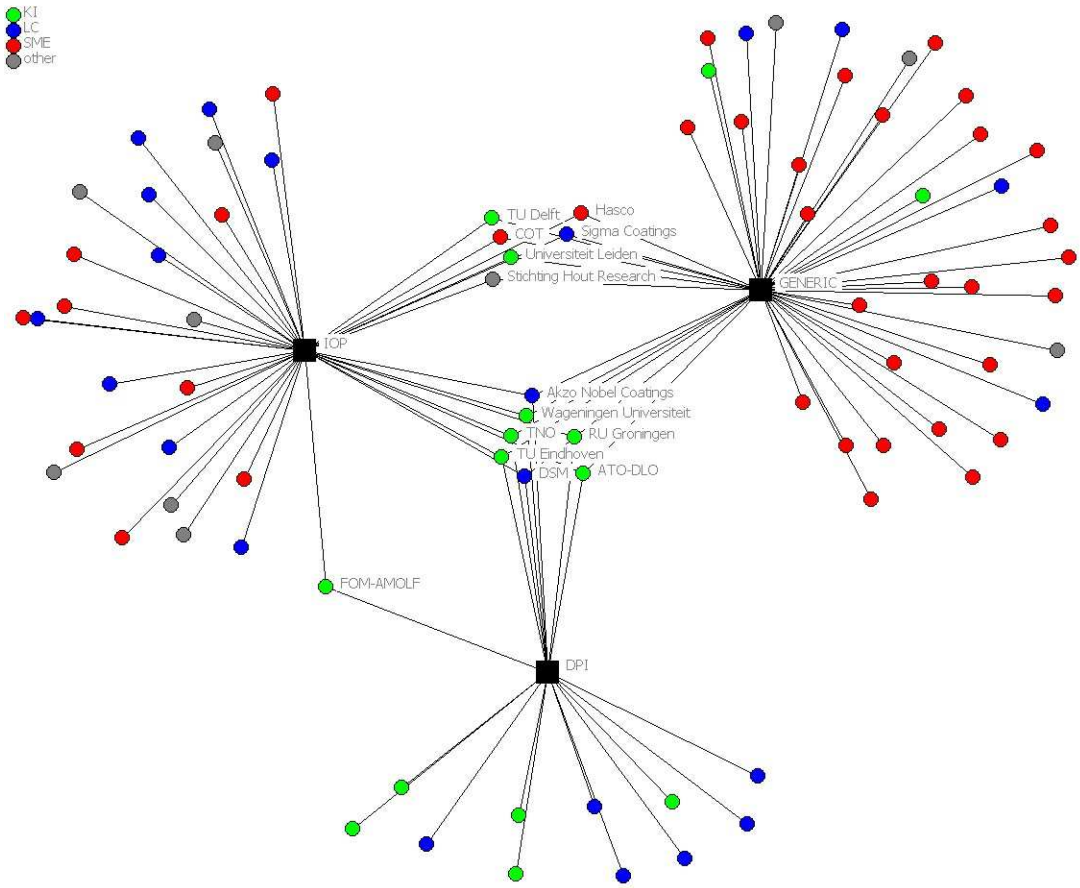
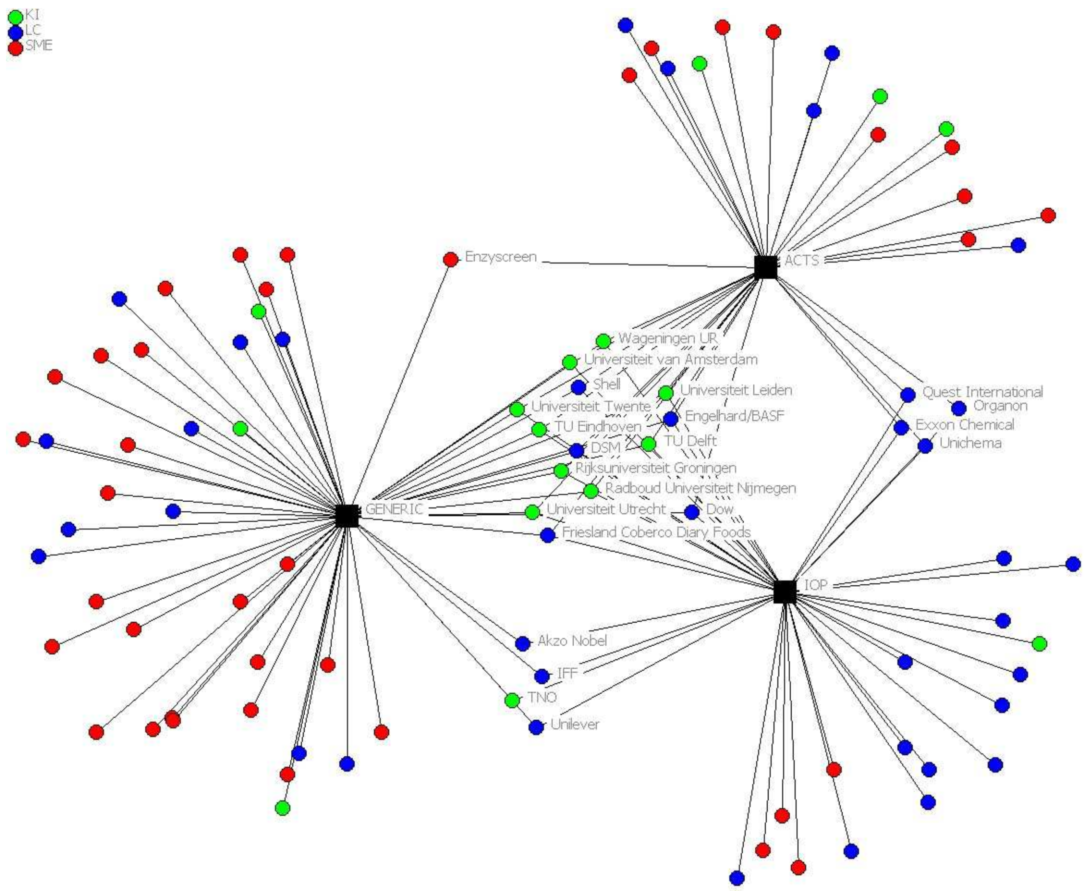
Appendices

Appendix 1: Simplified 2-mode network image Paintings



Appendix 2: Simplified 2-mode network image Catalysis



Appendix 3: Importance of actors in the Paintings network

Painting: 2-mode degree centrality (participation in unique projects, minimum=2)

1991-2010		1991-1998		1999+	
Organization	**Amount**	**Organization**	**Amount**	**Organization**	**Amount**
DSM	50	Sigma Coatings	18	DSM	37
Akzo Nobel Coatings	46	Akzo Nobel Coatings	16	Akzo Nobel Coatings	30
TU Eindhoven	38	DSM	13	TU Eindhoven	25
Dow	28	TU Eindhoven	13	Dow	24
TNO	17	TU Delft	7	Evonik Degussa	13
Oce	14	TNO	6	Oce	12
Evonik Degussa	13	Wageningen Universiteit	5	TNO	11
Sigma Coatings	12	ATO-DLO	4	Shell	7
Wageningen Universi	10	Bedrijfschap Schilderbedri	4	Wageningen Universitei	5
Sigma Coatings	9	COT	4	RU Groningen	4
Shell	8	Dow	4	Bayer	3
TU Delft	7	E. Nagel Soepenberg	4	DPI	3
ATO-DLO	6	Fokker Aircraft	4	FPL Stuttgart	3
Stichting Hout Resear	5	General Electric Plastics	4	Sigma Coatings	3
Van Wijhe	5	Stichting Nederlands Corro	4	ATO-DLO	2
Bedrijfschap Schilderb	4	Van Wijhe	4	Condea Servo	2
COT	4	Ned.Bon v. Timmerfabrika	3	COT	2
E. Nagel Soepenberg	4	Remmers Bouwchemie	3	Feyecon Development &	2
Fokker Aircraft	4	S.C. Johnson Polymer	3	Stichting Hout Research	2
General Electric Plast	4	Stichting Hout Research	3	Stork Textile Printing Gr	2
Remmers Bouwchem	4	Zeneca Resins	3	TU Delft	2
Rijksuniversiteit Groni	4	Oce	2	Universiteit Leiden	2
Stichting Nederlands (	4	Philips	2	Universiteit Twente	2
Zeneca Resins	4			Universiteit van Amsterd	2
Bayer	3				
DPI	3				
FPL Stuttgart	3				
Ned.Bon v. Timmerfal	3				
Philips	3				
S.C. Johnson Polyme	3				
TU Delft	3				
Universiteit Twente	3				
Condea Servo	2				
COT	2				
Feyecon Developmen	2				
FOM-AMOLF	2				
Grace Coatings Gmbl	2				
Hasco	2				
Stork Textile Printing (	2				
Universiteit Leiden	2				
Universiteit van Amste	2				

Appendix 4: Importance of actors in the Catalysis network

Catalysis: 2-mode degree centrality (participating in unique projects, minimum=2)

1990-2010		1991 - 2001		2002+	
Organization	**Amount**	**Organization**	**Amount**	**Organization**	**Amount**
DSM	105	DSM	87	Engelhard/BASF	22
Shell	61	Quest International	44	Johnson Matthey	19
TU Delft	53	Shell	44	DSM	18
Engelhard/BASF	50	TU Delft	42	Shell	17
Universiteit Utrecht	47	Solvay Duphar	32	Dow	16
Quest International	45	Universiteit Utrecht	32	Rijksuniversiteit Groningen	15
Rijksuniversiteit Groningen	39	Akzo Nobel	30	Universiteit Utrecht	15
Dow	35	Engelhard/BASF	28	Exxon Chemical	13
Universiteit van Amsterdam	34	Universiteit van Amsterdam	26	Wageningen UR	13
Solvay Duphar	32	Rijksuniversiteit Groningen	24	Sabic	11
Akzo Nobel	31	IFF	23	TU Delft	11
Wageningen UR	30	Gist-Brocades	21	Universiteit Leiden	9
Exxon Chemical	27	Dow	19	Organon	8
IFF	24	TNO	18	Radboud Universiteit Nijmeg	8
Gist-Brocades	21	Wageningen UR	17	TU Eindhoven	8
Johnson Matthey	19	Exxon Chemical	14	Universiteit van Amsterdam	8
TNO	19	Norit	13	Albemarle	7
Organon	16	Unichema	13	Universiteit Twente	6
Unilever	16	Unilever	13	Syncom	3
Radboud Universiteit Nijmeg	15	ATO-DLO	12	Vrije Universiteit Amsterdam	3
TU Eindhoven	14	Tastemaker	12	Chiralix	2
Unichema	14	ABB Lummus	11	Enzyscreen	2
Universiteit Leiden	14	Organon	8	Friesland Coberco Diary Fo	2
Norit	13	Procede Twente	7	Isobionics	2
ATO-DLO	12	Radboud Universiteit Nijmeg	7	Selact BV	2
Tastemaker	12	Akcros	6	Stichting Technology Consu	2
ABB Lummus	11	Purac	6	Unilever	2
Sabic	11	TU Eindhoven	6		
Universiteit Twente	11	Universiteit Leiden	5		
Albemarle	7	Universiteit Twente	5		
Procede Twente	7	Bioclear Milieubiotechnologi	4		
Akcros	6	Cerec Twente B.V.	4		
Purac	6	Gastec N.V.	4		
Stichting Technology Consu	5	Hercules	4		
Bioclear Milieubiotechnologi	4	PFW Aroma Chemicals	4		
Cerec Twente B.V.	4	Chera B.V.	3		
Friesland Coberco Diary Fo	4	KTI	3		
Gastec N.V.	4	Stichting Technology Consu	3		
Hercules	4	Denka	2		
PFW Aroma Chemicals	4	Friesland Coberco Diary Fo	2		
Chera B.V.	3	Head Consultancy	2		
KTI	3	KEMA NV	2		
Selact BV	3				
Syncom	3				
Vrije Universiteit Amsterdam	3				
Atofina Vlissingen BV	2				
Chiralix	2				
Denka	2				
Enzyscreen	2				
Isobionics	2				
KEMA NV	2				

Appendix 5: Interview questions (Dutch)

1. Netwerkontwikkeling
   - Gevonden ontwikkeling verifieren. Een bepaalde ontwikkeling en rol van de organisatie is in de dataset te zien. Herkent de interviewee dit beeld?
   - Missen er nog activiteiten in het overheidsgedreven (gesubsidieerde) netwerk?
   - Zijn er buiten het gevonden netwerk andere samenwerkingen? 'Niet zichtbare' netwerken.
   - De additionele samenwerkingen, met welke partijen vinden die plaats? Analyse: komen deze partijen ook in het specifiek voor of niet.
   - Wat voor soort samenwerkingen, hoe frequent? (Hoe begonnen…). Verschillen deze samenwerkingen inhoudelijk van gesubsidieerde projecten?
2. Ontstaan & rol overheid
   - Bestonden relaties al die in een IOP of DPI enkel geformaliseerd en geintensiveerd werden? Met voorbereiding specifieke geval van de organisatie bekijken.
   - Wie nam het voortouw in het traject – overheid, industrie, wetenschap? Is gesubsidieerd dus ook per defintie beleidsgedreven?
   - "What if" scenario voorleggen, zonder overheidssteun: minder samenwerking, langere projectduur, kleinere projecten, zelfde project, geen project? =input additionaliteit. Wordt indicatief gemeten dus niet per afzonderlijk project.
3. Causaliteit & effect
   - Organisaties die elkaar van IOP/DPI/ACTS kennen en daarbuiten samenwerken in generiek beleid. Wat was eerst? Generieke projecten kunnen een opstapje zijn tot specifiek, een gevolg ervan, of compleet op zichzelf staan.
   - Wat is de invloed van externe factoren (e.g. techn.ontw.) op de dynamiek van het netwerk?
4. Motivaties per KIs en bedrijven & output
   - KIs: Scientific contributions, publicaties, carriere, conferenties, toegang tot funding.
   - Industrie: Toegang tot kennis, kosten reductie, nieuwe markten, schaalvoordelen
   - Was er een barriere tussen de wetenschappers en het bedrijfsleven? Kon de overheid hierin helpen door een gemeenschappelijke visie te faciliteren?
   - Waren er knelpunten in het innovatieproces? Wat was de rol van de overheid hierin?
   - Afhankelijkheid van de periode (het beleidtype dat gevoerd werd), opzet IOP en TTI / ACTS verschilt aanzienlijk – verandert dit de motivaties om deel te nemen?
   - Werd aan de verwachtingen voldaan die de organisatie had voor deelname? Zijn er concrete resultaten behaald? Zijn die behaald? Wederom organisatie specifiek (KI vs industrie).
5. Ontwikkeling samenwerkingen over lange termijn
   - Voor terugkerende relaties, zijn er strategische doelen, gemeenschappelijke lange termijn visie, voorgeschiedenis, voldoen behaalde resultaten. Waarom continueert een langedurige relatie?
   - Instappers, uitstappers en 'harde kern' verschillend benaderen. Waarom doet een organisatie na een tijd niet meer mee of juist wel?
   - Afhankelijkheid van de periode (het beleidtype dat gevoerd werd)

Appendix 6: List of interviewees, alphabetical order

- Dr. Eugene Kuijpers, BASF (former Engelhard De Meern). IOP Catalysis and program board of ACTS, participant Roadmap Catalysis, VIRAN.
- Dr. Leendert Molhoek, DSM Resins. DPI-CT and IOP Self Healing Materials.
- Dr. Peter Berben, BASF (former Engelhard De Meern). IOP Catalysis and program board of ACTS-Aspect. Participant Roadmap Catalysis.
- Dr. Pieter Geurink, Akzo Nobel Car Refinishes. DPI-Coatings Technology cluster and IOP Self Healing Materials.
- Dr. Ton van der Weerdt, Quest International (retired). IOP Catalysis, participant Roadmap Catalysis.
- Drs. Jochum Beetsma, current Meritus Group Zwolle but presented DSM Resins during IOP Paintings, disperse.
- Prof.dr. Bert de With, Technische Universiteit Eindhoven. DPI-CT and IOP Self Healing Materials.
- Prof.dr. Freek Kapteijn, TU Delft. IOP Catalysis and program board of ACTS-Aspect, NIOK.
- Prof.dr. Martien Cohen Stuart, Wageningen University. IOP Paintings and DPI-CT, also Scientifid Director DPI.
- R&D Manager Akzo Nobel Decorative Paints. IOP – Paintings, wood protection.