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Managing Innovation Networks in the Engineering Industry: Moderating Effects of Spatial Proximity

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Abstract

Our research aims at a further development of the interaction oriented network approach. Empirical evidence supports the positive effect of the innovation networks? balanced management, social interaction as well as network stability on network retention. It materializes for the proposed four management functions within innovation networks. Furthermore, we pay special attention to the moderating effect of spatial proximity.
We specified the conceptual framework as a structural equation model. Based on a sample of 79 respondents we found diverging results between national and international innovation networks.

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Managing Innovation Networks in the Engineering Industry:

Moderating Effects of Spatial Proximity

Introduction

In the highly competitive and largely globalized business environment, organizations constantly need to innovate in order to remain successful. However, companies must paradoxically collaborate with their competitors in order to succeed with their innovation tasks (Dooley and O Sullivan, 2007). Owing to the accelerated rate of acquiring knowledge, organizations are forced to focus their innovative efforts, which require the outsourcing of some areas (Störmer, 2001).

As with any powerful concept, that of network is necessarily all-encompassing and therefore vague; it is given different meanings and subjected to various usages. (DeBresson and Amesse, 1991). For this study, we therefore had to define the concept of a network more precisely before we could start to collect comparable data. In recent studies, interorganizational networks have been discussed and analyzed intensely (Brass et al., 2004). Yet the notion networks aiming specifically at fostering innovation has only recently found more attention. This is surprising, particularly as "[…] the innovation process has taken on a more integrated and networked model" (Dooley and O Sullivan, 2007). Rampersad also states that extant literature focuses on existing business networks, especially supply chain networks, rather than on emerging innovation networks (Rampersad et al., 2010). The focus mainly applies to inter-firm cooperation (Smith et al., 1991; Teubal et al., 1991; Wissema and Euser, 1991; Dittrich and Duysters, 2007), which has actually shifted slightly in the last few years.

Effects of regional agglomerations of companies on the output of collaborative projects have been analyzed in multiple studies (Davenport, 2005; Giuliani, 2007). Porter (1990) stated that regional competitive advantages evolve from knowledge intense relationships and collaboration under geographic proximity that distant rivals cannot meet. Spatial proximity is assumed to enable personal interaction among partners (Schartinger, Rammer, Fischer, & Frohlich, 2002) and thus to facilitate the development of strong ties (Granovetter, 1973).

Furthermore it has been shown that the frequency of interaction increases if the cooperating company is nearby. Paier and Scherngell (2011) perform a discrete choice analysis investigating the determining factors of companies to collaborate with others. They find a significant negative effect of spatial distance on the likelihood for collaboration. "For any additional 100 km between two organizations the mean collaboration frequency decreases by about 11.1 per cent" (Paier & Scherngell, 2011, p.100). Due to these effects, regionalization enables regional actors to reduce the transaction costs accompanied with flexible production processes (Sternberg, 1999). The better understanding and precise expectation about the partners reliability reduce the need for control cost, second, the high frequency of interaction and the conditions for knowledge transfer increase the effectiveness and efficiency of joint activities between firms (Iammarino & McCann, 2006).

For this study, innovation networks were likewise distinguished by their spatial proximity in order to analyze the moderating effects of spatial proximity on network management, network stability, social interaction and network retention. Geisler (1997) noted that industry, universities and government laboratories: "[…] can be advised, courted, induced, provided with a friendly and supportive environment and brought to a common forum […][but that] cooperation will then occur if and when the parties are willing to undertake it" (Geisler, 1997, p. 318). Firms also have to reach out for other partners on a national or international level, as there might be a lack of available partners in their close geographic proximity, a reluctance to cooperate or a mismatch of information, knowledge and services (Kaufmann, 2001).

Our research aims at a further development of the interaction oriented network approach, which fits in with the group of interorganizational theories (Sydow, 2002). The interaction oriented network approach was conceptualized as networks of interacting firms by the Swedish research group (IMP= International Marketing and Purchasing of Industrial Goods), led by Håkansson of the University of Uppsala (Håkansson 1982; Turnball and Valla 1986). More recent publications extend the interaction oriented approach towards mutual technological development (Håkansson 1987). Entering inter-firm alliances for the purpose of collaborative innovation provides access to complementary assets. Thereby, companies can reduce risks and uncertainties (Teece, 1986). Innovation is often the driving force behind the formation of networks (Ojasalo, 2008; (Johanson and Mattson, 1992).

The question regarding what levers are most important for achieving high internal network retention needs to be answered. Answering this question is of particular relevance in the context of limited literature on innovation network management. Möller and Svahn (2009) note that there is a gap in the research on the innovation networks' management processes, which would be of great importance to managers and researchers in that field. Other scholars agree that further research in this area is needed: As "[…] the knowledge of management methods in inter-organizational networks is still scarce" (Ojasalo, 2008), "more research is necessary for improving the rigor and reliability of empirical network research" (Rampersad et al., 2010). If empirical evidence supports the positive effect of the innovation networks' balanced management, social interaction as well as network stability on network retention would also materialize for the proposed four management functions within innovation networks. Furthermore, we pay special attention to the moderating effect of spatial proximity. Hence, our study responds to the need for empirically based research on innovation network management, which has major implications for innovation network management design.

We proceed as follows: first, we develop a conceptual framework and derive hypotheses on cause-and-effects of network management, social interaction, network stability on network retention as well as consider the moderating effects of spatial proximity. Second, we explain our methodology in terms of research setting and measures. Third, we present our findings of empirical assessment of the hypotheses. Fourth, we discuss and sum up our findings and derive implications for both managers and innovation researchers.

Conceptual Framework and Hypotheses

Interaction Oriented Network Approach

We aim at a further development of the interaction oriented network approach, which fits in with the group of interorganizational theories. The interaction oriented network approach was conceptualized as networks of interacting firms by the Swedish research group (IMP= International Marketing and Purchasing of Industrial Goods), led by Håkansson of the University of Uppsala (Håkansson 1982; Turnball and Valla 1986). Entering inter-firm alliances for the purpose of collaborative innovation provides access to complementary assets. Thereby, companies can reduce risks and uncertainties (Teece, 1986). Innovation is often the driving force behind the formation of networks (Ojasalo, 2008; (Johanson and Mattson, 1992). Incentives for participating in networks are sharing risks, granting access to complementary assets, mitigating critical-mass problems, getting access to readily skilled staff, acquiring scarce competences (Dooley and O'Sullivan, 2007), as well as the "[…] shortened innovation cycles that favor collaboration" (Hagedoorn, 2002). The conceptual further development is based on each interaction influencing other interactions within other relationships (Gemünden and Heydebreck, 1994). The researchers of this approach primarily assign two functions to those partner-like relationships between organizations: First they help to improve the efficiencies of the involved firms, and second, they foster the innovative potential of firms: "There is apparently a need for a certain amount of relations to increase the proportion of high-quality innovation ideas generated" (Björk and Magnusson, 2009).

Several scholars describe the interaction-oriented network approach as a potential theoretical framework for strategic management (Mattsson, 1987; Håkansson, 1989). In order to improve their competitive positions, firms can organize their external relationships in line with their strategic positions. These external relationships are important for product development performance (Knudsen, 2007). Scholars agree that uncertainty is one of the major reasons why organizations decide to enter networks (DeBresson and Amesse, 1991).

Considering that each of the firms has several of those partner-like relationships with other firms and strategies, the network becomes very complex. Moreover, the interdependency of relationships accelerates the dynamic of the network. The interactions between the networking partners are similar to the notion of prices in markets, and orders in hierarchies. The focus of this paper is on structural, administrative (e.g. allocation and regulation) and cultural aspects. We explore single aspects that contribute to retention of participating members in an innovation network with special focus on spatial proximity.

Network Management and Network Retention

Network management is usually the function of the participating organizations but it can also be transferred to specialized organizations (Ritter and Gemünden, 1998). In accordance with Sydow and Windeler (1994), we refer to four central management functions of interorganizational relationships within an innovation network: the selection function, the regulation function, the allocation function, and the evaluation function. Those four functions constitute the central configuration of the research model. Focus was placed on managements' recurring practices, and the management functions were researched on a higher aggregation level in order to capture all relevant information. Literature suggests that the mix of heterogeneous parties in R&D collaborations enhances the probability of developing new products (Becker and Dietz, 2004), as well as the degree of innovation novelty (Nieto and Santamaría, 2007). The mixing of different organizational cultures, for example of firms and science institutions, can however result in conflicts regarding the management of the network (Davenport et al., 1999). Owing to the diverse backgrounds and organizational cultures of collaborating partners, innovation networks need to be managed thoroughly in order to be successful (Barnes et al., 2002) and to engender commitment from the participating members, given that the "networking fit" between the members is established.

The first aspect of network management is the selection function, which particularly focuses on networks that are already up and running. Selection's management task includes constantly considering the scope of alliance (Khanna, 1998) in order to effectively handle the positive and negative selection of partners. "The benefits of cooperation may only be enjoyed when the parties involved establish effective and efficient coordination of the various activities to be undertaken" (Biemans, 1990). Coordination is included in the second function of the network management, namely the allocation function. The allocation of tasks and resources is critical in network settings. It is important to ask whether activities suit the network. People in charge of managing network relationships "[…] need to be able to identify when an agreement needs a contract or should be based on good faith" (Pittaway et al., 2004). Although literature suggests that in most innovation networks' hierarchical structures do not exist (Koller et al., 2006), and therefore their influence on the direction of the activities is limited, an elected board or an appointed network manager nevertheless normally steers the network. In fact, reducing hierarchies is one of the important functions of a network (Achrol and Kotler, 1999) but, in order to distinguish which kind of quasi-formal hierarchy might influence network retention, we had to include this aspect in the regulation function. Evaluation is important, because planning and control belong to the network management task and they influence innovation success (Ritter and Gemünden, 2003). According to Galbraith, network organization is held together by constant negotiation (Galbraith, 1998). It seemed most important to regularly monitor the contribution of the partners, to ensure even success participation and to provide all participants with tailored information throughout the process, as well as to continuously document progress.

Achieving the circumstances in which partners would be willing to enter the network again is quite a rare construct in network literature, called network retention. Malewicki (2005) finds that normative (the extent to which members perceive a moral obligation to maintain a relationship with the organization/network) and instrumental (interest in the organization, based on the perceived financial cost associated with leaving an organization) commitment are both positively related to retention within entrepreneurial network organizations.

Applying the logic of the interaction oriented network approach, multiple and interdependent relationships between various partners within a network are valuable and should be nurtured to gain the most from them. Generally, technological developments, such as new product developments, are only achievable in a network if the circumstances are appropriate and assist the intended joint innovation process. Apart from the actual output of a network (e.g. an improved/new product, collaborative research results etc.), something else has to evolve over time: ties between the network parties. The investments in these relationships can bear fruit repeatedly, if the network partners are willing to continue the network or are willing to enter the network again.

Hypothesis 1: Extensive network management will increase network retention.

Social Interaction and Network Retention

According to the interaction oriented network approach, the relationship between partners is characterized by cooperation rather than by competition. Hence, this approach differs from the transaction cost approach, which assumes that there are opportunistic individuals within the network (Morath, 1996). The transaction cost theory was used as the theoretical frame with regard to network studies (Veugelers and Cassiman, 2005; Segarra-Blasco and Arauzo-Carod, 2008; Nooteboom, 1999; Iammarino and McCann, 2006; Hagedoorn et al., 2000; DeBresson and Amesse, 1991). As mentioned earlier, an unsuccessful match can be corrected with structural or administrative adaptations. So, apart from active management, there is a social component to this study. The social component consists of two aspects, harmony and trust, which have proven to be most influential in the behavioral culture that causes and affects the relationships between the partners within the network. The organizations' network representatives are individuals, so the nature of relationships strongly depends on the involved persons themselves. Therefore, even if management functions were fulfilled fairly well, network retention could still be reduced if either trust or harmony were not given features in the network setting.

Trust is a construct that is regularly included when networks or other kinds of collaborations are analyzed (Huber et al., 2010; Dooley and O'Sullivan, 2007; Möller and Rajala, 2007; Brass et al., 2004; Sherer, 2003; Harris et al., 2000; Davenport et al., 1999; Häusler et al., 1994). The results of the prefaced qualitative study convinced us that trust is also essential in our investigation of network retention. Even the best network management will not yield any significant success if the collaborating parties do not trust each other. The interaction oriented network approach states that interorganizational interaction starts with comparatively meaningless transactions that require only a small degree of trust. In time, more complex relationships develop as partners' level of trust grows (Sydow, 2002). Trust can be expressed by reliability, honesty and the conviction that a partner is not trying to take advantage of another. Additionally, trust is inevitable as cooperation agreements can't include all potential occurrences in a network.

Harmony

In their study, Rampersad et al. (2010) show that trust can positively influence harmony within networks of different industries. This is a little surprising, as conflicts are far easier to handle if the involved parties generally collaborate in a harmonious atmosphere. Hence, the social interaction construct that enhances our research model must also include harmony. Harmony can be identified in a network if there is an understanding of give-and-take, a preparedness to understand the others parties' standpoints and if the rivalry is kept on a very low level, even if the network includes competitive organizations (Bengtsson and Sören, 2000).

Hypothesis 2: The extent of social interaction influences network retention positively.

Network Stability and Network Retention

In addition to network management and social interaction, we had to acknowledge another construct for the proposed analysis model, namely network stability. Innovation networks typically consist of loosely coupled organizations and are characterized by high flexibility. Individuals can play a powerful role in stabilizing the network. Moreover, our qualitative pre-study indicated that the regularity of network gatherings can act as a highly stabilizing factor as well.

"Power is first and foremost a structural phenomenon." (Burkhardt and Brass, 1990). Interview partners suggested that a typical network often includes at least one comparatively large or dominant (focal) organization and several smaller businesses. The power distribution within the network is usually uneven. The allegedly ideal situation of an even power distribution is, however, not common sense; to the contrary, the asymmetry of power is often a necessary prerequisite for handling the interdependencies between the members. Sources of power within the network can result from technological competence, expert knowledge, gained trust or the control over critical resources, which might lead to a more central position in the network (Sydow, J., 2002); Störmer, E., 2001); Burkhardt and Brass, 1990). Generally, partners within the network must be prepared to give up authoritative power (Dooley and O Sullivan, 2007). This is a common understanding of collaborative innovation. Huber et al. (2010) have shown that a symmetric power distribution has a positive impact on trust, which might lead to the conclusion that an uneven or asymmetric power distribution has the opposite effect. However, more powerful members tend to boost network activities by acting as "orchestrators" (Dhanaraj and Parkhe, 2006) and thereby promote network stability (Kenis and Knoke, 2002; Madhavan et al., 1998), which in turn can increase network efficiency. This might positively influence network retention. Network members are generally willing to accept more powerful organizations, as the dominant partners often take on various responsibilities, such as coordination tasks, and they are often prepared and capable to give financial support in times of difficulty. According to the interaction oriented network approach, unsuccessful matches can, amongst others, be overcome with financial adaptations. Different circumstances require individual network settings. So, the question is if more powerful members as a stabilizing dimension within the network can have a significant impact on network retention, too.

A second aspect of network stability is regular network gatherings (also investigated as frequency, e.g. Mora-Valentin et al. 2005). Being part of a creative and flexible innovation network requires a rhythm of gatherings in which participants can exchange ideas, discuss (preliminary) results, and decide upon the next steps. This assists in ensuring that the collaborative innovation process does not suffer from the unavailability of individuals, which would consequently reduce the stability of the entire network.

Hypothesis 3: The higher the level of network stability, the higher the positive influence is on network retention.

Moderating Effect of Spatial Proximity

Huggins and Johnston (2010) show that firms that collaborate in the same region are more likely to build strong social relationships. This can be linked to the way of how proximate firms are working together. First, if firms are located close by, trust can be build through face-to-face interactions (Watts, Wood, & Wardle, 2003). Since the representatives of cooperating parties get to know each other in person, they develop a deeper understanding for the behavior and the reliability of the partner. In the course of reoccurring personal interactions partners can assess the trustworthiness of the other precisely (Lorenzen, 2007; Westlund & Bolton, 2003).

Second, spatial proximity is assumed to foster the transfer of implicit knowledge between the partners (Lagendijk & Lorentzen, 2007). Whilst the transfer of codified knowledge is a straightforward process that can be utilized automatically via mail or telephone, personal interactions are crucial for the transfer of tacit knowledge (Asheim & Gertler, 2005). The transfer of tacit knowledge requires special transmission channels and becomes increasingly costly with geographical distance (von Hippel, 1994). Gellner (1994) postulates that the dissemination of knowledge requires a social framework where an open discourse about new ideas as well as a joint investigation of problems can take place. Tacit knowledge incorporates not only process related know-how but also the emergence of a shared meaning among the partners. In the course of an intense interaction-oriented relationship, partners learn to understand each other and how to interpret the behavior of the other correctly. Within spatial proximity firms thus develop implicit social norms and behavioral rules that are embedded in the social environment and thus specific to the community (Lorenzen, 2007). This leads to self enforcing effects of relationships in regional proximity, since close interaction enables knowledge transfer as well as the development of close ties (Iyer, Kitson, & Toh, 2005). Social norms are assumed a major informal coordination mechanism of interorganizational relationships (Dwyer, Schurr, & Oh, 1987) and therefore can lead to a substitution of formal control (Yang, Zhou, & Jiang, 2011).

In order to achieve a high level of network retention, the settings – influenced by network management – for innovating in networks have to be desirable for all participants. If this is the case, then the relationships will probably outlast a network that was set up for a certain amount of time or to accomplish a particular goal. Rampersad et al. (2010) have shown that different key factors, such as coordination or communication, have significant impact on network effectiveness in different industries. Hence, it is likely that effective network management, which includes factors such as communication and coordination, will improve the commitment of the members, which in turn will increase network retention (Malewicki 2005).

Social interaction can produce strong social interaction based in spatial proximity. Naturally, high trust in each other and constantly maintained harmony will increase the likelihood of participating in a network again. Hence, sustaining trust and harmony can strengthen social bonds and intensify relationships between network members. With regard to the interaction oriented network approach, relationships become stronger and enrich the entire network. The study by Mora-Valentin et al. (2005) investigates the positive influence of higher trust, which also includes the harmony construct on the cooperative success between firms and research organizations. This success was partially gauged by asking collaborating members questions about their general satisfaction. The study's networks predominantly included universities and research organizations, and satisfaction seems to be a necessary prerequisite for retention; therefore, the preceding studies allow us to establish a link between the social interaction in networks and network retention.

The network stability component further broadens our understanding of achieving network retention with special respect to spatial proximity. Previous research focused on power distribution's influence on trust (Huber et al., 2010) and powers' exchangeability, as well as trust as a steering mechanism (Kumar et al., 1995). We suggest that these two constructs are needed to further explore network retention in this context. Power's steering role is indisputable, particularly when orchestrating hub firms fulfill that role. Previous studies have shown that the lower the network's stability is, the lower the network's value creation capabilities are (Lorenzoni and Lipparini, 1999). However, higher network stability can generate higher network innovation output (Dhanaraj and Parkhe, 2006). This aligns with the interaction oriented network approach, which suggests that the stability of relations can lead to a higher exchange of process and innovation knowledge.

Since spatial proximity supports the development of social norms and reduces the costs of interorganizational transactions formal network functions can be substituted to some extend by social mechanisms. Vice versa, the effects described above vanish with an increasing spatial distance between the actors in a network (Iyer et al., 2005).

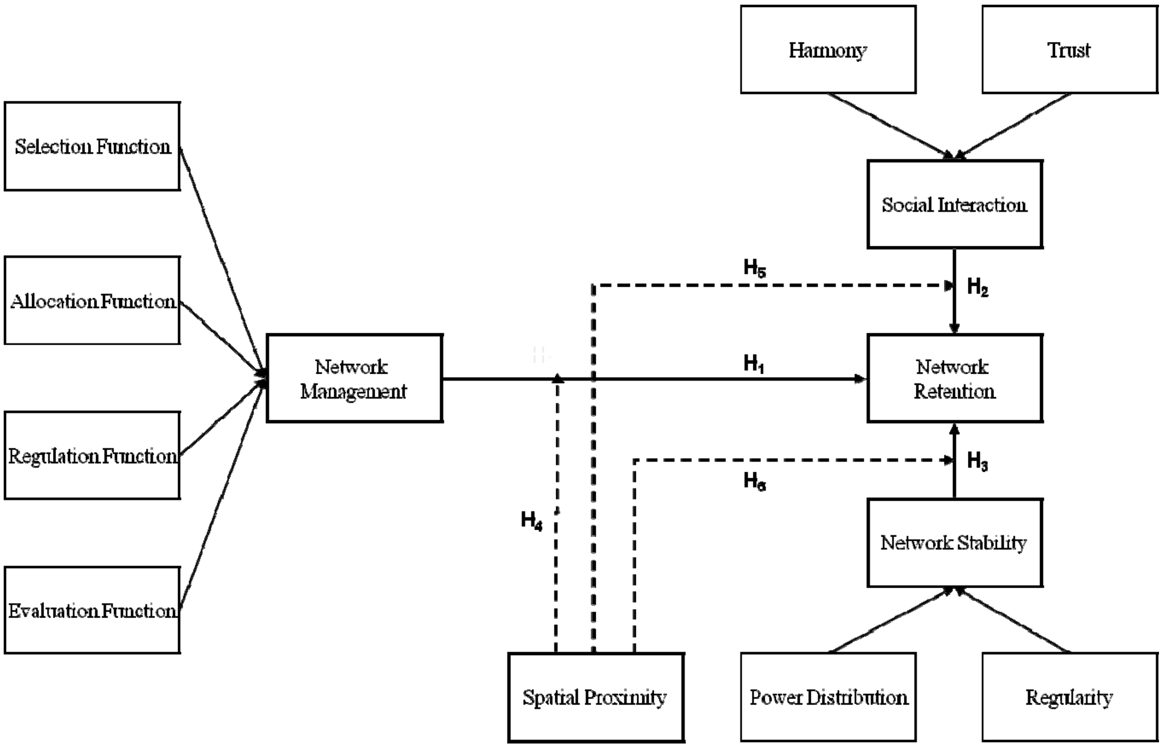
Hypothesis 4: Spatial proximity (spatial distance) reduces (enhances) the effect of a formal network management on network retention of the actors involved in the innovation network.

Hypothesis 5: Spatial proximity (spatial distance) reduces (enhances) the effect of social interaction on network retention of the actors involved in the innovation network.

Hypothesis 6: Spatial proximity (spatial distance) enhances (reduces) the effect of network stability on network retention of the actors involved in the innovation network.

The entire conceptual model is illustrated in Figure 1.

Figure 1: Conceptual model of network retention including moderator effects



Methodology

Research Setting

Our sample concentrates on the German industrial goods sector, which receives international recognition for its highly innovative products. In order to maintain its successful performance in the international market, the industry must constantly innovative, which forces companies in this industry to collaborate with other firms, communities, and especially with universities (Braczyk and Heidenreich, 2000). Mechanical engineering is one of the powerful drivers of the German economy. Accounting for sales of roughly € 160 billion and 920,000 employees, mechanical engineering is one of the largest industrial sectors and sources of employment in Germany. The engineering industry's products and services are highly regarded worldwide and roughly two thirds of German production is exported.

We chose to study this sector because "[…] many sectors of the German mechanical engineering industry are moving towards the end of their product cycle and basic innovations are relatively rare […] product innovations are basically new developments using well-known technologies" (Grotz and Braun, 1997). Grotz (1997) also indicates that the industry tends to concentrate on internationalization with transnational network settings.

We generated hypotheses after conducting an in-depth literature review in order to match a subsequent context-sensitive online questionnaire. This questionnaire was distributed with the support of the German Engineering Federation (VDMA = Verband Deutscher Maschinen- und Anlagenbauer) and was directed at pre-identified key respondents, preferably CEOs and R&D heads of the VDMA member companies. The VDMA is a key association service provider and offers the largest engineering industry network in Europe. The VDMA represents 3,000, mainly small or medium sized, member companies in the engineering industry, making it one of the largest and most important industrial associations in Europe. A national design was chosen in order to ensure a sufficient sample size when applying the above mentioned criteria. We received a total of 84 responses. In order to control for common method bias (Ernst, 2002; and Lee and Grewal, 2004), the survey data were validated via document analysis (Weber, 1990). The final sample of n=79 respondents consists of 55 national innovation networks and 24 international innovation networks.

National innovation networks represent the first group within our total sample. The constituting boundary is the participants´ location within the German national border. National innovation networks can – similar to regional clusters – be incentivized by national policy makers, e.g. a tendering for research on a specific field. As "countries differ with regard to the extent, nature, and motives of inter-firm collaboration" (Hotz-Hart, 2000, p.437), one has to bear in mind that the focus on the German Industrial goods sector, will yield results that have to be analyzed under consideration of the national innovation network characteristics, such as public policies, technology infrastructure, the national labor market or the educational system. In literature, national innovation systems (NIS) are comprehensively investigated with both theoretical and empirical research (for an overview, see Edquist, 1997). However, this paper focuses more on organization-driven networks in which the organizations' actions lead to the formation of new innovation networks.

More and more international innovation networks evolve since national borders loose their meaning as economic boundaries for organizations of any kind. If organizations strive for collaboration with foreign actors the circumstances of the according country are crucial in this respect. Hence, Germany´s country size and core industrial industries will influence the organizations´ efforts as well as the strategies of resident multinational firms. International innovation networks gain in importance with the advancing process of globalization. "Globalization of the economy is applicable to companies as well as to the economy as a whole" (Hotz-Hart, 2000, p.439). These encompass actors that go beyond national borders and overcome the obstacles of implicitly given foreign (corporate) cultures. Highly industrialized countries, such as Germany, have to deal with competitors on a global base; innovations will only yield success if the innovativeness of not only domestic but also foreign counterparts is reached.

Measures

We used existing scales – whenever possible – to measure the constructs of interest. We used five-point Likert-type scales, anchored by "strongly disagree" and "strongly agree". Table 1 summarizes the wording for the measurement models.

Network management is measured with four constructs, in line with Sydow and Windeler's concept (1994). The first construct, *selection function,* describes defines innovation network partners' scope of alliance, to effectively handle the positive and negative selection of partners. We used three items, based on previous research, and implemented established scale items from Sydow (2006). The second construct *allocation function* queries whether innovation network firms indeed have allocated a minimum level of particular resources to the innovation network, and whether they were allocated specific tasks within the innovation network. Overall, we used five items, based on Rampersad et al.'s (2010) work. The third construct *regulation function* describes the extent of legislation, communication and hierarchy. We concentrated on characteristics that are explicit, easy to comprehend and comprehensive in their manifestation. After conducting 22 interviews with managers and R&D heads of German mechanical engineering companies, we identified three essential regulatory aspects, which were also based on previous work by Blomqvist et al. (2005), Ojasalo (2008) and Rampersad et al. (2010). Finally, w pre-tested this scale with ten innovation management experts to assure scale content validity, improve item wording and remove ambiguities. The fourth construct, *evaluation function*, describes the extent of partners' regular contribution monitoring, continuous provision of all participants with tailored information, as well as continuous progress documentation. We aligned this construct with prior conceptual work. In addition, we used results from our pre-study with 22 practitioners to enrich our understanding of evaluation functions' relevant aspects in the innovation network context. In particular, the experts helped us to determine the different minimum evaluation levels.

Social interaction consists of two aspects, harmony and trust, that exert an influence on the behavioral culture in which network relationships operate. The organizations' representatives within the network are individuals, so the relationships and their characteristics strongly depend on the involved persons. We measured social interaction with two constructs, in line with Sherer (2003) and Rampersad et al. (2010). The first construct, *harmony,* comprises an understanding of give-and-take, a preparedness to understand the others parties' standpoints, and keeping rivalry on a very low level, even if the network includes competitive organizations. We used three previously operationalized scale items. The second

construct, *trust*, describes reliability, honesty and the conviction that the partners are not taking advantage of one another. We used four established indicators.
For measuring *network stability,* we also used qualitative findings from our interviews with practitioners to enrich our understanding of network stability according to innovation networks' relevant aspects. Innovation networks typically consist of loosely coupled organizations that are highly flexible. Regular network gatherings can act as a highly stabilizing factor. Finally, network stability is influenced by power distribution and regularity. *Power distribution* is operationalized by building on previous research and by using two established scale items (Huber et al., 2010). This construct describes the asymmetry of power as a necessary prerequisite for handling the interdependencies between the members. *Regularity* describes the regular occurrence of network gatherings. Here, we followed Sherer (2003) and used one established item.
Network retention describes the willingness of the innovation network partners to continue collaborating in the network, or their willingness to enter the network again. The results of the same preceding interview phase of 22 interviews with managers and R&D heads of German mechanical engineering companies indicated that network retention has the greatest influence on innovation networks' short-term success. Originating in marketing literature (Morgan and Hunt, 1994; Garbarino and Johnson, 1999), the construct of customer retention was transferred onto the innovation network for scale development. Ten innovation management experts pre-tested the scale to assure scale content validity, improve item wording and remove ambiguities. Three established items captured this construct.
To control for the moderating effect of spatial proximity, we measured the scope of the network based on a dichotomous variable. In accordance with recent literature we separate those networks with a national focus – representing close physical proximity- from those with an international scope – indicating a larger spatial distances between firms.
First, we assessed the measurement models to establish valid constructs. In Table 1, we indicate factor loadings, Cronbach's Alpha (CA), composite reliability (CR), and average variance extracted (AVE). All figures point to a high level of reliability and convergent validity of the measurements. We established discriminant validity with the Fornell-Larcker criterion (Fornell and Larcker 1981, Fornell and Cha 1994). Table 2 shows that the AVE is much larger than the squared correlation between each construct, as well as the other constructs in our model.
Since we intend to test the moderating effect of spatial proximity, the data set was initially split into two non-overlapping samples. National innovation networks comprise a total of 55 firms and international innovation networks a sample of 24. Before testing the hypotheses, we assessed measurement equivalence across sub-samples. Therefore we calculated the indicators of the measurement evaluation for each model. These did not deviate significantly from the total data sample so that we stated measurement invariance to be confirmed. Therefore we can ensure that differences between the path coefficients of the structural models are related to differing effects and not caused by group specific interrater differences.

Table 1: Measurement model

Constructs and items	Factor load-ing	CA	AVE	CR
Network Management (NM)		**0.91**	**0.55**	**0.92**
Selection Function		*0.71*	*0.67*	*0.89*
• A selection as well as a removal - if needed - of participants takes/took place while running the innovation network.	0.84			
• An administrative unit takes/took care of compatibility of objectives for all partners of the innovation network.	0.85			
• Necessary resources are managed by an administrative unit and – if required - allocated to the innovation network.	0.72			
Allocation Function		*0.87*	*0.64*	*0.94*
• Our firm's programs were well-coordinated with the innovation network's program.	0.78			
• Our activities with this network were well-coordinated.	0.91			
• Our tasks within the innovation network are/were in line with our competences.	0.77			
• Allocation of tasks is/was undertaken in joint and equitable decision-making processes.	0.71			
• While running the innovation network, allocation of tasks and resources is/was adapted continuously to the needs of the innovation network.	0.64			
Regulation Function		*0.88*	*0.79*	*0.97*
• In preparation of the innovation network we jointly and accurately developed a cooperation agreement.	0.83			
• Communication in the network was clear and accessible.	0.85			
• A strong hierarchy leads to a blockade of resources.	0.82			
Evaluation Function		*0.77*	*0.63*	*0.91*
• The contribution of each network partner to the overall innovation network performance is/was surveyed and documented regularly.	0.75			
• Each network partner participates equally in the innovation network success.	0.64			
• The network partners continuously receives/received all relevant information regarding the running innovation network.	0.84			
• Network progresses are/were accessible to every member.	0.87			
Network Retention (one-dimensional)		**0.70**	**0.68**	**0.89**
• I would enter that particular innovation network again.	0.93			
• The time spent in the collaboration was worthwhile.	0.89			
• We perceive a satisfactory level of network effectiveness.	0.74			
Social Interaction (SI)		**0.87**	**0.70**	**0.91**
Trust		*0.83*	*0.67*	*0.87*
• The reliability of the innovation network partners is/was granted.	0.75			
• Our network partners are/were honest.	0.91			
• There was a belief among all participants that other participants will not try to take advantage of each other.	0.92			

• Our partners kept promises they made to our organization/innovation network.	0.69			
Harmony		*0.84*	*0.75*	*0.90*
• During negotiation, meetings or discussions, there was give-and-take among all participants. Each challenged the others and tried to understand the others' points of view.	0.90			
• The research institution and the industry partner were involved in the early phases of discussion in setting the research agenda.	0.82			
• There was compromise among participants in decision-making and each party obtained value from the innovation network.	0.88			
Network Stability (NS)		**0.83**	**0.75**	**0.90**
Power Distribution		*0.93*	*0.93*	*0.96*
• The power distribution in the innovation network is/was even.	0.97			
• One/more large participants dominated the network. (rvd)	0.96			
• Our organization had the same amount of power as the other participants' organizations.	0.94			
Regularity		*1*	*1*	*1*
• We have/had regular network meetings with all members of the innovation network.	1			

Table 2: Discriminant validity assessment

	1	2	3	4	5	6	7	8	9
1 NM: Selection function	0.67								
2 NM: Allocation function	0.32	0.64							
3 NM: Regulation function	0.28	0.58	0.79						
4 NM: Evaluation function	0.33	0.42	0.31	0.63					
5 Network Retention	0.10	0.46	0.12	0.25	0.68				
6 SI: Trust	0.04	0.23	0.08	0.16	0.41	0.67			
7 SI: Harmony	0.01	0.28	0.16	0.16	0.36	0.30	0.75		
8 NS: Power distribution	0.08	0.24	0.20	0.14	0.15	0.03	0.13	0.93	
9 NS: Regularity	0.04	0.58	0.07	0.11	0.47	0.22	0.17	0.26	1

Numbers on the diagonal show the AVE.
Numbers below the diagonal represent the squared correlation between the constructs.

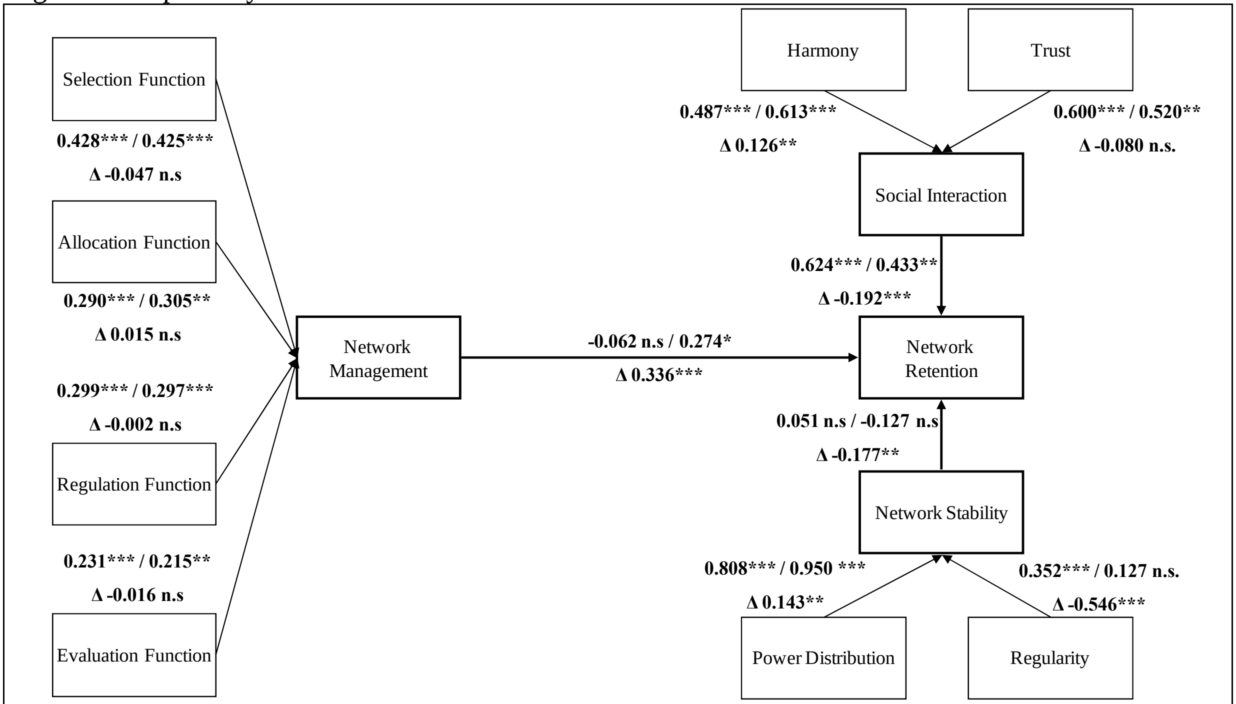
Findings

We specified the conceptual framework as a structural equation model. Since our research intent focuses primarily on the different effects of network management, Due to the resulting sample size restriction we opt for using the Partial Least Squares (PLS) approach. PLS analysis requires a small sample sizes about 20 to 30 (Chin and Newsted 1999) and recently proposed to be the most robust approach for samples smaller than 250 (Reinartz et al. (2009). Due to the use of variance analytic calculation instead of the reproduction of an empirical covariance matrix PLS does not provide interference statistical criteria for the assessment of the goodness of the holistic structural model. Therefore we apply the PLS specific criteria (Henseler et al. 2009): First we interpret the path-coefficients, while significance is assessed by bootstrapping of the data sample and t-statistics of the re-sampled results. Second, like for linear regression, the coefficient of determination R^2 indicates the fit between the regression function and the empirical data basis. Chin (1998) classifies the effects substantial for values higher than 0.67, moderate for 0.33 and weak for 0.19. To test the moderating effect of spatial proximity we further calculate the difference between the path coefficients between the two models. As suggested by Chin (2000), we assessed path differences by taking standard errors for the structural paths from bootstrapping with 300 iterations for the two sub- groups and treating the standard error estimates from each re-sampling in a parametric sense via t-tests. Further we compare the R^2 values to evaluate if the explanative power of the model in the case of national versus international clusters. To estimate the predictive capability of the model, we applied a blindfolding approach (Fornell and Bookstein 1982).

Figure 2 shows the results of the empirical analysis. The path coefficients of the endogenous model show significant effects. The model shows that management leads to a significant increase of network retention in the case of international networks (0.274), while in national settings this effect vanishes. Thus hypothesis 1 can partially be approved by the data. Network management positively influences the network retention of the partners in international settings. The significant delta between networks in physical proximity compared to those with a larger distance between the partners (0.336) also supports the moderator hypothesis 4. Therefore international networks need a higher degree of formal network management to achieve retention. On the other hand both path coefficients between social interaction and network retention (0.624/0.433) are positive and highly significant, what confirms hypothesis 2 for national as well as international networks. However the effects differ significantly in their size by -0.192. This indicates that social interaction increases network retention to a higher degree in national networks as in international networks and provides empirical evidence for hypotheses 5. Like hypothesized, spatial proximity can be seen as an accelerator of the positive effects of social interaction. Finally neither the in the national nor in the international sample, the effect of network stability on network retention lead to significant results. Thus network hypothesis 3 is rejected by the data. Although the path coefficients differ significantly, also hypothesis 6 can therefore not be confirmed.

To assess the overall we calculated the explanatory power of the model for network retention. R^2 values were calculated for the national sample, with 0.35 and the international sub sample with 0.39. According to the classification of Chin (1998) our model provides a moderate determination. About 40% of Variance of the dependent variable can be explained by network management, social interaction and network stability. Consequently our conceptual model can be accepted for an adequate explanation of network retention. The Q^2-value for network retention is 0.26 for national and 0.28 for international networks. These differ significantly from zero, which indicates predictive power of both models for this variable (Geisser 1974; Stone 1974).

Figure 2: Empirically validated structural model



Legend: The left path coefficient represents the effect for the national sample, the right one the effect for international sample. Delta values are an indicator of the moderating effect of spatial proximity.

In addition to the hypothesized basic effects, all path values of the second order formative constructs are reported to control for significant differences regarding these parameters. It can be seen that the particular functions of network management do not differ to a major extend, indicating that the relevance of these is equally distributed nationally and internationally. Significant differences are found for the effects of harmony, power distribution and regularity. The importance of harmony in social interactions is interestingly significantly for networks in international settings. It can be assumed that this is perceived as a more basic condition of social interaction that bridges the physical distance between partners. Differences of the stability parameters display that power distribution leads to a higher network stability in international networks while that regularity is mandatory for stability in national cooperation. Especially the second effect is of interest. Partners in national settings seem to stabilize the network by regular meetings while in international settings regularity looses relevance. This is in line with the different importance of social interaction, since regular meetings require intense social relationships to stabilize the network.

To shed some light on the differences of national compared to international networks regarding the specific characteristics, we calculated an analysis of variance over all model constructs (see Table 3). Altogether, this does not reveal an extensive discrimination power between national and international networks. This is an indicator of residual heterogeneity in the separated samples among these variables, so that for most measures no significant F-values can be found. However some interesting level differences are related to proximity. First, international networks apply mechanisms of partner selection in their network management to higher extend. This is in line with our hypotheses, since the bindings effects of social interaction diminish internationally and formal characteristics of the partners are weighted higher. Second, the evaluation function decreases in international networks. Considering that a major part of evaluation is the distribution of outcomes and the documentation of results, this follows our argumentation line. In international networks these processes will primarily follow formal, predefined processes. In national networks, the opportunity for personal face-to-face interaction enables partners to share especially intangible results directly. Third, power is unequally distributed in international networks. This indicates a high divergence power divergence of these networks.

Table 3: ANOVA of the factor means between the samples

ANOVA										
Construct		**Selection Function**	**Allocation Function**	**Regulation Function**	**Evaluation Function**	**Power Distribution**	**Harmony**	**Trust**	**Regularity**	**Network Retention**
	F	6.278	1.174	.102	4.152	3.58	1.57	0.76	2.02	1.54
	Sig.	**0.01**	0.28	0.75	**0.05**	**0.05**	0.21	0.39	0.16	0.22
national	Mean	-0.19	0.08	0.02	0.15	0.13	-0.09	0.10	0.11	0.10
	n	49	52	53	51	55	55	49	49	52
	STDev	1.03	0.94	1.02	0.89	0.96	1.01	1.09	0.89	1.05
inter-national	Mean	0.43	-0.19	-0.05	-0.37	-0.31	0.21	-0.21	-0.24	-0.20
	n	22	23	24	21	24	24	23	23	25
	STDev	0.80	1.13	0.97	1.16	1.03	0.96	0.75	1.18	0.87
Sum	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	n	71	75	77	72	79	79	72	72	77
	STDev	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Discussion and Conclusion

This article introduces the novel concept of network retention as a goal of collaborative network innovation. The research framework enabled us to focus on some important network management characteristics, without neglecting decisive social and structuring factors. This study contributes to the literature by empirically testing and discussing the interaction oriented network view of innovation network management with special focus on spatial proximity as a moderating effect.

The empirical results support our initial assumption that spatial proximity act as a crucial moderator in innovation networks. We found diverging results in the two contexts of national and international innovation networks. These findings support theoretical assumptions by Biemans (1990), Sydow and Windeler (1994), Barnes (2002), Pittaway (2004), Ritter (2003), and Sydow (2006). It underlines the logic of the interaction oriented network approach's multiple and interdependent relationships between several partners within a network. The relationship investments in network parties can repeatedly bear fruit if the network partners are willing to continue in the network or are willing to enter the network again. Second, our results show that social interaction has a strong, directly positive effect on network retention. This finding supports our initial proposition, as well as similar observations by Bengtsson and Sören (2000), Mora-Valentin et al. (2005), and Rampersad et al. (2010). Third, the hypothesized positive relationship between network stability and network retention was not supported by the results. Our findings do not support theoretical assumptions by Lorenzoni (1999), Dhanaraj (2006), and Huber et al. (2010). This aligns with the interaction oriented network approach, which suggests that the stability of relationships can lead to greater process and innovation knowledge exchange.

Our research has several limitations that can be addressed in further studies. The study results should be interpreted in the light of the following limitations: First, the sample size of 79 is appropriate for the accomplishment of this study; however, a larger sample size would strengthen the results and allow the grouping of sub-samples, for instance with regard to the degree of innovation novelty (Freel and De Jong, 2009), or the diversity of partners (Nieto and Santamaría, 2007): "The evidence demonstrates that science partners tend to be most important where the innovation is relatively radical in orientation" (Pittaway et al., 2004). Second, we empirically tested the research model in the German mechanical engineering industry. Further studies can focus on other industries. The model can be adjusted accordingly and can then be compared with our study results. Management tasks and network stabilizing aspects might differ with regard to other industries and partners. Third, we validated the hypotheses using a questionnaire design, with a preceding qualitative study that focused on cross-sectional data. Our method was appropriate for the research purpose but, due to the high dynamics within networks, it would be useful to collect longitudinal data from network participants that collaborated repeatedly. Fourth, another factor that might noticeably influence both the management functions and the social and structural aspects is the existence of an appointed network manager. Studying the differences between networks with and without such an organizing and structuring figure can shed light on the value of this role.

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