Dissertation

Structure and dynamics of policy induced networks in systems of innovation

Struktur und Dynamiken von politikinduzierten Netzwerken in Innovationssystemen

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Für *Anna-Katharina* sowie
meine Eltern, Geschwister und Großeltern.

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EC	European Commission
EPO	European Patent Office
ERA	European Research Area
ESPRIT	European Strategic Program on Research in Information Technology
EU	European Union
EURATOM	European Nuclear Community
FP	Framework Programme for Research and Technological Development
GOF	Goodness of Fit
ICT	Information and Communications Technology
IS	Innovation System
KBBE	Knowledge Based Bio-Economy
OLS	Ordinary least Square
R&D	Research and Development
SAOM	Stochastic Actor-Oriented Model
sd	Standard Deviation
SIENA	Simulation Investigation for Empirical Network Analysis
SME	Small and medium-sized Enterprises
U.S.	United States
ZIM	Central Innovation Programme for SMEs

I. Introduction

Due to a growing awareness about limited natural resources caused in part by the depletion of raw materials and the forecast put forward in *The Limits to Growth*, presented by the Club of Rome in 1972 (Meadows et al., 1972), technological progress had become an economic focus. The 1973 oil crisis led to a period of economic stagnation in many industrialized Western countries, which strengthened public concern about the scarcity of raw materials, such as crude oil. Given the prospect of a long-term worldwide economic slowdown, technological development was found to be a promising opportunity for further economic prosperity.

All this led to a remarkable change in economists' thinking regarding technological change. At that time Solow's theory (1956) was the prevailing growth model, based on capital accumulation and labor, interpreting technological progress as somewhat exogenous – like manna falling from heaven – which enables the labor force to become continuously more efficient. An alternative model of economic growth was presented by Romer (1989), in which the understanding of technological progress is considered more endogenous, which can be influenced through a reduction of consumption and an investment in research and development (R&D) activities. Thus, many social scientists began searching for determinants of technological change, a task in which Joseph Schumpeter was already engaged (Schumpeter, 1942). The interdependence between R&D, innovations, and the economic performance of a country in conjunction with the characterization of R&D as a public good, requires and legitimizes a certain degree of governmental intervention (Arrow, 1962; Nelson, 1959).

At the end of the 1980s the idea of national innovation systems became popular (Freeman, 1987; Lundvall, 1988; Freeman, 1991), introducing a systematic approach that helps to explain the degree of innovation in an economy through the configuration of institutions, relationships, and organizations inside the private and public sectors. The approach stresses the dependency of a country's innovative performance on inter-organizational research collaborations between firms, universities, and research centers carried out within formal and informal networks. Moreover, Powell et al. (1996) emphasized that “when knowledge is broadly distributed and brings a competitive advantage, the locus of innovation is found in a network of interorganizational relationships.” In addition, cost-economizing incentives also play a role, such as economies of scale, resource pooling, risk sharing, and gaining access to new markets (Hagedoorn, 1993; Mowery et al., 1998). The network-related approach implies the understanding of an innovation as a non-linear process (Kline, 1985; Pyka, 1999), since the current configuration of the network is affected by the previous stages of the innovation system. By this, the actual stage of the innovation system represents the outcome of experience-accumulation and collective learning processes in the past (Ozman, 2009) triggered by stakeholders from various institutional backgrounds. These ideas coincide with the pulse of the time, as European firms were falling behind their competitors from the U.S. and Japan due to low investment in R&D activities and a weak interface with research organizations. Thus Europe, triggered by this shock, began facilitating its collaborative research efforts through the implementation of a new innovation policy.

In the EU, this policy was realized via the initiation of the first Framework Programme for Research and Technological Development (FP) in 1984. From the beginning of the program, transnational research joint ventures between different organizations were central to the FP in order to facilitate the emergence of a pan-European research network. In 2000, the EU strengthened its ambitions with a revision of the actual policy and proclaimed a way “Towards a European Research Area” (EU, 2000). Even though the original perspective of the innovation system was a national one, this policy revision justified a transnational interpretation of the same approach, centralized at the level of the EU (Delanghe et al., 2009; Protogerou et al., 2013). To this day, researchers largely confirmed the emergence of a continent-wide research network resulting from research projects that have been supported by the EU (Breschi and Cusmano, 2004; Roediger-Schluga and Barber, 2006; Protogerou et al., 2013).

Furthermore, in the national context, collaborative research joint ventures became key instruments of governmental innovation policies. Even if the initial share was rather low compared to the European FP, the German federal government started to support pre-competitive joint projects during the 1980s (Fier and Harhoff, 2002). The breakthrough for collaborative projects in Germany came in 1999, when the number of joint projects exceeded the number of single-funded projects for the first time (Czarnitzki and Fier, 2003). As a consequence, Germany developed a national research network (Broekel and Graf, 2012), strengthening the country’s innovative competitiveness.

Since a frequent number of possible market imperfections have been investigated, for example, private underinvestment in R&D by private firms (Arrow, 1962), the unavailability of adequate infrastructure (Smith, 2000) or due to connectivity problems between the organizations within an innovation system (Woolthuis et al., 2005), the necessity for government intervention is evident. However, it is important to address whether or not the policy design implemented by the government is efficient, in order to prevent unintended distortions to the market such as harming the incentive to innovate, rent-seeking activities, or fostering market power.

One of the first observations concerning the pan-European research network was the identification of a highly clustered core at the center of the network and, as a consequence of this, a poorly connected periphery (Breschi and Cusmano, 2004). Another finding was that to a large extent the network configuration tends to replicate itself among subsequent FPs (Roediger-Schluga and Barber, 2006). Thus, central players in the research network gradually become even more central, which implies several risks for an economy's innovative performance. A policy that focuses unilaterally on the emergence of a dense network of organizations (Breschi and Cusmano, 2004) or that enables too much clustering (Cowan and Jonard, 2004) has the potential of facing path dependencies, technological lock-ins, institutional constraints, a consolidation of technological paradigms, and coordination failures. Another pitfall would be the ineffectiveness of the mechanisms used to facilitate knowledge flows. All of these would be detrimental to the original aim of the policy, which is to strengthen innovative performance.

The rising importance of collaborative project grants in light of the possibility of government failure has addressed several questions, such as whether the revision of innovation policies in industrialized countries fosters the emergence of the network structures discussed above, encourages rent-seeking, or promotes market power. In order to analyze the processes that shape these outcomes the next sections will investigate, theoretically and empirically, what shapes the current implemented innovation policy in Germany and the EU.

Therefore, this study has the following structure. Chapter II gives an overview concerning the rising importance of networks for innovation processes and innovation systems in economic theory, and summarizes the historical implementation of network-related instruments used in governmental innovation policies. According to the literature, collaborative project grants will soon become, or already are, the dominant policy instrument of industrialized countries in the promotion of innovations, and thus a deeper insight into the mechanism of funding is quite urgent. The literature overview lead ultimately to further research questions for the remaining empirical Chapters III through

V.

Chapter III discusses the European innovation policy, since high-quality data are available, including accepted as well as rejected collaborative projects for the European FPs. Furthermore, because of the convergence mechanism and the political aim to interconnect the national innovation systems of EU member states, the European policy becomes highly relevant even to national innovation systems. The chapter explores the case of the biotechnology sector and the allocation mechanism of project grants for the 7th Framework Programme. In that chapter, we investigate which mechanisms trigger the evolution of a core periphery structure within the European R&D network. The biotechnology is illustrative of future markets, as the sector is a rather new emerging industry, with significant economic potential. Thus, inefficient policy implementation could possibly jeopardize Europe's position as a forerunner within this or other industries in the coming years.

Chapter IV shifts the perspective to the innovation policy in Germany and focuses on the dynamics of the funding system. To evaluate Germany's funding strategy the empirical investigation of the chapter reveals connection between the allocation mechanism of project grants and the research network's architecture. For this purpose, the manufacturing industry was selected since Germany's economic success depends to a large extent on its capabilities within the machinery sector. The analysis confirms the dependency of the allocation process on the network structure, which ultimately causes a feedback cycle between the formation of the network and the allocation process of project grants. This finding led to the motivation to explore whether the promotion of collaborative project grants is a suitable policy instrument for the promotion of collaborative innovations.

Chapter V analyzes the interrelationship between research joint ventures and innovations for the automotive and chemical industries in Germany. The sectors chosen for this investigation are highly relevant to Germany's economy, underpinning the current export surplus. Thus, innovations within these sectors help to sustain Germany's competitiveness in the global market. The investigation helped to understand that both types of collaborative activities – research as well as innovation – are highly related to each other, and that network links present in one are highly likely to transit. This observation raises the question as to which type of network formation evolves over time within a policy-promoted research network, since it is highly likely that rather static policy legislation tends to preserve once-established network patterns.

Chapter VI concludes the major findings of the study from a general perspective and outlines research questions for further investigation.

Bibliography

Arrow, K. (1962). 'The Rate and Direction of Inventive Activity: Economic and Social Factors'. In: *The rate and direction of inventive activity: Economic and social factors*. Ed. by R. Nelson. Princeton University Press. Chap. Economic Welfare and the Allocation of Resources for Invention, pp. 609–626.

Breschi, S. and L. Cusmano (2004). 'Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes'. In: *International Journal of Technology Management* 27, pp. 747–772.

Broekel, T. and H. Graf (2012). 'Public research intensity and the structure of German R&D networks: a comparison of 10 technologies'. In: *Economics of Innovation and New Technology* 21.4, pp. 345–372.

Cowan, R. and N. Jonard (2004). 'Network structure and the diffusion of knowledge'. In: *Journal of Economic Dynamics and Control* 28.8, pp. 1557–1575.

Czarnitzki, D. and A. Fier (2003). *Publicly Funded R&D Collaborations and Patent Outcome in Germany*. ZEW - Centre for European Economic Research Discussion Paper. ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research.

Delanghe, H., B. Sloan, and U. Muldur (2009). 'European Science and Technology Policy: Towards Integration or Fragmentation?' In: ed. by H. Delanghe, U. Muldur, and L. Soete. Edward Elgar Publishing. Chap. Transnational collaboration in pubilc research funding and publicly supported research in Europe, pp. 175–188.

EU (2000). *Communication COM(2000) 6 - Towards a European Research Area (ERA)*. EU Commission, EU Parliament, the Economic and Social Committee and the Committee of the Regions.

Fier, A. and D. Harhoff (2002). 'Die Evolution der bundesdeutschen Forschungs- und Technologiepolitik: Rückblick und Bestandsaufnahme'. In: *Perspektiven der Wirtschaftspolitik* 3, pp. 279–301.

Freeman, C. (1987). *Technology, Policy, and Economic Performance : Lessons from Japan*. London; New York: Pinter Publishers.

Freeman, C. (1991). ‘Networks of innovators: A synthesis of research issues’. In: *Research Policy* 20.5, pp. 499–514.

Hagedoorn, J. (1993). ‘Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences’. In: *Strategic Management Journal* 14.5, pp. 371–385.

Kline, S. J. (1985). ‘Innovation is not a Linear Process’. In: *Research management*, pp. 36–45.

Lundvall, B. (1988). ‘Technical Change and Economic theory’. In: *Technical Change and Economic theory*. Ed. by Dosi, G. et. al. (eds.) Pinter. Chap. Innovation as an Interactive Process: From User Producer Interaction to National systems of Innovation.

Meadows, D. H., D. L. Meadows, J. Randers, and W. W. B. III (1972). *The Limits to Growth*. Universe Books.

Mowery, D. C., J. E. Oxley, and B. S. Silverman (1998). ‘Technological overlap and interfirm cooperation: implications for the resource-based view of the firm’. In: *Research Policy* 27.5, pp. 507–523.

Nelson, R. R. (1959). ‘The Simple Economics of Basic Scientific Research’. In: *Journal of Political Economy* 67.3, pp. 297–306.

Ozman, M. (2009). ‘Inter-firm networks and innovation: a survey of literature’. In: *Economics of Innovation and New Technology* 18.1, pp. 39–67.

Powell, W. W., K. W. Koput, and L. Smith-Doerr (1996). ‘Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology’. In: *Administrative Science Quarterly* 41.1, pp. 116–145.

Protogerou, A., Y. Caloghirou, and E. Siokas (2013). ‘Twenty-five years of science-industry collaboration: the emergence and evolution of policy-driven research networks across Europe’. In: *The Journal of Technology Transfer* 38.6, pp. 873–895.

Pyka, A. (1999). *Der kollektive Innovationsprozess: Eine theoretische Analyse informeller Netzwerke und absorptiver Fähigkeiten*. Berlin: Dunker & Humbolt.

Roediger-Schluga, T. and M. J. Barber (2006). *The structure of R&D collaboration networks in the European Framework Programmes*. Tech. rep. United Nations University - Maastricht Economic et al.

Romer, P. (1989). *Endogenous Technological Change*. Working Paper 3210. National Bureau of Economic Research.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. New York, London: Harper & Brothers.

Smith, K. (2000). 'Innovation as a Systemic Phenomenon: Rethinking the Role of Policy'. In: *Enterprise and Innovation Management Studies* 1.1, pp. 73–102.

Solow, R. M. (1956). 'A Contribution to the Theory of Economic Growth'. In: *The Quarterly Journal of Economics* 70.1, pp. 65–94.

Woolthuis, R. K., M. Lankhuizen, and V. Gilsing (2005). 'A system failure framework for innovation policy design'. In: *Technovation* 25.6, pp. 609–619.

II. The rising importance of networks for innovation policies

1. Theoretical background

By promoting R&D activities, governments aim to secure the economic, social, and cultural development of their territories. Hence, the question often asked is, do collaborative research grants or network-oriented funding strategies contribute to the innovative performance and economic prosperity of a country or continent? Answering this the following sections provide a theoretical overview concerning the outstanding importance of cooperative research activities for innovating.

As already mentioned, this perspective requires that technological change can be influenced, which is a point of view that was not accepted by all economists. Various economic schools explained technological change differently. The understanding of technical progress as a residue between economic growth and other explaining factors was supported, as well as the opinion that technical change is an endogenous factor. The latter is shared across "Endogenous Growth Theory," "New Institutional Economics", and "*Evolutionary Economics*" (Grupp, 1997).

1.1. Innovating and technological progress

Innovating is a general concept, thus various definitions can be found within the literature and requires that the term be interpreted within its respective context. Occasionally, innovating and technical progress are used as synonyms, which leads to some confusion if there is no contextual definition as they are different expressions for related events. Both refer to a process that explores something new. However, the terminus of innovating includes an economic, technological, political, cultural, and social perspective, and is therefore broader than the meaning of technical progress, which has only a technological dimension (Grupp, 1997). Schumpeter's (1942) understanding of an innovation includes all, which can lead to quasi-rents that result from entrepreneurial advantages. As the following chapters focus on technological R&D activities, it is reasonable to define innovating as a process to create new technologies.

Within the macroeconomic context, technical progress increases the competitiveness of an economy (Solow, 1956; Freeman, 1987; Romer, 1989) in terms of productivity and the ability to support new markets. This means that the same economic output can be achieved with less input or that for a country's given resource allocation, the output becomes enlarged due to the availability of more efficient production processes and new technological capabilities.

1.2. Innovation process

Linear approach

The microeconomic foundation of technical progress in the linear approach is grounded on the organization's decision to undertake an innovation activity. The organization will invest its scarce resources for the exploration and development of a new technology, process, or product if it can expect a net profit after deducting opportunity costs and development expenditures derived from the innovation process (Dosi, 1988). The idea of innovation as a sequential or a linear process mostly refers to Schumpeter (1912; 1942), who divides the process into three consecutive steps: (1) the invention phase, (2) the innovation phase, and (3) the diffusion and imitation phase. The invention phase discovers a new product or technique by the application of basic or experimental research. Within the innovation phase, the initial invention is processed to an economically utilizable product, and thereafter introduced to the market. In the case of market success, the innovation will reach the third stage. Other firms start to imitate the development of the innovation, thus the innovation becomes diffused. This initiates technical progress within the overall economy (Pyka, 1999; Grupp, 1997; Forrest, 1991).

Collective approach

The linear approach has been heavily criticized since the 1980s, as it does not take into consideration the possibility of feedback links among different stages of the innovation process. It also highlights unilateral in-house R&D activities without having interconnections to other organizations, and restricts contributions from the research and academic sector to the first (invention) stage of the process (Kline, 1985; Kelly and Kranzberg, 1978). A major shift towards a renewal of the theoretical framework of the innovation process occurred the prevailing interests concerning the knowledge-based economy approach, which stresses the importance of knowledge as an additional production factor. First thoughts were made by Marshall (1920), but it was Penrose's (1959) resource-based view of a firm that introduced knowledge as an essential part of a company's collection of productive resources. Hence, the productive capacity of a firm is not only determined by its specific composition of human and physical capital, but also from its accumulated knowledge over time (Pyka, 1999). The understanding of a company as a repository of productive knowledge and routines (Nelson, 1982; Winter, 1988) widens the firm's strategic ability to compete by stimulating the internal production, and external acquisition, of new knowledge.

The shortcomings of the linear approach led to the emergence of the collective approach, which emphasizes the complexity and interconnectivity of an innovation process as well as the dependency of innovating on knowledge accumulation (Pyka, 1999). In the collective approach, the process is no longer seen as a sequence of consecutive stages but as a heavily intertwined procedure (Kline, 1985) that includes frequent feedback loops between the stages and involves various actors from different institutional backgrounds. The coordination of countless innovation processes taking place simultaneously within a complex economy is carried out by a self-organizing network, following the principle of Complementarity and reciprocity. Building upon the approach of a knowledge based economy, this new innovation concept stresses knowledge as an additional production factor, linking the success of an innovation process directly to the available accumulated knowledge base of the involved organizations. With the rising complexity of innovations, especially in high-tech sectors, it became more urgent than ever before to collaborate, as the origin of innovations lies among firms, research centers, universities, consumers, and suppliers rather than inside one particular entity (Graf, 2006; Powell, 1990). The recombination of already-existing knowledge is a fertile source of technical progress (Boschma, 2005; Nooteboom, 2000), thus external information sources were of particular importance since within a complex economy knowledge is dispersed among numerous organizations (Brusoni et al., 2001).

Various types of arrangements regulate the transfer of knowledge between different actors (Graf, 2006). In a market situation, contracts formalize the exchange between involved organizations by defining clear property rights. In that case, most of the communication is carried out by the price mechanism of the market. In a hierarchical relationship, for example between the head and the research staff of a department, personal contracts formalize the flow of knowledge. Another constellation is inter-organizational cooperation, which constitutes a hybrid between markets and hierarchies which requires trustworthy relationships and reciprocity (Granovetter, 1985; Powell, 1990; Uzzi, 1996). This is required as most of the transferred knowledge is informal or tacit, which an organization will only share with reliable partners (Hippel, 1988; Kogut and Zander, 1992). Moreover, an organization would not engage itself in a research joint venture if it could not expect to learn from other organizations (Graf, 2006).

Furthermore, an organization needs the capability to absorb external knowledge. Access alone is not a sufficient condition for learning, since the organization needs to translate the external knowledge into in-house routines. Cohen and Levinthal (1990) shaped the concept of the absorptive capacity, which describes an organization's ability to identify, assimilate, and exploit knowledge. The absorptive capability of an organization can be trained by internal R&D activities since a significant share of the skills are related to learning-by-doing experiences and learning-by-using processes (Graf, 2006). Besides the knowledge argument, cost-economizing incentives also play a role, such as economies of scale, resources pooling, risk sharing, and gaining access to new markets (Hagedoorn, 1993; Mowery et al., 1998). Furthermore, an organization needs the capability to absorb external knowledge. Access alone is not a sufficient condition for learning, since the organization needs to translate the external knowledge into in-house routines. Cohen and Levinthal (1990) shaped the concept of the absorptive capacity, which describes an organization's ability to identify, assimilate, and exploit knowledge. The absorptive capability of an organization can be trained by internal R&D activities since a significant share of the skills are related to learning-by-doing experiences and learning-by-using processes (Graf, 2006). Besides the knowledge argument, cost-economizing incentives also play a role, such as economies of scale, resources pooling, risk sharing, and gaining access to new markets (Hagedoorn, 1993; Mowery et al., 1998).

1.3. Innovation system

The collective innovation process entails an extremely complex actor-network, which requires a systematic approach to analyze the multilateral relations and institutions enforcing the mechanism of innovation (Edquist, 1997). Innovations are no longer seen as isolated or independent R&D activities, but as heavily intertwined learning processes of different organizations (Edquist, 2004; McKelvey, 2002), such as firms, suppliers, customers, competitors, research centers, and universities. The behavior of the actors inside the innovation system (IS) is shaped by the institutional setting (laws, rules, norms, and routines). The idea for a systematic approach originates from Freeman (1987; 1991) and

Lundvall (1988). Both introduced the concept of a national innovation system, which aims to explain the determinants affecting the innovation process. Their approach can be seen as a reaction to the theoretical incapability to understand Japan's economic catch-up process during the 1980s. It attempts to explain the innovativeness of an economy over the configuration of its institutions in the public and private sector. Freeman (1987) described the national innovation system as a "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies," and emphasized the role of politics, the R&D activity of private firms, the available industrial infrastructure, and the educational system. It became apparent that cooperation is a vital determinant for a country's economic prosperity. Using these premises, different countries form their individual national innovation systems, and each evolves over time depending on its preexisting institutions, historical events, technical maturity, key industries, and accumulated knowledge (McKelvey, 2002).

Since innovation processes are omnipresent but each location and sector has its own pattern, other approaches of ISs were conceptualized so that regional (Cooke et al., 1997; Braczyk et al., 1998), sectoral (Breschi and Franco, 1997; Malerba, 2002), technological (Carlsson, 1995), and transnational approaches of ISs (Coe and Bunnell, 2003; Steg, 2005) can be distinguished. Notwithstanding their differences, all IS approaches commonly place innovation and learning processes at the center of their attention.

Components of the innovation system

There is an overwhelming consensus that a system, as a set of "interrelated components working toward a common objective" (Carlsson, Jacobsson, et al., 2002), consists of components, relationships, and attributes whereby the elements mutually affect each other, with the consequence that the whole system cooperates together.

Transferred into the context of the IS approach, the system is represented by its organizations, institutions, and interactions (see Figure II.1). Although there is a broad consensus regarding the main components of an IS (Carlsson, Jacobsson, et al., 2002; Edquist, 1997; Edquist, 2004), there are discontinuities concerning their understanding. The main components of the IS have to be clarified.

Organizations are the operators of the system, consisting of individuals in formal structures are joined together to achieve a common goal. They can come from various organizational backgrounds, such as private firms, banks, universities, research centers, or public policy agencies (Carlsson, Jacobsson, et al., 2002; Edquist, 2004).

Institutions are a collection of common laws, norms, habits, routines, or established practices that are shared among the organizations inside the system, regulating the relations between them. They are the result of a long-term process constituted by collective rather than individual actions. As a consequence, the institutions of different systems can vary, which is particularly true for national innovation systems since laws or regulations (such as patent laws, ethical guidelines, public funding) are mostly defined and carried out by national legislative acts and governmental agencies. Unlike organizations, institutions are unable to act by themselves (North, 1990; Edquist and Johnson, 1997; Edquist, 2004).

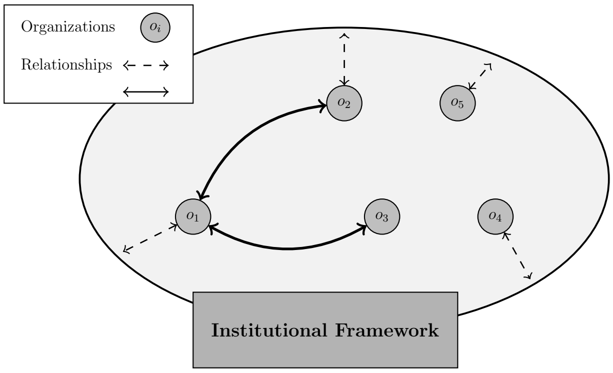


Figure II.1.: Stylized components of the innovation system

Relationships link the components of the system; thus, the behavior of the organization is limited by its radius of action. This is defined by the number and strength of channels found in the components of the IS, and the ability of the organization to select and coordinate its relationships. The relationships bring a social aspect to the system, since actions and characteristics of an organization become visible to others and thus affect the behavior of these other organizations. At the end, the entire system is more than the sum of its single components, because of bridging links that include both market and non-market relationships. Each single relation as well as the activities of a single organization contributes to the dynamic of the system, which would otherwise be static (Carlsson, Jacobsson, et al., 2002). Interactions between organizations, labor mobility, and informal networks are prerequisites for a knowledge-based economy and the collective innovation process, in which networks are an irreplaceable stimulant for technological progress. Through its direct and indirect relationships, the network enables the exchange of information. Knowledge, thus, can diffuse through the channels of the network, stimulating knowledge accumulation of other organizations and, by this, the creation of new knowledge and innovations. Relations between organizations and institutions are a vital source for the emergence of new institutions and vice versa. Organizations are not restricted by their institutional environment, as they often play an active role as incubators for new ones (Edquist and Johnson, 1997). This entails adjustments to the institutional environment, such as new standards for technical norms or policy rules from the government. Several interactions among institutions compete or complement each other. One example is illustrated by informal cartels competing with formal antitrust laws and scientific publications, which is a complement to patent publication.

Boundaries of the innovation system

The main levels of the IS approach are regional, national, transnational, and sectoral. As it would be possible to identify more (for example an international IS), the boundaries of the IS have to be addressed (McKelvey, 2002; Graf, 2006). Even for a national IS where the geographical boundary is easy to identify, the globalization trend, transnational convergence policies, and numerous dominating multinational enterprises raise the question of which distinctive boundaries to analyze. Similar problems arise in the context of sectoral innovation systems. Even if the sector is relatively clear, there are different industry classifications that shape different boundaries of the system (Graf, 2006). If a new industry emerges from preexisting branches the situation increases in complexity, as classification schemes are useless to describe the new sector due to a lack of detail. In the case of a regional IS, defining the boundaries of the system fails again as the conceptualization of a region itself remains unclear (cities, public regional authorities, labor markets). Edquist (2004) clarifies that there is no certain limit for the boundaries of an IS from which interactions with the outer environment come to an end. Thus, the appropriate choice of boundaries depend on the circumstances of the respective analysis (Graf, 2006). Nonetheless, the national IS approach constitutes a meaningful and practical instrument to analyze the efficiency of a country's innovation policy (McKelvey, 2002), since most of the regulations are carried out by institutions within the national context.

Activities of the innovation system

Edquist (2011) summarized several key activities of an IS (see Table II.1). In his understanding, activities are the determinants of the overall system that shape an environment for the countless innovation processes by supporting the development and diffusion of innovations. The overview of the activities heavily relates to Edquist's broad understanding of an IS, which includes "all important economic, social, political, organiza-

(i) Provision of knowledge inputs to the innovation process
(1) Provision of R&D results and, thus, creation of new knowledge, primarily in engineering, medicine and natural sciences.
(2) Competence building, for example, through individual learning (educating and training the labor force for innovation and R&D activities) and organizational learning. This includes formal learning as well as informal learning.
(ii) Demand-side activities
(3) Formation of new product markets.
(4) Articulation of new product quality requirements emanating from the demand side.
(iii) Provision of constituents for ISs
(5) Creating and changing organizations needed for developing new fields of innovation. Examples include enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms; and creating new research organizations, policy organizations, etc.
(6) Networking through markets and other mechanisms, including interactive learning among different organizations (potentially) involved in the innovation processes. This implies integrating new knowledge elements developed in different spheres of the IS and coming from outside with elements already available in the innovating firms.
(7) Creating and changing institutions-for example, patent laws, tax laws, environment and safety regulations, R&D investment routines, cultural norms, etc. – that influence innovating organizations and innovation processes by providing incentives for and removing obstacles to innovation.
(iv) Support services for innovating firms
(8) Incubation activities such as providing access to facilities and administrative support for innovating efforts.
(9) Financing of innovation processes and other activities that may facilitate commercialization of knowledge and its adoption.
(10) Provision of consultancy services relevant for innovation processes, for example, technology transfer, commercial information, and legal advice.

Adapted from Edquist (2011).

Table II.1.: Key activities in systems of innovation tional, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist, 1997). Edquist emphasized the relevance of an appropriate innovation policy, since virtually every activity requires a certain public engagement, such as governmental incentives or legislative acts.

A classical public engagement is the provision of knowledge inputs to stimulate innovation processes (see Table II.1, i). These inputs are usually offered through the provision of basic and experimental research conducted in public universities and research institutes financed in part by the government. In addition to this, the educational system is also critical for individual and social competence accumulation. A well-trained labor force is a basic prerequisite for high-tech industries and economic success in the long-run. On the demand side, the government could support the emergence of new markets by setting, for example, environmental standards or product quality requirements (see Table II.1, ii).

The government could also support the setting-up of new constituents for a system of innovation (see Table II.1, iii). To diversify organizations, the government could create or enhance the foundation of new firms, political organizations, interest groups, and the like. Moreover, a central element of the IS is organizational learning, which requires cooperation among a number of different actors. Firms incubating innovation require access to public science services, such as universities and research facilities, to acquire new knowledge of the public sector that was gained from basic as well as experimental research activities. Therefore, policy makers should avoid concentrating on a single organization and instead concentrate on the relationships among them. Even when product and process innovations are largely carried out by private firms, Edquist (2011) stressed that in long-term the success of a company depends on the intensity of cooperation with other actors rather than private firms alone.

Another important activity of the government is to provide services for innovative organizations (see Table II.1, iv). Financial incentives, for example, could encourage organizations to innovate. By providing financial support, such as subsidies, tax credits, tax rebates, or interest-free credits, the public sector could facilitate the utilization of innovation. In the case of an inadequately developed finance sector, inventions could be derailed at an early stage of the innovation process due to the limit of the organization's creditworthiness. Finally, the government could also provide consultancy services for business start-ups or SMEs, which are unfamiliar with administrative as well as innovation processes, by providing legal advice, innovation audits with experts, and access to information generally.

Policy implications of the innovation system

In a mature innovation system most of the activities are well-coordinated via the market mechanism. However, under certain circumstances, the government plays a significant role in canalizing market pressure in an orderly manner (Carlsson, 1992), for example, in periods of rapid technological progress with several transitions. This is generally institutionalized in a government's innovation policy. In order to obtain a well-defined innovation policy, the problems of the actual system have to be identified. Edquist (2011) stated that all the activities an IS are carried out by both private and public organizations, thus public innovation policies partly come into contact with each activity that triggers the innovation process.

Generally speaking, governmental intervention becomes legitimized with the intention to solve distortions to the market economy caused by imperfections. For example, in the case of a suboptimal provision of private R&D investments (Arrow, 1962), intervention could be the provision of public R&D expenditures until the economy's overall R&D activities reach the socially desired level. Another pitfall would be strong or weak network failures, evolving from too few or excessive linkages between the organizations an IS (Carlsson and Jacobsson, 1997). Other risks potentially might arise because of infrastructural failures or even more important institutional failures, which can reduce economic activity and interaction, and thus hinder innovation (Woolthuis et al., 2005). However, since government interference into a market brings the potential risk of state failure (Krueger, 1990), even worse systematic malfunctions can arise if the intervention introduces further unintended distortions. To avoid this, a government has two standard conditions that must be achieved before an intervention into a market economy is legitimized (Edquist, 2001):

1. Private organizations were unable to achieve the objectives that were desired by the public. Otherwise, there would be no reason for the government to intervene. The innovation policy should neither duplicate nor replace well-functioning mechanisms of the free market. There must be a market imperfection that cannot be solved by the self-healing power of market forces.

2. The government must be able to eliminate or alleviate the systematic problem. Otherwise there shall be no action, as the outcome would be an additional distortion to the market.

Therefore, neither the first nor the second condition alone is sufficient for governmental intervention, but the combination of both legitimizes government action on the respective policy level, be it transnational, national, sectoral, regional, or local.

The formulation of political agendas is usually couched in weak statements (Edquist, 2011), such as stimulating economic growth, ensuring sustained development, or the protection of the natural environment. In regards to the IS, the formulation of defined objectives is also a difficult task, since the problems of IS, are simply too diverse to completely anticipate. There is an abundant literature concerning the various system imperfections (Carlsson and Jacobsson, 1997; Edquist, Hommen, et al., 1998; Smith, 2000; Woolthuis et al., 2005; Graf, 2006; Johnson and Gregersen, 2007). Woolthuis et al. (2005) provided a categorization which enables one to differentiate four main problems that could potentially affect the functionality of an IS.

Infrastructure failures might arise since organizations within an IS require reliable infrastructure for both their everyday business and a long-term perspective for their investment decisions (Woolthuis et al., 2005). This includes, most importantly, a high-performance transportation infrastructure (information, goods, and energy) as well as a developed educational infrastructure (Woolthuis et al., 2005; Edquist, Hommen, et al., 1998; Smith, 2000).

Institutional failures can be distinguished into hard and soft (Woolthuis et al., 2005). Hard institutional failures relate to formal or written institutions, such as laws, ethical guidelines, technical standards, public funding, and legal contracts. Institutional failures might crystallize if a government tries to regulate every detail or prohibits excessively. Thus, a strict public-policy regime might hinder interactions between actors and thereby the diffusion of knowledge. Even worse the mechanism that works towards the creation of new institutions and could also lead to the emergence of more efficient ones would be dismissing or ignoring. Soft institutional failures affecting the broader environment of the political and social culture. They shape the way in which daily business is done (Smith, 2000). Moreover, they affect society's collective willingness to share resources, spirit to seek new business opportunities, ability to trust in their own strengths, and so on (Woolthuis et al., 2005).

Interaction failures may occur if organizations of the IS are hindered in their communication. Therefore, it should be questioned whether bridging relationships are present or too strong for an efficient flow of knowledge between organizations (Graf, 2006; Woolthuis et al., 2005). Depending on the strength of the interaction it is possible to distinguish between weak and strong network failures. Although strong networks can be productive, they have various inherent risks. Organizations might be forced into less efficient technological paths due to existing social pressure within their peer-group (Carlsson and Jacobsson, 1997). Problems also arise if weak ties are missing (Granovetter, 1973), since they provide access to subgroups within the network with more diverse skills and knowledge, fleshing out a knowledge pool that was previously inadequate. Moreover, the dependency on an important actor could cause an organization to be inextricably linked to specific singular technologies due to prior investments, switching cost, or the unavailability of alternative partners (Woolthuis et al., 2005). In cases of inadequate connectivity within the network, actors are unable to get in contact with each other. This potentially causes a weak network failure, when knowledge is not transmitted because of missing links. In this case, the possibility of interactive learning and innovating are reduced. The problem of reciprocity could emerge when potential partners fear hazards from bilateral or multilateral cooperations, due to opportunistic behavior (Graf, 2006). The exchange of information, in particular tacit knowledge, is disrupted as mutual trust and credibility are basic prerequisites for a smooth transfer of knowledge inside the IS network. Too much reciprocity can lead to path dependence and technological lock-in, as this reduces the diversity of knowledge and thus reduces the promotion of new innovations.

Capability failures might arise when organizations are able to contact each other but lack sufficient communication (Woolthuis et al., 2005). For some businesses, the research branches only play a tangential role, whether in the form of basic, experimental, or applied research. Thus, in these sectors investments in R&D are scarce and the businesses may prefer to purchase technology from other branches (Graf, 2006). Organizations are unable to "leap from an old to a new technology or paradigm" (Woolthuis et al., 2005). Businesses subsequently lose their self-renewal potential and cannot implement new technologies by themselves, since R&D activities are a basic requirement for the assimilation of external knowledge. When it comes to radical innovation or to a phase of rapid transitions, the organizations inside the same IS begin to diverge in different technological directions. If cognitive gaps arise, knowledge exchanges become problematic, and companies within the IS are no longer able to compete against other companies. If the problem is confirmed, politicians should utilize their problem-solving abilities and identify a comprehensive strategy.

Weaknesses of the innovation system

One major weakness of the IS was highlighted by Edquist (2004), who emphasized that the IS is not a formal theory as it does not supply clear causal links between the determinants and the performance of the system. The approach does provide presumptions for empirical investigations, but due to the scarcity of these empirical studies the IS approach should be treated as a conceptual framework rather than a formal theory.

2. Policies promoting research joint ventures

In retrospect, dependencies can be identified worldwide between the theoretical view on innovation and the implementation of governmental innovation policies. Interestingly, the direction of influence is two-sided. Economic theory affects policy practices and policy practices influence the development of economic theory, even if sometimes with long delays. Historically, it was Arrow (1962) who provided groundbreaking contributions to the economic literature that explained the necessity of supporting private R&D efforts with public subsidies. This was because of the intrinsic uncertainty of innovation activities that leads to a non-optimal allocation of resources, as the output of the undertaking is unpredictable. However, economists' awareness of the critical importance of collaborative research activities heightened following Japan's phenomenal economic success by stimulating cooperative research joint ventures rather than economic theory alone.

This implies that innovation policies in different countries vary substantially, particularly in view of the government's degree of engagement, since policy implementation depends significantly on a country's history, cultural background, stage of industrial development, capabilities, and needs (Caloghirou et al., 2002).

As already mentioned, Japan has been a forerunner in subsidizing cooperative research activities in the period after the Second World War in order to catch up with the development of Western countries. Japanese firms performed so well that at the beginning of the 1980s, the national champions of the Western countries were falling behind their Japan competitors. This spurred a strong discussion about Japan's fundamental success factors (Freeman, 1987).

The United States and the United Kingdom were the first adopters of Japan's strategy (Caloghirou et al., 2002). Interestingly, it was therefore demanded that the American legislation renew its antitrust regulation, which was restricting cooperation among firms to case-by-case allowances from the government. The United Kingdom was the first European country, implement a funding program in 1983 by supporting collaborative research projects in information technologies. Their early experiences within this field motivated them to later participate in the European Framework Programme for Research and Technological Development (FP).

In Germany, cooperative project grants became popular during the 1980s. The predominant idea that the results of basic and experimental research become automatically transferred into marketable products was replaced by a policy that supports knowledge transfer among enterprises, universities, and research centers (Fier and Harhoff, 2002; Czarnitzki and Fier, 2003). The implementation of the new policy was rather smooth. Prior to this revolutionary approach, a major proportion of the government's R&D spending was focused on contributions to single organizations. However, in terms of the financial budget it takes more than 20 years for cooperative R&D projects to reach the level of individual projects (see Figure II.2).

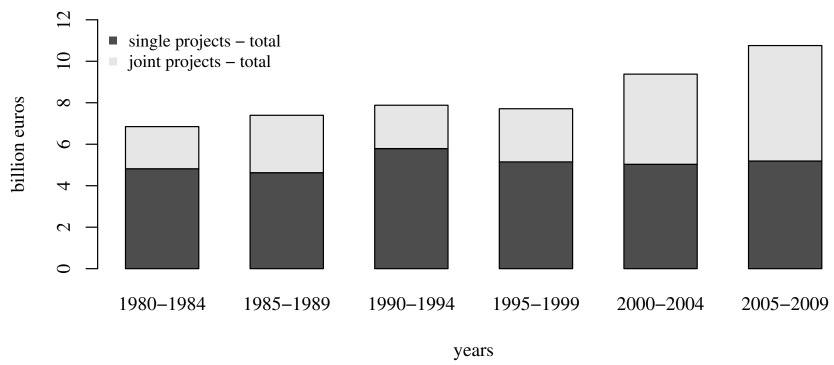


Figure II.2.: Governmental spending for R&D projects in Germany

Source: Förderkatalog of the German federal government

The first cooperation between organizations within the EU dates back to the foundation of the European Nuclear Community (EURATOM) in 1957. As the name suggests, the program was initiated to bring forward competitiveness in the field of energy provisioning as Europe feared falling into a technological dependence on the U.S. However, the absolute impact (800 million euros) of the treaty was rather low in comparison to the FP launched in 1984 (3,300 million euros) (Guzzetti, 1995; Caloghirou et al., 2002). From its beginning, the FP promoted transnational joint projects for precompetitive research activities among the member states of the EU.

Subsequent parts of this research project will analyze several aspects of the German (see Chapters IV and V) and the European (see Chapters III) innovation policies in detail, thus the following sections will provide a more detailed overview concerning their historical development and address open research questions for the policies.

2.1. German Policy

Historical background

In 1955, Germany founded the Federal Ministry for Nuclear Affairs and made its first step towards a renewal of its innovation policy by becoming a founder member of the EURATOM community (Fier and Harhoff, 2002). During the initiation phase, the priority rested clearly upon the support of nuclear projects. However, Germany's focus widened to other large-scale projects in the 1960s. During that time, most public spending was allocated to universities and self-governed of academic entities, such as the Fraunhofer Society or the Max Planck Society. Even today, this form of institutional contribution ("institutionelle Förderung") provides a financial budget to the receiver of the promotion (BMBF, 2014), which leaves a substantial degree of freedom concerning the spending of the money.

Research projects sponsored by the public, which are restricted to specific technological activities, are called direct project contributions ("direkte Projektförderung") (BMBF, 2014). These projects are usually bundled into a specific, predefined technological field. The first program in 1967 contributed to projects in the field of data processing, which was followed by a program for marine research (1969) and later on by a wide list of other supported key technologies (Fier and Harhoff, 2002; Aschhoff, 2009). Another important characteristic is that an organization had to apply for a single project ("Einzelprojekt"). During the 1970s this became a particular problem for SMEs, as the government requested a demonstration of the project's additional social benefit and available capacities inside the firms from the grant recipients. This overcharged the capabilities of almost all SMEs. The decision to grant project promotions was carried out by a committee that decides whether to support or reject the submitted proposal. The time horizon for these projects is short- and medium-term oriented, with an average duration of approximately three years (Umlauf, 2014).

Research joint ventures on the move

Considering the theoretical discussion around innovation processes and innovation systems as well as the first international experiences concerning governmental incentives for collaborative research joint ventures, Germany started rethinking its actual policy instruments in the early 1980s (Czarnitzki and Fier, 2003). The approach that innovative performance depends on research alliances among large companies, SMEs, research laboratories, and universities was implemented quickly. Thus, Germany was one of the first

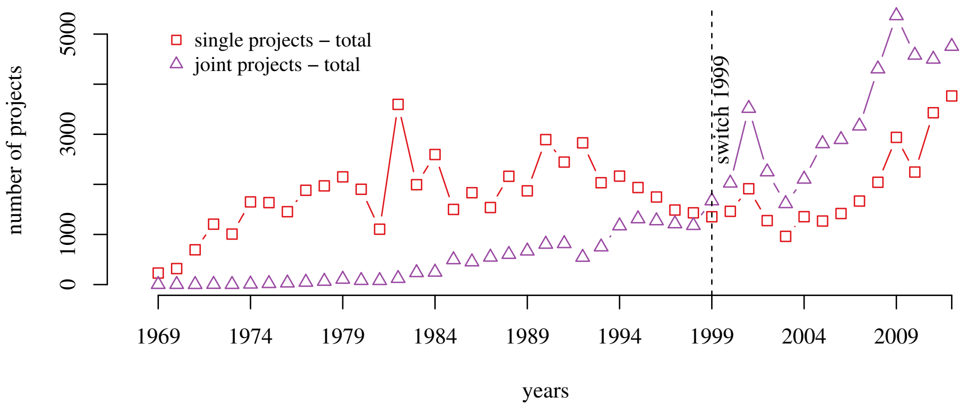


Figure II.3.: Number of governmental sponsored R&D projects in Germany

Source: Förderkatalog of the German federal government

countries in Europe to introduce cooperative funding instruments. The new objective of the Federal government became supporting the diffusion of knowledge and innovations, rather than trying to determine or plan the technological progress in detail (Fier and Harhoff, 2002).

The implementation of the new policy went smoothly, as it was only necessary to readjust the previously dominant instrument of direct project contributions. For that purpose, the new contribution form of joint projects ("Verbundprojekte") was added to the preexisting funding instruments. Organizations still needed to apply for a project grant, restricted to a specific task and a certain period of time, but it became necessary to apply for a joint project in the form of a self-organized consortium consisting of several independent organizations (Welsch, 2005). Apart from the argument that collaborative research activities trigger the exchange of knowledge, cost and resource sharing rationales also contributed to the implementation of this policy.

At the end of the last century, the discussion concerning regional ISs attained great attention. Thus, Germany was affected by a trend that aims to regionalize innovation policies in order to foster competition among regions as well as the promotion of regional clusters (Dohse, 2000). Therefore, not only did the interconnection of organizations play a role, but also the motivation to strengthen the inner and outer connectivity of whole regions (Fier and Harhoff, 2002), as it has become evident that agglomeration effects play a major role in the R&D activities of private firms.

Since their initiation, joint projects have become a key instrument of Germany's direct project contributions (see Figure II.3.). The remarkable breakthrough happened in 1999 when for the first time the number of joint projects exceeded the number of single projects. This marks a system switch that is still in place today. Since the late 1960s more than 152,000 projects were sponsored by the federal government, whereas now 60,000 projects – more than one-third – have been carried out as research joint ventures. This of course entails the formation of a network linking thousands of actors from different organizational backgrounds. Broekel and Graf (2012) found evidence that even sub-networks for industry sectors exist with remarkable differences regarding their network structure. For example, they may have relatively weak connections in geoscience, but heavily intertwined actors in information and communication technologies (ICT) as well as in biotechnologies.

2.2. European Policy

After an intensive discussion the European Commission started the European Strategic Program on Research in Information Technology (ESPRIT) in 1982 as a one-year pilot program. This served in many ways as a blueprint for the later European FP (Guzzetti, 1995; Caloghirou et al., 2002). The promotion of precompetitive research joint ventures between twelve major European firms in the electronic sector was a particular feature of this program. Over 50 percent of the project's financial costs were covered by a contribution. The research activities fell between fundamental and applied industrial research in order to maintain a distance from the market and prevent unintended distortions (Roediger-Schluga and Barber, 2006). This was done to secure compliance with European competition laws. The pilot phase was followed by four additional ESPRIT programs running between 1984 and 1998. Research within the program was carried out by firms, research institutes, and universities. It was required that at least two organizations come from different EU member states to secure the transnationality of the program. At the end of the project, all members were allowed to make use of the research results. Because of the remarkable success of this program, which attracted proposal submissions from numerous consortia, additional programs were initiated for several other technological fields, such as telecommunications, biotechnology, and medicine.

The First Framework Programme (FP1) was launched in 1984. It united most of the preexisting and proposed programs under a common umbrella, and was based on the experiences of the ESPRIT forerunner program. The program rejected the linearity of the innovation process and emphasized the complexity and interdependency of the same, since the Work Programme of the FP was structured as a multi-dimensional matrix providing certain overlaps in frequent technological fields (Roediger-Schluga and Barber, 2006; Guzzetti, 1995). The FP institutionalized the idea " that the importance of the system did not lie in the sum of the individual programs, but rather in their interaction as they worked together towards the aims of Community policy" (Guzzetti, 1995). The main motivation for the program was to start a convergence process to reduce the fragmentation of national industries, innovation policies, and markets throughout the EU. In addition, it was the purpose of the program, to overcome the technology gap between Europe and Japan by exploiting Europe's potential transnational-advantages (Breschi and Cusmano, 2004), in order to maintain international competitiveness. Overall, the innovation system approach had a significant impact on the formulation of the EU innovation policy, as subsequent FPs concentrated upon the training of professionals, the inclusion of SMEs, the integration of costumers, and the diffusion of new technologies in accordance with economic theory (Roediger-Schluga and Barber, 2006). Like the ESPRIT program, applicants needed to include organizations from at least two different EU member states, and 50 percent of the overall project's cost is eligible for financing by the EU Commission.

Towards a revision of the EU policy

A remarkable shift occurred with the launch of the sixth FP (2002–2006), which was highly affected by the development plan of the Lisbon Strategy (EU, 2000). Dissatisfied with the convergence process regard to the persistent fragmentation of national innovation policies, the EU Commission formulated a new ERA (European Research Area) strategy in 2000 with the adoption of the Communication "Towards a European Research Area." The Commission clearly called for intensive efforts to create a pan-European research network, as even after twenty years Europe was still falling behind its target of catching up with the U.S. and Japan. The FP was selected as the main instrument to achieve that goal (Hoekman et al., 2013). Therefore, the financial budget of the next FP was disproportionately enlarged and new network-related instruments, such as the networks of excellence and integrated projects, were installed. The objective was to bring forward the European Research Area (ERA), which promoted the idea of the EU as a continent-wide transnational innovation system. It focused upon the deduplication of national or regional policy redundancies, as well as a better coordination of R&D activities to achieve the critical mass of resources necessary to close the technological gap.

Framework Programme	Period	Projects	Budget (billion euro)
FP1	1984 - 1987	3,283	3.3
FP2	1987 - 1991	3,885	4.4
FP3	1991 - 1994	5,529	6.6
FP4	1994 - 1998	15,061	13.1
FP5	1998 - 2002	15,559	15.0
FP6	2002 - 2007	73,399	17.5
FP7	2007 - 2013	130,390	50.5
FP8	2013 - 2020	/	70.2

Until FP6 adapted from Roediger-Schluga and Barber (2006). EURATOM projects are excluded from the table.

Table II.2.: Overview about European Framework Programmes

Since the initial launch, seven consecutive programs have followed (see Table II.2). Each program exceeds its predecessor in terms of both the number of participants as well as its financial budget. With approximately 1 billion euros per year, the budget of the first FP was rather low in comparison to the eighth FP, which started in 2014 with an indicative budget of 13 billion euros per year until 2020. Over time, the number of organizations participating grew from 1,981 (Roediger-Schluga and Barber, 2006) to approximately 31,345 organizations in the seventh FP.

The thousands of projects funded by the Commission since the early 1980s led to the formation of a pan-European research network. The most complete analysis regarding the network formation through the consecutive programs was from Roediger-Schluga and Barber (2006). They found that among the FPs, which were running between 1984 and 2002, each network became more clustered and less fragmented over time. Moreover, the number of average cooperations per organization rose from 7.4 (FP1) to 28.1 (FP5). However, the most important observation was that a remarkable number of the organizations participated across subsequent FPs. During the second FP, more than 60 percent of the participants were organizations that had already taken part in the first FP (Roediger-Schluga and Barber, 2006). This is even more surprising when taken into account that the number of organizations was steadily growing during that time. It was not until the fifth FP that the proportion of recurring organizations diminished continuously to approximately 30 percent. To a great extent the overlap was shaped by larger firms, universities, and greater research centers. Thus, a large proportion of the network formation transits between consecutive FPs, which may constitute the backbone for the creation of the ERA as a pan-European research network (Roediger-Schluga and

Barber, 2006).

2.3. Open research questions

As discussed above, networks are important stimulants for innovation processes; thus, network policies have become a key asset for governments to intervene in the activities of an IS. All industrialized countries have undertaken certain activities to enforce collaborative research activities among the organizations in their respective ISs. However, the theoretical discussion has also revealed that public action originally intended to solve marked failures might induce worse malfunctions in an IS, because of the potential inability of the government to improve the situation. Identifying those failures is a difficult task, particularly for network politics since standard techniques are still not established. Several authors have paved the way toward a better understanding concerning the dynamics of organizational networks (Ter Wal, 2009; Broekel and Hartog, 2013; Balland, 2012; Hazir and Autant-Bernard, 2012). All of them have uniformly emphasized that the structure of the network depends highly on the choice of the organizations with whom they are partnered with (Ter Wal, 2009; Broekel and Hartog, 2013; Balland, 2012; Hazir and Autant-Bernard, 2012), which is affected, for example, by different forms of proximities (geographic, cognitive, institutional, and social) and the characteristics of the respective organizations.

However, focusing unilaterally on the actions of organizations might be misleading since this neglects the role of the governmental decision-making process regarding the allocation of project grants, which ultimately affects the formation of the network structure. Previous sections have shown that various industrialized countries have developed innovation policies that promote cooperative research joint ventures with an enormous financial budget. Thus, the allocation mechanism of collaborative subsidies entails a great potential to impact the overall configuration of the network and, therefore, the efficiency of the entire IS. Several studies have revealed that organizations' previous experiences are critical acquiring project grants from the government (Brockhoff et al., 1991; Barajas and Huergo, 2010; Paier and Scherngell, 2011; Aschhoff, 2009); however, this is misleading since their approach does not consider the difference between having experience with the formal application procedure and having previous cooperative experiences.

Research questions of Chapter III

The emergence of a large oligarchic core within the pan-European research network was one of the first observations made regarding the Commission's new ERA policy. Breschi and Cusmano (2004) identified for the third FP (1992–1994) and fourth FP (1992–1996) an intensely clustered area within the network, illustrating that a large fraction of projects were allocated to a relatively small number of organizations. Their findings particularly pointed to the role of "prime contractors" that have undertaken the coordinator function at least once within a funded project. Their assumption stems from the observation that nearly 80 percent of all organizations have only participated once in projects, whereas 60 percent of all prime contractors participated in at least two projects and 15 percent of those in more than ten projects (Breschi and Cusmano, 2004). Moreover, they emphasized the ambivalent role of such a network structure. On the one hand, the quantity and quality of transmission capacity and knowledge production is carried out in an effective manner in such a network formation, since it secures the small-word properties of the research network (Watts and Strogatz, 1998). But on the other hand, this network formation implies a certain vulnerability of the network, since the elimination of several organizations would cause a collapse of the network architecture and would induce a significant reduction to the communication capacity, including the potential to face path dependencies, technological lock-ins, institutional constraints, and consolidation of technological paradigms (Breschi and Cusmano, 2004). If the European innovation policy does not hold a sensible balance between network openness and closeness, strong or weak network failures might arise and cause a systematic malfunction of the IS (Woolthuis et al., 2005). To avoid such disturbances, the evolution becomes quite urged to explore, which patterns of the actual innovation policy support the emergence of the observed core-periphery network structure.

A research gap exist, since the investigation of Breschi and Cusmano (2004) neglects the role of organizations that transit between subsequent FPs, as shown by Roediger-Schluga and Barber (2006). The formation of an oligopolistic network structure is perhaps not only affected by prime contractors, but also from organizations that participate across programs. It is unrealistic that after several years in service the evolved network formation and multilateral relationships of a former FP should have no influence upon its successor when the actual FP comes to an end. For example, projects that started in the final year of the preceding FP, will continue service even if the next program has already started. It is possible that these initial starting advantages for various organizations accumulate over time toward the dense network structures observed by Breschi and Cusmano (2004). In this vein, to be a prime contractor is more than the outcome of a selection process affected by organizational experiences. Rather, it is a logical choice to select the most experienced organization to be the coordinator of a project.

Additionally, Hazir and Autant-Bernard (2012) analyzed the founding process of a consortium before an initial application for a project grant. In their empirical investigation the authors highlighted the importance of other project experiences in the decision of an organization to participate within a consortium. They found that organizations take into account the potential partners' access to further knowledge sources. Moreover, they observed that organizations differ according to their institutional backgrounds (firms, research centers, universities) and their geographical location with regard to their interest in participating within a consortium. However, their empirical findings are not convincing enough to explain the observed core–periphery structure. Their findings had a rather limited impact to the organization's overall decision, and they found no evidence for their hypothesis that organizations tend to preserve their cooperation partners across various applications.

As the Commission of the EU has the final say when it comes to the award of a project grant, it needs to be determined if the allocation process of the project grant contributes to the development of oligopolistic network structures. Therefore, Barajas and Huergo (2010) have analyzed a two-stage process. In the first stage, the organizations have to be aware of the funding possibility and have to join a consortium. At the second stage, the proposals of the consortia were rejected or approved by a group of experts delegated by the EU Commission. Barajas and Huergo (2010) found several significant determinants affecting the chances of an organization receiving a project grant and aimed to identify whether or not cooperative experiences have an impact. However, their understanding of experiences is misleading since they did not distinguish between having experience with the application procedure and having experience with cooperations.

Since the observation of an oligarchic core was made by Breschi and Cusmano (2004) in front of the proclamation of the ERA, which aimed to strengthen the formation of a dense network structure, a potential misunderstanding of the allocation process could cause drastic policy failures. The whole process needed to be evaluated, since the connectivity of the organizations did not seem to be the real problem of the actual policy. Extreme clustering is not better than fragmentation, as it can induce path dependence and technological lock-ins (Cowan and Jonard, 2004).

To investigate whether the EU's allocation mechanism for project grants affects the formation of an oligopolistic network structure, which divides the network into a highly clustered area and a weakly connected outer sphere around the cores. Chapter III makes use of a unique database that includes accepted as well as rejected project proposals of the seventh European FP. To approximate the allocation process, the prioritization of project grants is used to estimate a classical linear regression model, which explains how the formation process of the network is shaped by network-related and other exogenous factors.

Research questions of Chapter IV

For the case of Germany, Aschhoff (2009) has analyzed the allocation process of project grants. She found empirical evidence that the decision-making process of the government is highly affected by the characteristics of the respective firms. For her analysis she distinguished two different scenarios, namely the chance of an organization to obtain a project grant for the first time, and the possibility that the firm is rewarded with an additional project contribution to the preexisting award. Here results were highly significant. To a large extent, prior experiences do indeed affect the chances of an organization to receive a project grant. But other factors also played a role, such as alternative funding sources from regional and European entities the number of employees, the qualification of the employees, the location of a firm, or its amount of R&D expenditures.

A research gap exists in this context, since Aschhoff (2009) neglected the possible impact of network effects on the allocation process. She did not consider that to a large extent, awards are restricted to cooperative research projects. Organizations with previous experience in cooperative projects will have an advantage compared to organizations without, even if those organizations have participated in non-cooperative research projects. Therefore, it is questionable whether the formation of an R&D network by publicly sponsored R&D projects has an influence on the allocation process of further research projects. If so, this pattern could open the door for a self-enforcing mechanism with the potential to deliver unintended distortions to the allocation process, due to the installation of an unobserved selection process both in before and during the project allocation phase.

This question will be addressed in Chapter IV of this study by providing an analysis of the German funding system. Therefore, the Chapter employs a rich data set of government-subsidized project grants in Germany, and a statistical model using Markov chains to explore whether the dynamic of the funding regime is affected by the policy induced research network.

Research questions of Chapter V

Moreover, questions also arise surrounding the benefit of those cooperative research projects. Since government budgets are tight, policy instruments must be used in an efficient and effective manner to ensure that the innovation policy achieves its own objectives (Commission of Experts for Research and Innovation, 2013). For several years, the Commission of Experts established by the German government has called for systematic approaches to evaluate the impact of Germany's current funding scheme. Regarding the effect of R&D collaborations, Czarnitzki (2004) found evidence that the enterprises who received a cooperative R&D project grant have a higher patent activity than companies who obtained a non-cooperative project grant. Similar results were obtained by Fornahl et al. (2011) for the biotechnology sector in Germany.

However, it remains unclear whether cooperative project grants spur cooperative innovations, as all studies have controlled for single firms and not for a consortium of organizations. It is possible that enterprises follow a free rider strategy during their research joint ventures with universities, research centers, or other firms and focus on capturing as much knowledge as available. At the end of the project, the acquired knowledge is free for every one participating in the project to use. This could persuade firms to wait until the end of the project to innovate on their own. To test for this hazard, one would have to check whether the successful innovation is implemented by the same organization that participated in the research joint venture. It is worth questioning whether the observation of Czarnitzki (2004) is the outcome of a rent-seeking process. Many researchers found evidence (David et al., 2000; Wallsten, 2000; Lach, 2002) that firms, particularly larger companies, frequently try to reduce their R&D investment cost with public funds and since most of the sponsored projects are joint projects, this kind of strategy may have lent a distortion to Czarnitzki's results. It is appropriate to check whether cooperative R&D entails cooperative innovations or vice versa.

To disentangle the effects between R&D and innovation networks, Chapter V will make use of a stochastic actor-oriented model (SAOM) that is able to explain the interactions between two co-evolving networks. For the purpose of the investigation, the innovation network is approximated by a patent network based on data that are extracted from the European Patent Office (EPO) Patstat database. The research network that represents the governmental impact to the IS is constructed from a subsidized collaborative project of the German federal government.

Bibliography

Arrow, K. (1962). 'The Rate and Direction of Inventive Activity: Economic and Social Factors'. In: *The rate and direction of inventive activity: Economic and social factors*. Ed. by R. Nelson. Princeton University Press. Chap. Economic Welfare and the Allocation of Resources for Invention, pp. 609–626.

Aschhoff, B. (2009). 'Who gets the money? - The dynamics of R&D project subsidies in Germany'. In: *ZEW - Centre for European Economic Research Discussion Paper* 08–018.

Balland, P.-A. (2012). 'Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry'. In: *Regional Studies* 46.6, pp. 741–756.

Barajas, A. and E. Huergo (2010). 'International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms'. In: *Economics of Innovation and New Technology* 19, pp. 87–111.

Boschma, R. (2005). 'Proximity and Innovation: A Critical Assessment'. In: *Regional Studies* 39.1, pp. 61–74.

Braczyk, H.-J., P. N. Cooke, and M. Heidenreich, eds. (1998). *Regional Innovation Systems: The Role of Governances in a Globalized World*. London and Pennsylvania: UCL Press.

Breschi, S. and L. Cusmano (2004). 'Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes'. In: *International Journal of Technology Management* 27, pp. 747–772.

Breschi, S. and Franco (1997). 'Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries'. In: ed. by C. Edquist. Pi. Chap. Systems of Innovation Approaches - Their Emergence and Chracteristics, pp. 1–29.

Brockhoff, K., A. K. Gupta, and C. Rotering (1991). 'Inter-firm R&D co-operations in Germany'. In: *Technovation* 11.4, pp. 219–229.

Broekel, T. and H. Graf (2012). 'Public research intensity and the structure of German R&D networks: a comparison of 10 technologies'. In: *Economics of Innovation and New Technology* 21.4, pp. 345–372.

Broekel, T. and M. Hartog (2013). 'Explaining the Structure of Inter-Organizational Networks using Exponential Random Graph Models'. In: *Industry & Innovation* 20.3, pp. 277–295.

Brusoni, S., A. Prencipe, and K. Pavitt (2001). 'Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make?' In: *Administrative Science Quarterly* 46.4, pp. 597–621.

Caloghirou, Y., N. S. Vonortas, and S. Ioannides (2002). 'Science and technology policies towards research joint ventures'. In: *Science and Public Policy* 29.2, pp. 82–94.

Carlsson, B., ed. (1995). *Technological System and Economic Performance: The Case of Factory Automation.* Kluwer Academic Publishers.

Carlsson, B. (1992). 'Industrial dynamics : a framework for analysis of industrial transformation'. In: *Revue d'économie industrielle* 61.1, pp. 7–32.

Carlsson, B. and S. Jacobsson (1997). 'In Search of Useful Public Policies — Key Lessons and Issues for Policy Makers'. In: *Technological Systems and Industrial Dynamics.* Ed. by B. Carlsson. Vol. 10. Economics of Science, Technology and Innovation. Springer, pp. 299–315.

Carlsson, B., S. Jacobsson, M. Holmén, and A. Rickne (2002). 'Innovation systems: analytical and methodological issues'. In: *Research Policy* 31.2, pp. 233–245.

Coe, N. M. and T. G. Bunnell (2003). ''Spatializing' knowledge communities: towards a conceptualization of transnational innovation networks'. In: *Global Networks* 3.4, pp. 437–456.

Cohen, W. M. and D. A. Levinthal (1990). 'Absorptive Capacity: A New Perspective on Learning and Innovation'. In: *Administrative Science Quarterly* 35.1, pp. 128–152.

Commission of Experts for Research and Innovation (2013). *Report 2013: Research, Innovation and Technological Performance in Germany.* Berlin: Commission of Experts for Research and Innovation (EFI).

Cooke, P., M. G. Uranga, and G. Etxebarria (1997). 'Regional innovation systems: Institutional and organisational dimensions'. In: *Research Policy* 26.4–5, pp. 475–491.

Cowan, R. and N. Jonard (2004). 'Network structure and the diffusion of knowledge'. In: *Journal of Economic Dynamics and Control* 28.8, pp. 1557–1575.

Czarnitzki, D., B. Ebersberger, and A. Fier (2004). *The Relationship between R&D Collaboration, Subsidies and Patenting Activity: Empirical Evidence from Finland and*

Germany. Tech. rep. ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research.

Czarnitzki, D. and A. Fier (2003). *Publicly Funded R&D Collaborations and Patent Outcome in Germany.* ZEW - Centre for European Economic Research Discussion Paper. ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research.

David, P. A., B. H. Hall, and A. A. Toole (2000). 'Is public R&D a complement or substitute for private R&D? A review of the econometric evidence'. In: *Research Policy* 29, pp. 497–529.

Dohse, D. (2000). *Regionen als Innovationsmotoren: zur Neuorientierung in der deutschen Technologiepolitik.* Kiel Discussion Papers 366. Kiel Institute for the World Economy (IfW).

Dosi, G. (1988). 'Sources, Procedures, and Microeconomic Effects of Innovation'. In: *Journal of Economic Literature* 26.3, pp. 1120–1171.

Edquist, C., L. Hommen, B. Johnson, T. Lemola, F. Malerba, T. Reiss, and K. Smith (1998). *The ISE Final Report: Scientific Findings and Policy Implications of the 'Innovation Systems and European Integration' (ISE) Research Project.* Tech. rep. Linköping University, Linköping.

Edquist, C. (1997). 'Systems of Innovation: Technologies, Institutions, and Organizations'. In: ed. by C. Edquist. Pinter. Chap. Systems of Innovation Approaches - Their Emergence and Chracteristics, pp. 1–29.

– (2001). 'Major Socio-economic Trends and European Innovation Policy'. In: ed. by B. Lundvall and D. Archibugi. Oxford: Oxford University Press. Chap. Innovation Policy – A Systemic Approach.

– (2004). 'Oxford Handbook of Innovation'. In: ed. by J. Fagerberg, D. C. Mowery, and R. R. Nelson. Ox. Chap. Systems of Innovation - Perspectives and Challanges, pp. 181–208.

– (2011). 'Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures)'. In: *Industrial and Corporate Change.*

Edquist, C. and B. Johnson (1997). 'Systems of Innovation: Technologies, Institutions, and Organizations'. In: ed. by C. Edquist. Pinter. Chap. Institutions and Organizations in Systems of Innovation, pp. 41–63.

EU (2000). *Presidency Conclusions - Lisbon European Council.* EU Council.

Federal Ministry of Education and Research (2014). *Bundesbericht Forschung und Innovation 2014.*

Fier, A. and D. Harhoff (2002). 'Die Evolution der bundesdeutschen Forschungs- und Technologiepolitik: Rückblick und Bestandsaufnahme'. In: *Perspektiven der Wirtschaftspolitik* 3, pp. 279–301.

Fornahl, D., T. Broekel, and R. Boschma (2011). 'What drives patent performance of German biotech firms? The impact of R&D subsidies, knowledge networks and their location'. In: *Papers in Regional Science* 90.2, pp. 395–418.

Forrest, J. (1991). 'Models of the process of technological innovation'. In: *Technology Analysis and Strategic Management* 3, pp. 439–453.

Freeman, C. (1987). *Technology, Policy, and Economic Performance : Lessons from Japan*. London; New York: Pinter Publishers.

– (1991). 'Networks of innovators: A synthesis of research issues'. In: *Research Policy* 20.5, pp. 499–514.

Graf, H. (2006). *Networks in the innovation process : local and regional interactions*. Cheltenham: Edward Elgar Publishing.

Granovetter, M. (1973). 'The Strength of Weak Ties'. In: *American Journal of Sociology* 78.6, pp. 1360–1380.

– (1985). 'Economic Action and Social Structure: The Problem of Embeddedness'. In: *American Journal of Sociology* 91.3, pp. 481–510.

Grupp, H. (1997). *Messung und Erklärung des Technischen Wandels : Grundzüge einer empirischen Innovationsökonomik*. Ed. by H. Grupp. Springer.

Guzzetti, L. (1995). *A brief history of European Union research policy*. Office for Official Publications of the European Communities Luxembourg.

Hagedoorn, J. (1993). 'Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences'. In: *Strategic Management Journal* 14.5, pp. 371–385.

Hazir, C. S. and C. Autant-Bernard (2012). *Using Affiliation Networks to Study the Determinants of Multilateral Research Cooperation Some empirical evidence from EU Framework Programs in biotechnology*. Tech. rep. Groupe d'analyse et de théorie économique (GATE).

Hippel, E. von (1988). *The Sources of Innovation*. MIT Press.

Hoekman, J., T. Scherngell, K. Frenken, and R. Tijssen (2013). 'Acquisition of European research funds and its effect on international scientific collaboration'. In: *Journal of Economic Geography* 13.1, pp. 23–52.

Johnson, B. and B. Gregersen (2007). 'Systems of innovation and economic integration'. In: *Journal of Industry Studies* 2.2.

Kelly, P., M. Kranzberg, et al. (1978). *Technological innovation: A critical review of current knowledge*. San Francisco Press San Francisco.

Kline, S. J. (1985). 'Innovation is not a Linear Process'. In: *Research management*, pp. 36–45.

Kogut, B. and U. Zander (1992). 'Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology'. In: *Organization Science* 3.3, pp. 383–397.

Krueger, A. O. (1990). 'Economists' changing perceptions of government'. In: *Weltwirtschaftliches Archiv* 126.3, pp. 417–431.

Lach, S. (2002). 'Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel'. In: *The Journal of Industrial Economics* 50.4, pp. 369–390.

Lundvall, B. (1988). 'Technical Change and Economic theory'. In: *Technical Change and Economic theory*. Ed. by Dosi, G. et. al. (eds.) Pinter. Chap. Innovation as an Interactive Process: From User Producer Interaction to National systems of Innovation.

Malerba, F. (2002). 'Sectoral systems of innovation and production'. In: *Research Policy* 31.2, pp. 247–264.

Marshall, A. (1920). *The Agents of Production. Land, Labour, Capital and Organization.* London: Macmillan and Co., Ltd.

McKelvey, M. (2002). 'Rethinking economies, Markets, technology and evonomic evolution'. In: *Rethinking economics : markets, technology and economic evolution*. Ed. by G. M. Hodgson and E. Screpanti. Edwar. Chap. How do National Systems of Innovation Differ?: A Critical Analysis of Porter, Freeman, Lundvall and Nelson, pp. 117–138.

Mowery, D. C., J. E. Oxley, and B. S. Silverman (1998). 'Technological overlap and interfirm cooperation: implications for the resource-based view of the firm'. In: *Research Policy* 27.5, pp. 507–523.

Nelson, R. R. (1982). *An evolutionary theory of economic change*. Harvard University Press.

Nooteboom, B. (2000). *Inter-firm Alliances: Analysis and Design*. Reprinted. London, New York: Routledge.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.

Paier, M. and T. Scherngell (2011). 'Determinants of Collaboration in European R&D Networks: Empirical Evidence from a Discrete Choice Model'. In: *Industry and Innovation* 18.1, pp. 89–104.

Penrose, E. (1959). *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.

Powell, W. W. (1990). 'Neither market nor hierarchy'. In: *Research in Organizational Behavior* 23, pp. 295–336.

Pyka, A. (1999). *Der kollektive Innovationsprozess: Eine theoretische Analyse informeller Netzwerke und absorptiver Fähigkeiten*. Berlin: Dunker & Humbolt.

Roediger-Schluga, T. and M. J. Barber (2006). *The structure of R&D collaboration networks in the European Framework Programmes*. Tech. rep. United Nations University - Maastricht Economic et al.

Romer, P. (1989). *Endogenous Technological Change*. Working Paper 3210. National Bureau of Economic Research.

Schumpeter, J. (1912). *Theorie der wirtschaftlichen Entwicklung*.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. New York, London: Harper & Brothers.

Smith, K. (2000). 'Innovation as a Systemic Phenomenon: Rethinking the Role of Policy'. In: *Enterprise and Innovation Management Studies* 1.1, pp. 73–102.

Solow, R. M. (1956). 'A Contribution to the Theory of Economic Growth'. In: *The Quarterly Journal of Economics* 70.1, pp. 65–94.

Steg, H. (2005). *Innovationspolitik in translationalen Innovationssystemen: Relevanz - Institutionelle Gestaltung - Wirkung*. VDI/VDE Innovation + Technik.

Ter Wal, A. L. J. (2009). *The structure and dynamics of knowege networks: a proximity approach*. Utrecht University.

Umlauf, F. (2014). *Network Determinants of a Collaborative Funding System: The Case of the German Innovation Policy*. Papers on Economics and Evolution. Centre for Regional and Innovation Economics.

Uzzi, B. (1996). 'The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect'. In: *American Sociological Review* 61.4, pp. 674–698.

Wallsten, S. J. (2000). 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program'. In: *The RAND Journal of Economics* 31.1, pp. 82–100.

Watts, D. J. and S. H. Strogatz (1998). 'Collective dynamics of 'small-world'networks'. In: *Nature* 393.6684, pp. 440–442.

Welsch, J. (2005). *Innovaionspolitik - Eine problemorientierte Einführung*. Gabler.

Winter, S. G. (1988). 'On Coase, Competence, and the Corporation'. In: *Journal of Law, Economics, & Organization* 4.1, pp. 163–180.

Woolthuis, R. K., M. Lankhuizen, and V. Gilsing (2005). 'A system failure framework for innovation policy design'. In: *Technovation* 25.6, pp. 609–619.

III. Supporting the emergence of an oligarchic core: the case of the European innovation policy

1. Introduction

Since the early 1980s, the promotion of research networks attracted a lot of interest as a policy tool that could help to fully exploit the potential innovative performance of a region, country, or even a continent by uniting firms, universities, and research centers into precompetitive collaborative research projects. At the European level, this instrument is implemented through the Framework Programme for Research and Technological Development (FP), which was initially established in the early 1980s, during a phase in which the industry competitiveness of the European Union's (EU) enterprises was falling behind their competitors from the US and Japan (Breschi and Cusmano, 2004). This early step towards a policy that weaves a research network among European organizations was concretized in 2000 by the formulation of the Lisbon Strategy. Dissatisfied with the progress after a twenty years of ongoing catch-up, the heads of state revised the former European innovation strategy and agreed to a plan that aimed to develop a European Research Area (ERA), for which the FP was chosen as the key instrument to accomplish that goal (Hoekman et al., 2013). Meanwhile, there is a long tradition of eight consecutive FPs that spent approximately 180 billion euros to create a comprehensive R&D network across Europe. Fostering the integration of organizations at the European level, the revision of the innovation policy implies the understanding of the ERA as a transnational innovation system among the members of the EU (Delanghe et al., 2009). In this context, the strategy shares significant elements with Lundvall's (1988) and Freeman's (1991) idea of a national innovation system, which emphasizes the role of a complex network of organizations for the innovativeness of an economy, but with a transnational focus. In high-tech sectors in particular, such as the biotechnology industry (Powell et al., 1996), the knowledge is dispersed among various independent organizations. Thus, within a complex economy, innovating organizations are forced to collaborate (Brusoni et al., 2001) since innovations strongly depend on the recombination of diverse and complementary skills (Boschma, 2005; Nooteboom, 2000).

One of the first observations of the European research network was the discovery of a large oligarchic core, representing a dense cluster of various central organizations. Breschi and Cusmano (2004) identified this network formation for the thrid FP (1992–1994) and fourth FP (1992–1996). Since the revision of the EU policy was sought to foster a degree of network integration on the transnational level, it is highly probable that their observed network formation process continues today. Later findings of Roediger-Schluga and Barber (2006) support this argumentation, since they found that for all FPs large fractions of the organizations transit between separate but consecutive FPs. As a consequence, there is a significant overlap between the programs and a permanent replication of once established network formations. A certain degree of stability is definitely needed for organizational research partnerships. Repetitive collaborations are embedded in trustworthy relationships (Granovetter, 1985; Uzzi, 1996), which are known to be a prerequisite for innovations since they reduce the risk of the counterpart's unpredictable behavior (Larson, 1992), extending the organization's willingness to share its knowledge and resources (Hippel, 1988; Kogut and Zander, 1992). However, excessive interactions lower the chance for creative inputs (Cowan and Jonard, 2004; Boschma, 2005; Uzzi, 1997) and hinder new incumbents from acquiring central positions within the overall network.

The funds of the FP are distributed as financial and project-based contributions to groups of organizations that have submitted a project proposal to the European Commission (EC). After an application, the EC decides whether to award or to reject the financial contribution. During the seventh FP, the European administration awarded only 15 percent of all proposed projects with a grant, which illustrates that the allocation process for an EU funding award is extremely selective. Therefore, the decision-making process regarding the allocation of a project grant potentially has a significant impact on the performance of EU innovation policy. To a high degree, it is the administration that decides consciously or not about the formation of the pan-European research network. With each additional decision, the commission shapes the development of the network, and thus the stage of the network at the end of a funding phase represents just one specific network formation of endless alternative stages.

Contrary to the broad consensus about the emergence of oligopolistic network structures and significant overlaps between consecutive funding phases, the process that determines the formation of the network remains unclear. Breschi and Cusmano (2004) suspected this network pattern as being shaped by the coordinators of the projects, since they observed that those "prime contractors" are more frequent participants in promoted research projects than other organizations; but this explanation omits all previous contributions to the dynamics of networks that would direct the outstanding position of a "prime contractor" to the outcome of a process rather than its initiator. Another contribution to this topic comes from Hazir and Autant-Bernard (2012). Both analyzed the funding process before the consortium's initial application for a project grant. They emphasized that organizations consider their benefit from additional access to other external knowledge sources when they participate within a consortium, but the impact on the overall decision was rather limited, and they found no significance for their assumption that organizations try to preserve their cooperation partners across various applications.

It is expected in this research that the Commission's process of allocation is both affecting, and affected by, the formation of the network. For the application process, previous experiences play an important role (Brockhoff et al., 1991; Barajas and Huergo, 2010; Paier and Scherngell, 2011; Aschhoff, 2009). They correspond to the learning curve of the organizations and their ability in writing high-quality proposals. But it is also expected that experiences that become manifested in networks (Ahuja et al., 2012), such as trust, loyalty, and mutuality, also have a significant impact on the quality of a proposal. After the decision and the award of a cooperative project grant, the network transits into a new stage, representing the new experiences that are accumulated by the organizations of the network. This ultimately induces a feedback link between experiences, network-related as well as non-network-related, and the award of additional project grants.

Following the work of Barajas and Huergo (2010), the participation of an organization in the FP depends on a two-stage decision-making process. During the first stage, an organization that must be a member of a consortium decides whether to apply for an FP project; secondly, depending on its quality, the EC approves or rejects the proposal of the total consortium.

In the following sections, this paper analyzes whether or not the EU's allocation process of project grants is affected by the formation of the network. If so, this would only become possible due to two explanations. As the EU is the responsible agency with the authority over allocation, it is only possible that the administration appreciates or neglects the influence of the network. In both cases, knowingly or unknowingly, the administration would facilitate a selective process that promotes submitted proposals of well-connected consortia.

To bring clarity, this paper analyzes the evaluation procedure for two Knowledge Based Bio-Economy (KBBE) calls that were part of the seventh FP (2007–2013). As the funding decision of the EC strongly depends on the outcome of an expert evaluation procedure that attaches a certain score value to each submitted project proposal, it is possible to estimate the impact of network-related determinants on the allocation process by estimating two ordinary least-square models. The first model analyzes a KBBE call in 2013, asking whether the emerged network structure of the current FP determines the proposal's priority ranking. The second model investigates a KBBE call in 2007, lying directly between the transition phase among the sixth and seventh FP, if the network formation of a previous funding phase influences the selection process of the current one. To the best knowledge of the author, there have been no previous studies that have deployed this approach.

The next section gives a short introduction about the EU's project allocation process. The third section concludes with three theory-based hypotheses concerning the impact of network-related determinants. The fourth section presents the employed data for the empirical part of the paper as well as the construction of the networks. The fifth section will introduce the variables that have been used to specify the models required for testing the hypotheses. Section six discusses the results of the estimation. The paper concludes with a summary of the key findings and limitations of the paper, presenting ideas for further research as well.

2. The allocation mechanism of a project grant

As the EC is the responsible authority for the FP, the allocation process of the project grants is one of its key assets in achieving their vision of a pan-European research network. Since the first time the FP was established, only those consortia were eligible to apply for project grants that consist of several independent organizations coming from different EU member states or associated countries (Roediger-Schluga and Barber, 2006). Thus, each additional allocated project contributes to the formation of the transnational research network. Proposals that have passed the eligibility check, and therefore comply with the minimum requirements, are subject to an evaluation process, which prioritizes the submitted projects on the basis of a criteria catalog. In contrast to the rather inflexible eligibility check, this stage of the allocation process provides space for pursuing political aims, for example, allocating at least 15 percent of the funding to small and medium-sized enterprises (SMEs) (EU, 2006), or promoting the formation of a research network. Considering the results of the evaluation process, the Commission decides whether to support the proposal with a project grant or to reject.

The prioritization is carried out by an appointed group of experts (EU, 2013) that has to evaluate the submitted proposals under the following criteria: (1) scientific and technological excellence, (2) relevance to the program objectives, (3) the potential impact of the project results, and (4) the quality and efficiency of the implementation and management. While the second criterion is directly related to the promotion of research networks, as the formation of networks is a ubiquitous aspect within the "Work Programmes" for the FP (EU, 2013; EU, 2007), there are some additional indirect effects that occur when fostering the evolution of the research network through the first and third criterion. From an excellent proposal, the EC demands scientific and technological state of the art and an efficient plan for the project implementation, which needs to include significant coordination activities before of proposal submission, as the project consortium has to submit its proposal jointly. At the final stage of this process each proposal is assessed with a score value, which ranges usually between 0 and 100, signaling the quality of the proposal. Ultimately, considering the expert's prioritization, the EU administration distributes the funds of the FP to the proposals with the highest evaluation scores.

3. Hypotheses

The literature points to the important role of previous experiences for the application process (Brockhoff et al., 1991; Barajas and Huergo, 2010; Paier and Scherngell, 2011; Aschhoff, 2009). This is, however, misleading, since most of the researchers do not distinguish or recognize the difference between having experience with the application procedure and having experience with collaborative partnerships. For experiences with the application process, an organization only requires a frequent number of previous applications, which do not even need to be successful (Barajas and Huergo, 2010). On the contrary, experiences with R&D cooperations require the award of a project grant to establish a long-term research partnership. Since co-operative experiences become manifested in networks (Ahuja et al., 2012), it is reasonable to question whether the positioning of the consortium's members, and, indirectly, the formation of the overall network, has an impact on the expert committee's project prioritization.

Several theoretical arguments support this point of view. To ensure the quality of a proposal, organizations could seek to collaborate mostly with those partners that have already proven their credibility as reliable stakeholders. This reputation helps to mitigate the problem of incomplete contracts (Larson, 1992; Mora-Valentin et al., 2004) before and during the implementation phase of a project, which entails the possibility for hazards, such as free riding or opportunistic behavior. Under these circumstances, the trustworthiness of an organization becomes visible through their degree of social embeddedness in networks (Granovetter, 1985; Uzzi, 1996), or, as Powell et al. (1996) posit, by their "central connectedness." Furthermore, organizations with experience in collaborating and of a central network position are capable formulating a coherent project proposal due to their access to a more diverse knowledge pool (Powell et al., 1996). Similarly, Hagedoorn et al. (2006) and Umlauf (2014) have shown, in the case of general inter-firm and funded research partnerships, that firms with strategic network positions have a higher probability of obtaining additional partnerships or project funds.

Moreover, it harms the reputation of the experts if one of their chosen projects is abandoned during the project implementation phase; thus, experts might tend to select organizations that have already proven to be successful in completing a project, which in their view reduces the probability of project failure (Blanes and Busom, 2004; Cantner and Kösters, 2009; Aschhoff and Schmidt, 2008). If so, that would promote the selection of organizations with previous cooperative experiences, since these are the organizations which are likely to accomplish the project objectives. To evaluate whether the positioning of the consortium members within the research network influences the experts' scoring process, and ultimately the overall network formation, motivates hypothesis ***H1***.

> ***H1:*** *The better the strategic positioning of the consortium within the network, the higher the evaluation score.*

The leading organization in the consortium is the project coordinator (*prime contractor*). The composition of the consortium members usually depends on the coordinator's choice and its ability to attract other organizations to participate, for which the coordinator requires both a large bundle of contacts and a good reputation. Moreover, it is the task of the prime contractor to coordinate the activities of the participants during the initiation and implementation phase of the project (Breschi and Cusmano, 2004). Thus, to a large extent, the success of the project application depends on the capabilities and cooperative experiences of the coordinator (Barajas and Huergo, 2010). The importance of prime contractors for the formation of the network is confirmed by the frequency of their participation in other projects (Breschi and Cusmano, 2004), which lies significantly above the average. The implication of these thoughts is concentrated in hypothesis ***H2***, expecting, in accordance to the ***H1***, that the quality of the submitted proposal is associated with the coordinator's position within the research network.

> ***H2:*** *The better the strategic positioning of the coordinator within the network, the higher the evaluation score.*

Additionally, it is expected that the degree of preexisting interlinkages among the members of a consortium improves the quality of the project proposal. While the previous two hypotheses focus on the external network of the consortium, the question arises whether the connection within the group has an effect or not. Particularly first hand experiences, which come from previous bilateral relationships, reduce the probability of a hidden agenda of the counterpart (Granovetter, 1985; Uzzi, 1996). Moreover, the exchange of project-relevant knowledge among the potential partners requires long-term cooperations (Hippel, 1988; Kogut and Zander, 1992). Previous give-and-take relationships that have satisfied the expectations of the organizations are a prerequisite for a non-defensive attitude, which enables the transfer of tacit knowledge through preexisting communication channels (Cavusgil et al., 2003), and organizations can therefore collaborate more efficiently. The logic behind these preferential relationships leads to a replication of the same relationships, entailing a strong social cohesion between organizational subgroups (Duysters and Charmianne, 2003; Rosenkopf and Padula, 2008; Walker et al., 1997). All these factors lead to hypothesis ***H3***.

> ***H3:*** *The more preexisting relationships within the group of a consortium, the higher the evaluation score.*

4. Data

To investigate whether the scoring process of the expert committee is affected by the factors named in the hypotheses, the empirical analysis of this paper makes use of different sets of databases related to the European FP. The evaluation results of the KBBE calls are taken from the proposal database of the seventh FP[1], which contains various information about the group of applicants, such as organization names, contact persons, required budgets, or whether the organizations are SMEs. The extraction of

[1]The proposals were extracted from the ECORDA database, June 2014 version.

the database includes 414 proposals for the KBBE call 2007-1 and 467 for the KBBE call 2013-7, respectively (see Table III.1). In total, 136 of 841 eligible proposals were accepted for the Commission's main list, which names all selected proposals that will receive a project grant. Those proposals that have been named on the Commission's reserve list obtain a second chance to receive a project grant if the call's budget is not depleted by the projects from the main list. Proposals that have not been mentioned on the main or reserve list have been rejected (332) and have no further opportunity to access funding. Moreover, the database includes 11,101 entries about organizations that have taken part in both calls. Due to the rather limited quality of the database, it was necessary to apply an intensive deduplication procedure, which identified 4,832 unique organizations in both calls. Since most proposals name the highest legal entity of the applying organization, subdivisions where aggregated to their highest legal level, to secure the comparability between the organizations. Since ineligible proposals do not receive an evaluation value from the group of experts, 41 proposals were excluded from the estimation process.

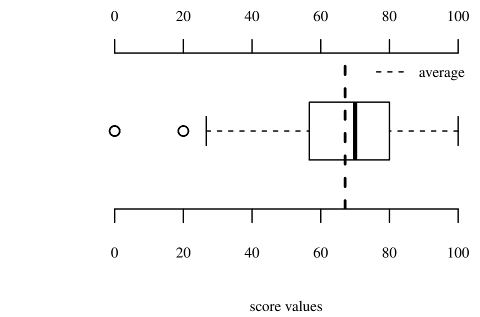
call	proposals	ineligible	eligible	main list	reserve	rejected	participants	organizations
2007-1	414	17	397	64	157	176	4,248	2,035
2013-7	467	24	443	72	175	196	6,853	3,468
total	881	41	840	136	332	372	11,101	4,832

Source: E-CORDA database of the European Commission

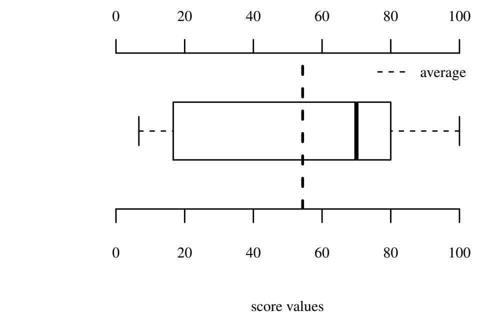
Table III.1.: Overview KBBE calls

Despite the approximately equal number of project proposals for both KBBE calls, there are some differences regarding the distribution of score values (see Figures III.1(a) and III.1(b)), which could lead to difficulties comparing the estimation results for both calls. While both evaluation processes lead to score values ranging from the highest possible value of 100 to the lowest possible value of 0, the standard deviation of the KBBE in 2013 (31.2) lies 60 percent above the deviation (19.1) in 2007. The mean score value reaches 67.1 in 2007, compared to 54.3 in 2013. Both findings suggest, except for the significance levels, that direct comparisons between the later estimated parameter values should be avoided.

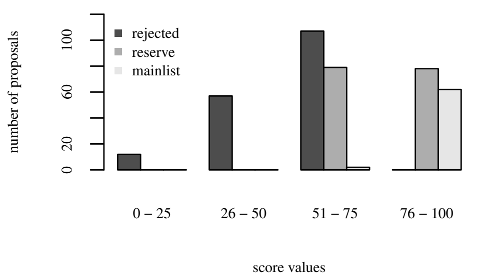
The ultimate grant decision of the EC is highly influenced by the expert's prioritization (see Figures III.1(c) and III.1(d)). Those proposals that obtained the highest evaluation scores from the group of experts are usually named on the Commission's main list. However, in some situations, proposals are not part of the main list even if they have



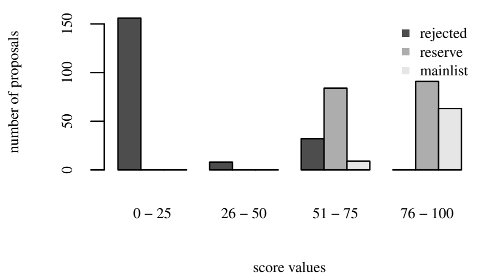
(a) KBBE call 2007 expert evaluation



(b) KBBE call 2013 expert evaluation



(c) KBBE call 2007 grant decision



(d) KBBE call 2013 grant decision

Figure III.1.: Results of the allocation process

Source: E-CORDA database of the European Commission higher comparative scores. This is because each call has some specific thematic subdivisions. For each sub-field there is a specific amount of money that can be spent and if the budget's limit is reached, proposals with relatively high scores are also added to the reserve list.

The networks were extracted from two different databases. For the KBBE call 2007, the network was constructed from the project database of the sixth FP, because in 2007 the network of the seventh FP was in its embryonic stage. As a by-product, it is possible to evaluate whether the network configuration of the previous FP affects the scoring procedure of the following one. As this approach requires a unification of the sixth and seventh FP, the network was restricted due to the manageability of the matching procedure to those projects that fall within the scope of biotechnology-related topics.[2] The network for the 2013 call was built on the project database of the seventh FP, considering all projects which belong to the specific cooperation program and whose initial starting dates lie before the call's deadline for the proposal submission. To focus on organizational interlinkages, the initial affiliation network which consists of vertices representing projects as well as organizations, is projected to a unipartite graph of organizations (Breschi and Cusmano, 2004) which has the advantage of using network-related measures that are only available for one-mode networks.

characteristics	network KBBE *2007-1*	network KBBE *2013-7*
organizations	8,826	18,793
edges	196,542	396,602
density	0.005	0.002
components	53	77
greatest component		
organizations	8,490	18,611
share	96%	99%
average distance	2.75	2.74
isolates	16	48
degree centralization	0.18	0.25
betweenness centralization	0.04	0.11
average degree	44.5	42.2
transitivity	0.22	0.12
average transitivity	0.82	0.82
diameter	6	6

Table III.2.: Network structure of Framework Programmes

[2] Therefore, only those projects were selected from the 6th FP, which belong to the following sub-themes: (1) life sciences, genomics and biotechnology for health, (2) food quality and safety, and (3) sustainable development, global change, and ecosystems.

The observed networks differ in terms of the number of organizations and the number of edges (interlinkages). While the network for the KBBE call 2007 only includes 8,826 organizations, the network for the KBBE call 2013 consists of 18,793 organizations, which is more than double. The same is true for the number of interlinkages, where there are 196,542 edges against 396,602. The primary reason for this is the restriction of the KBBE 2007 network to biotechnology-related projects and the different time horizon, as the time frame for the KBBE 2007 network includes only four (2003–2007) instead of six (2007-2013) years. Another factor that plays a role is that each subsequent FP over-exceeds its precursor in terms of the financial budget and the number of subsidized projects (Roediger-Schluga and Barber, 2006). In contrast to the different size, the structural patterns of the networks is similar. For both networks the share of the greatest component is close to 1 and the average transitivity (0.82) is identical to the second decimal place. The same is reflected by the average degree that reaches a value of 44.5 in the case of the KBBE 2007 network and lies only slightly above the value of 42.2. The structural similarity between both networks ensures the comparability of the model results within the next sections.

5. Variables

Using an ordinal least square (OLS) model for the estimation of the score values that have been awarded by the expert committees, it is necessary to include several exogenous variables in order to check the relevance of the underlying hypothesis. Due to the different closing dates for the analyzed KBBE calls, it is necessary to calculate the variables for two different time points (see Table III.3).

Several measures are able to describe the centrality of an organization within the research network, with each concept pointing to a specific role and position of actor's in relation to the rest of the network. To verify ***H1***, that is the centrality of a consortium has an influence on the expert's evaluation processes, the model includes two distinctive centrality measures. As the perspective focuses on the level of the whole consortium, the individual centrality measures need to be aggregated to the level of the group. The first indicator ($group\ degree_{avg}$) summarizes the average number of connections (degree) that each member of the group has established to other organizations within the research network. By doing that, a large number of neighbors reflect both past gained knowledge and experiences through previous collaborations as well as preexisting external knowledge sources. The expected improvement of the submitted proposal should encourage the expert group to give a higher priority score to the submitted proposal. The second centrality measure refers to the group's overall centrality within the network. While the degree only reflects the direct neighborhood of the consortium, the eigenvector centrality reviews the groups position with respect to the entire network. Measuring the importance with respect to the entire network leads to a self-referential, problem since the importance of an organization depends on the importance of its neighbors. This can be solved due to the calculation of the research network's eigenvector (Jackson, 2008; Bonacich, 1987). For the construction of the variable *group* $evcent_{sum}$, the individual eigenvector centrality measures of the organizations were added up to the level of the consortium. As the variable quantifies the quality of the group's neighborhood, it is supposed that a higher variable value improves the score value of the proposal.

Hypothesis ***H2*** is similar to the first one, but with a different focus. It aims at the centrality of the project coordinator instead of the centrality of the consortium. The underlying assumption is that the primary contractor is of higher relevance in comparison to the ordinary project participant. To describe the coordinator's network positions, the same indicators, as in the case of the first hypothesis, are used, with the only difference being that the centrality measures are not aggregated to the level of the group.

While the first two hypotheses have an outward-looking perspective regarding the consortium's network position within the overall network, hypothesis ***H3*** gives attention to the inner connectivity of the group. Previous bilateral project participations are manifested in organizational interlinkages signaling both previous experiences and mutual trust, and formed through face-to-face contacts and contract compliance. The connectivity between the project applicants is measured by their subgroup's network connectivity. The value of the indicator varies between 0 and 1, 1 indicating whether all members of the consortium are connected directly or indirectly with each other.[3] In that case, each member of the consortium has access to everyone else in the consortium. A value of 0 would signal that the members of the group are totally unknown to each other. For the confirmation of hypothesis ***H3***, it is expected that indicator variable *group connectivity* has a positive impact on the experts' evaluation process.

As stated in the funding rules of the EU Commission, the project consortium should contain at least three independent organizations. That is why the smallest consortium counts three participants, whereas the greatest submitted proposal has 55 organizations on its list. A key rationale behind R&D cooperation is to diversify the costs and risks of

[3]Therefore, the number of components within group's sub-network is divided through the number of organizations within the consortium. This subtracted from 1 represents the subgroup's connectivity.

an innovation process across different organizations. However, is has been shown, in line with to the transaction-cost theory (Coase, 1937; Williamson, 1981), that costs start to grow with the administrative efforts are required to coordinate greater groups (Barajas and Huergo, 2010). Moreover, the exchange of knowledge becomes more complex and difficult; thus, the benefit comes to an end if the marginal profit of an additional project participant does not exceed its own cost. To investigate the effect, the variable $members_{count}$ was added, counting the number of applications to a submitted proposal.

The EC has to meet a balance of national interests regarding the allocation of the FP budget. Since the budget for the European FP comes directly from the member states, it is usual that national authorities claim a proportion of the project funding, which is equivalent to their specific contribution. This leads to the expectation that the final list of contributed consortia represents approximately the proportional origin of the public funds. To ensure this, the experts' evaluation procedure has to consider that no country is overrepresented regarding their financial contribution to the program. Therefore, several variables were added to the model, counting the consortium's number of applicants coming from a specific country. A comparison between the variable $country\ es_{count}$ and $country\ de_{count}$ for the KBBE call 2013 explains that (see Table III.3), on average, Spanish organizations (2.0) are overrepresented compared to German (1.6), as it can be assumed that Germany's financial contribution to the budget of the FP exceeds the Spanish one. Consequently, it can be expected that the evaluation process prioritizes those consortia that ensure a balance of national interests.

Many authors have highlighted the importance of the geographic proximity (Ponds et al., 2007; Broekel and Hartog, 2013; Ter Wal, 2013; De Stefano and Zaccarin, 2013; Hoekman et al., 2013) for organizational cooperation. Closeness eases the communication between the members of the consortium; personal meetings become more likely and therefore more affordable, which stimulates the creation of mutual trust, stimulating the exchange of information and tacit knowledge (Kogut and Zander, 1992; Cavusgil et al., 2003). Nevertheless, it is possible to substitute geographic proximity by other confidence-inspiring factors, such as previous experiences or social proximity (Autant-Bernard et al., 2007; Paier and Scherngell, 2011). To evaluate whether the geographic proximity has an influence on the quality of a submitted proposal, the model includes the variable $coordinator\ distance_{sum}$, measuring the sum of the geographic distances between the project coordinator and the rest of the consortium.

For the objective of the paper, it is necessary to distinguish network-related experiences from those reflecting the organizational learning-curve concerning the formal application process (Barajas and Huergo, 2010; Yelle, 1979). While network-related experiences become explained through the variables for the hypotheses, the organizational know-how has not been implemented up to now. It describes the extent of the organization's professionalization in seeking and proposing further projects, which is shaped most widely by former proposal submissions (Levinthal and Fichman, 1988; Mora-Valentin et al., 2004; Aschhoff and Schmidt, 2008; Barajas and Huergo, 2010). Organizations with previous submissions can build upon preexisting communication channels with the EU administration, which entails an information advantage over other organizations when formulating a high quality application. Taking this effect into account, the model includes three different variables. Counting the number of successfully acquired projects, the variable $\textit{log experience positive}_{count}$ explains the sum of positive experiences that a consortium has collected before a submission deadline, the *KBBE call 2013* variable is based on the seventh FP, and the *KBBE call 2007* uses the sixth FP, respectively.[4] For the *KBBE call 2013* it is also possible to consider negative experiences ($\textit{log experience negative}_{count}$) in the form the consortium's list of rejected project proposals. In contrast to the positive experiences, the number of negative project applications is considered to have a negative impact on the experts' evaluations. Possibly, a large share of rejected proposals is a signal for a kind of spamming strategy, where a large set of low quality submissions are used to obtain project funds from time to time.

Most importantly, the experts' evaluations should reflect the scientific expertise of the written proposal. It is obvious that the best approximation for the accumulated knowledge of the consortium is their academic publication activity in recent years (Umlauf, 2014). For that purpose, the variable $\textit{log publications}_{count}$ includes all publications of the consortium members that refer to the topics of the KBBE calls. The publication data was extracted for each organization from the Web of Science, the time horizon starting in 2000 and ending at the closure date of the respective call. The number of publications is logarithmized since it is assumed that each additional publication is less important.

It is a special aim of the EC to internationalize the participants of the seventh FP (EU, 2013). The inclusion of third-party countries is an important objective under the cooperation program, if those participants contribute to the innovative potential of the elaborated proposal. A third-party country is neither a member of the EU nor a currently associated country of the FP. The variable $\textit{thirdparty countries}_{bool}$ signals whether a third-country is under the list of organizations.

[4]Another model setting which included the number of the coordinator's positive and negative project experiences was also tested, but it was rejected,

variable	KBBE 2013 mean	min	max	sd	KBBE 2007 mean	min	max	sd
members$_{count}$	15.12	3.00	55.00	6.93	10.21	1.00	25.00	4.40
country uk$_{count}$	1.31	0.00	8.00	1.45	0.93	0.00	6.00	1.09
country de$_{count}$	1.57	0.00	10.00	1.64	0.85	0.00	5.00	1.08
country es$_{count}$	1.97	0.00	20.00	1.97	0.79	0.00	7.00	1.12
country it$_{count}$	1.49	0.00	8.00	1.68	1.13	0.00	8.00	1.33
country fr$_{count}$	1.10	0.00	8.00	1.49	0.65	0.00	6.00	0.96
country nl$_{count}$	1.00	0.00	9.00	1.41	0.46	0.00	3.00	0.76
country be$_{count}$	0.59	0.00	6.00	0.97	0.40	0.00	5.00	0.76
country pt$_{count}$	0.49	0.00	6.00	0.96	0.21	0.00	5.00	0.61
thirdparty countries$_{bool}$	0.25	0.00	1.00	0.43	0.29	0.00	1.00	0.46
thirdparty lower middle$_{count}$	0.28	0.00	6.00	0.81	0.44	0.00	8.00	1.20
coordinator distance$_{sum}$	1,377.46	0.00	7,356.75	1,093.31	1,542.98	0.00	7,058.80	1,171.02
log experience negative$_{count}$	6.62	0.00	8.27	1.13				
log experience positive$_{count}$ *	8.02	1.10	9.70	1.11	4.14	0.00	5.91	1.24
log publications$_{count}$	10.54	0.00	12.84	1.70	10.31	0.00	12.83	1.95
group degree$_{avg}$	375.18	5.50	1,177.33	212.44	25.80	0.00	73.89	14.54
group evcent$_{sum}$	2.60	0.01	9.09	1.62	1.01	0.00	4.51	0.84
coordinator degree	723.86	0.00	4,647.00	872.05	31.91	0.00	114.00	39.20
coordinator evcent	0.32	0.00	1.00	0.31	0.14	0.00	0.99	0.24
group connectivity$_{share}$	0.47	0.00	0.94	0.24	0.14	0.00	0.75	0.17
theme I$_{bool}$	0.26	0.00	1.00	0.44	0.49	0.00	1.00	0.50
theme II$_{bool}$	0.31	0.00	1.00	0.46	0.35	0.00	1.00	0.48
theme III$_{bool}$	0.43	0.00	1.00	0.50	0.16	0.00	1.00	0.36
theme IV$_{bool}$					0.003	0.00	1.00	0.05
employee less 250$_{count}$	6.35	0.00	22.00	3.87	4.20	0.00	14.00	2.91
turnover ls 50$_{count}$	6.81	0.00	26.00	4.08	5.44	0.00	18.00	3.25
coordinator university education$_{bool}$	0.37	0.00	1.00	0.48	0.46	0.00	1.00	0.50
coordinator research$_{bool}$	0.35	0.00	1.00	0.48	0.34	0.00	1.00	0.47
experts$_{share}$	0.02	0.00	0.27	0.04	0.02	0.00	0.50	0.06
number of observations	443				397			

* For the KBBE call 2013 mesured in project aquisitions during 7th FP and in case of the KBBE call 2007 mesured in project aquisitions during 6th FP.

Table III.3.: Variable statistics

Roediger-Schluga and Barber (2006) have shown that the institutional affiliation of an organization also plays a role to a large extent. They reported that universities and research organizations show a greater persistency among consecutive FPs in comparison to firms and other organizations. Thus, they were able to gain in experience in regarding the application processes in recent years. Another factor that might play a role for the allocation process is that universities and research centers are experts in managing basic research, since this activity is a major part of their daily business. To investigate whether the sectoral affiliation of the coordinator plays a role, the variables *coordinator research*$_{bool}$ and *coordinator university*$_{bool}$ have been added to the model, the variable equals 1 if the organization belongs to the specific sector, and 0 otherwise.

Tanayama (2009) found some evidence that SMEs and large firms are treated differently, but it is unclear whether the consortium benefits more from the participation of SMEs or large firms. While a regulation from the EC requires that at least 15 percent of the overall funding goes to SMEs (EU, 2006), large organizations have the advantage of economies of scale and lower vulnerability in terms of sunk cost and other risks. Moreover, the "picking-the-winner" strategy contributes to the selection of larger firms (Wallsten, 2000; Cantner and Kösters, 2009). To measure this effect, two variables were added to the model, containing the number of organizations in the consortium with less than 250 employees ($employee\ less\ 250_{count}$) or an annual turnover below 50 million euro ($turnover\ less\ 50_{count}$). The limits of the variables are exactly equivalent to the limits of the EU definition of whether an organization is an SME or not.

Each KBBE call is divided into different activities; thus, each call addresses several specific research questions related to the respective technological field. During the application process, organizations are able to decide for which kind of sub-activities they want to submit their proposal. Notwithstanding the possibility considering a thematic sub-field below the activity level, the model includes as much thematic dummy variables as possible to represent the activity of the respective call. This procedure assumes that the expert group's evaluation procedure differs between the various activities, which is possible since the composition of the expert group changes case-by-case.

The role of the expert group cannot be overstated. For the composition of the expert group, the EC maintains a list of appropriate persons. To become an expert, persons require a high level of expertise and competence regarding the requested scientific sub-field (EU, 2011). Beside this, the group should reflect a sensible balance, between academics, industrial experts and users, a reasonable gender balance and a reasonable distribution of geographical origins and the principle of rotation. The requirement of a person's expertise entails the possibility of a conflict of interest. It's very likely that highly educated persons having a similar scientific background are familiar with each other. Thus, personal acquaintances between experts and applicants cannot be avoided. As a consequence, experts have to indicate whether they are in a conflict of interest or not, and, if so, experts are usually excluded from the relevant decision. However, it remains widely unclear whether further effects influence the decision, such as unconscious preferences or even agreements between the experts in advance of the evaluation process. To approximate this effect, the variable $experts_{share}$ was added to the model. Based upon the persons named in the respective proposal, the variable explains the share of the consortium's members that have also been announced as experts evaluating a KBBE call between the years 2007 and 2013.

6. Results

The model results of several OLS estimations are shown in Table III.4 and III.5. Unfortunately, both models (1a, 1b) that have been estimated first lead to the problem of multicollinearity. Thus, it was necessary to reduce the list of parameters by those variables, which have been indicated through the variance inflation factor. This is particularly the

	model 1b				model 2b			
variable	β	s.d.	t-value	sign.	β	s.d.	t-value	sign.
constant	43.44	4.92	8.82		44.18	4.77	9.26	
$members_{count}$	0.34	0.58	0.59		0.12	0.46	0.27	
$country\ uk_{count}$	2.13	0.84	2.55	*	2.11	0.84	2.52	*
$country\ de_{count}$	1.81	0.90	2.01	*	1.81	0.90	2.01	*
$country\ es_{count}$	1.53	0.80	1.91	.	1.59	0.80	1.99	*
$country\ it_{count}$	-0.91	0.70	-1.30		-0.89	0.70	-1.28	
$country\ fr_{count}$	2.13	0.95	2.25	*	2.09	0.94	2.21	*
$country\ nl_{count}$	3.05	1.30	2.34	*	2.93	1.29	2.28	*
$country\ be_{count}$	1.78	1.17	1.53		1.73	1.16	1.49	
$country\ pt_{count}$	-0.35	1.36	-0.26		-0.38	1.36	-0.28	
$thirdparty\ countries_{bool}$	-3.72	2.30	-1.62		-3.66	2.29	-1.60	
$coordinator\ distance_{sum}$	0.00	0.00	1.85	.	0.00	0.00	1.86	.
$log\ experience\ positive_{count}$	2.14	1.28	1.67	.	2.16	1.28	1.70	.
$log\ publications_{count}$	0.21	0.66	0.33		0.27	0.65	0.42	
$group\ degree_{avg}$	0.00	0.02	0.20		-0.01	0.02	-0.30	
$group\ evcent_{sum}$	-2.01	3.24	-0.62					
coordinator degree	-0.03	0.04	-0.98		-0.04	0.03	-1.01	
coordinator evcent	8.383	5.73	1.46		8.60	5.71	1.51	
$group\ connectivity_{share}$	17.24	9.43	1.83	.	15.05	8.73	1.72	.
$theme\ II_{bool}$	-8.27	1.86	-4.46	***	-8.28	1.85	-4.47	***
$theme\ III_{bool}$	-2.63	2.53	-1.04		-2.61	2.53	-1.03	
$theme\ V_{bool}$	4.89	17.18	0.29		7.79	16.52	0.47	
$employee\ less\ 250_{count}$	-1.37	0.66	-2.07	*	-1.33	0.66	-2.01	*
$turnover\ less\ 50_{count}$	1.132	0.65	1.73	.	1.18	0.65	1.81	.
$coordinator\ university_{bool}$	3.28	2.46	1.34		3.16	2.45	1.29	
$coordinator\ research_{bool}$	1.04	2.49	0.42		0.85	2.47	0.34	
$experts_{share}$	17.94	13.87	1.29		18.54	13.83	1.34	
Adjusted R^2	0.315				0.316			
AIC	3,345.1				3,343.5			
BIC	3,456.7				3,451.1			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table III.4.: Estimation results KBBE call 2007

variable	model 1a β	model 1a s.d.	model 1a t-value	model 1a sign.	model 2a β	model 2a s.d.	model 2a t-value	model 2a sign.	model 3a β	model 3a s.d.	model 3a t-value	model 3a sign.	model 4a β	model 4a s.d.	model 4a t-value	model 4a sign.
constant	55.80	16.43	3.40	***	33.50	10.93	3.07	**	36.49	9.73	3.75	***	36.83	9.71	3.79	***
members$_{count}$	-1.42	0.59	-2.39	*	-1.35	0.59	-2.28	*	-0.40	0.40	-1.00		-0.41	0.40	-1.03	
country uk$_{count}$	1.00	1.05	0.95		1.15	1.05	1.09		1.74	1.02	1.71	.	1.71	1.01	1.69	.
country de$_{count}$	2.21	0.96	2.31	*	2.27	0.96	2.37	*	2.32	0.95	2.44	*	2.39	0.95	2.52	*
country es$_{count}$	-2.66	0.77	-3.44	***	-2.93	0.76	-3.84	***	-2.79	0.76	-3.66	***	-2.77	0.76	-3.64	***
country it$_{count}$	-0.81	0.97	-0.83		-1.17	0.96	-1.22		-1.11	0.95	-1.16		-1.07	0.95	-1.13	
country fr$_{count}$	1.75	0.99	1.77	.	1.99	0.99	2.02		2.23	0.98	2.28	*	2.10	0.98	2.16	*
country nl$_{count}$	1.45	1.09	1.33		2.24	1.08	2.08	*	2.08	1.07	1.95	.	1.96	1.07	1.83	.
country be$_{count}$	2.87	1.43	2.01	*	2.86	1.44	1.99	*	3.32	1.42	2.33	*	3.36	1.42	2.36	*
country pt$_{count}$	1.31	1.48	0.89		0.73	1.48	0.49		1.16	1.48	0.79		1.28	1.48	0.87	
thirdparty countries$_{bool}$	-4.06	3.71	-1.09		-3.45	3.74	-0.92		-4.18	3.73	-1.12		-4.32	3.72	-1.16	
coordinator distance$_{sum}$	0.00	0.00	1.43		0.002	0.001	1.44		0.002	0.001	1.63		0.002	0.001	1.64	
log experience positive$_{count}$	21.15	7.89	2.68	**	9.14	3.24	2.82	**	4.80	2.58	1.86	.	4.72	2.57	1.84	.
log experience negative$_{count}$	-13.17	7.78	-1.69	.												
log publications$_{count}$	-3.53	1.51	-2.33	*	-3.88	1.50	-2.58	*	-3.19	1.47	-2.17	*	-3.22	1.47	-2.20	*
group degree$_{avg}$	-0.04	0.01	-2.54	*	-0.03	0.01	-2.26	*								
group evcent$_{sum}$	4.48	2.45	1.83	.	4.10	2.42	1.70	.								
coordinator degree	-0.002	0.01	-0.31						0.004	0.002	2.44	*				
coordinator evcent	19.81	15.54	1.28										14.43	5.08	2.84	**
group connectivity$_{share}$	17.94	9.39	1.91	.	20.94	9.39	2.23	*	20.68	8.50	2.43	*	19.72	8.50	2.32	*
theme II$_{bool}$	-13.76	3.71	-3.71	***	-15.17	3.67	-4.14	***	-14.17	3.63	-3.91	***	-13.63	3.63	-3.76	***
theme III$_{bool}$	3.83	3.49	1.10		3.41	3.49	0.98		3.62	3.47	1.04		3.87	3.47	1.12	
employee less 250$_{count}$	1.53	1.28	1.19		1.40	0.62	2.26	*	1.18	0.56	2.12	*	1.21	0.55	2.18	*
turnover less 50$_{count}$	-0.065	1.16	-0.06													
coordinator university$_{bool}$	-4.35	3.73	-1.17		-0.97	3.41	-0.28		-2.32	3.48	-0.67		-3.77	3.58	-1.05	
coordinator research$_{bool}$	-2.62	3.75	-0.70		1.66	3.46	0.48		-1.62	3.73	-0.43		-2.20	3.73	-0.59	
experts$_{share}$	91.59	34.01	2.69	**	93.83	34.32	2.73	**	91.14	34.26	2.66	**	90.56	34.18	2.65	**
Adjusted R^2	0.29				0.28				0.28				0.28			
AIC	4,181.4				4,186.5				4,183.9				4,181.7			
BIC	4,296.0				4,284.7				4,278.0				4,275.8			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table III.5.: Estimation results KBBE call 2013 case for the variables *log experience* $positive_{count}$ and *log experience* $negative_{count}$, showing a high degree of positive correlation. Thus, it was decided to omit the latter one from the model. The same applies to the parameters *employee less* 250_{count} and *turnover less* 50_{count} in the case of the KBBE 2013 call, since both employment and turnover are quite interdependent. Due to the lower significance of the turnover, the variable *turnover less* 50_{count} was eliminated from the model. Additionally, the variables explaining the hypotheses ***H1*** and ***H2*** were separated into two different models, since the variables for both hypotheses caused further multicollinearity problems.

The findings for hypothesis ***H1*** differ, depending on the circumstances of the respective call. While the hypothesis is rejected for the *KBBE 2007 call*, the hypothesis is broadly supported from the results of the KBBE 2013 call in model (2b). Interestingly, the results confirm the broadly observed and often theorized pattern that the quality of interconnections counts more than the pure quantity of neighbors (Hagedoorn et al., 2006; Rosenkopf and Padula, 2008; Umlauf, 2014). This is expressed by the significant parameter values of the variables *group* $degree_{avg}$ and *group* $evcent_{sum}$. The value of the degree variable indicates a negative influence on the experts' evaluation score caused by each additional link maintained by the consortium. This highlights the circumstance that the maintenance of interconnections is a costly matter, which can exceed the benefit.[5] Contrastingly, the estimated parameter of the variable *group* $evcent_{sum}$ explains that what really matters is the relative importance of the group's neighborhood. Indeed, if the members of a consortium are partnered with organizations obtaining central positions within the network, why should this be more important than being linked to many, albeit unnecessary, organizations? The quality dimension possibly induces the observed core–periphery structure of the network since this entails the organization's strategy to partner with the most central organizations within the overall network, irrespective of their current centrality, even if they have already reached a central network position. Due to the problem of collinearity, the variable *group* $evcent_{sum}$ was removed from the model for the KBBE call 2007 (model 2b). However, this does not change the results regarding the insignificance of the variable *group* $degree_{avg}$ for the KBBE call 2007, which aimed to explore the transition between two consecutive FPs. The observation that both network measures are insignificant is surprising. It remains unclear whether the network formation breaks between consecutive funding programs or if this observation is caused by a selection bias since some compromises were made due to the manageability of the

[5] A quadratic influence of the variable *group* $degree_{avg}$ was also tested, but it was rejected, refusing a relation that follows an inverted U-shape.

network construction. Another possible explanation for this pattern would be if the Work Programmes for the respective calls differ in terms of their addressed thematic priority; but there were no indicators in the outline of the programs that support this point of view. In addition to that, it was checked whether differences occur between the thematic priorities of the sixth and seventh FP; however, the little differences seem to be negligible. Moreover, the group of experts that have evaluated the proposals of the sixth FP was not accessible. Maybe information above the organization's centrality gets lost when it comes to a radical break regarding the member of the expert group between consecutive FPs.

Similar observations were made concerning the role of the coordinator's centrality (***H2***). Two models (3a, 4a) were estimated for the KBBE call 2013, measuring the effect of the coordinator's network position. The finding that both centrality indicators of the coordinator's network position were found to be positive and significant might be caused by the fact that it was impossible to combine the variables into one single model, as the single model would run into the problem of multicollinearity. Otherwise, the explanatory power of the variable *coordinator degree* might have turned out to be insignificant or have a negative impact, as indicated by the model 1a, which is now possibly overestimated in model 3a, caused by the missing variable *coordinator evcent*. Nevertheless, the centrality of the consortium's coordinator is an important factor in terms of the experts' evaluation. Well connected coordinators can use their networking capabilities for the composition of a promising and well-shaped consortium, enabling the group to deliver a high quality proposal for the application process compared to others.

The support for the hypothesis ***H3*** is overwhelming. No estimated model questions the positive effect that originates from the group's internal connection resulting from previous collaborations. To a great extent, the group's performance depends on the pre-existing relationships among the members, explained by the subgroup's network density. Bilateral relations, ideally formed through personal contacts, entail a sphere of trust and familiarity among the project partners, which eases the exchange of tacit information and knowledge due to already established information channels and elaborated routines. In contrast to centrality, the group's internal connectivity survives the regime switch between two consecutive FPs since the variable *group connectivity*$_{share}$, based on the network of the sixth FP was able to explain the experts' prioritization within the seventh FP.

The influence of the consortium's size was found to be negative for the models of the KBBE call 2013 and insignificant in the case of KBBE call 2007. It seems that the coordination costs of large consortiums exceed the benefit of additional group members, due to the complexity of administrative efforts in larger groups.[6]

As theorized, the composition of nationalities represented within the applicant group affects the prioritization of the expert committee. The case of the Spanish organizations is an illustrative example. Compared to others, Spanish organizations were overrepresented within proposals for the KBBE call 2013, but they were underrepresented within the KBBE call 2007 (see Table III.3.). This observation is reflected by the estimators for the variable *country* es_{count}, counting the number of Spanish organizations within the respective call. Due to their overrepresentation in the first case, the impact of the variable was estimated to be negative for the KBBE call 2013 and positive for the KBBE call 2007. This tendency reflects the aim of the EU administration to consider a certain degree of balance between the member states. The parameter of the variable *thirdparty* $countries_{bool}$, explaining whether the consortium includes an international organization, was insignificant; thus, the internationalization of the program plays a secondary role or is carried out through the eligibility check.

Interestingly, the geographic distance, expressing the distance between the coordinator and the rest of the participants, has a positive but weak impact on the evaluation score, in the case of the KBBE call 2007. This is contradictory since proximity is usually a key driver for organizational collaboration (Broekel and Hartog, 2013; Ter Wal, 2013). This might reflect the circumstance that there is a political aim behind the prioritization process. Constructing the ERA, the administration might favor collaborations between distant organizations to enlarge the pan-European research network. Another possible explanation is that the geographic proximity was substituted through other factors, reducing the importance of being located close to each other, such as social proximity or previous experiences (Autant-Bernard et al., 2007; Paier and Scherngell, 2011).

Less surprisingly, consortia with a large amount of previous experience obtain higher evaluation scores. The overall significance of the variable *log experience* $positive_{count}$ proves that producing high quality proposals is an iterative learning process, triggered by a professionalization in writing submissions and preexisting communication channels to the administration. The more project or proposal submissions are accumulated by the members of the consortium over time, the better the result, as explained by the learning curve.

Most surprisingly, the number of publications has a negative impact on the experts'

[6] A digressive impact of the variable was tested within an alternative model, but it was found to be insignificant.

prioritization for the KBBE call 2013. It seems counterintuitive that the degree of academic expertise that is related to the biotech sector should not contribute to the quality of the proposal. A possible explanation might be that the large amount of publications leads to a concentration of academic actors within the consortium, which is unintended by the administration's policy since the EU tries to stimulate innovations by bringing different sets of actors together.

The awarded score value depends on the respective activity of the call for which an application has been submitted since the estimated parameters for variable *theme* II_{bool} were significant for both KBBE calls. The exact cause of this remains unclear since several effects come into question, such as a different composition of the expert group or higher requirements for the consortium.

The results for the variables measuring the size of the firm are diverging. For the KBBE call 2013, the variable *employee less* 250_{count} explains that a consortium benefits from each additional organization having less than 250 employees. This outcome likely reflects the fact that a large number of projects that were offered by the call in 2013 explicitly require that at last 15 percent of the total EU contribution go to SMEs.[7] The fact that the KBBE call 2007 does not contain an equivalent requirement for the applying consortia potentially leads to a change in the variable's influence. The absence of the SME requirement might induce a greater influence of economies of scale; thus, consortia with larger human resources were able to succeed against those consortia with a higher proportion of SMEs. The variable *turnover less* 50_{count} was found to have a positive influence in case of the *call KBBE 2007*, meaning that organizations with a rather low annual turnover raise the experts' evaluation score, which reduces the negative impact of the preceding variable, if the same organization falls under the definition of SMEs. If so, both effects nearly compensate for each other; thus, SMEs are seen as somewhat neutral within the KBBE call 2007.

The institutional background of the coordinator does not play a role for the observed calls. The explanatory power of the parameters *coordinator* $university_{bool}$ and *coordinator* $research_{bool}$, explaining the affiliation of the coordinator to the academic or research sector, was insignificant.

The share of the experts named in the list of appropriate persons has a great influence concerning the experts' evaluation scores for the KBBE call 2013. Theoretically, a proposal would receive a score value of nearly 100 percent if the composition of the

[7] An alternative model specification, using a variable explaining the number of organizations falling under the EU definition of an SME, was also tested, but the result was insignificant.

consortium consists completely of the expert group. However, the highest observed value of the variable $experts_{share}$ was 0.27; thus, this is only an intellectual game. As stated earlier, it remains mostly unclear what shapes this effect. Undoubtedly, the members of the expert group have rich expertise in the field of biotechnology. Thus, it is very likely that these persons are able to write high quality proposals. However, this might indicate the possibility of an existing conflict of interests, if personal relations within the group of experts have an influence on the decision-making process.

7. Conclusion

The aim of this paper was to analyze the factors that shape the formation of the pan-European research network. Therefore, the paper argues that the allocation mechanism of project grants is both affecting and affected by the formation of the research network. The allocation mechanism is a political process regulated by the EU administration, which is highly selective, and thus the resulting research network represents only one possible stage of endless alternatives. With each additional awarded project, the EC fosters the intended or unintended formation of the pan-European research network. In evaluating this outcome, several hypotheses were formulated, postulating that the project allocation is influenced by both the centrality of the consortium and coordinator within the overall research network, as well as by the group's internal network configuration. Therefore, the empirical part of this paper used micro data from two FP calls that were related to the biotechnology sector, representing 4,832 organizations in 881 proposals. Several OLS models were estimated to analyze the impact of the hypotheses on the experts' prioritization, which represents the Commission's basis of decision-making for project allocation. Hypothesis ***H1***, suggesting that the network centrality of the group and the coordinator affects the experts' assessments, was supported in the case of the *KBBE call 2013* but not in case of the *KBBE call 2007*. An explanation for this might be that centrality is not transmitted or forwarded between two consecutive FPs, since two different FP databases were used to construct the network for the respective calls. The idea behind this was to show that the network configuration is maintained between two different regimes, but the result does not support this point of view. The same applies to hypothesis ***H2***, investigating whether the centrality of the coordinator plays a role for the experts' evaluation procedure, which was found to be significant for the call in 2013, but insignificant for the call in 2007. The outward-looking perspective was complemented by the result of hypothesis ***H3***, which focused on the internal connectivity of the group's members. Interestingly, this last hypothesis was important for the formation of the network, as bilateral relations are stable even between two consecutive FPs. Nevertheless, both findings, the impact of the group's centrality and internal affiliation with the prioritization of the experts, induce a feedback link between the allocation mechanism and the formation of the network during the funding phase of a single FP. The awarded projects of the analyzed KBBE calls lead to a reconfiguration of the current network state and contribute, as a result of these additional impacts, to further project allocations.

The result that the impact of centrality does not transits between consecutive FPs was surprising. A possible explanation for this pattern might be a radical break between two different FPs, for example, in terms of the research objective or the staff composition of the expert committee. Another possibility is that those projects started in the final year of the preceding FP will continue operating even if the next program has already started, so that the same relations are shared across the FPs. To evaluate whether the same observation is true for technological fields other than the biotech sector, further investigations are needed for additional calls. Another interesting question would be whether the identified pattern has something in common with the Matthew Effect in social networks. The effect explains the formation of an oligopolistic network structure by small starting differences that accumulate over time into a winner-takes-it-all network formation, due to the preference of other actors in being tied to extraordinarily embedded organizations. This contributes to the following interpretation: small starting differences are secured between subsequent FPs by preexisting bilateral relations, which compromise the initial network formation and the first central organizations. Due to the preference of central actors, these initial advantages accumulate over time, ending in the formation of the oligopolistic network structure as observed by Breschi and Cusmano (2004). To buttress this presumption, further investigation is highly recommended for the empirical analysis to evaluate whether the impact of the network rises over time.

By facilitating a network that has oligopolistic patterns, the allocation process induces several risks in European innovation policy. Of course, a network requires some degree of clustering and closeness for an efficient transmission and production of knowledge, which is known as the small-word property of a research network (Watts and Strogatz, 1998). However, many repetitions of the same network patterns entail the risk of technological lock-ins and path dependencies, due to the homogenization of the knowledge, routines, and interests among a large fraction of the network. New incumbents are forced to the periphery of the network, from where it is difficult to get access to the promoters of new technologies. The displacement of diverse knowledge patterns decreases the chance for innovations, as heterogeneity is a key driver for both incremental and, especially, radical innovations. By this, the allocation process might counteract the political aim of the EC, which is stimulating the performance of the EU by helping develop new innovations. Additionally, the core–periphery network structure is likely to affect other networks, due to cross-effects between various coexisting networks, which might induce the transition of the same structure to non-target networks. This would be problematic and cause state failure, since there is no imperfection in the market mechanisms that would possibly legitimize governmental intervention.

It sounds less problematic if the oligopolistic structure of the research network is unable to transit between two consecutive FPs. If so, this would ensure that in the case of a transition, the core–periphery structure becomes broken so that there is a new round in the race for the most central positions within the network. However, the duration of the FPs has continuously risen in the past, which can indeed become a problem, since grater durations help to prevent the oligopolistic formation of the network.

To soften the automatism that seems to increase the advantage of central and well-connected organizations within a funding phase, the European Commission could modify the allocation process of forthcoming project calls. That could be, for example, a wildcard for an organization that shows great potential, or financial pre-submission contributions that mitigate the risk in an application. Another possibility would be that consortia have to meet a threshold, which requires that a certain amount of the funding goes to less connected organizations, similar to the basic requirement that allocates at least 15 percent of the funding to SMEs. Any of these suggestions can contribute to political decryption of the allocation process that mostly favors central organizations.

Further research is needed, since the results of this paper only rely on two selected calls of the seventh FP, and it is questionable whether the same applies to sectors other than the biotech industry. The selection of the *KBBE call 2007* might have induced several insignificant parameters of the estimated model, since the observed variance of the score values was rather low, compared to the *KBBE call 2013*. Another interesting question might be how the allocation of the projects and the resulting network would look without the influence of the network effects. Knowing the impact of the network-related determinants, it becomes possible to approximate an alternative setting of the network formation one shaped only by non-network-related determinants. The results could help to identity alternative outcomes of the European innovation policy.

Bibliography

Ahuja, G., G. Soda, and A. Zaheer (2012). 'The Genesis and Dynamics of Organizational Networks'. In: *Organization Science* 23.2, pp. 434–448.

Aschhoff, B. and T. Schmidt (2008). 'Empirical Evidence on the Success of R&D Cooperation – Happy Together?' In: *Review of Industrial Organization* 33.1, pp. 41–62.

Aschhoff, B. (2009). 'Who gets the money? - The dynamics of R&D project subsidies in Germany'. In: *ZEW - Centre for European Economic Research Discussion Paper* 08–018.

Autant-Bernard, C., P. Billand, D. Frachisse, and N. Massard (2007). 'Social distance versus spatial distance in R&D cooperation: Empirical evidence from European collaboration choices in micro and nanotechnologies'. In: *Papers in Regional Science* 86.3, pp. 495–519.

Barajas, A. and E. Huergo (2010). 'International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms'. In: *Economics of Innovation and New Technology* 19, pp. 87–111.

Blanes, J. V. and I. Busom (2004). 'Who participates in R&D subsidy programs?: The case of Spanish manufacturing firms'. In: *Research Policy* 33.10, pp. 1459–1476.

Bonacich, P. (1987). 'Power and Centrality: A Family of Measures'. In: *American Journal of Sociology* 92.5, pp. 1170–1182.

Boschma, R. (2005). 'Proximity and Innovation: A Critical Assessment'. In: *Regional Studies* 39.1, pp. 61–74.

Breschi, S. and L. Cusmano (2004). 'Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes'. In: *International Journal of Technology Management* 27, pp. 747–772.

Brockhoff, K., A. K. Gupta, and C. Rotering (1991). 'Inter-firm R&D co-operations in Germany'. In: *Technovation* 11.4, pp. 219–229.

Broekel, T. and M. Hartog (2013). 'Explaining the Structure of Inter-Organizational Networks using Exponential Random Graph Models'. In: *Industry & Innovation* 20.3, pp. 277–295.

Brusoni, S., A. Prencipe, and K. Pavitt (2001). 'Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make?' In: *Administrative Science Quarterly* 46.4, pp. 597–621.

Cantner, U. and S. Kösters (2009). *Picking the winner? Empirical evidence on the targeting of R&D subsidies to start-ups*. Jena Economic Research Papers 93. Friedrich Schiller Universität Jena.

Cavusgil, S. T., R. J. Calantone, and Y. Zhao (2003). 'Tacit knowledge transfer and firm innovation capability'. In: *Journal of Business & Industrial Marketing* 18.1, pp. 6–21.

Coase, R. H. (1937). 'The Nature of the Firm'. In: *Economica* 4.16, pp. 386–405.

Cowan, R. and N. Jonard (2004). 'Network structure and the diffusion of knowledge'. In: *Journal of Economic Dynamics and Control* 28.8, pp. 1557–1575.

De Stefano, D. and S. Zaccarin (2013). 'Modelling Multiple Interactions in Science and Technology Networks'. In: *Industry & Innovation* 20.3, pp. 221–240.

Delanghe, H., B. Sloan, and U. Muldur (2009). 'European Science and Technology Policy: Towards Integration or Fragmentation?' In: ed. by H. Delanghe, U. Muldur, and L. Soete. Edward Elgar Publishing. Chap. Transnational collaboration in pubilc research funding and publicly supported research in Europe, pp. 175–188.

Duysters, G. and L. Charmianne (2003). 'Alliance Group Formation Enabling and Constraining Effects of Embeddedness and Social Capital in Strategic Technology Alliance Networks'. In: *International Studies of Management and Organization* 33.2, pp. 49–68.

EU (2006). *The new SME definition – User guide and model declaration*. Ed. by E. Commission. Publications Office.

– (2007). *Cooperation Work Programme 2007*. EU Commission.

– (2011). *Decision 4617/2008 - Related to the rules for proposals submission, evaluation, selection and award procedures for indirect actions under the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013) and under the Seventh Framework Programme of the European Atomic Energy Community (Euratom) for nuclear research and training activities (2007-2011)*. EU.

– (2013). *Cooperation Work Programme 2013*. EU Commission.

Freeman, C. (1991). 'Networks of innovators: A synthesis of research issues'. In: *Research Policy* 20.5, pp. 499–514.

Granovetter, M. (1985). 'Economic Action and Social Structure: The Problem of Embeddedness'. In: *American Journal of Sociology* 91.3, pp. 481–510.

Hagedoorn, J., N. Roijakkers, and H. Van Kranenburg (2006). 'Inter-Firm R&D Networks: the Importance of Strategic Network Capabilities for High-Tech Partnership Formation'. In: *British Journal of Management* 17.1, pp. 39–53.

Hazir, C. S. and C. Autant-Bernard (2012). *Using Affiliation Networks to Study the Determinants of Multilateral Research Cooperation Some empirical evidence from EU Framework Programs in biotechnology.* Tech. rep. Groupe d'analyse et de théorie économique (GATE).

Hippel, E. von (1988). *The Sources of Innovation.* MIT Press.

Hoekman, J., T. Scherngell, K. Frenken, and R. Tijssen (2013). 'Acquisition of European research funds and its effect on international scientific collaboration'. In: *Journal of Economic Geography* 13.1, pp. 23–52.

Jackson, M. O. (2008). *Social and Economic Networks.* Princeton University Press.

Kogut, B. and U. Zander (1992). 'Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology'. In: *Organization Science* 3.3, pp. 383–397.

Larson, A. (1992). 'Network Dyads in Entrepreneurial Settings: A Study of the Governance of Exchange Relationships'. In: *Administrative Science Quarterly* 37.1, pp. 76–104.

Levinthal, D. A. and M. Fichman (1988). 'Dynamics of Interorganizational Attachments: Auditor-Client Relationships'. In: *Administrative Science Quarterly* 33, pp. 345–369.

Lundvall, B. (1988). 'Technical Change and Economic theory'. In: *Technical Change and Economic theory.* Ed. by Dosi, G. et. al. (eds.) Pinter. Chap. Innovation as an Interactive Process: From User Producer Interaction to National systems of Innovation.

Mora-Valentin, E. M., A. Montoro-Sanchez, and L. A. Guerras-Martin (2004). 'Determining factors in the success of R&D cooperative agreements between firms and research organizations'. In: *Research Policy* 33.1, pp. 17–40.

Nooteboom, B. (2000). *Inter-firm Alliances: Analysis and Design.* Reprinted. London, New York: Routledge.

Paier, M. and T. Scherngell (2011). 'Determinants of Collaboration in European R&D Networks: Empirical Evidence from a Discrete Choice Model'. In: *Industry and Innovation* 18.1, pp. 89–104.

Ponds, R., F. Van Oort, and K. Frenken (2007). 'The geographical and institutional proximity of research collaboration'. In: *Papers in Regional Science* 86.3, pp. 423–443.

Powell, W. W., K. W. Koput, and L. Smith-Doerr (1996). 'Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology'. In: *Administrative Science Quarterly* 41.1, pp. 116–145.

Roediger-Schluga, T. and M. J. Barber (2006). *The structure of R&D collaboration networks in the European Framework Programmes.* Tech. rep. United Nations University - Maastricht Economic et al.

Rosenkopf, L. and G. Padula (2008). 'Investigating the Microstructure of Network Evolution: Alliance Formation in the Mobile Communications Industry'. In: *Organization Science* 19.5, pp. 669–687.

Tanayama, T. (2009). *Rationales and reality of R&D subsidies: Are SMEs and large firms treated differently?* Helsinki Center of Economic Research - Discussion Papers. Helsinki School of Economics and HECER.

Ter Wal, A. L. J. (2013). 'The dynamics of the inventor network in German biotechnology: geographic proximity versus triadic closure'. In: *Journal of Economic Geography.*

Umlauf, F. (2014). *Network Determinants of a Collaborative Funding System: The Case of the German Innovation Policy.* Papers on Economics and Evolution. Centre for Regional and Innovation Economics.

Uzzi, B. (1996). 'The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect'. In: *American Sociological Review* 61.4, pp. 674–698.

– (1997). 'Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness'. In: *Administrative Science Quarterly* 42.1, pp. 35–67.

Walker, G., B. Kogut, and W. Shan (1997). 'Social Capital, Structural Holes and the Formation of an Industry Network'. In: *Organization Science* 8.2, pp. 109–125.

Wallsten, S. J. (2000). 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program'. In: *The RAND Journal of Economics* 31.1, pp. 82–100.

Watts, D. J. and S. H. Strogatz (1998). 'Collective dynamics of 'small-world'networks'. In: *Nature* 393.6684, pp. 440–442.

Williamson, O. E. (1981). 'The Economics of Organization: The Transaction Cost Approach'. In: *American Journal of Sociology* 87.3, pp. 548–577.

Yelle, L. E. (1979). 'The learning curve: Historical review and comprehensive survey'. In: *Decision Sciences* 10.2, pp. 302–328.

IV. Network determinants of a collaborative funding system: the case of the German innovation policy

1. Introduction

Since the 1980s, the innovation policy of Germany and other industrialized countries developed toward an increased importance of government-funded research joint ventures (Fier and Harhoff, 2002; Eickelpasch and Fritsch, 2005). Triggered by the awareness of the innovation-stimulating nature of cooperative research activities – because of, for example, knowledge spillovers, resource pooling, or risk sharing (Levinthal and March, 1993; Gulati and Gargiulo, 1999) – most of Germany's publicly sponsored research projects inherently integrate collaborative elements. What is new about this policy is that no longer can a single organization apply for such a collaborative funding award, but rather a whole consortium. During the project-implementation phase, organizations have to collaborate within the scope of the project as well as to give access to their knowledge and to the outcome at the end of the project (Broekel and Graf, 2012). Because of the huge number of joint projects that intertwined thousands of organizations, a complex network has evolved, which is determined by policy-driven rules and organizational behaviors. There is a rich literature on the dynamics of organization networks (Ter Wal, 2009; Broekel and Graf, 2012; Balland, 2012; Hazir and Autant-Bernard, 2012) and policy implications (Aschhoff and Schmidt, 2008; Barajas and Huergo, 2010) that drive the evolution of such a complex system, but interestingly less is known about the way both sources of change are related to one another.

This becomes even more problematic since the government has had to comply with EU-wide regulatory standards preventing distortions to the market, such as reducing incentives to innovate, promoting existing market power, or a cross-subsidization of poorly performing enterprises. To some extent, the innovation policy of the German federal government anticipates the possibility of such a failure, since financial support is only granted for a certain period of time (BMBF, 2012). But the idea of strict regulation is misleading, since there is no upper bound regarding the number of projects an organization be awarded consecutively or in parallel. There is no doubt that governmental innovation policy dominates the funding regime to a high degree, but there are some concerns that the regime is highly affected by its own self-enforced mechanisms that potentially induces unintended feedback loops and distortions to the market.

The purpose of this paper is to analyze the extent to which the dynamics of the system are influenced by its own structural patterns. Therefore, the next section gives a systematic overview of the allocation mechanism of a project grant. The third section presents some hypotheses, exploring the dependency of the funding system on network-related determinants. The fourth section describes the empirical background of the paper. The fifth section introduces the model and the employed data for the model estimation. Section six discusses the results of the estimated models. The final section summarizes the outcome of the paper and gives an outlook on further research questions.

2. The allocation mechanism of a project grant

Since the allocation of a project grant is a long-term process, it is necessary to analyze the overall decision-making process in detail (see Figure IV.1.). For the purpose of the following analysis, it is useful to split the process into single steps: the "Eligibility", "Awareness", "Application", "Acceptance", and "Execution" of a project grant (Tanayama, 2007; Keese et al., 2012). While the government regulates whether or not organization is eligible for an application, it is the organization itself that decides to seek a contribution and, moreover, to apply for a project grant. The granting of the promotion is the responsibility of the administration. At the end of the process, the organization ultimately decides whether to start the project or not. Within these steps, a lot of influences affect the decision-making process.

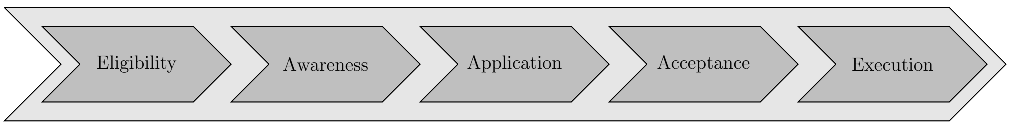


Figure IV.1.: Decision-making process

2.1. Eligibility of the organization

The administration checks the eligibility of an organization on the basis of a criteria catalog. On this account, it may be necessary to belong to a specific target group of addressed organizations. Some of these criteria might be strong enough to have an impact on the occurrence of differing organizations. An illustrative example might be the "Central SME Innovation Programme" (ZIM) of the German government, which explicitly aims to allocate a large amount of the finical budget to small- and medium-sized enterprises (SMEs) (Brautzsch et al., 2015), thus SMEs may be overrepresented within the funding system. Another example is the "InnoRegio" program, which was specifically designed for the eastern states of Germany (Eickelpasch and Fritsch, 2005); it becomes possible that therefore organizations of eastern Germany have a higher probability of being represented within the system. Even the sectoral affiliation of an organization possibly has an effect, since some programs are restricted to specific technologies or industries. Furthermore, the awarding of a cooperative project grant requires that a group of organizations applies jointly for a project grant (Eickelpasch and Fritsch, 2005). So, without being a member of a consortium, an organization has no chance to obtain a cooperative contribution.

2.2. Awareness of the funding programs

Without the awareness of a funding opportunity, no single organization would apply for a project grant (Heckman and Smith, 2003) and the decision to seek funding can only be taken by the organization itself. However, several additional factors have to be considered. First of all, the government could support the visibility of the program by providing information about the funding programs (Tanayama, 2007). Secondly, an organization can benefit from previous project applications (Aschhoff, 2009), as monitoring is costly process which becomes more efficient in case of preexisting information channels between applicants and administrations are preexisting and routines to seek information are already trained (Nelson, 1982). Additionally, previous project acquisitions promote both the prominence of the organization in administrative circles as well as the familiarity with administrative procedures.

2.3. Project application

The decision of an organization whether or not to apply for a governmental project grant takes into account the expected costs and benefits of the potential project (Tanayama, 2007). Therefore, the organization has to consider the financial aspects of the project grant, but also the additional utility of a cooperative project that stimulates the probability of innovation (Czarnitzki and Fier, 2003; Fornahl, Broekel, et al., 2011) due to, for example, knowledge spillovers, risk sharing, or economies of scale (Levinthal and March, 1993; Powell et al., 1996; Gulati and Gargiulo, 1999). The more the expected profit exceeds the expected costs, the more attractive the project application becomes. A general problem for this consideration is that the costs of a project cannot be completely specified before the project has come to an end. This is even more evident for cooperative projects, since incomplete contracts entail the possibility of opportunistic behavior among partners (Eickelpasch and Fritsch, 2005). The application requires the formulation of a project proposal, which is a time consuming process, since the requested information must be prepared, and each organization has to justify their financial requirements (Tanayama, 2007; Eickelpasch and Fritsch, 2005). Moreover, detailed reports have to be submitted during and at the end of the funding phase.

2.4. Project acceptance

A jury of experts, consisting of administrative members or other external professionals, has to decide whether to award a financial contribution or to reject the application. Thus, additional effects come into account affecting the decision-making process. The legitimacy of R&D subsidies is always in question, since governmental interventions could lead to unintended distortions to the market mechanism. This places a certain pressure on the government. If too many projects are canceled or fail during the implementation phase, the impression of government failure could arise. Since projects always run the risk of failure, the committee of experts could systematically tend to select a previously successful organization or consortium with the aim minimizing the likelihood of an abandonment – known as the "picking-the-winner" strategy (Wallsten, 2000; Blanes and Busom, 2004; Colombo et al., 2007; Cantner and Kösters, 2009).

2.5. Project execution

The project execution is the ultimate phase of the decision-making process. By the start of the project prior expectations become concrete. During the phase of implementation the organization benefits from knowledge accumulation and, in case of an additional cooperative project, from knowledge spillovers.

3. Hypotheses

The previous section has discussed how the allocation process is affected by various circumstances. Based on these preliminary considerations, some hypotheses are formulated to evaluate whether the German dynamics of the funding regime are affected by network-related determinants.

The discussion of the decision-making process highlighted the importance of previous project experiences for the allocation mechanism of a project grant. However, it remains unclear which experiences are relevant for the application process. Various researchers emphasized the importance of a rich expertise with the formal procedure of the application process (Tanayama, 2007; Aschhoff and Schmidt, 2008; Bannò and Sgobbi, 2010), but neglected the role of cooperative experiences. Following Ahuja et al. (2012), these cooperative experiences are manifested in network relationships, thus it is possible to measure the cooperative experience of an organization using the methodology of social network analysis (Wasserman and Pattison, 1996).

Relationships serve as preexisting communication channels that possibly cause an information advantage to organizations without prior cooperative experiences (Gould and Fernandez, 1989; Burt, 2000). Thus, with each additional connection, an organization becomes increasingly visible to others. By this, it becomes more likely for an organization to obtain an additional project in the long run, if the organization joins a consortium that applies collectively for a cooperative project. Furthermore, having previous cooperations with other organizations signals trust and credibility to potential partners (Granovetter, 1985; Uzzi, 1996; Mora-Valentin et al., 2004). As the monitoring of project partners is a costly and time–consuming process, other organizations could tend to prefer to collaborate with firms they already know. This would entail an area of mutual trust, and is well known as a promotion for the exchange of information and tacit knowledge (Kogut and Zander, 1992; Cavusgil et al., 2003), which is highly important for research partnerships especially in high-tech sectors (Hippel, 1988). These presumptions are concentrated into the first and second hypotheses.

The first hypothesis states rather conservatively whether a new project grant is more likely to be accepted because of the participation within a joint project.

> ***H1:*** The participation of an organization in a joint project raises the probability of the organization receiving a new project grant.

The second hypothesis is similar to the first but goes into more detail in terms of the quantity and quality of the relationships. It states that the position of the organization within the network positively affects the chance of obtaining an additional project grant.

> ***H2:*** The better the position of an organization within the network, the more likely an organization is to receive a new project grant.

High priority should be given to the organization's ability to absorb circulating knowledge flows available from external knowledge spillovers (Cohen and Levinthal, 1990). Within a complex economy, knowledge is dispersed among different organizations (Brusoni et al., 2001); thus, it becomes urgent to bring different skills together. This is why the last hypothesis concentrates on the argument that the heterogeneity of the knowledge base to which an organization has access, stimulates the chance to obtain a further project grant, since the success of R&D depends to a large extent on the recombination of diverse and complementary capabilities (Boschma, 2005; Nooteboom, 2000).

Therefore, a diversified knowledge pool should be both an advantage for the respective organizations and a benefit for the rest of the potential cooperation partners, since knowledge heterogeneity is known to be a promising driver of innovation (Mowery et al., 1998; Boschma and Frenken, 2009; Fornahl, Broekel, et al., 2011). If an organization is surrounded in the network by partners with close cognitive proximity, organizations may exchange too much redundant information, thus the initiation of a creative process might be harmed. In contrast, less cognitive proximity complicates the exchange of information (Nooteboom et al., 2007) if the knowledge of the counterparts is incompatible. Mowery et al. (1998) found evidence for an inverted U-shaped interrelation between the likelihood to cooperate and the cognitive proximity, so that a pair of organizations is more likely to cooperate owing to their promising heterogeneous knowledge structure.[1]

Therefore, the third hypothesis states that an organization has a higher probability of obtaining another project grant when the organization has a certain degree of heterogeneity within its direct neighborhood.

> ***H3:*** The better the access to heterogeneous knowledge, the more likely an organization is to receive a new project grant.

[1]Networks that are subsidized by the government represents only a rather small fraction of organizations' embeddedness in knowledge networks, but it is assumed that the observed subsidized network approximates realistically the organizations' general knowledge environment.

4. Empirical background

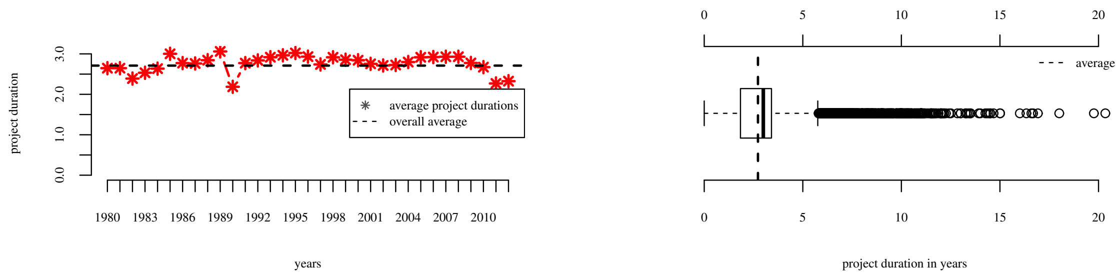
4.1. Data

The empirical analysis of the German direct-funding system employes the "Förderkatalog", which is a publicly available database that contains all funded projects of the federal government. Reporting ministries are: the Federal Ministry of Education and Research (BMBF); the Federal Ministry of Economics and Technology (BMWi); the Federal Ministry of Transport, Building and Urban Development (BMVBS); and the Federal Ministry for the Environment (BMU). The database reaches back to the late 1960s and includes more than 152,000 projects until the end of 2012. Each entry reports the name of the organization which received funding, co-funded organizations, the location of the organization, the amount of funding, the duration of funding, the project's task and a classification number concerning the project's technological affiliation. In line with Broekel and Graf (2012), we assume an intensive knowledge exchange through cooperative research efforts among the participants of joint projects. Organizations that obtain a public grant accepted the requirement to give every partner unrestricted access to the outcome of the project and fee-free usage of its know-how and intellectual property rights. The selected entries of the database are restricted to those projects dealing with "technology and innovations," "research and development" and "basic research," to exclude irrelevant projects such as "non R&D related expenditures on education".

4.2. Individual approach

There is no official regulation that limits the duration time or the number of projects an organization is allowed to have in parallel or subsequently. However, there are some informal patterns that can be identified. Therefore, the time span between the beginning and end of each project was averaged since 1980 for each respective year (Figure IV.2(a)). The average varies around the overall mean value of 2.7 years. The approximately constant variance of the average indicates the absence of major structural breaks among the years, but the idea of a constant project duration is misleading (Figure IV.2(b)). The percentile values of $p_{0.25} = 1.838$ and $p_{0.75} = 3.411$ indicate some hidden variance behind the mean value, thus remarkable inequalities regarding the treatment of projects should not be ignored.

Figure IV.3(a) addresses this question by controlling for the organization's number of projects for several distinct years (1990, 2000, 2005, and 2012). It is normal for



(a) Average duration of projects

(b) Boxplot of project durations

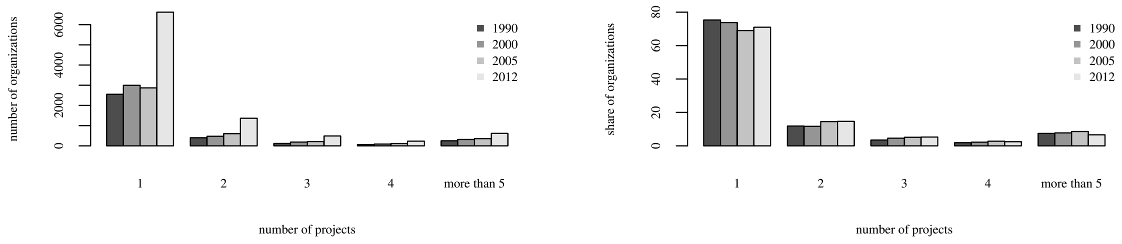
Figure IV.2.: Project durations since 1980

Source: Förderkatalog of the German federal government

an organization to obtain just a single project, but there are some organizations that obtained two or even more subsidized projects at the same time. Furthermore, Figure IV.3(a) indicates a growing number of subsidized projects and organizations every year. The number of funded projects increased tremendously (4,100) between 2005 and 2012. At the same time, the distribution of organizations that have received a grant for one, two, three, four, or even more projects is unaffected (Figure IV.3(b)). If an organization is funded, the probability of being funded for exactly one single project equals 70 percent. The others are supported by more than one project, whereas approximately 10 percent of all organizations have more than four projects in parallel. Over the years, there is a tendency towards more projects per organization, as the share of organizations with a single project decreases over time.

4.3. Aggregated approach

This section shifts the focal point toward an aggregated perspective of the Germany funding system, understanding the totality of all projects as a complex and involving system shaped by the organizations that enter, stay in, or quit the system. Organizations with a current funding represent the system's stock of organizations. The system grows or shrinks due to continuously entering or quitting organizations (Figure IV.4). If an unfunded organization obtains a contribution, the organization enters the funding system, and leaves the system again if the funding comes to an end and there is no other ongoing project. The number of organizations that enter, quit, or stay within the system (Table IV.1) shapes the overall structure of the funding system. If more organizations



(a) Number of projects (b) Relative share

Figure IV.3.: Projects per organization

Source: Förderkatalog of the German federal government

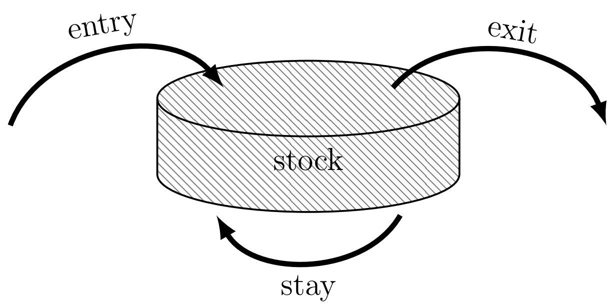


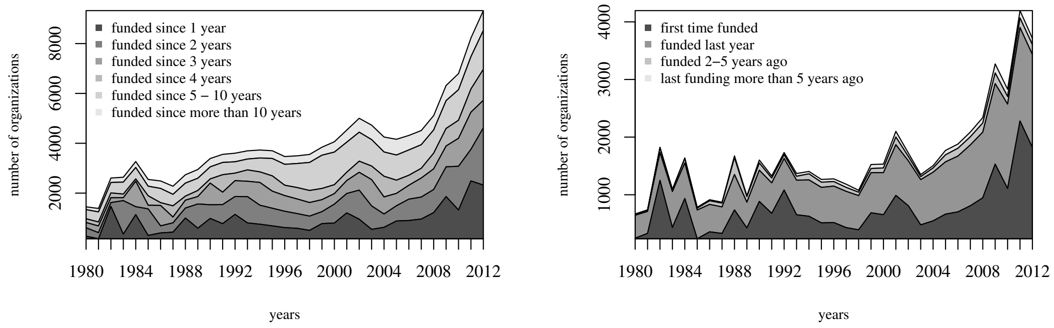
Figure IV.4.: Dynamics within the funding regime

Source: Förderkatalog of the German federal government

flow/years	2005	2006	2007	2008	2009	2010	2011	2012
+ entry	882	901	961	1,217	1,862	1,322	2,489	2,323
+ stay	3,278	3,414	3,550	3,896	4,457	5,474	5,734	7,000
- exit	973	746	765	615	656	845	1,062	1,223
= stock	4,160	4,315	4,511	5,113	6,319	6,796	8,223	9,323

Until FP6 adapted from Roediger-Schluga and Barber (2006). EURATOM projectes are excluded from the table.

Table IV.1.: Stock changes within the funding system between 2005 and 2012



(a) Length of stay (b) Duration since last funding

Figure IV.5.: Persistence of organizations within the funding system

are entering than leaving, the system is expanding; whereas, in the reverse case, the system is shrinking. In recent years there was a dynamic of entering organizations (Table IV.1). Between 2005 and 2012, the number of organizations within the system doubled from 4,160 in 2005 to 9,323 in 2012 and the stock of organizations grew by about 5,163.

The amount of organizations staying within the system indicates a strong persistence of once-funded organizations. In 2010, for example, 5,474 organizations stayed in the funding system (Figure IV.5(a)), whereas approximately one third of them received funding for more than five years. Organizations with a newly funded project are mostly organizations which have previously received funding (Figure IV.5(b)). In 2010, 2,831 organizations obtained at least one additional project, and, of those, 61 percent (1,723) had an earlier contribution, while the others received their first funding. Thus, if an organization is already present within the system, the probability of obtaining additional funding increases significantly.

5. Model

5.1. Methodology

The analysis employs a model which was initially published by Gourieroux (2000). The same approach was applied by various other authors (Nguyen Van et al., 2004; Fryges, 2007; Aschhoff and Schmidt, 2008), whereas this paper aims to estimate the effect of an organization's characteristics to the dynamic of the funding system. The model approximates the dynamic of the system by a series of Markov chains, where each transition–

probability depends the characteristics of an organization. Through the application of a maximum-likelihood estimation, it is possible to check whether network-related as well as other determinants have an impact the actual status of an organization.

Some definitions have to be made for the model. An organization $i = \{1, .., N\}$ at time point t can have the status $Y_{it} = \{0, 1\}$, whereas $Y_{it} = 1$ describes the status in which organization i obtains a new project grant. Correspondingly, $Y_{it} = 0$ describes the situation in which organization i remains without a newly funded project (Gourieroux, 2000; Aschhoff and Schmidt, 2008), thus the occurrence of $Y_{it} = 1$ depends on how often an organization acquires a new project over time $t = \{0, ..., T\}$. The reason to consider only time point t is because the decision to award a project is taken only once by the committee and not continuously over time. Four possible combinations of transitions can be distinguished. If an organization changes its actual status, the organization switches either from unsubsidized to subsidized $(0 \rightarrow 1)$ or from subsidized to unsubsidized $(1 \rightarrow 0)$. If the current status remains, the organization preserves its unsubsidized status $(0 \rightarrow 0)$ or obtains a further promotion $(1 \rightarrow 1)$. Therefore, it is necessary to know the transition matrix M_i for each organization i, whereas each value reflects the likelihood of an organization changing its present status into the next state. The transition–probability of an organization from the status j at t into state $j^{'}$ at $t + 1$ is explained by the probability $P_{ijj'}$. Since the Markov process is independent from its previous stages, the actual transition only depends on current time (Chiang and Wainwright, 2005).

$$\mathbf{M}_i = \begin{bmatrix} P_{i00} & P_{i01} \\ P_{i10} & P_{i11} \end{bmatrix} \tag{IV.1}$$

The rows of a transition matrix add up to 1, so $P_{i00} + P_{i01} = 1$ and $P_{i10} + P_{i11} = 1$. Simple transformations lead to Equation IV.2.

$$\mathbf{M}_i = \begin{bmatrix} 1 - P_{i01} & P_{i01} \\ 1 - P_{i11} & P_{i11} \end{bmatrix} \tag{IV.2}$$

The substitution reduces the number of unknowns within the matrix $\mathbf{M}_i$. The variables P_{i01} and P_{i11} represent the likelihood of an organization changing its actual status from $0 \rightarrow 1$ and $1 \rightarrow 1$, respectively. Using logistic regression techniques, it is possible to analyze whether the probabilities are determined by organizational characteristics

(Gourieroux, 2000).

$$P_{ijj'}(t+1) \equiv P(Y_{it+1} = j^{'} | Y_{it} = j) = \frac{\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{jj'}\right)}{\sum_{j'=0}^{1}\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{jj'}\right)} \tag{IV.3}$$

Therefore, it is necessary to implement the probability $P_{ijj'}$ into a logit model (Stock and Watson, 2007; Greene, 2002). The vector $\mathbf{x}_{it} = (1, x_{it_1}, x_{it_2}, \ldots, x_{it_p})$ contains a regression constant and several specific characteristics of the organization i. The impact of the variables on the transition-probability $P_{ijj'}$ is captured by the vector $\boldsymbol{\beta} = (\beta_0, \beta_1, \ldots, \beta_p)$. Inserting $\beta_{j0} = 0$ and $j^{'} = 0, 1$ into Equation (IV.3) leads to:

$$P_{ij1}(t+1) = \frac{\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{j1}\right)}{1 + \exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{j1}\right)}. \tag{IV.4}$$

Substituting Equation (IV.4) into $P_{ij0} = 1 - P_{ij1}$ constitutes, after several transformations:

$$P_{ij0}(t+1) = \frac{1}{1 + \exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{j1}\right)}. \tag{IV.5}$$

Inserting Equations (IV.4) and (IV.5) into the transition matrix leads to:

$$\mathbf{M}_i = \begin{bmatrix} \frac{1}{1+\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{01}\right)} & \frac{\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{01}\right)}{1+\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{01}\right)} \\ \\ \frac{1}{1+\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{11}\right)} & \frac{\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{11}\right)}{1+\exp\left(\mathbf{x}_{it+1}\boldsymbol{\beta}_{11}\right)} \end{bmatrix} \tag{IV.6}$$

The vectors $\boldsymbol{\beta}_{11}$ and $\boldsymbol{\beta}_{01}$ can be estimated by the application of the maximum-likelihood method (Gourieroux, 2000) (Equation IV.7). Each organization i can choose one of four possible statuses between time points t and $t+1$. Therefore, $n_{i,t,t+1}(jj^{'})$ equals 1 for organization i if an organization changes its status between t and $t+1$ from j to $j^{'}$ and 0 otherwise.

$$\ln L = \sum_{j=0}^{1}\sum_{j'=0}^{1} \ln L_{jj'} \text{with} \ln L_{jj'} = \sum_{i=0}^{N}\sum_{t=0}^{T} n_{i,t,t+1}(jj^{'}) \ln Pij^{'}(t+1). \tag{IV.7}$$

Variable vectors $\boldsymbol{\beta}_{01}$ and $\boldsymbol{\beta}_{11}$ are endogenous within the log-likelihood function. Their choice determines the values $\sum_{j'=0}^{1} \ln L_{0j'}$ and $\sum_{j'=0}^{1} \ln L_{1j'}$. Since both depend on the choice of $\boldsymbol{\beta}_{01}$ and $\boldsymbol{\beta}_{11}$, it is possible to divide the log-likelihood function into two independent parts (see Equation IV.8), so that if $\sum_{j'=0}^{1} \ln L_{0j'}$ and $\sum_{j'=0}^{1} \ln L_{1j'}$ reach their individual maximum, the log-likelihood function is maximized. By this, the model equals two binary choice models, one estimating the influences on the transition-probability between event I and II, and the other between event III and IV, respectively. The maximization of the log-likelihood function is carried out by the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm.

$$\ln L = \sum_{j'=0}^{1} \ln L_{0j'} + \sum_{j'=0}^{1} \ln L_{1j'} \tag{IV.8}$$

An alternative approach model using fixed effects was considered. However, this method would not be capable estimating the parameter for the different states, since such a model only includes a single dummy variable for each respective case, so that an alternative method was applied.

5.2. Employed data

Within the empirical model, exogenous variables are used to explain the dynamic of the funding system. The estimation employs a database containing 88,758 firms of the manufacturing sector.[2] In addition to the name and the industrial affiliation of an enterprise, the database includes the annual turnover, the number of employees, the founding year, and the geographical location of the German headquarter. Due to incomplete data it was necessary to excluded 5,966 firms from the estimation. A matching procedure identified that 2,954 of the enterprises have obtained a project grant.[3]

The model includes 248,376 profiles of firms between the years 2009 and 2012, of which 244,176 belong to firms have never received a project grant (*event I*, $0 \rightarrow 0$).[4] Firms

[2]Section C of the WZ-2008, see Destatis (2008).

[3]In the case of the "Förderkatalog", the entry "Zuwendungsempfänger" is used, naming the organization which receives the project grant.

[4]King and Zeng, 2001 warns of possible errors within the parameters if one of the events occurs quite seldom. Since the event of no change ($0 \rightarrow 0$) occurs more frequently than all the other cases, this could lead to distortions of the estimated parameters $\hat{\beta}_{11}$ and $\hat{\beta}_{01}$. To exclude this failure, the models were estimated by once again applying an alternative method, using the method proposed by King and Zeng (2001). Since the results of both estimation procedures are very close, it does

without previous project grants were newly funded in 1,727 situations (*event II*, $0 \rightarrow 1$, see Figure IV.6), while in 1,873 cases firms did not obtain further funding (*event III*, $1 \rightarrow 0$). A further grant was awarded in two consecutive years exactly 600 times (*event IV*, $1 \rightarrow 1$). Using these occurrences, it is possible to calculate the event probabilities in order to construct the transition matrix (Equation IV.9).[5]

$$\mathbf{M}_{Dynamik} = \begin{bmatrix} 244,176 & 1,727 \\ 1,873 & 600 \end{bmatrix} = \begin{bmatrix} 0.993 & 0.007 \\ 0.757 & 0.243 \end{bmatrix} = \begin{bmatrix} event\ I & event\ II \\ event\ III & event\ IV \end{bmatrix} \quad \text{(IV.9)}$$

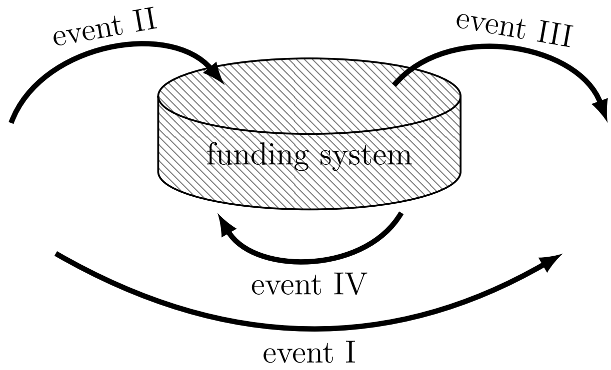


Figure IV.6.: Events of the model

5.3. Network construction

The network is constructed on the basis of the project database, including all organizations of the funding system, such as firms, research centers, and universities.[6] The

not matter, for the interpretation of the results, if the standard model is used in the following. The estimation algorithm of the alternative model is published by Imai et al. (2008) and included in the *Zelig* package for the statistical software package R.

[5] Alternatively, a model specification was considered, in which not only the receipt of a new funding project causes a status change. Within the alternative model, a firm also stays within the funded status (*event IV*) if the duration of the project funding was granted for more than one year, so that *event III* only occurs when all projects of a company have expired. Since the results of the alternative model neither reject nor support the hypotheses, the estimated model results are omitted within the scope of this paper. The results differ, because within the alternative model the network positions of the most firms start to degenerate on the first day after of the project's initiation. While most firms obtain a project grant for a single time and do not change their neighbors in the subsequent years, the overall network keeps on evolving, so that older network structures become less important and migrate to the periphery of the network.

[6] In order to distinguish collaborations between companies and departments of the Fraunhofer Society, the Leibniz Association, the Helmholtz Association or Max Planck Society, the departments are

network of year t includes newly funded projects as well as continued projects from previous years. The interrelationships of the cooperative projects constitute the overall network. Since the database includes no information about the degree of cooperation among the organizations, it is assumed that the intensity of the relations diminishes by a growing number of participants within the same project. The more organizations participate, the less likely it is that all partners will cooperate intensively (Newman, 2001), so that the intensity of a relationship can be approximated by the number of all possible relationships among the partners of a consortium (Equation IV.10).

$$w_{ik} = \binom{n}{k}^{1} = \left(\frac{n!}{2!(n-2)!}\right)^{1} = \frac{1}{n*(n-1)*2} \qquad \text{(IV.10)}$$

	2005	2006	2007	2008	2009	2010	2011	2012
organizations	4,160	4,315	4,511	5,113	6,319	6,796	8,223	9,323
edges	14,448	16,285	17,915	21,492	26,220	28,891	30,799	32,505
density	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
components	1,162	1,076	1,105	1,070	1,432	1,547	2,785	3,710
greatest component								
organizations	2,863	3,132	3,314	3,939	4,748	5,133	5,315	5,475
share	69%	73%	73%	77%	75%	76%	65%	59%
avgerage distance	3.07	3.04	2.98	2.99	3.01	2.98	2.97	2.96
isolates	1,092	1,014	1,043	1,009	1,343	1,462	2,690	3,619
degree centralization	0.24	0.26	0.28	0.29	0.28	0.29	0.25	0.23
betweenness centralization	0.21	0.23	0.24	0.26	0.24	0.25	0.18	0.15
avarage degree	6.9	7.5	7.9	8.4	8.3	8.5	7.5	7.0
transitivity	0.12	0.11	0.11	0.09	0.09	0.09	0.09	0.09
diameter	4	4	5	4	4	4	4	5
max. intensity	8.8	13.3	9.9	10.3	10.5	11.2	9.9	10.3

Table IV.2.: Organizational collaboration within the networks

The structural characteristics differ over time (Table IV.2). As already observed for the empirical background, the number of organizations has risen between 2005 and 2012. The same applies for the number of cooperative ties, which reaches its maximum value (32,505) in 2012. A significant structural break occurs around 2008, when the federal government decided to counteract the economic crisis. The share of the network's

differentiated due to their geographical location. Further problems could arise if organizations change their names. To minimize these distortions, some corrections within the database were made and the model was limited to a reasonable time horizon.

greatest component reaches its highest value in 2008 (77 percent) and its lowest value in 2012 (59 percent). This observation is unexpected as it indicates that a large share of the allocated projects between 2008 and 2012 did not contribute to the connectivity of the entire network. This point of view is supported by the growing number of isolated organizations during that phase, and the same is reflected by the average number of partners of an organization. In 2012, an organization has an average degree of 7.0 compared to 8.5 in 2010.

5.4. Variables

Hypotheses variables

	event			event		
	I	II		III	IV	
	$0 \rightarrow 0$	$0 \rightarrow 1$	t-test	$1 \rightarrow 0$	$1 \rightarrow 1$	t-test
$log\ age_t$	3.46	3.33	***	3.34	3.45	*
$log\ employees_t$	3.22	4.62	***	4.71	6.04	***
$log\ turnover_t$	1.40	2.93	***	3.04	4.56	***
$small\ enterprise_{bool\ t}$	0.69	0.35	***	0.32	0.18	***
$east_t$	0.15	0.23	***	0.24	0.18	**
$project_{bool\ t}$	0.01	0.36	***	1.00	1.00	***
$project_{count\ t}$	0.02	0.66	***	1.83	7.57	***
$publication_{bool\ t}$	0.02	0.14	***	0.16	0.35	***
$publication_{count\ t}$	0.01	0.15	***	0.19	0.74	***
$cooperation_{bool\ t}$	0.01	0.34	***	0.93	0.98	***
$cooperation_{count\ t}$	0.02	0.60	***	1.65	6.62	***
$degree_{avg\ t}$	0.08	2.95	***	4.19	21.60	***
$betweenness_{avg}$	8.91	783.95	***	842.76	16,916.69	***
$eigenvector_{avg\ t}$	0.00	0.01	***	0.01	0.05	***
$knowledge\ heterogeneity_t$	0.01	0.19	***	0.55	0.55	
$food\ industry_{bool\ t}$	0.07	0.02	***	0.02	0.01	**
$textile\ industry_{bool\ t}$	0.05	0.02	***	0.02	0.01	**
$wood\ industry_{bool\ t}$	0.15	0.04	***	0.04	0.01	***
$chemical\ industry_{bool\ t}$	0.20	0.21		0.23	0.20	
$metal\ industry_{bool\ t}$	0.29	0.21	***	0.21	0.15	***
$machinery\ industry_{bool\ t}$	0.43	0.67	***	0.67	0.79	***
$others_{bool\ t}$	0.10	0.11		0.10	0.09	
number of obervations	244,248	1,693		1,846	595	

Significances of a t-Test compairing the average values of the events I & II and of the events III & IV: *** 0.1%, ** 1%, * 5%, . 10%

Table IV.3.: Variable statistics

This section describes all explanatory variables that are relevant in evaluating whether the determinants affect the allocation process. Therefore, Table IV.3 provides an insight into the influence of the explanatory variables. It focuses on the different transition-possibilities and checks whether the average values of the variables differs regarding the current transition stage of a firm. The comparison between the variables is carried out by a t-test.

For the confirmation of hypothesis ***H1***, two variables $cooperation_{bool\ t}$ and $cooperation_{count\ t}$ were constructed, evaluating whether the participation of an enterprise within a joint project raises the probability of obtaining a further project grant. The variable $cooperation_{bool\ t}$ equals 1 in time t for those firms, which have participated in a cooperative project within the preceding three years, and 0 otherwise. This indicates whether a firm has participated in a prior joint project or not. The average value of 0.34 implies that 34 percent of all firms that enter the funding system (*event II*) have previously participated in a joint project. In contrast, only 1 percent of all enterprises remaining outside the funding system (*event I*) have participated in a cooperative project. Firms that obtain a further funding award (*event IV*) have a higher average value compared to those that do not obtain additional funding (*event III*). However, the differences regarding the number of joint projects ($cooperation_{count\ t}$) are even more obvious. Firms that receive additional funding (*event IV*) have on average 6.62 funded projects within the preceding three years, which lies four times above the average of those firms which do not obtain a further project grant (*event III*). As a consequence, it is assumed that previous experiences in cooperative projects stimulate the chance of an enterprise of obtaining an additional project grant.

Hypothesis ***H2*** predicts that the centrality of a firm within the funding network has a positive impact on the likelihood of obtaining a further project grant. To analyze the extent to which the dynamic of the system is influenced by the centrality of a firm, three different concepts of centrality come into question: (1) the degree centrality, (2) the betweenness centrality and (3) the eigenvector centrality.

Firstly, the degree centrality ($degree_{avg\ t}$) informs about a firm's number of interconnections with other organizations (Wasserman and Faust, 1994; Jackson, 2008). The more neighbors, the more opportunities arise for a firm to initiate further collaborations with these partners, due to preexisting experiences and trust. Since the partners usually maintain their relations on an informal basis (Ter Wal, 2013; Fleming et al., 2007), it makes sense to average the degree centrality of a firm for several years, of which it is necessary to exclude the current year t. Otherwise the regression might possibly run into causality problems, since the effect of a change cannot explain the change itself. For this purpose, only the past three years are considered, in order to measure the centrality indicators for the model. Secondly, the betweenness centrality ($betweenness_{avg\ t}$) measures how often a firm is located on the shortest paths of all indirectly connected organizations. If the betweenness centrality is high, the company has a function for the network that is similar to the role of a broker, who ensures an efficient transfer of information. The brokerage is an information–advantage for these firms (Gould and Fernandez, 1989), since they are better informed about, for example, new funding offerings, technologies, or cooperation opportunities. The betweenness centrality is measured as proposed by Freeman (1978), who calculated the centrality indicator on the basis of a weighted funding network. It is assumed that a high betweenness centrality increases the probability of a company receiving an additional project grant. Finally, the eigenvector centrality is used to indicate the importance of a company. The eigenvector centrality measures the importance of a company, based upon the importance of its neighbors and the weighted network. This entails a self-referential problem which can be solved due to the calculation of the network's eigenvector (Jackson, 2008; Bonacich, 1987). Therefore, the eigenvector centrality indicates the interconnectedness of an organization within the overall network, which leads to the assumption that a high eigenvector centrality entails a higher chance of obtaining a further project grant. It is worth mentioning that all the average values of the variables used to explain hypothesis ***H3*** support the expectation.

Hypothesis ***H3*** assumes that the probability of receiving an additional project grant depends on the diversity of knowledge within the neighborhood of a company. Therefore, the heterogeneity of the external knowledge base is measured by the variable *knowledge heterogeneity*$_t$, which ranges between 0 and 1, indicating whether the external knowledge base of a company is completely divergent or congruent to the organization's knowledge base. Since a certain degree of heterogeneity is needed to stimulate the gain from new knowledge, it is expected that both extremes of the variable point to the least productive situations, as the genesis of innovations requires complementary capabilities. In accordance with Nooteboom (2007) and Mowery (1998), it is assumed that the relation between the heterogeneity and probability of obtaining a project grant follows an inverted U-shape, so the optimal value lies somewhere between 0 and 1. Because of this, it is necessary to implement an additional squared term of the variable to the model. The external knowledge base of a company can be explained as the sum of the weighted (w) cognitive proximities among the firm and all its K neighbors (see Equation (IV.11)). The cognitive proximity is calculated by the cosine similarity of two vectors (v_i, v_k), with the vectors containing the capabilities of organization i and neighbor k, respectively. Again, the values of the current year are excluded due to the possibility of causality problems.

$$knowledge\ heterogeneity_{it} = \frac{\sum_{k=1}^{K} cos\text{-}sim_{ikt_{-1}} * w_{ikt_{-1}}}{\sum_{k=1}^{K} w_{ikt_{-1}}} \tag{IV.11}$$
$$\text{with} \qquad cos\text{-}sim_{ikt} = \frac{v_{it} * v_{kt}}{\|v_{it}\| \, \|v_{kt}\|}$$

It is assumed that the technological knowledge of a company is manifested through the firm's prior experiences in R&D, thus the capability vector v of a company can be described as the number of R&D projects in different technological fields (Equation (IV.12)). Since each funded project is assigned to a certain category of 24 technological fields (Broekel and Graf, 2012), it is possible to construct the vector by adding up the number of previous projects. Each year, 20 percent of the capabilities of a company are subtracted, as it is assumed that the firm loses some of its capabilities over time due, for example, to organizational oblivion or labor mobility.

$$v_{it} = p_{it} + v_{it_{-1}} * 0.8 \tag{IV.12}$$

Other variables

It is assumed that the size of a firm matters, due, for example, to economies of scale, the costs or the "picking-the-winner" strategy (Blanes and Busom, 2004; Aschhoff, 2009; Tanayama, 2009; Bannò and Sgobbi, 2010). Fixed costs diminish with increasing size, thus potential sunk costs play a tangential role for larger firms. If a smaller firm cannot afford the costs of an unsuccessful application, the application is canceled due to the limited amount of financial resources. Therefore, the model includes two different variables indicating the size of an enterprise: the number of employees ($log\ employees_t$) as well as the annual turnover ($log\ turnover_t$). It is expected that the influence of both variables is not linear, but degressive, so that the original value of the variables is logarithmized. To observe as many firms as possible, some values were interpolated to fill the gaps of missing data. An additional variable indicates whether the company is an SME, since several funding programs are especially designed for enterprises with less than 250 employees and a turnover below 50 million euros per year (EU, 2006). The variable $small\ enterprise_{bool\ t}$ equals 1 if a firm is a SME. Otherwise, the value of the variable equals 0. Surprisingly, Table IV.3 gives an unexpected outlook, as it predicts a lower probability of an SME to obtain a new project grant, which is contrary to theory, but matches the findings of Tanayama (2009).

Another determinant that plays a role is the firm's age. Similar to smaller companies, younger firms usually have scarce resources and limited access to the financial market (Tanayama, 2007; Aschhoff, 2009; Bannò and Sgobbi, 2010). This entails a disadvantage, which should be compensated by the governmental innovation policy. It is assumed that each additional year contributes less to the probability of obtaining a new project grant, thus variable is logarithmized ($log\ age_t$). The averages do not clearly support this expectation, since both t-tests predict contrary impacts of the variable.

As mentioned earlier, it is possible for enterprises to gain experience from previous project participations (Tanayama, 2007; Aschhoff and Schmidt, 2008; Bannò and Sgobbi, 2010). Due to the routine of practicing, further applications become easier and the probability of receiving a project grant increases. To approximate the firm's learning curve, two variables are added to the model. The first variable $project_{bool\ t}$ explains whether a company has obtained a project within the preceding three years. The same applies for the second variable $project_{count\ t}$, with the difference being that the variable counts the number of projects. For both variables, Table IV.3 indicates a positive influence of former experiences.

Prior R&D activities are advantageous for a company (Aschhoff and Schmidt, 2008; Tanayama, 2007), since the investment of equity sends a positive signal to the government and partners, which implies that the company believes in its own success. Because the database does not contain any information about internal R&D investments, it is necessary to approximate this information. Therefore, R&D expenditures are measured by the number of scientific publications. This assumes that a firm which invests in R&D is willing to informs sooner or later, the public about the outcome of the research, as a kind of marketing. Two variables were constructed on the basis of the "*Web of Science*" publication database. The variable $publication_{bool\ t}$ informs whether a company has published a scientific publication since 1990[7], whereas the variable $log\ publication_{count\ t}$ counts the number of publications during that period. It is assumed that each additional publication contributes less, thus the number of publications was logarithmized. In accordance with the averages of the variables in Table IV.3, it is expected that having one or more publications positively affects the probability of receiving a new project grant.

Moreover, the sectoral affiliation of an enterprise should increase the chance of obtaining project funding, since some branches are more R&D affiliated than others (Broekel

[7] The relatively long time period was chosen since the decision to invest is medium- and long-term oriented rather than short-term.

and Graf, 2012), and some subsidization programs were designed to support a specific industry (Eickelpasch and Fritsch, 2005). Because of this, a set of variables captures the industry effect, with each variable indicating whether a company belongs to a sector. This is possible due to the German classification scheme of economic activities. Seven variables were included to indicate whether a firm belongs to the food, textile, wood, chemical, machinery industry, or another category.

The intensity of public subsidies differs among Germany's regions (Fornahl and Umlauf, 2014), especially since funding programs are sometimes intended for the development of regions (Eickelpasch and Fritsch, 2005). Germany's reunification, for example, induced several promotion programs for the eastern states, thus it is expected that the location of a firm's headquarters in one of the new states of Germany increases the probability of the company obtaining a project grant. To capture this effect, the variable $east_{bool\ t}$ equals 1 if the company's headquarters lie in the eastern states, or 0 otherwise.

The condition index (CI) was calculated to analyze whether the estimation process could be affected by problems of collinearity (Belsey et al., 1980; Greene, 2002). The index rejects the possibility of collinearity within the model, since the calculated CI (29.79) does not exceed the conservative upper bound of 30.

6. Results

For the verification of the hypotheses, three different models were estimated. During the estimation, no variables were eliminated from the models, so that it is possible to observe which variables lose their explanatory power due to the inclusion of additional variables.

The formulated hypotheses aim to prove the importance of network-related determinants for the dynamic within the funding system. The variables $cooperation_{bool\ t}$ and $cooperation_{count\ t}$ were included in order to check hypothesis ***H1***, which argues that the participation of a firm in a cooperative project raises the probability of the firm obtaining a further project grant. Interestingly, both variables remain insignificant within the first model, but, even more surprisingly, the variable $cooperation_{count\ t}$ was found to be significantly negative for a new project grant (event II) in the second and third models. This is contradictory to hypothesis ***H1***, since the reverse seems to be true. A possible explanation for this outcome refers to a trend that dates back to the 1990s. The year 1999 was the first year in which the number of joint projects exceeded the number of funded single projects (Figure IV.7). This trend continued until 2012, when the num-

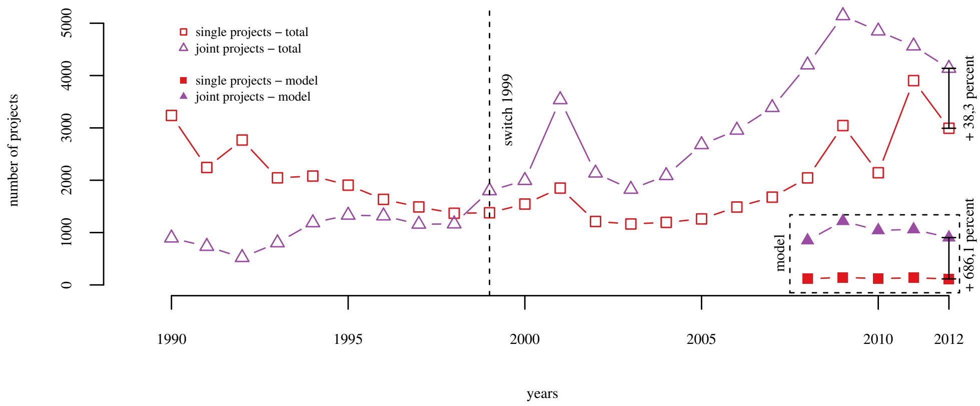


Figure IV.7.: Comparison between model and overall projects per year

Source: Förderkatalog of the German federal government

ber of joint projects exceeds the number of single ones by 38.3%. However, this overall ratio is low compared to the data used for the model, as the number of funded joint projects exceeds the number of single projects in 2012 by approximately 681% (Figure IV.7). Since the system change in 1999, receiving a single project has become something exclusive. Because of this, the second and third models are telling the truth – as they indicate a higher probability of a firm with less cooperative projects but therefore more single project grants – since the difference between the estimated variables $project_{count\ t}$ and $cooperation_{count\ t}$ indicates still a positive probability to obtain a funding.

The second hypothesis, ***H2***, goes into more detail, asking whether the centrality of an enterprise increases the likelihood of receiving a new project grant. The centrality of a company was operationalized through the degree, the betweenness and the eigenvector centrality. The expectations are basically confirmed, since the degree and the eigenvector centrality are significantly positive in the second model. Interestingly, the betweenness centrality ($betweenness_{avg\ t}$) does not reach any significance, which leads to the result that the ownership of a broker position neither stimulates nor diminishes the chance of a company obtaining a project grant. This could be an indication that firms prefer to communicate at arm's length rather than at long distances. In contrast, the degree centrality ($degree_{avg\ t}$) is positive and highly significant for both events. The more connected a firm is to other organizations the higher the likelihood of the firm to obtain a new project grant. The more contacts a firm has, the more potential partners the firm has gained for further cooperation. Interestingly, the degree parameter for the *event II* is twice as high as same parameter for the *event IV*, which indicates that additional effects play a role if a firm wants to obtain a further project grant. The eigenvector centrality seems to fit into this explanatory gap, since the variable $eigenvector_{avg\ t}$ behaves contrarily to the degree centrality. Both estimated parameters are positive and significant within the second model, but the explanatory power and the impact of the variable $eigenvector_{avg\ t}$ is higher in the case of the *event VI* and thus more relevant in obtaining an additional project grant. To receive an additional project grant (*event VI*) it seems to be more relevant to whom a firm is connected, whilst it is more important to have a lot of connections if a company seeks for a project grant without having ongoing funding (*event II*). Therefore, the overall network position of a company is the second-most important network determinant, which shapes the dynamic of the funding system.

Hypotheses ***H3*** assumes that a specific mixture of heterogeneity within the neighborhood of an enterprise has a positive impact on the likelihood of obtaining a new project grant. In contrast to the previous hypothesis, which concentrates on the centrality of a firm, this hypothesis investigates for a balance of knowledge within the neighborhood of a firm. To estimate this effect, the variables $knowledge\ heterogeneity_t$ and $knowledge\ heterogeneity_{square\ t}$ were added to the third model. The estimated parameters support hypothesis ***H3***. It is most satisfying that the value of the first variable is positive and the squared variable is negative, which supports the parabolic relationship between the knowledge heterogeneity and the probability of a new project grant. This shows that those firms which have access to a diverse knowledge base in their direct neighborhood are more likely to acquire a new project grant. For a closer look Figure IV.8 presents the estimated curves for the inverted U-shaped relationships. Both curves reach their maximum close to 0.4. If the similarity of the knowledge within the neighborhood reaches an index value of 0.8, the effect becomes negative, thus the overall likelihood obtaining a new project grant deceases.

The remaining variables calibrate the model. All of them are in line with the theory or previous. As the estimation results for the other variables do not differ among the models, the variables will be discussed on the basis of the first model.

The constant is the baseline probability of a firm obtaining a project grant. Irrespective of the other variables, it depends on the present status of a firm whether the chance of a company receiving a new project grant is 0.2% or 4.7%. Therefore, it seems to be the normal case that a company does not receive subsidization. Moreover, the estima-

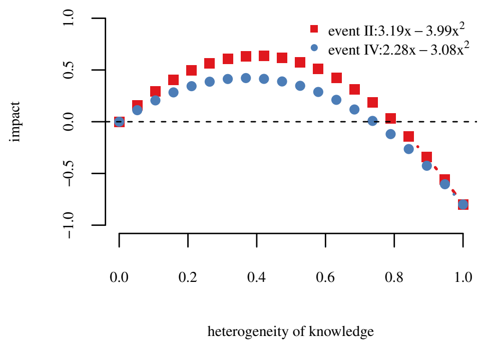


Figure IV.8.: Effect of knowledge heterogeneity

tion proved a preference for younger companies (*log age*$_t$), since older firms are less likely to get a further project grant. The size of a company is represented within the model by the number of employees (*log employees*$_t$) and the annual turnover (*log turnover*$_t$). The assumption that size positively affects the probability of a company obtaining a new project grant is supported. Only in cases of a further project grant, the variable *log turnover*$_t$ was found to be insignificant. Due to their size, larger firms are less affected by the problem of fixed costs or other risks. The variable for SMEs (*small enterprise*$_{bool\ t}$) is insignificant. Not even special programs for SMEs seem to change their probability of obtaining a project grant.

It was assumed that the location of the firm's headquarters within the eastern states of Germany has a positive impact. Therefore, the variable *east*$_{bool\ t}$ was constructed to capture whether the location of the headquarters has an impact or not. The expectation is validated for the *event II*, since the estimated parameter is positive and strongly significant.

There can be no doubt that previous project experience stimulates the probability of a firm obtaining a new project grant. Both variables *project*$_{bool\ t}$ and *project*$_{count\ t}$ were found to be positive and highly significant. The *project*$_{bool\ t}$ variable was excluded from the estimation process for the *event IV*, since the variable is identical to the regression constant. The findings proved that companies can benefit from their former experience, which entails an information advantage for those firm.

The extent of former R&D investments was approximated by the scientific engagement of a firm within the academic discussion. Two variables, *publication*$_{bool\ t}$ and *publication*$_{count\ t}$, were included to capture this effect. Interestingly, only the variable *publication*$_{bool\ t}$ has a positive effect for the case of new funding. All the other cases remain insignificant. Maybe these variables are outperformed by the variable for previous project experiences, since both indicators refer to experiences in R&D investments.

Interestingly, most of the sectoral parameters are negativly significant for those companies that receive a new project without having a previous one. This can be observed for the food, textile, wood, and metal industries. Only firms within the machinery industry, and those who fall within the "others" category, have a higher chance of receiving a new project. For the case of an additional project (*event IV*), only the parameter of the machinery industry remains significant.

	unsubsidized → subsidized				subsidized → newly subsidized			
variable	parameter	s.d.	t-value	sign.	parameter	s.d.	t-value	sign.
constant	-6.12	0.17	-35.78	***	-3.10	0.45	-6.89	***
log age$_t$	-0.28	0.03	-9.50	***	-0.11	0.07	-1.68	.
log employees$_t$	0.35	0.04	8.84	***	0.02	0.08	0.31	
log turnover$_t$	0.11	0.03	3.56	***	0.14	0.06	2.11	*
small enterprise$_{bool\ t}$	-0.01	0.08	-0.07		0.19	0.18	1.10	
east$_t$	0.43	0.07	6.32	***	-0.11	0.16	-0.71	
project$_{bool\ t}$	2.50	0.26	9.80	***				
project$_{count\ t}$	0.40	0.15	2.59	**	0.29	0.07	4.07	***
publication$_{bool\ t}$	0.76	0.11	7.19	***	0.26	0.17	1.54	
log publication$_{count\ t}$	-0.01	0.06	-0.24		0.05	0.08	0.62	
cooperation$_{bool\ t}$	-0.27	0.26	-1.01		0.14	0.32	0.45	
cooperation$_{count\ t}$	-0.07	0.16	-0.43		0.11	0.08	1.43	
food industry$_{bool\ t}$	-1.06	0.19	-5.47	***	-0.62	0.65	-0.96	
textile industry$_{bool\ t}$	-0.52	0.18	-2.80	**	-0.24	0.55	-0.44	
wood industry$_{bool\ t}$	-0.75	0.13	-5.79	***	-0.61	0.45	-1.37	
chemical industry$_{bool\ t}$	0.07	0.07	1.04		0.00	0.16	0.01	
metal industry$_{bool\ t}$	-0.26	0.06	-4.09	***	-0.07	0.15	-0.48	
machinery industry$_{bool\ t}$	0.53	0.07	7.92	***	0.51	0.16	3.24	**
others$_{bool\ t}$	0.32	0.08	3.79	***	0.20	0.19	1.06	
log-likelihood	-7937.0				-1046.9			
AIC	15915.9				2129.7			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.4.: Estimation results model 1

variable	unsubsidized → subsidized parameter	s.d.	t-value	sign.	subsidized → newly subsidized parameter	s.d.	t-value	sign.
constant	-6.05	0.17	-35.28	***	-2.92	0.45	-6.44	***
$log\ age_t$	-0.28	0.03	-9.51	***	-0.12	0.07	-1.81	.
$log\ employees_t$	0.33	0.04	8.48	***	-0.01	0.08	-0.07	
$log\ turnover_t$	0.12	0.03	3.59	***	0.13	0.06	2.02	*
$small\ enterprise_{bool\ t}$	-0.02	0.08	-0.30		0.13	0.18	0.73	
$east_t$	0.43	0.07	6.27	***	-0.15	0.16	-0.93	
$project_{bool\ t}$	2.37	0.25	9.30	***				
$project_{count\ t}$	0.40	0.15	2.63	**	0.29	0.07	4.16	***
$publication_{bool\ t}$	0.71	0.11	6.62	***	0.21	0.17	1.22	
$log\ publication_{count\ t}$	-0.01	0.06	-0.16		0.09	0.08	1.08	
$cooperation_{bool\ t}$	-0.19	0.27	-0.71		0.24	0.32	0.77	
$cooperation_{count\ t}$	-0.38	0.17	-2.26	*	-0.06	0.08	-0.78	
$degree_{avg\ t}$	0.08	0.01	6.74	***	0.04	0.01	3.70	***
$betweenness_{avg}$	-5.1E-07	9.5E-06	-0.05		3.7E-06	4.6E-06	0.79	
$eigenvector_{avg\ t}$	2.76	1.63	1.70	.	4.00	1.47	2.72	**
$food\ industry_{bool\ t}$	-1.05	0.19	-5.39	***	-0.50	0.65	-0.76	
$textile\ industry_{bool\ t}$	-0.52	0.19	-2.79	**	-0.29	0.57	-0.52	
$wood\ industry_{bool\ t}$	-0.75	0.13	-5.78	***	-0.65	0.46	-1.42	
$chemical\ industry_{bool\ t}$	0.09	0.07	1.22		0.04	0.16	0.27	
$metal\ industry_{bool\ t}$	-0.27	0.06	-4.13	***	-0.10	0.15	-0.63	
$machinery\ industry_{bool\ t}$	0.51	0.07	7.60	***	0.48	0.16	3.01	**
$others_{bool\ t}$	0.31	0.08	3.69	***	0.14	0.20	0.71	
log-likelihood	-7908.6				-1033.1			
AIC	15861.21				2108.3			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.5.: Estimation results model 2

variable	unsubsidized → subsidized parameter	s.d.	t-value	sign.	subsidized → newly subsidized parameter	s.d.	t-value	sign.
constant	-6.04	0.17	-35.23	***	-2.84	0.46	-6.22	***
$log\ age_t$	-0.29	0.03	-9.58	***	-0.12	0.07	-1.82	.
$log\ employees_t$	0.33	0.04	8.45	***	-0.01	0.08	-0.11	
$log\ turnover_t$	0.12	0.03	3.65	***	0.13	0.07	1.96	*
$small\ enterprise_{bool\ t}$	-0.03	0.08	-0.32		0.11	0.18	0.62	
$east_t$	0.44	0.07	6.39	***	-0.13	0.16	-0.82	
$project_{bool\ t}$	2.38	0.26	9.33	***				
$project_{count\ t}$	0.41	0.15	2.65	**	0.28	0.07	4.00	***
$publication_{bool\ t}$	0.71	0.11	6.54	***	0.19	0.17	1.12	
$log\ publication_{count\ t}$	-0.03	0.06	-0.45		0.08	0.08	0.96	
$cooperation_{bool\ t}$	-0.45	0.32	-1.41		0.10	0.39	0.26	
$cooperation_{count\ t}$	-0.36	0.17	-2.11	*	-0.06	0.08	-0.72	
$degree_{avg\ t}$	0.07	0.01	6.05	***	0.04	0.01	3.38	***
$betweenness_{avg}$	4.8E-07	9.6E-06	0.05		3.4E-06	4.6E-06	0.73	
$eigenvector_{avg\ t}$	-0.09	0.11	-0.80		3.48	1.45	2.41	*
$knowledge\ heterogeneity_t$	3.22	0.88	3.67	***	2.34	1.02	2.29	*
$knowledge\ heterogeneity_{squared\ t}$	-4.04	0.88	-4.60	***	-3.14	0.99	-3.17	**
$food\ industry_{bool\ t}$	-1.05	0.20	-5.36	***	-0.45	0.66	-0.68	
$textile\ industry_{bool\ t}$	-0.51	0.19	-2.76	**	-0.27	0.57	-0.48	
$wood\ industry_{bool\ t}$	-0.75	0.13	-5.78	***	-0.63	0.46	-1.36	
$chemical\ industry_{bool\ t}$	0.08	0.07	1.12		-0.02	0.16	-0.14	
$metal\ industry_{bool\ t}$	-0.26	0.06	-4.03	***	-0.08	0.15	-0.50	
$machinery\ industry_{bool\ t}$	0.51	0.07	7.58	***	0.46	0.16	2.82	**
$others_{bool\ t}$	0.30	0.09	3.53	***	0.12	0.20	0.63	
log-likelihood	-7893.6				-1024.1			
AIC	15835.3				2094.1			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.6.: Estimation results model 3

	unsubsidized → subsidized				subsidized → newly subsidized			
variable	parameter	s.d.	t-value	sign.	parameter	s.d.	t-value	sign.
constant	-6.11	0.17	-35.75	***	-3.03	0.45	-6.78	***
$log\ age_t$	-0.28	0.03	-9.50	***	-0.11	0.06	-1.69	.
$log\ employees_t$	0.35	0.04	8.82	***	0.02	0.08	0.28	
$log\ turnover_t$	0.11	0.03	3.57	***	0.14	0.06	2.12	*
$small\ enterprise_{bool\ t}$	-0.01	0.08	-0.08		0.19	0.18	1.09	
$east_t$	0.43	0.07	6.34	***	-0.10	0.15	-0.68	
$project_{bool\ t}$	2.51	0.26	9.83	***				
$project_{count\ t}$	0.40	0.15	2.58	**	0.28	0.07	3.92	***
$publication_{bool\ t}$	0.76	0.11	7.20	***	0.26	0.17	1.57	
$publication_{count\ t}$	-0.01	0.06	-0.22		0.05	0.08	0.62	
$cooperation_{bool\ t}$	-0.27	0.26	-1.04		0.10	0.31	0.33	
$cooperation_{count\ t}$	-0.07	0.16	-0.43		0.12	0.08	1.54	
$food\ industry_{bool\ t}$	-1.05	0.19	-5.39	***	-0.47	0.64	-0.73	
$textile\ industry_{bool\ t}$	-5.0E-01	1.8E-01	-2.72	**	-1.4E-01	5.5E-01	-0.25	
$wood\ industry_{bool\ t}$	-0.75	0.13	-5.74	***	-0.54	0.45	-1.21	
$chemical\ industry_{bool\ t}$	0.08	0.07	1.06		0.00	0.16	0.03	
$metal\ industry_{bool\ t}$	-0.26	0.06	-4.07	***	-0.07	0.15	-0.46	
$machinery\ industry_{bool\ t}$	0.53	0.07	7.91	***	0.50	0.16	3.21	**
$others_{bool\ t}$	0.32	0.08	3.81	***	0.21	0.19	1.10	
log-likelihood	-7.937,05				-1.046,85			
AIC	15.912,09				2.129,70			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.7.: Estimation results model 1 (rare events)

	unsubsidized → subsidized				subsidized → newly subsidized			
variable	parameter	s.d.	t-value	sign.	parameter	s.d.	t-value	sign.
constant	-6.04	0.17	-35.24	***	-2.85	0.45	-6.34	***
$log\ age_t$	-0.28	0.03	-9.51	***	-0.12	0.07	-1.81	.
$log\ employees_t$	0.33	0.04	8.46	***	-0.01	0.08	-0.08	
$log\ turnover_t$	0.12	0.03	3.60	***	0.13	0.06	2.02	*
$small\ enterprise_{bool\ t}$	-0.03	0.08	-0.32		0.13	0.18	0.72	
$east_t$	0.43	0.07	6.28	***	-0.14	0.16	-0.89	
$project_{bool\ t}$	2.38	0.25	9.34	***				
$project_{count\ t}$	0.40	0.15	2.61	**	0.28	0.07	4.01	***
$publication_{bool\ t}$	0.72	0.11	6.62	***	0.21	0.17	1.26	
$publication_{count\ t}$	-0.01	0.06	-0.14		0.09	0.08	1.07	
$cooperation_{bool\ t}$	-0.19	0.27	-0.73		0.21	0.31	0.66	
$cooperation_{count\ t}$	-0.38	0.17	-2.26	*	-0.06	0.08	-0.67	
$degree_{avg\ t}$	0.08	0.01	6.70	***	0.04	0.01	3.73	***
$betweenness_{avg}$	-1.6E-07	9.5E-06	-0.02		2.8E-06	4.6E-06	0.61	
$eigenvector_{avg\ t}$	2.75	1.63	1.69	.	3.89	1.46	2.67	**
$food\ industry_{bool\ t}$	-1.04	0.19	-5.31	***	-0.35	0.64	-0.54	
$textile\ industry_{bool\ t}$	-0.50	0.19	-2.70	**	-0.19	0.56	-0.34	
$wood\ industry_{bool\ t}$	-0.74	0.13	-5.74	***	-0.57	0.46	-1.26	
$chemical\ industry_{bool\ t}$	0.09	0.07	1.23		0.04	0.16	0.28	
$metal\ industry_{bool\ t}$	-0.27	0.06	-4.12	***	-0.09	0.15	-0.61	
$machinery\ industry_{bool\ t}$	0.51	0.07	7.59	***	0.48	0.16	2.98	**
$others_{bool\ t}$	0.32	0.08	3.71	***	0.14	0.19	0.75	
log-likelihood	-7.908,607				-1.033,137			
AIC	15.861,21				2.108,3			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.8.: Estimation results model 2 (rare events)

	unsubsidized → subsidized				subsidized → newly subsidized			
variable	parameter	s.d.	t-value	sign.	parameter	s.d.	t-value	sign.
$log\ age_t$	-0.29	0.03	-9.58	***	-0.12	0.07	-1.83	.
$log\ employees_t$	0.33	0.04	8.44	***	-0.01	0.08	-0.12	
$log\ turnover_t$	0.12	0.03	3.64	***	0.13	0.06	1.96	*
$small\ enterprise_{bool\ t}$	-0.03	0.08	-0.34		0.11	0.18	0.61	
$east_t$	0.43	0.07	6.34	***	-0.12	0.16	-0.79	
$project_{bool\ t}$	2.38	0.26	9.33	***				
$project_{count\ t}$	0.41	0.15	2.68	**	0.27	0.07	3.84	***
$publication_{bool\ t}$	0.70	0.11	6.50	***	0.20	0.17	1.17	
$publication_{count\ t}$	-0.02	0.06	-0.38		0.07	0.08	0.95	
$cooperation_{bool\ t}$	-0.45	0.32	-1.39		0.08	0.39	0.22	
$cooperation_{count\ t}$	-0.38	0.17	-2.26	*	-0.05	0.08	-0.61	
$degree_{avg\ t}$	0.07	0.01	5.92	***	0.04	0.01	3.41	***
$betweenness_{avg}$	1.9E-06	9.6E-06	0.20		2.5E-06	4.6E-06	0.55	
$eigenvector_{avg\ t}$	1.90	1.59	1.19		3.37	1.43	2.35	*
$knowledge\ heterogeneity_t$	2.89	0.80	3.60	***	2.25	1.01	2.22	*
$knowledge\ heterogeneity_{squared\ t}$	-3.68	0.80	-4.58	***	-3.05	0.98	-3.10	**
$food\ industry_{bool\ t}$	-1.03	0.20	-5.28	***	-0.30	0.65	-0.46	
$textile\ industry_{bool\ t}$	-0.50	0.19	-2.68	**	-0.17	0.57	-0.30	
$wood\ industry_{bool\ t}$	-0.75	0.13	-5.75	***	-0.55	0.45	-1.20	
$chemical\ industry_{bool\ t}$	0.08	0.07	1.11		-0.02	0.16	-0.13	
$metal\ industry_{bool\ t}$	-0.26	0.06	-3.99	***	-0.07	0.15	-0.48	
$machinery\ industry_{bool\ t}$	0.51	0.07	7.54	***	0.45	0.16	2.79	**
$others_{bool\ t}$	0.30	0.09	3.56	***	0.13	0.20	0.66	
log-likelihood	-7,893.23				-1,024.06			
AIC	15,830.0				2,096.1			

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table IV.9.: Estimation results model 3 (rare events)

7. Conclusion

The aim of the paper was to analyze whether the dynamic of the German funding system is influenced by network-related structural patterns. The preceding theoretical and empirical investigation has shown that the allocation process shapes the dynamic of the system and is more than just a stochastic process, since some organizations seem to remain permanently within the funding system, while others are not. Some determinants were previously identified by other authors, but, surprisingly, none of them have taken network effects into account, which appears even more dubious since joint projects have become a popular policy instrument in Germany and the rest of the world. To analyze this, three theoretically motivated hypotheses were presented, aiming to explore the relatedness of a firm's embeddedness within the subsidy network and its probability of obtaining further funding. Using the empirical model of Markov chains, it was possible to distinguish between firms receiving a funding without having a previous one and companies with subsequent funding. The basic sample includes 88,758 firms from the manufacturing sector between 2009 and 2012.

The first hypothesis that the participation of an enterprise in a joint project raises the probability obtaining a new project grant was rejected. This was surprising and counterintuitive, but explainable due to the large amount of single projects for a relatively exclusive group of firms. The government has to be aware of this effect, which results from current R&D policy, since this indicates the privilege of a small group. The hypothesis that the centrality of a firm stimulates the chance of a new project grant was broadly supported. Three measures were employed to test the most important centrality measures of networks. The degree was found to be the most important one, indicating a high significance of preexisting information channels and trustworthy relations with other organizations for securing new funding opportunities. No other network effect was similarly significant, but the variable loses some of its explanatory power if a firm obtains additional funding. This gap was closed by the eigenvector centrality, so that both centrality parameters seem to complement one another. This entails that the obtaining of an additional project grant requires a central position within the overall network, whereas a firm without a prior funded project needs to have a high degree centrality.

Surprisingly, brokers do not own a privileged position within the funding system, since the parameters of the betweenness centrality were insignificant. Firms seem to prefer to seek partners within their direct neighborhood, thus bridging links are less necessary for the communication patterns within the funding system. Overall, it seems necessary to keep a useful scope of centrality on the one hand, and enough openness for new competitors within the funding system on the other, since the high impact of the network effects signals a tendency of the funding regime to reproduce itself.

Finally, a diverse external knowledge base is significant for a firm to obtain a new funding project. Since this finding was important for both situations, for a new as well as for an ongoing project grant, all involved stakeholders in the allocation process seem to acknowledge the high importance of a certain degree of heterogeneous capabilities within an R&D project.

Further research questions arise, due to the limitation of this paper, in that only successful project applications of firms have been taken into account. To conclude, whether the funding regime is systematically reproducing itself or not, it is necessary to include the rejected project proposals within the analysis. Without these observations there can be no final certainty as to whether the patterns evolve because of the strong network effects or due to a low number of applicants. Moreover, the focus on the manufacturing industry restricts the generality of the results. Further investigations are needed to validate the outcome for other industries.

Bibliography

Ahuja, G., G. Soda, and A. Zaheer (2012). 'The Genesis and Dynamics of Organizational Networks'. In: *Organization Science* 23.2, pp. 434–448.

Aschhoff, B. and T. Schmidt (2008). 'Empirical Evidence on the Success of R&D Cooperation – Happy Together?' In: *Review of Industrial Organization* 33.1, pp. 41–62.

Aschhoff, B. (2009). 'Who gets the money? - The dynamics of R&D project subsidies in Germany'. In: *ZEW - Centre for European Economic Research Discussion Paper* 08–018.

Balland, P.-A. (2012). 'Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry'. In: *Regional Studies* 46.6, pp. 741–756.

Bannò, M. and F. Sgobbi (2010). 'Firm participation in financial incentive programmes: The case of subsidies for outward internationalisation'. In: *Journal of Policy Modeling* 32.6, pp. 792–803.

Barajas, A. and E. Huergo (2010). 'International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms'. In: *Economics of Innovation and New Technology* 19, pp. 87–111.

Belsey, D. A., E. Kuh, and R. E. Welsch (1980). *Regression diagnostics: Identifying influential data and sources of collinearity*. New York: John Wiley.

Blanes, J. V. and I. Busom (2004). 'Who participates in R&D subsidy programs?: The case of Spanish manufacturing firms'. In: *Research Policy* 33.10, pp. 1459–1476.

Bonacich, P. (1987). 'Power and Centrality: A Family of Measures'. In: *American Journal of Sociology* 92.5, pp. 1170–1182.

Boschma, R. (2005). 'Proximity and Innovation: A Critical Assessment'. In: *Regional Studies* 39.1, pp. 61–74.

Boschma, R. and K. Frenken (2009). *The Spatial Evolution of Innovation Networks: A Proximity Perspective*. Papers in Evolutionary Economic Geography (PEEG) 0905. Utrecht University, Section of Economic Geography.

Brautzsch, H.-U., J. Günther, B. Loose, U. Ludwig, and N. Nulsch (2015). ‘Can R&D subsidies counteract the economic crisis? – Macroeconomic effects in Germany’. In: *Research Policy* 44.3, pp. 623–633.

Broekel, T. and H. Graf (2012). ‘Public research intensity and the structure of German R&D networks: a comparison of 10 technologies’. In: *Economics of Innovation and New Technology* 21.4, pp. 345–372.

Brusoni, S., A. Prencipe, and K. Pavitt (2001). ‘Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make?’ In: *Administrative Science Quarterly* 46.4, pp. 597–621.

Burt, R. S. (2000). ‘The network structure of social capital’. In: *Research in Organizational Behavior* 22, pp. 345–423.

Cantner, U. and S. Kösters (2009). *Picking the winner? Empirical evidence on the targeting of R&D subsidies to start-ups*. Jena Economic Research Papers 93. Friedrich Schiller Universität Jena.

Cavusgil, S. T., R. J. Calantone, and Y. Zhao (2003). ‘Tacit knowledge transfer and firm innovation capability’. In: *Journal of Business & Industrial Marketing* 18.1, pp. 6–21.

Chiang, A. C. and K. Wainwright (2005). *Fundamental methods of mathematical economics*. McGraw-Hill.

Cohen, W. M. and D. A. Levinthal (1990). ‘Absorptive Capacity: A New Perspective on Learning and Innovation’. In: *Administrative Science Quarterly* 35.1, pp. 128–152.

Colombo, M. G., L. Grilli, and C. Verga (2007). ‘High-tech Start-up Access to Public Funds and Venture Capital: Evidence from Italy’. In: *International Review of Applied Economics* 21.3, pp. 381–402.

Czarnitzki, D. and A. Fier (2003). *Publicly Funded R&D Collaborations and Patent Outcome in Germany*. ZEW - Centre for European Economic Research Discussion Paper. ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research.

Destatis (2008). *Klassifikation der Wirtschaftszweige*. Statistisches Bundesamt.

Eickelpasch, A. and M. Fritsch (2005). *Contest for Cooperation - A New Approach in German Innovation Policy*. DIW Discussion Papers. Freiberger Working Papers.

EU (2006). *The new SME definition – User guide and model declaration*. Ed. by E. Commission. Publications Office.

Federal Ministry of Education and Research (2012). *Bundesbericht Forschung und Innovation 2012*.

Fier, A. and D. Harhoff (2002). 'Die Evolution der bundesdeutschen Forschungs- und Technologiepolitik: Rückblick und Bestandsaufnahme'. In: *Perspektiven der Wirtschaftspolitik* 3, pp. 279–301.

Fleming, L., C. King, and A. I. Juda (2007). 'Small Worlds and Regional Innovation'. In: *Organization Science* 18.6, pp. 938–954.

Fornahl, D., T. Broekel, and R. Boschma (2011). 'What drives patent performance of German biotech firms? The impact of R&D subsidies, knowledge networks and their location'. In: *Papers in Regional Science* 90.2, pp. 395–418.

Fornahl, D. and F. Umlauf (2014). 'Zukunft der Wirtschaftsförderung'. In: Beck, R., Heinze R., and Schmid J. Chap. FuE-Förderung zur Entwicklung ländlicher Räume: Empirische Bestandsaufnahmen und Entwicklungspotenziale, pp. 497–518.

Freeman, L. C. (1978). 'Centrality in social networks conceptual clarification'. In: *Social Networks* 1.3, pp. 215–239.

Fryges, H. (2007). 'The Change of Sales Modes in International Markets: Empirical Results for German and British High-Tech Firms'. In: *Progress in International Business Research* 1, pp. 139–185.

Gould, R. V. and R. M. Fernandez (1989). 'Structures of Mediation: A Formal Approach to Brokerage in Transaction Networks'. In: *Sociological Methodology* 19, pp. 89–126.

Gourieroux, C. (2000). *Econometrics of Qualitative Dependent Variables.* Ed. by P. C. Phillips. Cambridge University Press.

Granovetter, M. (1985). 'Economic Action and Social Structure: The Problem of Embeddedness'. In: *American Journal of Sociology* 91.3, pp. 481–510.

Greene, W. H. (2002). *Econometric Analysis.* Ed. by R. Banister. Fifth Edition. Pearson Education.

Gulati, R. and M. Gargiulo (1999). 'Where Do Interorganizational Networks Come From?' In: *American Journal of Sociology* 104.5, pp. 1439–1493.

Hazir, C. S. and C. Autant-Bernard (2012). *Using Affiliation Networks to Study the Determinants of Multilateral Research Cooperation Some empirical evidence from EU Framework Programs in biotechnology.* Tech. rep. Groupe d'analyse et de théorie économique (GATE).

Heckman, J. J. and J. Smith (2003). *The Determinants of Participation in a Social Program: Evidence from a Prototypical Job Training Program.* University of Western Ontario, CIBC Centre for Human Capital and Productivity Working Papers 2003-4. University of Western Ontario, CIBC Centre for Human Capital and Productivity.

Hippel, E. von (1988). *The Sources of Innovation.* MIT Press.

Imai, K., G. King, and O. Lau (2008). 'Toward a Common Framework for Statistical Analysis and Development'. In: *Journal of Computational and Graphical Statistics* 17.4, pp. 892–913.

Jackson, M. O. (2008). *Social and Economic Networks*. Princeton University Press.

Keese, D., R. Philipp, and N. Rüffer (2012). 'Determinants for the Application Decision for Innovation Subsidies'. In: *Center for SME Research and Entrepreneurship University of Mannheim*.

King, G. and L. Zeng (2001). 'Logistic Regression in Rare Events Data'. In: *Political Analysis* 9.2, pp. 137–163.

Kogut, B. and U. Zander (1992). 'Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology'. In: *Organization Science* 3.3, pp. 383–397.

Levinthal, D. A. and J. G. March (1993). 'The myopia of learning'. In: *Strategic Management Journal* 14, pp. 95–112.

Mora-Valentin, E. M., A. Montoro-Sanchez, and L. A. Guerras-Martin (2004). 'Determining factors in the success of R&D cooperative agreements between firms and research organizations'. In: *Research Policy* 33.1, pp. 17–40.

Mowery, D. C., J. E. Oxley, and B. S. Silverman (1998). 'Technological overlap and interfirm cooperation: implications for the resource-based view of the firm'. In: *Research Policy* 27.5, pp. 507–523.

Nelson, R. R. (1982). *An evolutionary theory of economic change*. Harvard University Press.

Newman, M. E. J. (2001). 'Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality'. In: *Physical Review E* 64, pp. 1–7.

Nguyen Van, P., F. Laisney, and U. Kaiser (2004). 'The Performance of German Firms in the Business-Related Service Sector'. In: *Journal of Business & Economic Statistics* 22.3, pp. 274–295.

Nooteboom, B. (2000). *Inter-firm Alliances: Analysis and Design*. Reprinted. London, New York: Routledge.

Nooteboom, B., W. V. Haverbeke, G. Duysters, V. Gilsing, and A. van den Oord (2007). 'Optimal cognitive distance and absorptive capacity'. In: *Research Policy* 36.7, pp. 1016–1034.

Powell, W. W., K. W. Koput, and L. Smith-Doerr (1996). 'Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology'. In: *Administrative Science Quarterly* 41.1, pp. 116–145.

Roediger-Schluga, T. and M. J. Barber (2006). *The structure of R&D collaboration networks in the European Framework Programmes.* Tech. rep. United Nations University - Maastricht Economic et al.

Stock, J. H. and M. W. Watson (2007). *Introduction to Econometrics.* Ed. by D. Clinton. Pearson.

Tanayama, T. (2007). *Eligibility, awareness and the application decision: An empirical study of firm participation in an R&D subsidy program.* Helsinki Center of Economic Research - Discussion Papers 161. Helsinki School of Economics and HECER.

– (2009). *Rationales and reality of R&D subsidies: Are SMEs and large firms treated differently?* Helsinki Center of Economic Research - Discussion Papers. Helsinki School of Economics and HECER.

Ter Wal, A. L. J. (2009). *The structure and dynamics of knowege networks: a proximity approach.* Utrecht University.

– (2013). 'The dynamics of the inventor network in German biotechnology: geographic proximity versus triadic closure'. In: *Journal of Economic Geography.*

Uzzi, B. (1996). 'The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect'. In: *American Sociological Review* 61.4, pp. 674–698.

Wallsten, S. J. (2000). 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program'. In: *The RAND Journal of Economics* 31.1, pp. 82–100.

Wasserman, S. and P. Pattison (1996). 'Logit models and logistic regressions for social networks: I. An introduction to Markov graphs and p'. In: *Psychometrika* 61.3, pp. 401–425.

Wasserman, S. and K. Faust (1994). *Socal Network Analysis.* Cambridge University Press.

V. Disentangling effects between collaborative subsidies and innovations: a mulitplexity approach for R&D and innovation networks

1. Introduction

During recent decades, a major shift has occurred in the way governments of developed countries promote technical change through R&D oriented subsidies – away from the isolated support of a single organization towards a collaborative funding regime with several participants in each project. The idea behind this originates from the growing awareness of the stimulating nature of collaborative research efforts, which is grounded in the positive effects of, for example, collaborative learning, risk sharing or resource pooling (Levinthal and March, 1993; Powell et al., 1996; Gulati and Gargiulo, 1999). By triggering collaborative R&D projects, governments aim at stimulating interactions between organizations coming from academia, research centers or commercial firms, and, at the end and most importantly, the generation of innovations (Powell, 1990).

Recently, several papers analyzed which factors lead to the formation of collaborative relationships in R&D networks (Hazir and Autant-Bernard, 2012; Broekel and Hartog, 2013; Balland, 2012; De Stefano and Zaccarin, 2013; Ter Wal, 2013) and especially point to the role of Boschma's (2005) proximity concept in uncovering the sources of innovation. But the question of how networks or dyadic relations evolve in the context of multiplex relationships among R&D and innovation networks over time is still mostly open (Ferriani et al., 2013; Bergenholtz and Waldstrøm, 2011; McPherson et al., 2001). Although, economists have highlighted the bi-directional nature of science and technology networks (Murray, 2002) and stressed the importance of government-funded R&D collaborations as a major source of innovation (Lundvall and Johnson, 1994). Murray (2002) and Breschi (2010) found evidence for a distinctive overlap and a dependency on network position between both networks, but to our best knowledge there is no empirical evidence concerning how an R&D network and an innovation network will co-evolve over time.

To shed some light on this question, our paper examines the interdependence of a government-financed R&D network with a patent-oriented innovation network. In doing so, we will investigate the causality of the emergence of dyadic relations in both networks, disentangling the possibility of stimulating collaborative innovations between organizations through a governmental R&D policy and, in addition to that, examining how the resulting R&D network is influenced by already existing innovation alliances.

Addressing these questions, we formulated a set of hypotheses, exploring the drivers of change in the R&D and innovation network. To test our hypotheses, we performed an actor-oriented model – SIENA – provided by Snijders (2001), which allows for control of multiplex relationships between a set of actors who can decide to cooperate with each other. For the reliability of our results and the manageability of our calculations, we concentrate our analysis on the chemical and automotive industries in Germany. Both sectors are important for the German economy and are responsible for a large share of innovational activity. Additionally, we include all other organizations, such as research centers and universities, in our model, as research centers and universities are both major sources of collaborative innovation. We expect a significant effect working in the direction from the subsidization network to the innovation network and the same in reverse. Additional effects mostly come from Boschma's (2005) proximity concept, while other explanatory variables are also included, such as structural network characteristics representing properties of the entire network, nodal effects describing actor-dependent attributes of the organizations, and dyadic covariate effects characterizing the kind of relationship between two organizations. For the construction of the subsidy network, we make use of the German "Förderkatalog", which includes project-based R&D subsidies provided by the German federal government. For the innovation network, we employ the PATSTAT database provided by the European Patent Office. The networks were observed between 2005 and 2008.

The outcome of the model confirms the expectations. The emergence of both networks deeply intertwined. The probability of collaborative innovation becomes significantly higher if the organizations have previously been involved in a collaborative research project together, and we found the same to be true for collaborations inside the R&D network. Interestingly, all the network determinants coming from the proximity concept are also verified, suggesting that we found an additional explanation for the tie creation process inside the R&D and innovation networks. Our findings confirm the possibility of the government stimulating innovations through bilateral R&D projects, but the outcome also indicates that policymakers have to be aware of the bi-directional effects of network multiplexity. While we have proved that policy instruments are capable of influencing the innovation processes, we have also found that the governmental innovation policy is influenced by the innovation network, which is governed by private firms and other organizations. In our opinion, future subsidization programs must take this into consideration in order to identify promising candidates for funding and uncover organizations that are, for example, mostly rent–seeking.

Our paper is structured as follows. The second section briefly theorizes about the drivers of multiplexity ties in R&D and innovation networks based on recent literature. The third section describes the data used for the construction of the networks and gives some information about the networks' statistics with a special focus on the occurrence of multiplex tie formations. The fourth section reviews the employed methodology. Section five explains the characterization of variables. In section six, we will present and discuss the results of the estimated models. The last section summarizes our findings and addresses further research questions.

2. Theory

During recent decades, the literature on organizational networks has mostly addressed single relations (Hazir and Autant-Bernard, 2012; Broekel and Hartog, 2013; Balland, 2012; De Stefano and Zaccarin, 2013; Ter Wal, 2013) while overlooking the complexity of intertwined relationships through multiple interaction platforms operating simultaneously (Robins and Pattison, 2006). However, there was an early awareness of the theory of networks concerning the bridging function of multiplex ties (White et al., 1976; Wasserman and Faust, 1994). The predominant absence of multiplex relationships in organizational networks is even more dubious as there was a large consensus that R&D and innovation are highly related processes. Because of the underinvestment of private firms in R&D, Arrow (1962) argued that the government should provide public funds in order to stimulate the innovational output of a nation, while Lundvall and Johnson (1994) went further when they stated, that public R&D expenditures become even more promising if they inherently integrate collaborative elements, connecting organizations that would otherwise be reluctant to cooperate.

In the following we concentrate on two kinds of relationships: an R&D network explaining which collaborations have been founded, and a collaborative innovation network indicating which relationships have successfully led to an innovation. We will investigate arguments theorizing the implication of interrelated networks and disentangle some major dependencies between R&D and innovation networks.

First of all, Granovetter (1985) and Uzzi (1996) argued, in their concept of social embeddedness, that for an initiation of collaboration, there may be nothing as valuable as having first-hand experience concerning the behavior of a potential partner. Those memories become manifested in networks, representing historical experiences through network ties (Ahuja et al., 2012). Having an extant cooperative project on the basis of a common R&D or innovation activity, therefore, allows the development of reliable expectations about the intention of the potential partner. This information reduces the risk of hidden agendas or radical changes compared to other organizations without prior collaborations (Ferriani et al., 2013). There is little that can exceed the benefit of knowing each other through other circles, except for the upcoming experiences gained through the outstanding collaboration itself (Uzzi, 1996). Maybe there are other promising cooperation alternatives for the potential partners, and such possibilities might become more plausible at the end of the process for one of the organizations, but as a whole the probability of the emergence of a new tie will be much more likely if there are preexisting ones. As innovation performance can be seen as one major driver of organizational performance, especially for firms in high-tech industries (Coad and Rao, 2008), collaborative innovation processes touch quite a sensitive aspect of organizations' interests. Because of that, a less sensitive collaboration, as in our case of a government-sponsored R&D project, can act as a door–opener for a more delicate innovation activity (Lundvall and Johnson, 1994). Nevertheless, trust is the crucial currency for establishing further collaborations. To initiate a common innovation, some collaborative learning (Powell et al., 1996) must have taken place, which becomes more through a collaborative R&D project (Hagedoorn, 2002), widening the capabilities necessary for success (Cohen and Levinthal, 1990), which leads us to hypothesis ***H1a***.

> ***H1a:*** *Collaborations on the basis of government-funded R&D projects do stimulate collaborative innovations.*

In a similar fashion, we expect prior collaborative innovation activities to increase the probalility of having a collaborative R&D project. Even here, prior experiences of cooperation form the basis for further interactions, but slight differences may occur, since governmental ambitions come into account (Aschhoff and Schmidt, 2008). Administrations may favor certain organizations that have already engaged successfully in collaborative innovations. In this vein, they are seeking security for their public investment, since they have to take responsibility for it, which is also known as the "picking the winner" strategy (Wallsten, 2000; Blanes and Busom, 2004; Cantner and Kösters, 2009). Ultimately, this habit could lead to a preference for organizations that have an extant collaborative tie. On the other hand, organizations that already innovate together may try to reduce their R&D expenditures through governmental contributions (David et al., 2000; Duguet, 2004). Their probability of receiving a contribution is increased if they apply for funded R&D projects together, since there are currently more collaborative-funded projects than single-funded ones; rent–seeking might also be a motivation for these organizations. Both circumstances explain hypothesis ***H1b***.

> ***H1b:*** *Collaborative innovation activities do increase the chance of receiving a government-funded joint project.*

The next best alternative, after knowing someone in person, is having a friend in common as an intermediary who vouches for the credibility of the counterpart. This is described by Uzzi (1996) as a "third-party referral network," where one organization stands as an intermediary between two potential partners. The organization in the middle acts as a trusted informant for both potential partners (Granovetter, 1985) and transfers its reputation and mutual experiences with both organizations from one side to the other (Gulati and Gargiulo, 1999). If the exchanged information convinces both organizations, a partnership should more likely arise. This situation is best described as a transitive triad.[1] Since transitivity is already proven as a major driver of dyadic tie evolution in organizational networks (Broekel and Hartog, 2013; Ter Wal, 2013; Hagedoorn, 2002), we suppose that transitive triads also work for multiple overlapping networks, connecting organizations through different dimensions, which leads to our next two hypotheses.

> ***H2a:*** *The likelihood of collaborative innovation between two organizations increases if both organizations have an R&D partner in common.*

[1] The definition of transitive triads is formulated for directed networks, but also works for undirected networks, if we leave the direction of ties aside. Having a trio of actors – i, j, and k – and the ties between them, a triad would involve actors i, j and k, if i is connected with j, j is connected with k and i is connected with k (Wasserman and Faust, 1994).

H2b *The likelihood of a collaborative R&D project between two organizations increases if both organizations have an innovation partner in common.*

3. Data

3.1. Data sources

For the empirical analysis, we employed different sets of data sources. The construction of the subsidization network is based on a publicly available database that contains all projects funded by the German federal government. The reporting ministries are: the Federal Ministry of Education and Research (BMBF); the Federal Ministry of Economics and Technology (BMWi); the Federal Ministry of Transport, Building and Urban Development (BMVBS); and the Federal Ministry for the Environment (BMU). The so called "Förderkatalog" goes back to the late 1960s and accounts for more than 152,000 projects until 2012. Each entry provides information about, for example, the organization that received the funding, co-funded organizations, the location of the organization, the funding amount, the funding period, the project themes and a classification number concerning the project's technological affiliation. In line with Broekel and Graf (2012), we assume an intensive knowledge exchange through collaborative research efforts between participants of those joint projects. Those organizations that receive a public grant accept the condition that they are to allow every partner unrestricted access to the project's results and allow fee-free usage of their know-how and intellectual property rights. Since not all projects included in this database are R&D related-projects, we make a restriction and include only those projects dealing with "technology and innovations," "research and development", and "basic research," excluding irrelevant projects such as "non-R&D-related expenditures on education".

The innovation network is based on patent data that have been extracted from the PATSTAT database published by the European Patent Office (EPO), since patent data receives growing attention as an empirical source for collaborative innovation activities (Ter Wal, 2009; Breschi and Lissoni, 2005). To construct the network, we followed Breschi and Lissoni (2003), who made the reasonable assumption that two organizations (o_1 and o_2, see Figure V.1) are linked to each other if both organizations applied for the same patent (p_1) or if any employee (w_2) working at a firm (o_2) is named as an inventor of a patent (p_2) applied by another firm (o_1). While there is no doubt concerning an interlinkage between both organizations in the first case (co-application), we also support the interlinking character of the second case (co-invention). When inventors of more than one organization have been directly involved in the process of a patent development, we assume those organizations to be interlinked, because of the knowledge transactions and the sharing of capabilities during the time of the collaboration, similar to R&D collaborations.

Hagedoorn (2003) mentioned that due to legal reasons it is common to split the property rights of a collaborative innovation into a standard patent held by one single organization, which issues licenses to the rest of the partners to avoid overlapping property rights. Doing so, Ter Wal (2009) concludes that inventors of different firms will appear jointly on a standard patent while they work for different organizations at the same time. According to Giuri et al. (2005), more than 20 of all patents were created through a collective R&D activity, whereas only 3.6 percent of total patents have been official jointly owned patents. If we try to control for co-inventions, Ter Wal (2009) hints at the possibility of observing an effect of labor mobility, when inventors appear on patents for different organizations, so that there is a possibility of misinterpreting labor mobility as a kind of collaboration. To minimize such misinterpretations, we applied a conservative two-stage process to identify collaborations based on co-inventions: (1) We defined a "home base" for each observed inventor, so that she/he is "at home" in the organization where she/he made most of her/his applications. An interlinkage between two organizations is possible if an inventor appears on a patent that has not been applied by her/his home organization. (2) To avoid declaring labor mobility as a collaboration, it is necessary for the inventor to return home at a later point in time, which is fulfilled when the inventor is named on a patent application of her/his "home base" at a later point in time. Otherwise, the establishing of a link between both organizations is refused. Due to the delay of patent publications, we concentrate our analysis on observations between the years 2005 and 2008. We approximate the time of the invention by the date of the patent application, since the application date is very close to the date of invention.

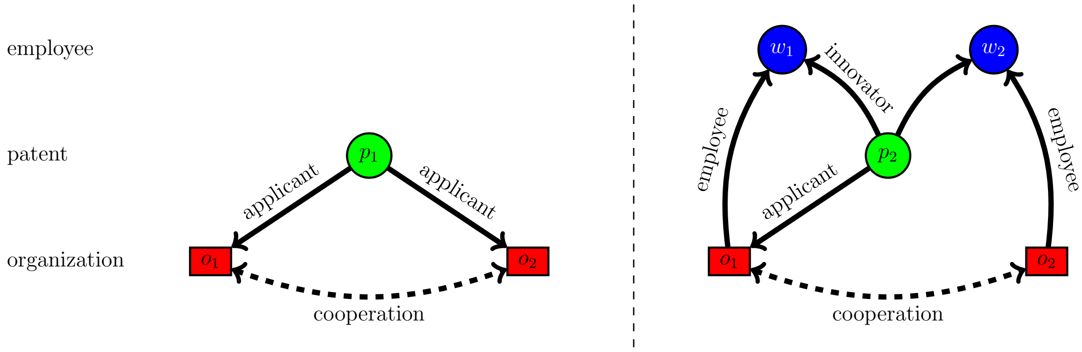
Even if our analysis is based on networks observed between the years 2005 and 2008, we started building up our subsidization networks in 2000. This means we are evaluating a mature network in 2005 that is evolving over the next three years. After the official end of a funded "joint-project" or the application date of a patent, we keep the interconnection between those organizations alive for three more years, since we suppose that informal channels will remain in place for a while between all collaborative partners even if there is no ongoing project. This is in line with other authors (Ter Wal, 2013; Fleming et al., 2007), but since our networks consider only a four-year time frame, we decide to limit the additional duration time to three instead of five years.

We are aware of the limitations that come from measuring innovativeness as a kind of patenting activity. But in our case, the major critique – that the patenting activity is distorted by strategic patenting or secrecy of innovations – is not convincing. We think that the outcomes of collaborative innovations are mostly codified (Hertzfeld et al., 2006), since the participating organizations need some kind of intellectual property rights to legalize their access to the innovation. Distortions due to strategic patenting should not arise in our selected data, since the most predominant motive for strategic patents is to block competitors (Blind et al., 2006), instead of collaborating together.

We build up our basic population on a firm database that contains more than 22,523 different organizations coming from academia (657), research centers (5,711), and commercial firms, including 12,963 organizations from the chemical industry and 7,174 organizations from the automotive industry. The sectoral distinction is possible due to the German classification scheme of economic activities which separates the organizations into categorical subgroups (Table V.1). It is worth mentioning that it is possible for an organization to be a member of more than one industry. Through a matching algorithm, we identified 960 organizations having received a contribution and 3,494 organizations having been mentioned on a patent application between 2005 and 2008. Since we want to evaluate the ability of subsidized projects to stimulate collaborative innovations, we decided to exclude all organizations having no funding or patent application. Ignoring organizations without patent applications does not lead to distortions, since only two organizations became excluded due to their missing patent application, while more than 2,500 organizations were excluded because they had not obtained any public contribution between 2005 and 2008.

3.2. Network statistics

In line with other authors (Murray, 2002; Breschi and Catalini, 2010; De Stefano and Zaccarin, 2013), we found serious structural differences between collaborative R&D and innovation networks (Table V.2 and V.3). The number of observed organizations inside the chemical network (815) exceed the number of organizations (671) being observed inside the automotive-related network. Interestingly, the reverse applies for the number of collaborations (edges) for the R&D network as well as for the innovation network, signaling a larger extent of cooperation inside the automobile industry in comparison to the chemical industry. This is also reflected through the *average degree* (acts of cooperation per organization), where the automotive industry always exceeds the chemical industry.



(a) cooperation in terms of co-application

(b) cooperation in terms of co-invention

Figure V.1.: Possible situations of collaborative innovations

subgroup	classification*	obs.	matches r&d	matches innovation	matches intersection
academia	854	657	142	148	142
research center	721	5,711	371	854	371
chemestry industry	19,20,21,22	12,963	355	1,895	354
automobile industry	29,30	7,174	364	1,504	362
total		22,523	960	3,494	958

*German classification scheme of economic activities, (edition 2008).

Table V.1.: Organizational matching results

characteristics	r&d network 2005	r&d network 2006	r&d network 2007	r&d network 2008	innovation network 2005	innovation network 2006	innovation network 2007	innovation network 2008
organizations	815	815	815	815	815	815	815	815
edges	2,880	2,613	2,619	2,914	159	192	181	172
density	0.009	0.008	0.008	0.009	0.000	0.001	0.001	0.001
components	400	386	371	339	690	678	681	684
greatest component								
organizations	416	428	440	476	104	126	118	119
share	51%	53%	54%	58%	13%	15%	14%	15%
average distance	2.58	2.59	2.58	2.61	3.46	3.68	3.57	3.65
isolates	399	383	366	337	673	668	667	674
degree centralization	0.24	0.26	0.29	0.31	0.04	0.04	0.04	0.04
betweenness centralization	0.09	0.10	0.13	0.14	0.01	0.01	0.01	0.01
average degree	7.1	6.4	6.4	7.2	0.4	0.5	0.4	0.4
transitivity	0.42	0.39	0.39	0.38	0.05	0.06	0.06	0.04
diameter	6	6	6	6	8	10	8	7

Table V.2.: Chemical industry network structure

Also the number of components expresses a difference regarding R&D and innovation networks. As with prior authors (Murray, 2002; Breschi and Catalini, 2010; De Stefano and Zaccarin, 2013), we found the innovation network to be fragmented, with frequent components, a low density, and a relatively small largest component compared to the alternative network coming from a more science-related background. Results provided by Breschi (2010) and De Stefano (2013) suggest that the largest component of innovation networks typically accounts for 9.3 percent and 33.8 percent of the total organizations, depending on the sector's technology-intensity. This is similar to our results, where the innovation network of the chemical industry reaches a share between 13 percent and 15 percent, while the share of the in comparison more technology-intensive automotive industry ranges between 22 percent and 26 percent. The share of the largest component inside the R&D network lies in both networks between 51% and 63%, which is consistent with R&D networks found by Broekel (2012). Even the *average distance* between organizations inside the largest component is higher for both sectors.

After all, it is not surprising that the transitivity of the R&D network is significantly higher in comparison to the innovation network, while the transitivity inside the automotive innovation network reaches nearly double that of their chemical counterparts. Summing up, it is much more common that our observed organizations collaborate in R&D projects, while collaborative innovations turn out to be quite rare. Reasons leading to a different set of rules and constraints can be found in the distinctive nature of both activities. On the one hand, the government can regulate the collaborative actions inside publicly funded R&D projects, while on the other hand, collaborative innovations are based on voluntariness.

Since our interest lies in tie-creation processes, Table V.4 reports the number of ties being created, dissolved, alive or absent for each industry sector and network type. The first column shows year-to-year comparisons, since network shift can only be observed between the years. For the chemical and automotive industries, the number of network changes inside the innovation network is rather low in comparison to the R&D network. There is no stringent pattern of growth or decline phases among the years. There are years showing a remarkable growth of new established ties ($0 \to 1$) in one network, while the corresponding network is losing ($1 \to 0$) connections. However, what they seem to have in common is a relatively stable share of network change, which is expressed by the column of the *Jaccard index*.[2] The lowest values for the *Jaccard index* can be found

[2] The *jaccard index* measures the amount of network change between two consecutive years. $N_{11}/(N_{11}+N_{01}+N_{10})$, N_{11} $(1 \to 1)$, N_{01} $(0 \to 1)$, N_{10} $(1 \to 0)$.

characteristics	r&d network 2005	2006	2007	2008	innovation network 2005	2006	2007	2008
organizations	671	671	671	671	671	671	671	671
edges	3,094	2,817	2,804	3,082	262	297	315	328
density	0.014	0.013	0.012	0.014	0.001	0.001	0.001	0.001
components	294	287	281	246	513	492	495	489
greatest component								
organizations	375	383	388	422	145	178	171	173
share	56%	57%	58%	63%	22%	27%	25%	26%
average distance	2.47	2.51	2.46	2.49	3.00	3.26	3.03	2.95
isolates	290	284	277	242	500	489	490	482
degree centralization	0.28	0.29	0.33	0.35	0.09	0.09	0.10	0.10
betweenness centralization	0.10	0.10	0.13	0.15	0.02	0.03	0.03	0.03
avarage degree	9.2	8.4	8.4	9.2	0.8	0.9	0.9	1.0
transitivity	0.42	0.40	0.40	0.40	0.09	0.09	0.10	0.09
diameter	5	5	5	5	7	10	7	8

Table V.3.: Automobile industry network structure

periods	chemistry industry 0⇒0	0⇒1	1⇒0	1⇒1	jaccard	automotive industry 0⇒0	0⇒1	1⇒0	1⇒1	jaccard
innovation										
2005→2006	337,209	65	31	126	0.568	225,111	82	47	216	0.626
2006→2007	337,205	35	46	145	0.642	225,095	63	45	253	0.701
2007→2008	337,214	37	45	135	0.622	225,075	65	53	263	0.69
R&D										
2005→2006	334,189	353	612	2,277	0.702	222,015	344	621	2,476	0.72
2006→2007	334,440	361	336	2,294	0.767	222,284	352	360	2,460	0.776
2007→2008	334,309	467	184	2,471	0.791	222,184	460	187	2,625	0.802

Table V.4.: Dyadic evolution of networks for the innovation networks, varying between 0.57 and 0.7. This mostly refers to the duration time of collaborative innovations, which we suppose to be three years after the date of application. For the R&D network, the *Jaccard index* reaches values between 0.7 and 0.8, signaling a higher stability of the existing ties throughout the observed time periods.

	chemical industry				automobile industry			
	2005	2006	2007	2008	2005	2006	2007	2008
existing multiplex ties	53	74	72	71	86	118	124	123
new multiplex ties	21	31	18	16	23	46	25	22
prior R&D cooperation	16	22	13	10	19	31	18	12
prior innovation cooperation	3	4	5	5	3	10	7	7
instant multiplex	2	5	0	1	1	5	0	3

Table V.5.: Occurrence of multiplex ties in networks

As multiplexity is of special interest to our work, Table V.5 reports occurrences of multiplex ties for the chemical and automotive industries between 2005 and 2010. For a multiplex tie, it is necessary that exactly two ties exist between a pair of actors, inside the R&D as well as inside the innovation network (see Figure V.2). The first row of Table V.5 reports the number of existing multiplex ties for each year and network. As the *average degree* of the automotive industry lies above the *average degree* of the chemical industry, it is no surprise that more multiplex ties occur for the automotive industry. The second row includes the number of new multiplex ties created each year, while the rows below explain the circumstances under which the new multiplex ties have been established. In most cases (141, including both sectors), there was a single prior R&D collaboration between both organizations before a second becomes established, representing a collaborative innovation (*type 1*, see Figure V.2(b)), while a collaboration on the basis of a prior innovation (*type 2*) occurs only in 22 percent (44) of all cases. The last possibility where the multiplex tie becomes installed instantaneously without any prior collaboration (*type 3*) is quite seldom and represents only 8 percent (17) of all cases.

Moreover, we compared the time needed to establish a multiplex tie after the initial R&D project or patent application. We found serious differences between both constellations. The creation of a multiplex tie based on a prior R&D collaboration (*type 1*) takes 3.6 years on average in the case of the chemical industry and 3.8 years on average for the automotive sector, while it takes 2.75 or 2.9 years, respectively, in the cases of the chemical and automotive sectors to establish a multiplex tie based on a former innovation tie (*type 2*). Additionally, Figure V.3 presents the distributions of the duration times, showing a peak for the *type 1* constellation in the third year and a peak for the *type 2* constellation in the second year. This meets our expectations, since the emergence of an innovation should naturally take some time after the start of an R&D project, whereas a collaborative R&D project can be started directly after a prior innovation.

These findings give us some certainty about our hypotheses. As the instantaneous genesis of multiplex ties is quite rare, it becomes more likely that the evolution of multiplex ties follows a process, where one collaboration entails the other, supporting hypotheses ***H1a*** and ***H1b***.

	chemistry industry				automobile industry			
triad closure innovation	2005	2006	2007	2008	2005	2006	2007	2008
existing (1)	199	212	278	259	471	383	382	481
new triads (2)	21	33	7	43	45	56	36	78
triad closure R&D	2005	2006	2007	2008	2005	2006	2007	2008
existing (1)	10	30	29	12	49	52	36	52
new triads (2)	3	3	0	0	0	3	5	1

Table V.6.: Occurrence of multiplex triads in networks

Our second objective is to shed light upon the tie-creation process of a multiplex triad, where two organizations are indirectly connected by an intermediary and the triad becomes closed through a parallel network. As we control for collaborations in R&D and innovation networks, Figure V.4 illustrates the architecture of the possible triads. At the beginning ($t = 0$), neither the triad in Figure V.4(a) nor the triad in Figure V.4(b) are closed, which means that in both situations two organizations have a partner in common.[3] Because of the effects we described for hypotheses ***H2a*** and ***H2b*** ("third-party referral network"), we suppose o_1 and o_3 to become very likely partners until the next point in time ($t = 1$), while the basis of the collaboration is different to the previous one. The first row of each section presents the occurrences of already existing multiplex triads inside the networks of the chemical and automotive industry. As can be found in the Table V.6, there are many more triads closed by a common innovation (*type 2*) than triads closed by a common R&D project (*type 4*). This is of little surprise, as there are many more configurations of *type 1* inside the networks

[3]This statement refers to network architectures labeled as *type 1* and *type 3* in Figure V.4.

of the chemical and automotive industries, which can be closed through collaborative innovation. The second row includes the number of new multiplex triads established each year. As the dynamic is higher for triads established by collaborative innovation activities, we expect a more significant result for our Hypothesis ***H2a***.

4. Method

For the empirical validation of the hypotheses we specified and estimated two Stochastic Actor-Oriented Models (SAOM), since the explanatory power of standard regression techniques and other alternatives, such as the log–linear and the Markov approach, are too limited to explain the dynamics of networks (Bunt and Groenewegen, 2007). The analysis is performed by a statistical software package called SIENA – shorthand for Simulation Investigation for Empirical Network Analysis. SIENA includes a set of functions for studying the evolution of networks over time driven by endogenous and exogenous effects, where the statistical inference is gained from a network simulation model (Snijders, 2001; Ripley et al., 2014). Since SIENA has become a standard tool for social scientists, the interest of economists is steadily growing (Ter Wal, 2009; Castro et al., 2014; Giuliani, 2013). SIENA assumes a continuous process of network evolution over time, where only actors (organizations) are allowed to establish or dissolve ties (cooperations). Since most of the network observations are made in discrete time, the micro steps of network change are unobserved. As a consequence, SIENA tries to simulate the evolutionary path of network transition between observed time points via Markov Chain Monte Carlo (MCMC) simulations. This simulation algorithm is repeated 1,000 times (Snijders, 2002). During each simulation process actors evaluating the entire network seek a chance to improve their actual network position into a more "pleasant" one, explained by the model as a utility function that the actor is trying to maximize, also known as the evaluation function. For the maximization of the utility, the evaluation function requires some model ingredients, including information about the nodal, dyadic and structural configuration, representing the costs and benefits of the alternatives, and additionally a random disturbance. Since only the actual composition of the network matters, an actor's decision is made without memory of prior stages. For undirected networks SIENA provides several decision rules for the negotiation of a new interlinkage between two actors, as reasons for an interaction can differ (Snijders and Steglich, 2007; Ter Wal, 2009). In our case, it seems reasonable to select the unilateral initiative and reciprocal confirmation algorithm, since it is sensible to expect that one actor takes the initiative for a collaboration and the counterpart accepts or refuses the offer. Less probable for our model would be, for example the "forcing model," where one actor can force another actor into a collaboration. At the end, the influence of the model effects is represented by a set of weighted parameters, covering the observed strengths of the model parameter. If the parameter value of an estimated effect equals zero, the effect has no influence on the tie-creation process, while a positive parameter explains a higher probability for the creation of a relational tie. The reverse applies for an effect with a negative parameter value. SIENA distinguishes between three classes of model effects: (1) structural effects depending on the characteristic of the network only (e.g. triadic closure, multiple network effects), (2) individual covariates reflecting the characteristics of the actors such as the number of employees, the annual turnover or the industry sector and (3) dyadic covariates representing tie-related attributes such as distance or proximity scores between potentially tied actors. Since the estimated model parameters have an approximate standard normal distribution, the significance of the parameter can be tested through a Wald-test (t-test) (Snijders, 2001; Ripley et al., 2014). The rate function of a SIENA model explains how often an actor has the opportunity to establish a new tie. As it seems reasonable that some differences occur between heterogeneous actors and their chance of being the next selected one, SIENA allows the inclusion of a set of special rate effects favoring or discriminating against actors according to their individual attributes. The model convergence is good if all t-ratios are below 0.1, which means that the model parameters can describe the simulated networks quite well. The reliability of the model can be evaluated with the help of *goodness-of-fit* measures, using network descriptives (for example, degree distribution, geodesic distance, or triadic census) for a comparison between the observed network and the obtained model networks.

5. Variables

For the verification of our hypotheses, we included a set of explanatory effects to the model. In line with Ahuja et al. (2012) we distinguished three differential sets of parameters that trigger the evolution of networks: (1) factors coming from the nodal (individual) level of the organizations, (2) the dyadic level of relationships between the organizations, and (3) the structure of links resulting from these interconnections. In our model, each set of parameters occurs twice, since we are dealing with two parallel evolving network formations.

Nodal attributes are related to organizational characteristics such as organization size, sectoral affiliation, received subsidies or the number of patent applications. Schwartz et al. (2012) found evidence that patent application, as the outcome of a R&D cooperation, is positively affected by the size of an organization, thus we expect that the creation of a new tie between a pair of organizations is affected by the size of both partners, too. In the first place, size reduces the administrative burden for the acquisition and implementation of R&D projects or patent applications because initiation costs, equivalent to sunk costs, are nearly fixed so that the impact diminishes as organizations grow in size (Blanes and Busom, 2004; Aschhoff and Schmidt, 2008; Tanayama, 2007). Even the cost for monitoring R&D projects and patents decreases with firm size, when professional departments support the process for the application and control of financial risks (Bannò and Sgobbi, 2010). But, at the same time, size may be an obstacle to cooperation, because, for example, of competition in similar markets. For the description of an organization's size, we used the number of employees and the annual turnover (in millions of euro), as both indicate different aspects of an organization's size. Finally, we applied the cube root to each value, since we expect a degressive influence of both variables, labeled as $\textit{sum employees}_{\textit{fix}}$ and $\textit{sum turnover}_{\textit{fix}}$ within the model. Because of limitations to our organizational data, we only have values of the year 2012 for both variables. However, these constraints should not be problematic, since we are mostly interested in differences in the levels between organizations.

Kirat (1999) pointed to inter-nodal characteristics of the network when he mentioned that "Technological innovation is a process that is based on relationships of proximity." Our model contains a set of dyadic effects reflecting those relationships of proximity. While nodal attributes refer to the probability that one node is becoming a tie, bilateral characteristics influence the likelihood of two organizations getting connected. The idea of lateral effects mostly refers to the contradicting concepts of homophily and heterophily. Coming from sociology, homophily describes an organizational preference to being tied to someone similar in the sense of common attributes (McPherson et al., 2001). In a reverse sense, heterophily suggests that organizations might prefer partners having some dissimilarities, as complementary skills might be more fruitful than having the same ones (Rivera et al., 2010). As Broekel and Hartog (2013) argued, homophily, and, according to our understanding, also heterophily, have most in common with the proximity approach of Boschma (2005), where cognitive, geographical, social, institutional, or organizational proximity enhance or reduce the probability of an organizational tie.

Cognitive proximity, also known as technological proximity, refers to the share of knowledge two organizations have in common. As the gain of knowledge often relies on the recombination of diverse capabilities, the genesis of innovations performs best between heterogeneous actors with complementary capabilities (Mowery et al., 1998; Boschma, 2005; Fornahl et al., 2011). Nooteboom (2000) directs this to a trade-off between a sufficient distance and meaningful closeness of organizational knowledge, where the distance provides space for complementarities and closeness for an efficient transfer of information. This relationship corresponds to an inverted U-shaped function of cognitive proximity and innovativeness, which has been shown by Nooteboom et al. (2007), Gilsing et al. (2008) and Fornahl et al. (2011). As our focus relies on technological innovations, we express cognitive proximity between two potentially tied organizations as the overlap of their knowledge base, which becomes operationalized as project participations and patent applications, differing for technological fields. As the *"Förderkatalog"* contains a technological–classification scheme, projects can be differentiated between a set of 19 technological areas (Broekel and Graf, 2010). As the innovation network is based on patent data, the international patent classification (IPC) describes the technological context of the innovation. Based on the IPC, Schmoch (2008) created a technology classification scheme indicating 35 fields of technological innovations coming from areas such as electrical engineering, instruments, chemistry, mechanical engineering, and others. Instead of the IPC, we will use Schmoch's technology classification scheme, as it reduces the technological spectrum to a convenient number of technological fields.

Equation V.1 shows the calculation of the *cognitive proximity* between two organizations (x and y), where c represents a capability vector, containing the knowledge base of an organization i at time point t. We suppose that organizations, once they have built up their capabilities, will start to lose them again because of, for example, organizational oblivion or labor mobility. This is implemented through a discount factor in Equation V.1, which subtracts 20 percent of the capabilities an organization had in the previous year. At the same time, c rises with the number of new capabilities p acquired by the organization i in year t. Capabilities c are explained through the number of newly funded R&D projects or patent applications at time point t. The cognitive proximity between both organizations is equal to the cosine-similarity of the vectors c_{xt} and c_{yt}. We expect organizations with a similar cognitive proximity to be more likely to collaborate than organizations having fewer capabilities in common.

$$\begin{aligned} \textit{cognitive proximity}_{xyt} = \textit{cosine-similarity}(c_{xt}, c_{yt}) \qquad & \text{with} \\ c_{it} = p_{it} + c_{it_{-1}} * 0.8 \qquad & \end{aligned} \tag{V.1}$$

Common institutions, consisting of formal rules, informal constraints, routines or habits, establish a space around organizations, regulating the behavior and interactions between members of a group (Kirat and Lung, 1999; Edquist, 2005). Institutional proximity refers to the institutional overlap between possibly connected organizations. Having a similar institutional background creates mutual trust between those organizations and increases the likelihood of being connected (Broekel and Hartog, 2013; Ponds et al., 2007). But, in the same manner, too much proximity can also hinder new ideas and innovations because of institutional lock-in and inertia (Boschma, 2005) caused by a limited perception of new opportunities and less flexibility. In this sense, institutional proximity should maintain the balance between well-established structures, openness, and flexibility.

Because the institutional setting is strongly correlated to sectoral background, we measure institutional proximity between two organizations in terms of being members of the same sector, in which we differentiate academia (A), research centers (R), and commercial firms (F). In order to identify homophilous preferences of an organization, which prefers to collaborate within a common space of shared institutions, we included three model variables.[4] In the same manner, we included three variables reflecting a heterophilous tendency of an organization.[5] Each of the variables reflects one of the possible institutional combinations, three homophilous (A-A, R-R, F-F) and three heterophilous variables (A-R, A-F, R-F). The values equal 1 if the variable matches the institutional situation between a pair of organizations. Otherwise, the values equal 0. Previous contributions (Belderbos et al., 2006; Aschhoff and Schmidt, 2008) have already shown that the involvement of universities and research laboratories within a research joint venture can be a significant fertilizer for the innovative outcome.

Organizational collaborations become more likely with geographic proximity, (Ponds et al., 2007; Broekel and Hartog, 2013; Ter Wal, 2013; De Stefano and Zaccarin, 2013). Being closely located to each other increases the opportunity for personal interaction, stimulating the exchange of information and tacit knowledge due to mutual trust (Hippel, 1988; Cavusgil et al., 2003). At the same time, geographic proximity requires cognitive proximity as otherwise both organizations would not be able to exchange knowledge efficiently (Boschma, 2005; McPherson et al., 2001; Rivera et al., 2010). Geographic proximity can help to overcome inadequate institutional or organizational settings be-

[4] Model variables for homophily: *inst-proximity business*$_{homo\ fix}$, *inst-proximity research*$_{homo\ fix}$, *inst-proximity academic*$_{homo\ fix}$.

[5] Model variables for heterophily: *inst-proximity business*$_{homo\ fix}$, *inst-proximity academic & business*$_{hetero\ fix}$, *inst-proximity academic & research*$_{hetero\ fix}$.

tween organizations, where mutual trust is needed to fix these gaps. In line with this, geographic proximity is neither a necessary nor a sufficient condition for collaborations, but an effective substitute for institutional differences (Boschma, 2005; Ponds et al., 2007). At the same time, it is possible to substitute geographic proximity through other confidence-building factors, for example, social proximity (Autant-Bernard et al., 2007; Paier and Scherngell, 2011). We measured geographic proximity as the physical distance between a pair of organizations, based on the great-circle distance. Again we applied the cube root to the variable, since we expect a degressive influence.

Social proximity is implemented as a structural effect, since social proximity can be well described through a transitive triad (Ter Wal, 2013), including the interlinkages of the whole network instead of the ego or bilateral level of organizations (Ripley et al., 2014). In contrast to geographic proximity, addressing physical distance, social proximity refers to the inner network distances of organizations. The triadic closure effect measures the tendency of an organization to become a friend of a friend, whereby both organizations are separated by one intermediary (Granovetter, 1973). Having a friend in common creates opportunities for interaction in subsequent time periods (Rivera et al., 2010), due to unintended encounters and the signal of trustworthiness as a reliable partner (Uzzi, 1996; Gulati and Gargiulo, 1999). Being isolated reflects an extreme form of social proximity. Without any neighbors within the network, the opportunity for involvement in the next cooperation will be reduced drastically, due to the low status of social embeddedness. As our data includes many organizations without any neighbors, we included a *network-isolate* effect to our model.

A SIENA model requires some *constant rate* effects, which can be seen as a kind of intercept for each time interval, explaining the likelihood of each organization receiving the next tie. Since the sectors differ significantly in their tendency to cooperate, we expect different rate effects for commercial firms, universities, and research centers. As the government tries to stimulate collaborative R&D projects between the sectors (Federal Ministry of Education and Research, 2010; Pyka, 1999; OECD, 1994), we expect universities to have a higher probability of cooperating with other organizations inside the R&D network. This is because a limited number of universities meet hundreds of firms and research centers. Since organizations are free to choose their partners in a patent application (innovation), the same effect should not be present for the innovation network. To represent this sectoral pattern, the model contains two rate parameters for each kind of network, explaining the sectoral affiliation of the organization (*bool research*, *bool university*). If an organization belongs to a sector, the organization is represented as a 1, or 0 otherwise. Similar to the sectoral rate parameters, we expect that prior activities affect the likelihood of receiving the next tie. Organizations benefit from experiences gained through former applications. Routines have already been trained to manage the different stages of the R&D projects and patent applications. This helps to minimize the risk and signals a good reputation to other organizations as a potential partner (Nelson, 1982; Aschhoff and Schmidt, 2008; Tanayama, 2007; Beesley, 2003). As an indicator for prior experiences we implemented one variable for each network. We approximate the extent of already gained knowledge from further R&D projects through the sum of contributions (*sum subsidies*$_t$) an organization has absorbed in the past. Each year, we discount the contributions of previous years by 20 percent as we expect organizations to lose knowledge over time (Nelson, 1982). The same is true for innovation experiences. Here, we used the number of patent applications as an indicator for the trained routines (*sum patents*$_t$). Even here we applied the cube root to each value, because we expect a degressive influence of both variables.

The *degree* effect has to be included into each SIENA model, since it serves as another kind of baseline parameter, indicating the tendency of organizations to increase or decrease the number of linkages they have already obtained. A negative estimated parameter value signals the cost, and a positive estimated parameter value signals the benefit of having an additional relation (Ter Wal, 2013; Ripley et al., 2014). Another important structural effect that should be implemented comes with the *degree of alter*$_{sqrt}$ effect, representing the preference of an organization to become tied with another organization with a large number of neighbors. Gulati and Gargiulo (1999) already found evidence for this effect, particularly for the case of the automotive industry. This organizational pattern is associated with the Matthew Effect in social networks, positing that the chance of getting a new tie is highly affected by the number of ties currently held by an organization (Rivera et al., 2010; Merton, 1968). The implemented square root lowers the importance of further access to highly connected organizations, if an organization already has some (Ripley et al., 2014).

Exploring our hypotheses, the model contains some additional structural effects. For an evolving multiplex tie between a pair of organizations within the innovation network, the *interaction subsidies* effect indicates the presence or absence (1 or 0) of a former collaborative R&D project (***H1a***). Equivalently, the *interaction patent* parameter describes the creation of a multiplex tie inside the R&D network, which is related to a former collaborative innovation (***H1b***). Additionally, the effects of *triadic closure subsidies* and *triadic closure patents* prove hypotheses ***H2a*** and ***H2b***. If the creation of a new dyad within the innovation network would link a pair of organizations that have formerly been connected indirectly by an intermediary inside the R&D network, the *triadic closure patents* effect indicates the presence of a multiplex triad by signaling a 1 or a 0 otherwise (***H2a***). Again, the *triadic closure subsidies* effect equivalently demonstrates the presence or absence of a multiplex tie formed within the R&D network by an additional tie (***H2b***).

6. Results

The model results are shown in Table V.9 and Table V.10. Both models – the chemical industry model as well as the automotive industry model – converged during the simulation process, since all convergence values lie below the absolute value of 0.1. To ensure the stability of our results, we estimated each model several times. The originally observed networks are well described by the networks simulated by the estimated model. All tests regarding the dissimilarity of the observed networks and their simulated equivalents can be rejected to the significance level of 0.1 (see Figure V.5 and Figure V.6).

The estimates support hypotheses ***H1a*** and ***H1b***. As shown by the model parameter *interaction patents*, there is indeed a positive and significant, effect between having a prior funded R&D project in the first place and having a collective innovation afterward, supporting hypothesis ***H1a***. In line with this, governmental subsidies significantly trigger innovations if collaboration is an elementary aim of the project. The effect of the variable *interaction patents* is quite strong compared to the rest of the model parameters, with 0.59 for the chemical industry and 0.54 for the automotive industry. As the parameter *interaction subsidies* is also positive and significant the same is true for the opposite direction. If two organizations have had a collective innovation at an earlier point in time, they are more likely to obtain a common R&D project. This finding matches hypothesis ***H1b***, that successfully innovating organizations attract the attention of governmental agencies, expecting a good public investment. Hypotheses ***H2a*** and ***H2b*** are not supported, since the parameters of *triadic closure innovation* and *triadic closure R&D* stay insignificant in both models.

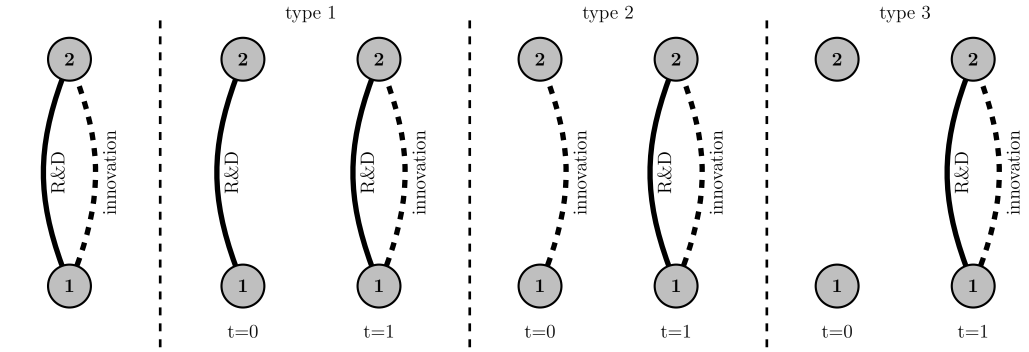
Size matters within the R&D network, but surprisingly in diverged directions. The positive-acting influence of the turnover encounters a negative impact of the employment variable. If large organizations, in terms of their annual turnover, come together, a collaboration between both becomes more likely; whereas a pair of organizations having

subsidy network	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	patent network	
(1)		0.49	0.35	0.19	0.26	-0.2	-0.42	0	0.41	0.03	-0.22	-0.25	-0.1	0.09	0.18	0.06	-0.32	0.19	-0.04	0.22	*bool research*	(1)
(2)	0.48		0.41	0.16	0.11	-0.5	0.01	0.29	0.47	0.53	0.28	-0.41	-0.21	-0.03	0.5	0.1	0.15	0.5	0.27	-0.23	*bool university*	(2)
(3)	-0.28	-0.26		0.26	0.06	-0.04	-0.03	0.09	0	-0.09	-0.15	-0.21	-0.2	0.23	0	-0.03	-0.13	0.04	0.07	-0.06	*sum subsidies*	(3)
(4)	0.04	-0.05	-0.01		0.1	-0.63	0.27	0.16	0.07	-0.15	-0.21	-0.03	-0.25	-0.02	0.03	-0.04	-0.45	0.47	0.21	-0.07	*degree*	(4)
(5)	0.23	0.33	-0.2	0.25		-0.15	-0.12	-0.05	0.1	-0.03	-0.07	-0.14	-0.11	0.03	0.07	0.03	-0.11	0.11	0.06	-0.01	*transitive triads*	(5)
(6)	0	-0.38	-0.01	-0.33	-0.58		-0.21	-0.36	-0.32	-0.48	-0.26	0.2	0.17	0.29	-0.43	-0.08	-0.11	-0.88	-0.39	0.2	*degree of alter*$_{sqrt}$	(6)
(7)	-0.03	-0.13	-0.25	0.06	-0.02	-0.03		0.2	0.12	0.08	0.34	0.21	-0.14	-0.02	0.16	0.22	0.06	0.1	0.05	-0.17	*isolate*	(7)
(8)	0.03	-0.01	0.02	-0.01	0.04	-0.12	0.04		0.22	0.42	0.25	0.03	-0.08	-0.04	0.31	0.07	0.18	0.28	0.35	-0.31	*geo-proximity*$_{fix\ i,j}$	(8)
(9)	0.38	0.05	-0.06	-0.43	-0.07	0.31	0.07	0.02		0.32	0.2	-0.18	0.09	-0.1	0.69	0.44	-0.31	0.2	0.1	-0.12	*inst-proximity research & business*$_{hetero\ fix}$	(9)
(10)	0.01	0.29	0.06	-0.76	0.04	-0.18	0.11	0.06	0.25		0.25	-0.27	-0.06	-0.25	0.69	-0.23	0.53	0.52	0.37	-0.28	*inst-proximity academic & business*$_{hetero\ fix}$	(10)
(11)	-0.12	0.41	0.09	-0.47	0.09	-0.23	-0.05	0	0.05	0.44		-0.09	-0.01	-0.05	0	0.52	0.53	0.22	0.04	-0.08	*inst-proximity academic & research*$_{hetero\ fix}$	(11)
(12)	0.1	-0.18	0.17	0.03	-0.08	0.09	-0.38	0.05	0.04	-0.19	-0.15		0.11	-0.07	-0.3	0.07	-0.11	-0.29	-0.2	-0.06	*cognitive-proximity*$_{lpsys/ipc\ i,j}$	(12)
(13)	-0.01	0.21	0.05	-0.08	0.08	-0.38	0.13	-0.01	0	0.29	0.33	-0.11		-0.63	0.03	0	0.04	-0.39	-0.21	-0.29	*employees*$_{fix}$	(13)
(14)	-0.12	-0.11	0.08	-0.05	-0.16	0.29	-0.17	0.01	-0.01	-0.15	-0.12	0.1	-0.83		-0.2	0.02	-0.2	-0.26	0.07	0.32	*turnover*$_{fix}$	(14)
(15)	0.05	0.01	0.04	-0.79	-0.14	0.12	0.08	0.1	0.54	0.8	0.07	-0.09	0.12	0.01		-0.09	-0.04	0.38	0.28	-0.34	*inst-proximity business*$_{homo\ fix}$	(15)
(16)	0.08	0.1	-0.09	-0.21	0.04	0.04	-0.01	0.05	0.42	-0.11	0.49	0	0.05	-0.03	-0.05		-0.18	-0.01	-0.15	0.07	*inst-proximity research*$_{homo\ fix}$	(16)
(17)	-0.24	0.2	0.15	-0.45	-0.03	-0.27	0.07	0	-0.23	0.63	0.71	-0.23	0.24	-0.07	0.19	-0.08		0.19	0.12	-0.13	*inst-proximity academic*$_{homo\ fix}$	(17)
(18)	0.01	0.3	-0.11	0.4	0.33	-0.71	-0.05	0.09	-0.28	-0.06	0.01	-0.14	-0.16	0.09	-0.25	-0.03	0.04		0.33	-0.08	*sum subsidies*$_{i,j}$	(18)
(19)	0.17	0.2	0.09	0.08	-0.01	-0.06	-0.18	0.02	-0.03	-0.05	0.01	0.04	-0.05	0.03	-0.09	0.03	-0.06	0.15		-0.61	*interaction patents/subsidies*	(19)
(20)	0.17	-0.05	-0.09	-0.12	0.04	0.06	-0.02	0.15	0.09	0.07	-0.01	0.07	0.02	-0.16	0.09	0	0	-0.13	-0.19		*triadic closure patents/subsidies*	(20)

Table V.7.: Chemical industry - correlation matrix

	subsidies network	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	patent network		
(1)			0.44	0.09	0.12	-0.07	0.16	0.67	0.08	0.32	0.1	-0.31	0.47	0.54	-0.43	0.5	-0.06	-0.14	-0.46	-0.04	-0.56		*bool research*	(1)
(2)		0.41		0.59	-0.22	-0.2	-0.11	0.04	0.02	0.31	0.67	0.18	-0.14	-0.09	-0.07	0.39	-0.24	0.42	0.31	-0.22	0.15		*bool university*	(2)
(3)		-0.55	-0.08		-0.17	0.04	-0.15	-0.35	0.22	-0.07	0.29	0.2	-0.25	-0.28	0.05	0.05	-0.22	0.33	0.44	-0.13	0.34		*sum subsidies/patents*	(3)
(4)		-0.1	-0.03	0.1		-0.05	-0.5	0.34	0.18	0.15	-0.3	-0.54	0.06	0.33	-0.18	-0.02	0.06	-0.65	-0.03	0.14	-0.38		*degree*	(4)
(5)		0.19	-0.18	-0.22	0.46		-0.16	-0.39	-0.04	-0.4	-0.27	0.07	0.04	0.13	-0.2	-0.24	-0.12	0.12	-0.05	0.04	0.03		*transitive triads*	(5)
(6)		-0.15	0.21	0.07	-0.49	-0.74		0.25	-0.02	0.03	-0.09	-0.15	0.24	0	0.15	0.07	0.07	-0.12	-0.63	-0.02	-0.19		*degree of* $alter_{sqrt}$	(6)
(7)		-0.17	0.45	0.24	0.06	-0.37	0.28		0.07	0.36	-0.03	-0.44	0.33	0.52	-0.26	0.32	0.2	-0.4	-0.56	0.05	-0.66		*isolate*	(7)
(8)		-0.11	-0.36	-0.03	-0.02	0.07	-0.16	-0.33		-0.1	0	-0.25	0	0.09	-0.09	0.1	-0.13	-0.1	-0.01	0.05	-0.14		$geo\text{-}proximity_{fix\ i,j}$	(8)
(9)		-0.12	0.29	0.33	-0.24	-0.35	0.27	0.36	-0.11		0.33	-0.15	0.02	0.15	-0.07	0.58	0.29	-0.37	-0.06	-0.2	-0.06		*inst-proximity research & business*$_{hetero\ fix}$	(9)
(10)		-0.05	-0.02	0.18	-0.17	0.21	-0.26	-0.02	0.13	0		0.17	-0.3	-0.21	0.1	0.51	-0.37	0.5	0.33	-0.27	0.32		*inst-proximity academic & business*$_{hetero\ fix}$	(10)
(11)		0.21	-0.02	-0.13	-0.7	-0.13	-0.04	-0.11	0.09	0.27	-0.01		-0.24	-0.42	0.18	-0.4	0.24	0.63	0.48	-0.08	0.5		*inst-proximity academic & research*$_{hetero\ fix}$	(11)
(12)		0.03	0.16	0	0.1	0.08	-0.14	0.12	-0.08	-0.04	0.11	-0.08		0.43	-0.29	0.1	-0.12	-0.21	-0.55	0.06	-0.52		$cognitive\text{-}proximity_{lpsys/ipc\ i,j}$	(12)
(13)		0.01	-0.22	-0.08	0.01	-0.19	-0.06	-0.09	0.13	0.08	-0.09	0.06	-0.2		-0.86	0.29	0	-0.32	-0.67	0.02	-0.68		$employees_{fix}$	(13)
(14)		0.06	0.06	-0.02	-0.04	0.28	-0.13	-0.08	-0.02	-0.15	0.17	0.05	0.17	-0.9		-0.23	0.05	0.09	0.32	0.04	0.47		$turnover_{fix}$	(14)
(15)		-0.2	0.12	0.33	0.05	0.12	-0.14	0.24	-0.07	0.22	0.65	-0.26	0.18	-0.15	0.09		-0.29	-0.1	-0.2	-0.15	-0.18		*inst-proximity* $business_{homo\ fix}$	(15)
(16)		0.03	0.02	0.06	-0.66	-0.42	0.2	0	0.07	0.53	-0.26	0.79	-0.25	0.22	-0.14	-0.28		-0.41	-0.05	0.07	-0.08		*inst-proximity* $research_{homo\ fix}$	(16)
(17)		0.11	-0.08	0.01	-0.49	-0.16	-0.07	-0.11	0.18	-0.08	0.48	0.45	-0.12	0.03	0.07	-0.12	0.22		0.39	-0.13	0.44		*inst-proximity* $academic_{homo\ fix}$	(17)
(18)		0.18	-0.11	-0.12	0.33	0.65	-0.8	-0.24	0.03	-0.3	0.26	0.07	0.17	-0.38	0.51	0.18	-0.29	0.05		-0.11	0.66		*sum* $subsidies_{i,j}$	(18)
(19)		-0.29	0.26	0.4	-0.21	-0.47	0.44	0.16	-0.1	0.32	-0.03	-0.05	-0.14	-0.12	-0.07	0.06	0.19	0.09	-0.36		-0.42		*interaction patents/subsidies*	(19)
(20)		0.12	-0.15	-0.3	-0.02	0.01	0.06	-0.21	0.16	-0.19	-0.22	-0.05	-0.08	0.16	-0.24	-0.26	0.01	-0.02	-0.16	-0.22			*triadic closure patents/subsidies*	(20)

Table V.8.: Automotive industry - correlation matrix



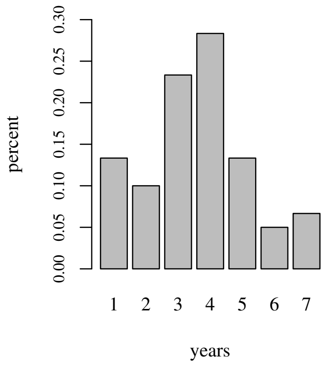
(a) multiplex tie (b) prior R&D tie (c) prior innovation tie (d) instant multiplex tie

Figure V.2.: Evolution of multiplex ties

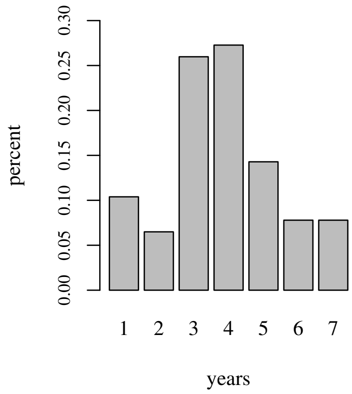
	model		estimation				
	type	effect	convergence	regressor	error	t-statistic	sign.
subsidy network	rate	*constant$_{t=1}$*	-0.01	3.37	0.32	10.44	***
	rate	*constant$_{t=2}$*	0.08	2.35	0.22	10.72	***
	rate	*constant$_{t=3}$*	0.002	2.08	0.21	9.78	***
	rate	*bool research*	-0.06	-0.28	0.12	-2.33	**
	rate	*bool university*	0.06	1.59	0.16	9.82	***
	rate	*sum subsidies*	0.03	0.28	0.04	7.99	***
	eval	*degree*	0.01	-2.37	0.15	-16.14	***
	eval	*transitive triads*	0.01	0.03	0.003	10.14	***
	eval	*degree of alter$_{sqrt}$*	-0.02	0.19	0.03	7.23	***
	eval	*isolate*	-0.003	3.21	0.47	6.83	***
	eval	*geo-proximity$_{fix\ i,j}$*	0.04	-0.08	0.01	-7.59	***
	eval	*inst-proximity research & business$_{fix}$*	0.02	-0.02	0.19	-0.08	
	eval	*inst-proximity academic & business$_{fix}$*	-0.07	-0.19	0.22	-0.87	
	eval	*inst-proximity academic & research$_{fix}$*	-0.002	0.36	0.14	2.53	**
	eval	*cognitive-proximity$_{lpsys\ i,j}$*	0.01	0.30	0.08	3.74	***
	eval	*sum employees$_{fix}$*	0.003	-0.03	0.01	-3.25	***
	eval	*sum turnover$_{fix}$*	0.02	0.05	0.01	4.84	***
	eval	*inst-proximity business$_{homo\ fix}$*	-0.04	-0.25	0.14	-1.71	*
	eval	*inst-proximity research$_{homo\ fix}$*	-0.02	0.16	0.06	2.57	**
	eval	*inst-proximity academic$_{homo\ fix}$*	-0.01	-0.30	0.09	-3.21	***
	eval	*sum subsidies$_{i,j}$*	-0.001	0.77	0.06	12.28	***
	eval	*interaction patents*	0.04	0.75	0.23	3.27	***
	eval	*triadic closure patents*	0.03	0.07	0.11	0.63	
patent network	rate	*constant$_{t=1}$*	0.03	1.84	0.28	6.48	***
	rate	*constant$_{t=2}$*	0.00	1.28	0.20	6.44	***
	rate	*constant$_{t=3}$*	-0.07	1.31	0.26	5.04	***
	rate	*bool research*	-0.02	0.10	0.26	0.38	
	rate	*bool university*	0.03	0.64	0.28	2.32	*
	rate	*sum patents*	-0.02	0.20	0.02	11.43	***
	eval	*degree*	0.01	-2.64	0.25	-10.59	***
	eval	*transitive triads*	-0.02	-0.01	0.09	-0.09	
	eval	*degree of alter$_{sqrt}$*	-0.01	0.23	0.18	1.22	
	eval	*isolate*	0.01	3.73	0.52	7.18	***
	eval	*geo-proximity$_{fix\ i,j}$*	-0.03	-0.12	0.03	-4.15	***
	eval	*inst-proximity research & business$_{hetero\ fix}$*	0.02	-0.16	0.46	-0.35	
	eval	*inst-proximity academic & business$_{hetero\ fix}$*	-0.05	0.01	0.63	0.02	
	eval	*inst-proximity academic & research$_{hetero\ fix}$*	-0.06	-0.38	0.44	-0.86	
	eval	*cognitive-proximity$_{ipc\ i,j}$*	-0.01	0.40	0.28	1.43	.
	eval	*sum employees$_{fix}$*	0.02	0.01	0.02	0.736	
	eval	*sum turnover$_{fix}$*	0.03	-0.03	0.02	-1.50	.
	eval	*inst-proximity business$_{homo\ fix}$*	0.01	0.04	0.23	0.17	
	eval	*inst-proximity research$_{homo\ fix}$*	0.02	-0.22	0.16	-1.36	.
	eval	*inst-proximity academic$_{homo\ fix}$*	0.04	0.11	0.21	0.53	
	eval	*sum pats$_{i,j}$*	0.02	0.22	0.07	3.11	***
	eval	*interaction subsidies*	-0.01	0.59	0.19	3.18	***
	eval	*triadic closure subsidies*	-0.01	0.001	0.01	0.12	

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

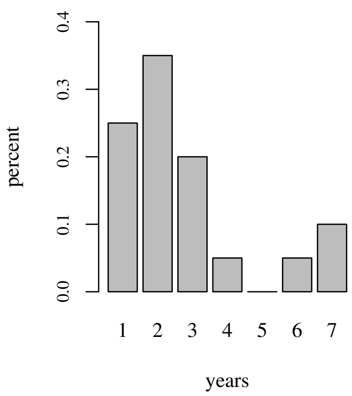
Table V.9.: Estimation results model - chemical industry



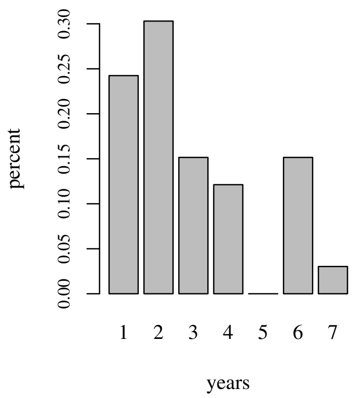
(a) Prior R&D chemical sector



(b) Prior R&D automotive sector



(c) Prior innovation chemical sector



(d) Prior innovation automotive sector

Figure V.3.: Evolution of multiplex ties in time

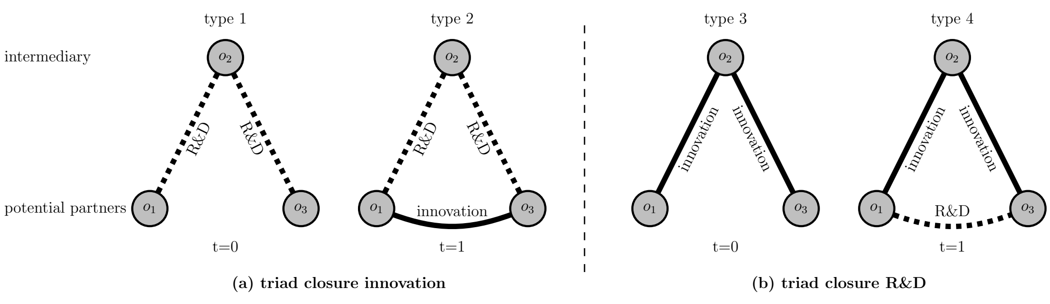
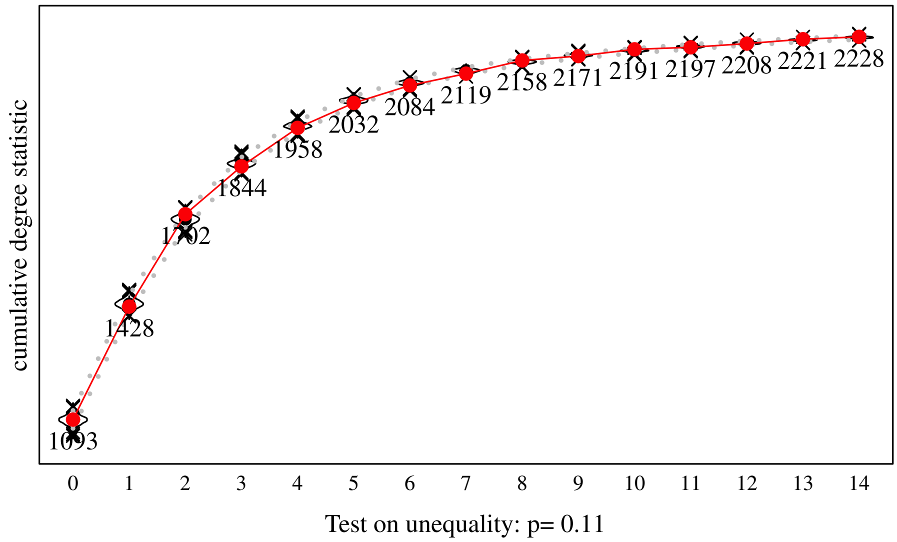
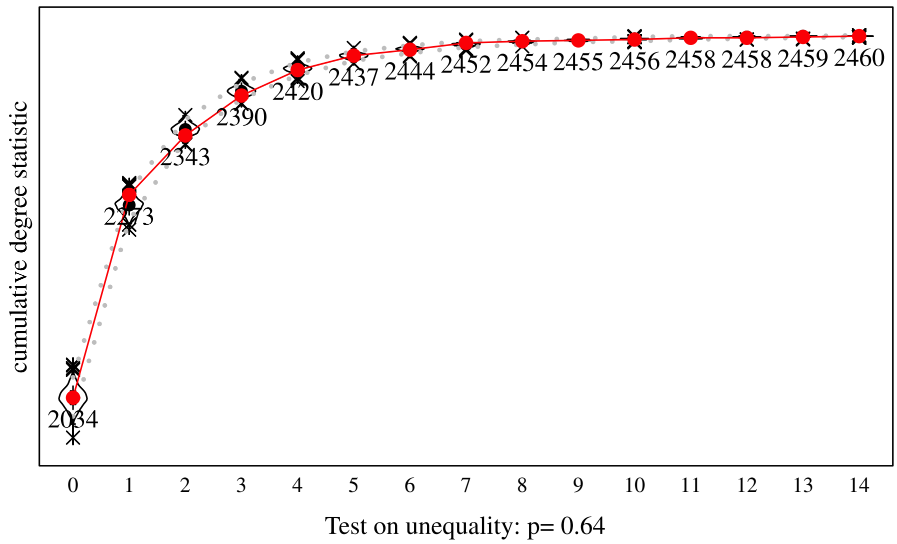


Figure V.4.: Evolution of multiplex triads



(a) Subsidy network



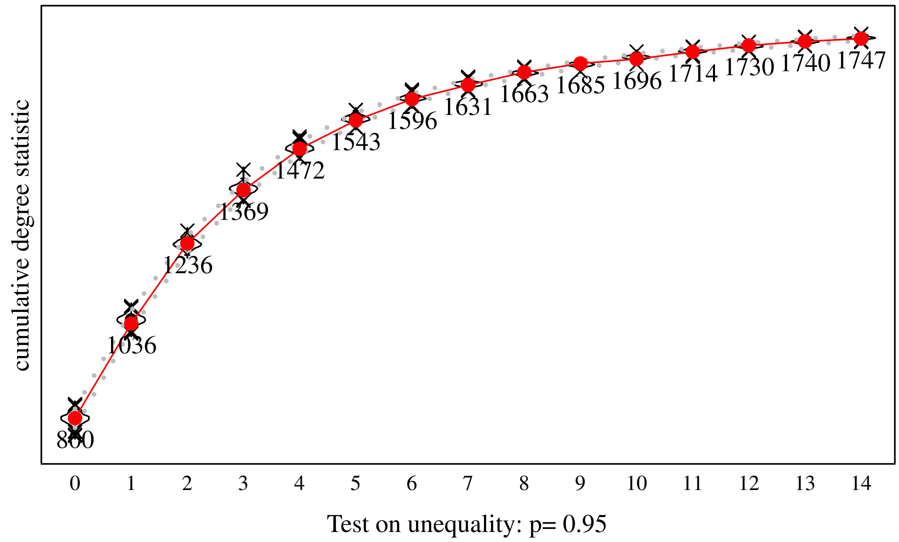
(b) Patent network

Figure V.5.: GOF – model chemical: degree distribution

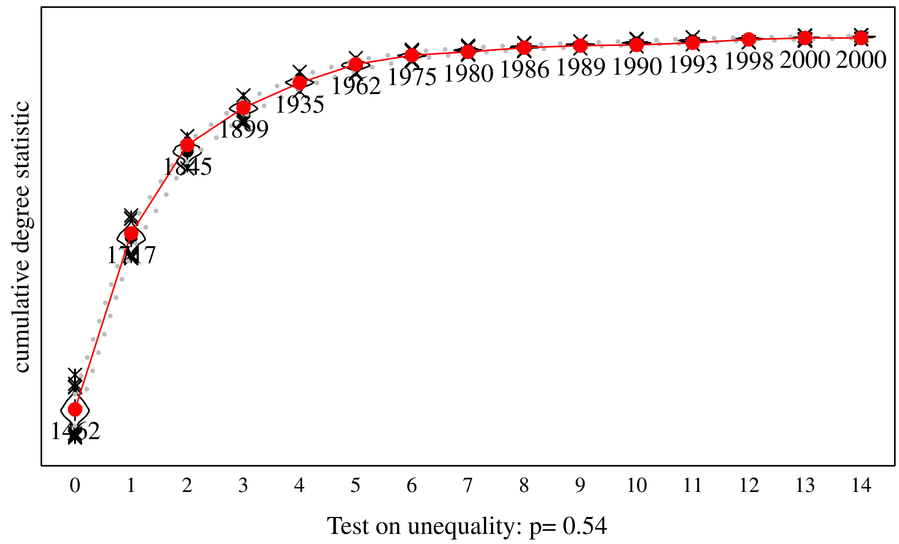
	model		estimation				
	type	effect	convergence	regressor	error	t-statistic	sign.
subsidy network	rate	*constant*$_{t=1}$	0.01	3.56	0.39	9.10	***
	rate	*constant*$_{t=2}$	-0.02	2.57	0.31	8.24	***
	rate	*constant*$_{t=3}$	0.05	2.24	0.28	7.99	***
	rate	*bool research*	-0.08	-0.54	0.14	-3.92	***
	rate	*bool university*	0.03	1.32	0.13	9.94	***
	rate	*sum subsidies*	0.03	0.32	0.05	6.41	***
	eval	*degree*	0.05	-2.56	0.13	-19.95	***
	eval	*transitive triads*	-0.06	0.03	0.004	6.87	***
	eval	*degree of alter*$_{sqrt}$	-0.05	0.22	0.03	7.09	***
	eval	*isolate*	-0.02	3.16	0.69	4.59	***
	eval	*geo-proximity*$_{fix\ i,j}$	-0.04	-0.08	0.01	-6.72	***
	eval	*inst-proximity research & business*$_{fix}$	0.04	0.39	0.17	2.33	**
	eval	*inst-proximity academic & business*$_{fix}$	0.01	0.10	0.18	0.54	
	eval	*inst-proximity academic & research*$_{fix}$	-0.03	0.41	0.12	3.38	***
	eval	*cognitive-proximity*$_{lpsys\ i,j}$	-0.02	0.28	0.08	3.48	***
	eval	*sum employees*$_{fix}$	-0.0003	-0.02	0.01	-2.36	**
	eval	*sum turnover*$_{fix}$	0.01	0.03	0.01	2.50	**
	eval	*inst-proximity business*$_{homo\ fix}$	-0.05	0.06	0.14	0.45	
	eval	*inst-proximity research*$_{homo\ fix}$	0.01	0.16	0.07	2.38	**
	eval	*inst-proximity academic*$_{homo\ fix}$	-0.004	-0.27	0.08	-3.45	***
	eval	*sum subsidies*$_{i,j}$	-0.03	0.64	0.08	8.42	***
	eval	*interaction patents*	0.04	0.66	0.31	2.12	*
	eval	*triadic closure patents*	0.02	0.06	0.06	1.02	
patent network	rate	*constant*$_{t=1}$	0.05	2.69	0.67	4.02	***
	rate	*constant*$_{t=2}$	0.05	1.95	0.47	4.18	***
	rate	*constant*$_{t=3}$	0.002	2.06	0.46	4.43	***
	rate	*bool research*	-0.06	-0.12	0.37	-0.33	
	rate	*bool university*	-0.04	-0.07	0.33	-0.21	
	rate	*sum patents*	0.06	0.09	0.01	6.21	***
	eval	*degree*	0.09	-2.54	0.22	-11.29	***
	eval	*transitive triads*	0.05	0.09	0.06	1.57	.
	eval	*degree of alter*$_{sqrt}$	0.05	0.07	0.11	0.58	
	eval	*isolate*	-0.05	4.03	0.79	5.11	***
	eval	*geo-proximity*$_{fix\ i,j}$	-0.08	-0.10	0.02	-4.17	***
	eval	*inst-proximity research & business*$_{hetero\ fix}$	-0.05	-0.49	0.34	-1.46	.
	eval	*inst-proximity academic & business*$_{hetero\ fix}$	-0.01	-0.48	0.54	-0.88	
	eval	*inst-proximity academic & research*$_{hetero\ fix}$	-0.04	-0.16	0.49	-0.32	
	eval	*cognitive-proximity*$_{ipc\ i,j}$	0.06	0.61	0.22	2.83	**
	eval	*sum employees*$_{fix}$	0.07	0.0001	0.02	0.004	
	eval	*sum turnover*$_{fix}$	0.08	-0.01	0.02	-0.37	
	eval	*inst-proximity business*$_{homo\ fix}$	0.07	-0.04	0.13	-0.31	
	eval	*inst-proximity research*$_{homo\ fix}$	0.08	-0.13	0.15	-0.88	
	eval	*inst-proximity academic*$_{homo\ fix}$	0.07	0.15	0.24	0.60	
	eval	*sum pats*$_{i,j}$	0.06	0.22	0.07	3.20	***
	eval	*interaction subsidies*	0.00	0.54	0.15	3.67	***
	eval	*triadic closure subsidies*	0.02	0.01	0.01	0.80	

Significances of the parameter: *** 0.1%, ** 1%, * 5%, . 10%.

Table V.10.: Estimation results model - automotive industry



(a) Subsidy network



(b) Patent network

Figure V.6.: GOF – model automotive industry: degree distribution a large number of employees is less likely to cooperate. For the innovation network, the effect of the annual turnover turns out to be negative in the case of the chemical industry, but the significance of this effect is close to zero.

The variable *geo-proximity* meets our expectations and thus stays in line with prior findings (Ter Wal, 2009). Organizations that are proximate in a geographic sense are significantly more likely to become connected, which is reflected by the negative value of the parameter *geo-proximity* for both models and networks.

In the case of *institutional proximity*, our findings differ for the observed networks and industry sectors. For collaborations on the basis of patent applications, we identified some institutional preference patterns that have been significant to the level of 0.1. In the case of the chemical sector, we found a negative attraction if both organizations are research centers. A second pattern is found inside the automotive sector. A collaboration between a commercial firm and a research organization seems to be less likely than other sectoral combinations. The overall low significance of the *institutional proximity* parameters reflects that there is no special favor for institutional openness or closeness when organizations could choose their cooperation partner freely, as inside the innovation network. This result has most in common with Boschma (2005), who pleads for an optimal mixture of institutional proximity in order to stimulate the innovational output of a collaboration. If organizations act this way, we should not see any patterns – neither homophilous nor heterophilous. In contrast to patent applications, R&D projects are influenced by governmental policy, so that the institutional mixture could be prejudged by administrative decisions, which is often the case of the R&D projects funded by the German government. For the R&D network, we found serious homophilous patterns, indicating that organizations coming from an academic background are less likely to cooperate, while in contrast research centers have a positive probability. Moreover, we found a positive and significant heterophilous effect across the sectors, which gives research centers and universities a higher probability of collaborating. We can only assume why those patterns emerge between both sectors. It seems to be the aim of the governmental policy to connect research centers and universities through government-funded projects, favoring the constellation of a limited number of universities and several research centers in each of the projects. Interestingly, commercial firms from the chemical and automotive sectors seem to have divergent interests. The significantly lower probability of chemical firms cooperating with each other maybe reflects strong competition inside the sector, while firms inside the automotive sector have a preference for cooperating with research centers, which can be the consequence of a higher grade of technology insensitivity inside the automotive industry.

Cognitive proximity connects organizations with a similar technological base, which leads to a significantly higher probability of becoming connected in our model. Similarly to geographic proximity, cognitive proximity turns out to be a universal connector, linking organizations within R&D and innovation networks and different industries.

Transitivity has a minor role for the innovation network. The *transitive triads* parameter reaches some significance for the automotive sector, increasing the chance of two indirectly connected organizations becoming connected through social proximity, but the overall relevance is constrained, since the parameter stays insignificant for the chemical sector. The situation within the R&D network is entirely different, since the governmental policy promotes transitivity. Due to collaborative projects normally involving more than two organizations, the *transitive triad* parameter is highly significant. After all, the *isolate* parameter points to the extreme case of social proximity, indicating the lowest possible extent of social embeddedness. It is not surprising that the value of this parameter is significantly positive, since the number of isolated organizations within our network is diminishing.

For the R&D network, in both models, the reduction of the *constant rate* parameter after each time step reflects a decline in the number of links being established in each time period. Furthermore, the additional rate parameters seem to confirm that our assumption of policy-caused differences between the sectors. Organizations with an academic background (*bool academia*) tend to have a significantly higher probability of sending the next tie to another organization, while research centers (*bool research*) have a significantly lower probability of doing so. The innovation network does seem to be affected in the same way, since the additional rate parameters related to the sectoral affiliation remain insignificant. As suspected, prior project and innovation activities have an influence on the likelihood of an organization receiving a tie during the next time step, as both variables – $\textit{sum subsidies}_t$ and $\textit{sum patents}_t$ – are positive and highly significant for the chemical and automotive industries.

Since the parameter value of the *degree* effect turns out to be negative and significant for both networks and models, organizations find it costly to establish new links, irrespective of the other effects. This finding is typical for SIENA models, because otherwise organizations would have as many cooperation partners as possible. Organizations favor neighbors with a high social prestige, since the parameter of the effect $\textit{degree of alter}_{sqrt}$ is positive and significant. Having a neighbor with many collaborations brings some advantages, since such a neighbor acts as an intermediary for new partners, and social prestige can be seen as an indicator for trustworthiness.

7. Conclusion

The aim of the paper was to investigate the interrelationships between two kinds of cooperation – research collaborations and cooperative innovations. Although there have frequently been other studies analyzing research collaborations and cooperative innovations, only a few authors were interested in the dependency of both. Each year, governments spend large budgets for the promotion of research joint ventures, but still less is known concerning the success of stimulating cooperative innovations. To bring some light to this discussion, this paper dealt with two kinds of networks. The funding network was derived from the German funding scheme, which supports precompetitive research joint ventures among various organizations. The innovation network was extracted from the EPO PATSTAT database, whereby a conservative procedure was applied to construct the innovation network from the patent data. Based upon theoretical thoughts, four hypotheses were formulated, expecting certain interdependencies between the evolutions of both networks. Evaluating the theoretical presumptions, a SIENA model was estimated to analyze the dynamics that shape the formation of two interrelated networks. For the robustness of the results, two different sectors were analyzed – the chemical sector and the automotive sector since both sectors are responsible for a large share of the German innovative capacity. The results are derived from frequent simulations for both sectors, whereby the network of the chemical sector includes 815 organizations and the automotive industry includes 671 organizations.

Hypothesis ***H1a*** was broadly supported, explaining that it is possible to stimulate collaborative innovations through government-funded research joint ventures. If a pairing of organizations receives a collaborative project grant, it becomes much more likely that both organizations will innovate together at a later time because of bilateral knowledge flows, mutual trust, and resource pooling. In this vein, public cooperative subsidies become an important policy tool for a government which aims to stimulate innovations. The original intention of subsidies as a support to overcome the private underinvestment in R&D is still valid, but beside this cooperative subsidies also act as a door-opener establishing long-term joint ventures for innovation between firms, universities and research centers. Notwithstanding, further investigations are needed to assess whether a public planning of cooperation outperforms the market mechanism. Hypothesis ***H1a*** was broadly supported, explaining that it is possible to stimulate collaborative innovations through government-funded research joint ventures. If a pairing of organizations receives a collaborative project grant, it becomes much more likely that both organizations will innovate together at a later time because of bilateral knowledge flows, mutual trust, and resource pooling. In this vein, public cooperative subsidies become an important policy tool for a government which aims to stimulate innovations. The original intention of subsidies as a support to overcome the private underinvestment in R&D is still valid, but beside this cooperative subsidies also act as a door opener establishing long-term joint ventures for innovation between firms, universities and research centers. Notwithstanding, further investigations are needed to assess whether a public planning of cooperation outperforms the market mechanism.

Similar applies for the other direction of influence, since hypothesis ***H1b*** was also verified. If two organizations have innovated together, it becomes more likely that both will obtain a contribution for a bilateral research activity. The government seeks public investment opportunities to close the gap of the firm's underinvestment in R&D. Since public funds are scarce and politicians require success to legitimize their policy, governments may be influenced by the "picking the winner" strategy, positing that governments tend to allocate funds to organizations which have already proven their ability to innovate. Another possible explanation might be that organizations that have already innovated together have a starting advantage compared to other organizations if it comes to a project application, due to preexisting experiences in cooperating. This observation contributes to the discussion concerning the rent–seeking activity of organizations. Hypothesis ***H1a*** clarifies that cooperative subsidies can entail bilateral innovations, which are additional, since previous relations did not exist among the partners; thus, it is very likely that otherwise it would never have come to this innovation. On the other hand, hypothesis ***H1b*** explains that research promotions are not always additional in terms of bringing together new organizational pairings, since organizations have innovated together successfully prior to receiving a governmental contribution.

Moreover, governments have to be aware of the effects resulting from both hypotheses when designing their innovation policies. If they largely support collaborative R&D activities, the result indicates, that the formation of the innovation networks becomes heavily influenced by the patterns that emerge within the funding network. This is alarming, since we know that governmental innovation policies already allow the formation of core structures within the funding network (Breschi and Cusmano, 2004; Roediger-Schluga and Barber, 2006), which entails risks such as technological lock-ins and a reduction of knowledge flows (Cowan and Jonard, 2004). In order to reduce an unintended market distortions the government should may check whether the funding award is additional to preexisting collaborations, and if so reduce the financial contribution or install incentives favoring collaborations that are non-additional.

Hypotheses ***H2a*** and ***H2b*** are rejected. Both investigated whether organizations are more likely to carry out a bilateral R&D activity or innovation if both organizations are connected through an intermediary, connecting the organizations indirectly. A possible explanation is that there are less observations of this pattern within the data set to gain significant results from the estimation. We strongly believe that organizations seek advice from intermediary regarding whom to partner with, but no evidence was to found.

This paper addressed whether cooperative subsidies are effective in stimulating cooperative innovations. But the question about the efficiency disentangling the cost and the benefit of the policy implementation remains unclear, so that further research in needed. Since the empirical investigation was limited to the automotive and chemical sector, as well as to the case of Germany, additional insights for other industrial sectors and countries are also recommenced. Instead of organizations, further research could focus on collaborating person that are embedded in research and innovation activities of organizations.

Bibliography

Ahuja, G., G. Soda, and A. Zaheer (2012). 'The Genesis and Dynamics of Organizational Networks'. In: *Organization Science* 23.2, pp. 434–448.

Arrow, K. (1962). 'The Rate and Direction of Inventive Activity: Economic and Social Factors'. In: *The rate and direction of inventive activity: Economic and social factors*. Ed. by R. Nelson. Princeton University Press. Chap. Economic Welfare and the Allocation of Resources for Invention, pp. 609–626.

Aschhoff, B. and T. Schmidt (2008). 'Empirical Evidence on the Success of R&D Cooperation – Happy Together?' In: *Review of Industrial Organization* 33.1, pp. 41–62.

Autant-Bernard, C., P. Billand, D. Frachisse, and N. Massard (2007). 'Social distance versus spatial distance in R&D cooperation: Empirical evidence from European collaboration choices in micro and nanotechnologies'. In: *Papers in Regional Science* 86.3, pp. 495–519.

Balland, P.-A. (2012). 'Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry'. In: *Regional Studies* 46.6, pp. 741–756.

Bannò, M. and F. Sgobbi (2010). 'Firm participation in financial incentive programmes: The case of subsidies for outward internationalisation'. In: *Journal of Policy Modeling* 32.6, pp. 792–803.

Beesley, L. G. (2003). 'Science policy in changing times: are governments poised to take full advantage of an institution in transition?' In: *Research Policy* 32.8, pp. 1519–1531.

Belderbos, R., M. Carree, and B. Lokshin (2006). 'Complementarity in R&D cooperation strategies'. In: *Review of Industrial Organization* 28.4, pp. 401–426.

Bergenholtz, C. and C. Waldstrøm (2011). 'Inter-Organizational Network Studies–A Literature Review'. In: *Industry & Innovation* 18.6, pp. 539–562.

Blanes, J. V. and I. Busom (2004). 'Who participates in R&D subsidy programs?: The case of Spanish manufacturing firms'. In: *Research Policy* 33.10, pp. 1459–1476.

Blind, K., J. Edler, R. Frietsch, and U. Schmoch (2006). 'Motives to patent: Empirical evidence from Germany'. In: *Research Policy* 35.5, pp. 655–672.

Boschma, R. (2005). 'Proximity and Innovation: A Critical Assessment'. In: *Regional Studies* 39.1, pp. 61–74.

Breschi, S. and C. Catalini (2010). 'Tracing the links between science and technology: An exploratory analysis of scientists' and inventors' networks'. In: *Research Policy* 39.1, pp. 14–26.

Breschi, S. and L. Cusmano (2004). 'Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes'. In: *International Journal of Technology Management* 27, pp. 747–772.

Breschi, S. and F. Lissoni (2003). *Mobility and Social Networks: Localised Knowledge Spillovers Revisited*. Tech. rep. 142. KITeS, Centre for Knowledge, Internationalization and Technology Studies, Universita' Bocconi, Milano, Italy.

– (2005). 'Knowledge Networks from Patent Data'. In: *Handbook of Quantitative Science and Technology Research*. Ed. by H. Moed, W. Glänzel, and U. Schmoch. Springer Netherlands, pp. 613–643.

Broekel, T. and H. Graf (2010). *Structural properties of cooperation networks in Germany: From basic to applied research*. Jena Economic Research Papers 78. Friedrich Schiller Universität Jena.

– (2012). 'Public research intensity and the structure of German R&D networks: a comparison of 10 technologies'. In: *Economics of Innovation and New Technology* 21.4, pp. 345–372.

Broekel, T. and M. Hartog (2013). 'Explaining the Structure of Inter-Organizational Networks using Exponential Random Graph Models'. In: *Industry & Innovation* 20.3, pp. 277–295.

Bunt, G. G. van de and P. Groenewegen (2007). 'An Actor-Oriented Dynamic Network Approach: The Case of Interorganizational Network Evolution'. In: *Organizational Research Methods* 10.3, pp. 463–482.

Cantner, U. and S. Kösters (2009). *Picking the winner? Empirical evidence on the targeting of R&D subsidies to start-ups*. Jena Economic Research Papers 93. Friedrich Schiller Universität Jena.

Castro, I., C. Casanueva, and J. L. Galán (2014). 'Dynamic evolution of alliance portfolios'. In: *European Management Journal* 32.3, pp. 423–433.

Cavusgil, S. T., R. J. Calantone, and Y. Zhao (2003). 'Tacit knowledge transfer and firm innovation capability'. In: *Journal of Business & Industrial Marketing* 18.1, pp. 6–21.

Coad, A. and R. Rao (2008). 'Innovation and firm growth in high-tech sectors: A quantile regression approach'. In: *Research Policy* 37.4, pp. 633–648.

Cohen, W. M. and D. A. Levinthal (1990). 'Absorptive Capacity: A New Perspective on Learning and Innovation'. In: *Administrative Science Quarterly* 35.1, pp. 128–152.

Cowan, R. and N. Jonard (2004). 'Network structure and the diffusion of knowledge'. In: *Journal of Economic Dynamics and Control* 28.8, pp. 1557–1575.

David, P. A., B. H. Hall, and A. A. Toole (2000). 'Is public R&D a complement or substitute for private R&D? A review of the econometric evidence'. In: *Research Policy* 29, pp. 497–529.

De Stefano, D. and S. Zaccarin (2013). 'Modelling Multiple Interactions in Science and Technology Networks'. In: *Industry & Innovation* 20.3, pp. 221–240.

Duguet, E. (2004). *Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non- experimental data*. Tech. rep. Université de Bretagne Occidentale and EUREQua.

Edquist, C. (2005). *Systems of Innovation: Technologies, Institutions and Organizations*. Routledge.

Federal Ministry of Education and Research (2010). *Ideen. Innovation. Wachstum. - Hightech-Strategie 2020 für Deutschland*.

Ferriani, S., F. Fonti, and R. Corrado (2013). 'The social and economic bases of network multiplexity: Exploring the emergence of multiplex ties'. In: *Strategic Organization* 11.1, pp. 7–34.

Fleming, L., C. King, and A. I. Juda (2007). 'Small Worlds and Regional Innovation'. In: *Organization Science* 18.6, pp. 938–954.

Fornahl, D., T. Broekel, and R. Boschma (2011). 'What drives patent performance of German biotech firms? The impact of R&D subsidies, knowledge networks and their location'. In: *Papers in Regional Science* 90.2, pp. 395–418.

Gilsing, V., B. Nooteboom, W. Vanhaverbeke, G. Duysters, and A. van den Oord (2008). 'Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density'. In: *Research Policy* 37.10, pp. 1717–1731.

Giuliani, E. (2013). 'Network dynamics in regional clusters: Evidence from Chile'. In: *Research Policy* 42.8, pp. 1406–1419.

Giuri, P., M. Mariani, S. Brusoni, G. Crespi, D. Francoz, A. Gambardella, W. Garcia-Fontes, A. Geuna, R. Gonzales, D. Harhoff, K. Hoisl, and Christia (2005). *Everything you Always Wanted to Know about Inventors (but Never Asked): Evidence from the PatVal-EU Survey*. LEM Papers Series 2005/20. Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies.

Granovetter, M. (1973). 'The Strength of Weak Ties'. In: *American Journal of Sociology* 78.6, pp. 1360–1380.

– (1985). 'Economic Action and Social Structure: The Problem of Embeddedness'. In: *American Journal of Sociology* 91.3, pp. 481–510.

Gulati, R. and M. Gargiulo (1999). 'Where Do Interorganizational Networks Come From?' In: *American Journal of Sociology* 104.5, pp. 1439–1493.

Hagedoorn, J. (2002). 'Inter-firm R&D partnerships: an overview of major trends and patterns since 1960'. In: *Research Policy* 31.4, pp. 477–492.

– (2003). 'Sharing intellectual property rights–an exploratory study of joint patenting amongst companies'. In: *Industrial and Corporate Change* 12.5, pp. 1035–1050.

Hazir, C. S. and C. Autant-Bernard (2012). *Using Affiliation Networks to Study the Determinants of Multilateral Research Cooperation Some empirical evidence from EU Framework Programs in biotechnology.* Tech. rep. Groupe d'analyse et de théorie économique (GATE).

Hertzfeld, H. R., A. N. Link, and N. S. Vonortas (2006). 'Intellectual property protection mechanisms in research partnerships'. In: *Research Policy* 35.6, pp. 825–838.

Hippel, E. von (1988). *The Sources of Innovation.* MIT Press.

Kirat, T. and Y. Lung (1999). 'Innovation and Proximity: Territories as Loci of Collective Learning Processes'. In: *European Urban and Regional Studies* 6.1, pp. 27–38.

Levinthal, D. A. and J. G. March (1993). 'The myopia of learning'. In: *Strategic Management Journal* 14, pp. 95–112.

Lundvall, B. and B. Johnson (1994). 'The Learning Economy'. In: *Journal of Industry Studies* 1.2, pp. 23–42.

McPherson, M., L. Smith-Lovin, and J. M. Cook (2001). 'Birds of a Feather: Homophily in Social Networks'. In: *Annual Review of Sociology* 27, pp. 415–444.

Merton, R. K. (1968). 'The Matthew effect in science'. In: *Science* 159.3810, pp. 56–63.

Mowery, D. C., J. E. Oxley, and B. S. Silverman (1998). 'Technological overlap and interfirm cooperation: implications for the resource-based view of the firm'. In: *Research Policy* 27.5, pp. 507–523.

Murray, F. (2002). 'Innovation as co-evolution of scientific and technological networks: exploring tissue engineering'. In: *Research Policy* 31.8–9, pp. 1389–1403.

Nelson, R. R. (1982). *An evolutionary theory of economic change.* Harvard University Press.

Nooteboom, B. (2000). *Inter-firm Alliances: Analysis and Design.* Reprinted. London, New York: Routledge.

Nooteboom, B., W. V. Haverbeke, G. Duysters, V. Gilsing, and A. van den Oord (2007). 'Optimal cognitive distance and absorptive capacity'. In: *Research Policy* 36.7, pp. 1016–1034.

OECD (1994). *Accessing and Expanding the Science and Technology Base*. Paris: Organisation for Economic Co-operation and Development.

Paier, M. and T. Scherngell (2011). 'Determinants of Collaboration in European R&D Networks: Empirical Evidence from a Discrete Choice Model'. In: *Industry and Innovation* 18.1, pp. 89–104.

Ponds, R., F. Van Oort, and K. Frenken (2007). 'The geographical and institutional proximity of research collaboration'. In: *Papers in Regional Science* 86.3, pp. 423–443.

Powell, W. W. (1990). 'Neither market nor hierarchy'. In: *Research in Organizational Behavior* 23, pp. 295–336.

Powell, W. W., K. W. Koput, and L. Smith-Doerr (1996). 'Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology'. In: *Administrative Science Quarterly* 41.1, pp. 116–145.

Pyka, A. (1999). *Der kollektive Innovationsprozess: Eine theoretische Analyse informeller Netzwerke und absorptiver Fähigkeiten*. Berlin: Dunker & Humbolt.

Ripley, R. M., T. A. B. Snijders, Z. Boda, A. Vöröos, and P. Preciado (2014). *Manual for RSiena*. Tech. rep. University of Oxford: Department of Statistics; Nuffield College.

Rivera, M. T., S. B. Soderstrom, and B. Uzzi (2010). 'Dynamics of Dyads in Social Networks: Assortative, Relational, and Proximity Mechanisms'. In: *Annual Review of Sociology* 36.1, pp. 91–115.

Robins, G. and P. Pattison (2006). *Multiple networks in organisations*. Tech. rep. Department of Psychology - School of Behavioural Science - University of Melbourne.

Roediger-Schluga, T. and M. J. Barber (2006). *The structure of R&D collaboration networks in the European Framework Programmes*. Tech. rep. United Nations University - Maastricht Economic et al.

Schmoch, U. (2008). *Concept of a technology classification for country comparisons*. World intellectual Property Organisation.

Schwartz, M., F. Peglow, M. Fritsch, and J. Günther (2012). 'What drives innovation output from subsidized R&D cooperation?–Project-level evidence from Germany'. In: *Technovation* 32.6, pp. 358–369.

Snijders, T. A. B. (2001). 'The Statistical Evaluation of Social Network Dynamics'. In: *Sociological Methodology* 31.1, pp. 361–395.

Snijders, T. A. B. (2002). 'Markov chain Monte Carlo estimation of exponential random graph models'. In: *Journal of Social Structure* 3.2, pp. 1–40.

Snijders, T. A. B. and C. E. Steglich (2007). *Analysing dynamics of non-directed social networks*. Tech. rep. University of Oxford.

Tanayama, T. (2007). *Eligibility, awareness and the application decision: An empirical study of firm participation in an R&D subsidy program*. Helsinki Center of Economic Research - Discussion Papers 161. Helsinki School of Economics and HECER.

Ter Wal, A. L. J. (2009). *The structure and dynamics of knowege networks: a proximity approach*. Utrecht University.

– (2013). 'The dynamics of the inventor network in German biotechnology: geographic proximity versus triadic closure'. In: *Journal of Economic Geography*.

Uzzi, B. (1996). 'The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect'. In: *American Sociological Review* 61.4, pp. 674–698.

Wallsten, S. J. (2000). 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program'. In: *The RAND Journal of Economics* 31.1, pp. 82–100.

Wasserman, S. and K. Faust (1994). *Socal Network Analysis*. Cambridge University Press.

White, H. C., S. A. Boorman, and R. L. Breiger (1976). 'Social Structure from Multiple Networks. I. Blockmodels of Roles and Positions'. In: *American Journal of Sociology* 81.4, pp. 730–780.

VI. Conclusions

Almost thirty years after their start, cooperative project grants have become the major policy instrument supporting innovative activities through financial contributions. Since 1999, joint projects have displaced single projects as the top instrument in Germany, and at the EU level other forms of contributions are quasi non-existent. The origin for this impressive development comes from the competitive pressure of the 1980s and Europe's fear of falling behind Japan's high-tech companies. The agenda at that time was dominated by political actions and experiences rather than by academic thoughts, thus most of the legitimization grounded in economic theory followed ex post. Progressive political decisions were based on the best available knowledge at that time. However, today's economists have to look critically at the rapid implementation phase as newer analyzes point to the possibility of unintended outcomes if the self-enforcing mechanism of network dynamics is underestimated.

It was the central objective of this research project to investigate the interdependency between government innovation policies and the dynamics of networks in view of organizational research joint ventures, with a special focus on network-related determinants that render the formation of an innovation system. The setup for that purpose was a theoretical framework in combination with a variety of empirical analyzes that applied both standard statistical tools and techniques originating from social network analysis. Since each of the preceding empirical chapters ends with a summary of the respective results, this final section intends to describe the overall outcome of the research project in a general perspective and outline further research questions.

1. Structure

The introductory part of this study complements the theoretical framework of the respective subsequent analytical chapters. It discussed the genesis of innovations as the outcome of a collective process of frequent players, and emphasized the functionality of the innovation system approach to systematically analyze the innovative performance of an economy. Furthermore, it provided an overview regarding the development of innovation policies in several industrialized countries, and specifically their support of collaborative research activities among independent actors. A closer look was given to the structure of the German and European innovation policies, since both were chosen as use-cases for the analytical parts of this study. Each respective use-case concludes with further research questions gained from the results, theoretical thoughts, and preceding empirical studies.

Two empirical chapters pertain to the German innovation policy, while the third discusses the European case. The first empirical chapter evaluated the allocation process of a project grant for the case of the European FP. Due to unique dataset containing the score values of the Commission's proposal prioritization, it was possible estimate the impact of the network architecture on the project allocation. The second empirical chapter presented a detailed analysis regarding the particular steps of the allocation process in Germany, and gives a broad statistical overview concerning the dynamic of the funding system. Furthermore, it used statistical approach of Markov chains to investigate whether the dynamic of the system is driven by the formation of the network or by other organizational characteristics. The last empirical chapter untangled the interrelationship between promoted research joint ventures and cooperative patent applications, in order to measure whether or not the German policy design stimulates cooperative innovations.

2. Results

The research results can be concentrated into two major findings. First, the organization's network position, and thereby the configuration of the overall network, affects the probability of a single organization or a group to obtain a project grant from the government. Secondly, a collaborative research promotion stimulates the likelihood of a cooperative innovation, and vice versa; thus, it is not unusual to find a cooperative innovation is later awarded with a cooperative project grant.

A closer look into the details of the allocation process reveals that the outcomes differ with regards to the particular position occupied by the respective organization or consortium. It is revealed in the German case that if an organization wants to receive its first promotion, it is useful to have had previous relationships with other organizations. Additionally, access to heterogeneous knowledge was identified as an important asset of an organization in acquiring projects. Moreover, it is important, from the beginning, to partner with the best connected organizations in the overall network, as it is the quality of the connections that decides further governmental promotions rather than the sheer number of partners. The results for the European policy support this finding, since the quality indicators had a strong and significant impact on obtaining a project grant. The mere quantity of connections was found to have a negative impact to the Commission's prioritization. A similar result for the German case was that having only participated in a research joint venture can entail a negative impact if an organization does not obtain various new partners or a central network position. A brokerage position in the network was unimportant. Overall, research networks show a high degree of clustering, which means that bridging intermediaries are irrelevant for the connectivity of the network.

Further insights contributed to the discussion concerning the emergence of oligopolistic structures within the research network. The investigation showed that subsequent funding rounds are influenced by extant organizational partnerships. These starting differences potentially accumulate over time, triggered by the self-enforcing mechanism of networks. This last finding becomes even more relevant due to the observation that both the innovation network as well as the R&D network are directly interrelated to each other. This demonstrates the possibility that if the core-periphery structure is once introduced to the R&D network, it has the potential to automatically transfer into the innovation network. This introduces the same risks into another network, which is invisible to the policy-maker at first glance.

For policy–makers, it is important to be aware of the bidirectional nature of their funding policy. Through allocating project grants to organizations policy makers are shaping the structure of the R&D network, as every additional awarded project grant leads to a reconfiguration of the current network. What makes the situation bidirectional is the fact that the policy makers' decision is affected by the current configuration of the network. Since well-connected organizations, in terms of centrality, connectedness, and access to heterogeneous knowledge are much more likely to receive additional project grants compared to other organizations. Ultimately, this demonstrated cycle induces a self-enforcing mechanism to the allocation process of project grants, with the consequence that central organizations within the policy induced R&D network are very likely to maintain or even consolidate their central position within the network.

Since the allocation process mostly relies on formal legislations, there are some options to avoid a growing impact of the self-enforcing mechanism. Policy makers should consider changes to the current funding rules. Equivalently to requirements of the EU that at least 30 percent of a consortium's total funding has to be allocated to SMEs, it is worth thinking about implementing the same mechanism for less-central organizations.

Such an additional requirement for less-connected organizations would ensure that the core and periphery of the network stop drifting apart and start becoming better connected again. Beside the traditional way, an alternative way to allocate project grants should be considered. Instead of requesting proposals for specific projects with predefined technologies, the government could invite initiative applications from organizations which would otherwise have no chance, as they are less connected than the average organization. Alternatively, policy–makers could request applications from numerous single organizations instead of a preexisting consortia and then start to establish consortia randomly. Using this approach, governments could ensure that a consortium includes several organizations with different degrees of centrality, which would deactivate the selection mechanism that is usually carried out by both the group of organizations prior to the application process, and the government through the allocation mechanism. However, this approach would be radical as it limits the freedom of choice of the organizations to decide whom to partner with.

For the planning of further funding programs, it is crucial for policy makers to be consider the preexisting network configuration. Supporting the emergence of collaborations and therefore network structures has become a political mantra, meaning more cooperation is always better. But, this helps to maintain the self-enforcing mechanism of the allocation process. To prevent unintended distortions, like technological lock-in, governments should be interested in whether they always support the same organizations, which means the same network structures, or if they might concentrate on organizations which are less central but induce new knowledge into the core region of the network.

Project grants are an effective instrument to support the creation of new innovations. However, the link between the policy induced R&D network and the innovation network, the network of interconnected innovation processes, also implies that network structures are able to transit between both networks. This might open Pandora's box if the oligopolistic network structure is also able to affect a network with unintended distortions; governments must be aware of this situation. If the evolution of the policy induced network remains uncontrolled and the number of awarded project grants grows steadily, the more likely unintended distortions to the innovation network will be.

To prevent policy failures, a regular monitoring of already existing network formations is highly recommended. Detailed information about the current network configuration would ease the possibility to design an R&D policy which fits to the actual needs. Before a government decides to support the emergence of network structures, the government should be aware of the already existing network structure. Without regular monitoring, it becomes highly likely that already existing relationships within the core can benefit from additional funding instead unconnected organizations in the outer periphery of the network.

3. Outline of further research questions

Contrary to the growing awareness of imperfect policy implementation, it remains unclear which new policy instruments are required, or how the existing ones have to be modified, to prevent unintended distortions in the foreseeable future. Some possible policy changes have been discussed here (for example, the implementation of a threshold to ensure that a certain amount of the government budget is allocated to weakly connected organizations to link them with central actors in the network), but practical recommendations of how to identify the most promising organizations or those contributing most to the overall connectivity of network are still lacking. Such a policy approach would require additional controlling instruments that continuously evaluate the evolution of the policy and draw attention to the network structure evolving in the wrong direction.

Moreover, it is unclear to what extend the structure is able to transit between different kinds of networks. Indications of the dependency between policy-induced research and an innovation network were found, but the degree of the interrelationship between both types of network remain less explored. Further research has to put forward the question of whether only single relationships, or even entire substructures of the network, are able to transit instantaneously.

Another theoretical, but also very interesting, question would be how the alternative network would look without the influence of the network-related determinants to the allocation process. Researchers can investigate this question by describing the allocation process of project grants with statistical models, in which they have to eliminate the influence that results from the previous network structure. Thus, this could contribute to the question of which situation would be a possible alternative to the current policy.

The empirical investigations were restricted to the manufacturing, chemical, automotive, and biotechnology sectors, but it should be clarified whether the results are also valid for other industries. Furthermore, the evaluation has proven that the promotion of cooperative R&D activities stimulates cooperative innovations. Hence, the instrument seems to be effective in accomplishing its objective, but the efficiency is still unclear.