The impact of network structure on knowledge transfer: An empirical application of social network analysis in the context of regional networks of innovation

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Abstract

A number of empirical studies provide evidence for the importance of networks concerning innovation. Besides this, the relevance of the spatial component in this context is confirmed by the studies on localized knowledge spillovers, which found the knowledge diffusion often concentrated around the source of its generation. But these analyses are lacking insights in the networks the benefits for innovation resulting from.

Overcoming these weaknesses as well as the problems when using patent data we apply social network analysis in the context of regional innovation networks. Our collection of primary data contains almost 300 firms and research organizations (each embedded in one of 16 German regional innovation networks) which collaborated in R&D at least over a period of 5 years in order to innovate. The data is covering information about partner links as well as the (ingoing and outgoing) extent of information and knowledge flow between these partners. Therefore the dataset allows for separation of variables serving for network construction and those that indicate the knowledge transfer that takes place on the basis of this structure. Thus, we are ready to study the impacts of single actor positions gained from ego-network-analysis as well as the impact of network characteristics on the knowledge transferred in the course of the R&D-collaborations while controlling for firm specifics (e.g. R&D-collaboration experience).

We got evidence that contrary to Granovetter's thesis ("the strength of weak ties") strong ties are without any doubt more favourable concerning knowledge exchanges as well as information flows within the regional innovation networks studied here.

Further we found indirect indications that confirm suppositions due to positive effects of non-redundancy on knowledge exchange. There are negative effects of redundancy (measured as degree of network cohesion) on the efficiency of the studied processes of knowledge exchange in terms of knowledge that was addressed to network partners which obviously weren't interested in its absorption. Moreover our results suggest that the occupation of broker positions (bridging structural holes) rather is associated with social returns than with private returns.

Keywords: regional innovation networks; R&D-collaboration; inter-organizational knowledge exchange; localized knowledge spillovers; structural holes; embeddedness; strong ties; redundancy; knowledge broker; economics of knowledge

1 Introduction

Following the resource based view of (the growth of) the firm (Montgomery 1995; Eisenhardt and Schoonhoven 1996; Mowery, Oxley et al. 1998; Combs and Ketchen 1999; Miotti and Sachwald 2003) enterprises for several reasons are dependent on the search for knowledge sources external to their boundaries in order to innovate and to survive on the long run. However, the knowledge they lack neither is freely available nor it can be obtained completely at the market (thin markets, information asymmetry, tacitness of knowledge).

The broad discussion on (regional) innovation networks already pointed out the network advantages in the context of innovation (Sternberg 2000, Fritsch 2001; Fritsch and Lukas 2001; Borgatti and Foster 2003). A number of empirical studies provide evidence for the importance of networks concerning innovation. Besides this, the relevance of the spatial component in this context (Camagni 1991) is confirmed by the studies on localized knowledge spillovers, which found the knowledge diffusion often concentrated around the source of its generation (Audretsch and Feldman 1996; Feldman 1999; Fritsch and Franke 2004; Audretsch and Lehmann 2005, Fritsch and Slavtchev 2007). But all these analyses are lacking insights into the structure of links (the networks) the benefits for innovation resulting from.

Another stream of literature is using individual patent data which allow for a bottom up construction of knowledge exchange patterns. But the restrictions of patent data not only result from the nature of patents by itself (patentability is not given for all knowledge which is generated, strategic options of firms, industry differences). But using patent data one is faced with another restriction: (1) Often there is no possibility to deal conveniently with the problem of „network boundary specification“. (2) Indeed the information is available easily but patent data displays the cooperation structure of organizations only at a fraction (Pavitt 1988; Griliches 1990). (3) Moreover on the basis of patent data it is not possible to analyse the impact of network structure on knowledge transfer, because there is no information about the extent of knowledge transferred.

Because of these above mentioned restrictions the focus of patent analysis mostly is the network structure by itself or the determinants of the changing structure over time (see for example Graf and Cantner 2006). This study has shown, contrary to Gulati's (1995) supposition, that job mobility of scientists and technological overlap between the network actors is influencing emerging network structure more than cooperation patterns of the past. Another analysis that was conducting case studies in four German regions highlights the central position of public science in regional patent networks (Graf and Henning 2005). Findings about the knowledge flows within innovation networks and the determinants of the flowing volume/extent one can not draw from those analyses.

In this paper we will take a look at the inner life of 16 German regional networks of innovation. Our aim is to provide a quantitative analysis that is resolving the weaknesses of case studies as well as the restrictions of patent data. We will highlight the influence of network structure and network positions on knowledge exchange. Our data allows for considering separately

- the transferring and the absorbing aspects of exchange processes,
- the exchange of information and knowledge, and
- several groups following the framework of (regional) systems of innovation.

In the following section of this paper we highlight relevant aspects discussed in the literature on knowledge exchange and network structure. In the section 3 we build up our hypotheses and give a short impression of the data used in this study. Moreover, the measurement of the variables is explicated in this section. The results we present in section 4 are discussed in section 5 where we draw some conclusions as well.

2 Information and knowledge exchange within regional networks of innovation

Integrating transaction cost economics and social network theories Jones, Hesterly et al. (1997) provide explanations under what conditions network governance has comparative advantage compared to market and hierarchy. The authors point out that the network form of governance can be seen as response to exchange conditions of asset specificity, demand uncertainty, task complexity, and frequency. If those conditions coming across, network advantages arise in terms of adapting, coordination, and safeguarding exchanges.

Within networks, especially concerning epistemic communities (Cowan, David et al. 2000), there are often to be found persons/organizations interested in (closely) related topics. Under these circumstances the likelihood for picking valuable information and knowledge is relatively high. Besides these advantages resulting from “technological and/or cognitive proximity”, network relations are endowed with “social proximity”. “Social relations (that typically meet with networks) make information credible and interpretable” (Uzzi 1996). Beyond this firms often engage in R&D-projects characterized by a high degree of division of labour. In contrast to arm’s length ties (that often don’t include direct feedbacks) “embedded ties" (like network ties) provide more rapid and explicit feedback and foster joint problem-solving arrangements that possibly enrich the network with new solutions and combinations of ideas (Uzzi 1996). On the basis on his field-work and statistical analysis Uzzi (1996) concludes, that "embedded ties can produce competitive advantages that are difficult to emulate with arm's length ties". Relations embedded in networks operate on a logic of exchange which is differing from the market (Uzzi 1996). Repeated interaction is shaping actors' expectations and is shifting the transaction into social ties which going along with feedback mechanisms and possibly result in trustful relationships as well as norms at the network level (Daskalakis and Kauffeld-Monz 2007). This in turn facilitates transactions and reduces their costs of governance. But as well it improves the processes of knowledge exchange (Daskalakis and Kauffeld-Monz 2007). In this way network forms of the division of innovative labour produce opportunities (but also constraints) resulting in outcomes (generation of trust and norms) not predicted by "standard economic explanations". Thus, the benefits of regional networks of innovation derive not only from reducing transaction costs and reducing risks but also in reason of access to valuable information and knowledge (Delany 1993; Malmberg and Maskell 2002). This means that networks are endowed with a strong "enabling character" concerning innovations.

The **regional aspect** of innovation networks is standing in close relation to the discussions about industrial districts, clusters (Oerlemans, Meeus et al. 2001) and localized spillovers (e.g. Breschi and Lissoni 2001) as well as to the concept of embeddedness. But the regional dimension in the discussion of networks is not only related to the arguments closed to the tradition of agglomeration economics (MAR-Externalities with focus on localization economies on the one hand and Jacobs-Externalities (Jacobs 1969) with focus on urbanization economies on the other). Standard agglomeration economics as well as the cluster approach focus rather market based relations (stressing scale and pooling effects as well as processes of cumulative causation) than network relations, which are to a certain degree only market transaction related or taking place beyond the market. Unintended knowledge spillovers are not explicitly involved in theses approaches just as little microeconomic features are discussed that can be seen as the fundamentals of knowledge exchanges.

The microeconomic mechanisms behind the "mystery of localized knowledge spillovers" (spillovers follow a clear „distance decay pattern", Varga 2006) refer to the nature of information and knowledge. While the costs of information transfer often tend to be invariant against the spatial dimension knowledge exchange doesn't similarly. Transfer of knowledge often requires face-to-face contacts, especially in cases where knowledge isn't available in codified forms (complex and ambiguous knowledge) but rather in its tacit dimension (Polanyi 1967). This applies to new technologies but also to incremental processes of innovation that involve the transfer of know-how and skills (Karlsson and Johansson 2005). This kind of knowledge is bound to persons and therefore it is not available ubiquitous (Teece 1981) and found to be “sticky” in places (von Hippel 1994, Asheim and Isaken 2002). These face-to-face contacts that are necessary for transferring tacit dimension of knowledge in turn foster trust building and therewith reduce uncertainty (social complexity) that is involved when dealing with collaborative innovation (Luhman 1989). Strong face-to-face contacts furthermore tend to increase the willingness for “collective learning” („a social process of cumulative knowledge, based on a set of shared rules and procedures which allow individuals to coordinate their actions in search for problem solutions“; Capello 1999). As Capello (1999) shows, “collective learning” for example is an important aspect due to small firms that are faced with high dynamics in product innovation.

But innovation economics (as well as new growth theories) has to be cautious for not overestimate localized spillovers. Criticisms point out that pure localized knowledge spillovers (externalities at the local level obtained without equivalent pay off via the market) are rather scarcely to be found compared to market transactions. As Zucker and Darby (1998) for example have shown, the positive impact of research universities on nearby firms relates to identifiable market exchange between particular university star scientists and firms and not to generalized knowledge spillovers. Additionally Morrison (2004) argues that leading firms cannot be interpreted as knowledge gatekeepers in Allen’s (1977) terms. Morrison’s findings suggest that leading firms absorb knowledge external to their region and spread it only to their own regional network of clients and providers. This supposes that it is rather the network aspect than the regional or spatial aspect that matters for knowledge transfer in its tacit dimension.

Unfortunately empirical work in the domain of innovation economics mostly refers only to the pure existence of network contacts without considering the type or structure of the networks (e.g. Becker 2003). But those studies typically are not able to analyse the inner life of the networks as a driving force of network benefits realized at the firm level. Often there is stated a relation between the participation in networks and the innovative performance, but the causal predication is especially problematic (without analysing longitudinal data) because the reverse relation (innovative firms appear relatively often within networks) is not less plausible if considering the time lags that probably occur between network transaction in the area of collaborative R&D and the introduction of products new to the market. These shortcomings on the one hand refer to the missing information on imputable outcomes of the network transactions (e.g. the extent of knowledge flows). On the other hand the analyses are not enriched with structural data on the networks.

But the discussion on the impacts of network structure has a long tradition. Discussions in the area of innovation economics often refer to the studies of Granovetter (1973, 1985, 2005). His "strength of weak ties" argument (Granovetter 1973) for example is based on the premise that strong ties characterize a dense cluster of actors who are all mutually connected to each other. Since this (sub)cluster of strongly connected actors is likely to interact frequently, much of the information circulating in this social system is redundant. Granovetter posits that *new* information is obtained through casual acquaintances (weak ties) rather than through close personal friends (strong ties). But adopting these findings seamlessly for innovation context appears in reason of several aspects problematic:

(1) Granovetter mainly discusses how social structures and social networks can affect economic outcomes like hiring, price, productivity (Granovetter 2005). But his foci of research mostly are far away from an innovation context (Granovetter 1973, 1985, 2005). If studying innovation at all the attention is dedicated to the diffusion of innovation (first of all the demand side is reflected) rather than to the generation of innovation. The most important benefit of strong ties, the involvement of high trust levels, hardly shows to advantage in these contexts (e.g. information on job offerings) where the diversity argument entails more virtue. But one can draw an important implication from this: If strong or weak ties turn out to be more favourable depends on the characteristics of those things that have to be circulated or exchanged. If taking a look at management science and organizational studies this notion is yet established. Hansen (1999) for example was arguing "when (such) complex forms of knowledge are considered, the instrumental benefits of weak ties are called into question. Weak ties may lead to search benefits in a social network but they may also cause problems in transferring complex forms of knowledge".

(2) Moreover, the most cited study of Granovetter within the literature on innovation economics (Granovetter 1973) doesn't refer to "whole networks". He only raised attention to the differentiation of dyadic weak or strong ties measured in terms of contact frequency. Moreover, it is unaccounted for scarce resources that restrict the possible number of strong ties. Logically it is more likely that the number of weak ties exceeds the number of strong ties.

(3) Finally, how stated by Burt: „information benefits are expected to travel over all bridges, strong or weak“ (Burt 1992:30). He argues that - although overlapping to a certain degree - not the tie strength can be seen as the main reason for access to new information but non-redundancy and broker positions (Burt 1992). He postulates that certain network positions (structural holes and structural constraints) have effects on individuals getting better positions or rewards in organizations. The structural holes theory is considering network ties as opportunities linking together separate agents of network segments through brokers. Structural holes create a competitive advantage for an individual whose relationship span the holes (Burt 2001b) because people on either side of the structural hole participate on different sources and flows of information. Structural holes are thus an opportunity to broker the flow of information between people, and control the projects that bring together people from opposite ends of the hole. Structural holes separate non-redundant sources of information. Non-redundant contacts (bridging and crossing structural holes) offer information that is rather additive than overlapping. Results of (McEvily and Zaheer 1999) indeed indicate that, consistent with the structural holes thesis, non-redundancy in the firm’s advice network explains the acquisition of capabilities and participation in regional institutions. Thus, it doesn’t amaze that with respect to intra-firm knowledge transfer the occupation of such broker positions becomes an instrument of knowledge management like the introduction of „relationship managers“ by IBM (Hoegl und Schulze, 2005).

However, an (supposed) opposing view argues that (instead of structural holes) network closure (in terms of high cohesiveness) would generate superior “social capital” and thus superior “economic rent” as one would have more trust, reputation and cooperation within a closed group with strong internal ties (Gudmundsson and Lechner 2006). Gudmundsson and Lechner (2006) discuss structural holes and social capital theory in the context of multilateral airline alliances and argue that the two concepts in combination advance our ability to explain alliance processes in the airline industry. Both cohesion and brokerage are necessarily involved in any network situation as a matter of fundamental theoretical necessity, but they occur under different circumstances in individual and organizational action. Studies show that effective relations both within and between organizations require both cohesive bases and brokerage between otherwise not well connected units (Kadushin 2002).

It becomes clear from these discussions that a bridge that connects people not otherwise connected can be seen itself as social capital (Burt 2001b). Thus, the two leading network mechanisms (bridging structural holes and cohesion) can be brought together in a productive way within a more general model of social capital. Structural holes are the source of value added, but network closure can be essential to realizing the value buried in the holes (Burt 2000). Probably for this reason some studies (theoretical as well as empirical work) more or less come to conclude that structural holes and social capital theory better to be look upon as complementary than opposite concepts. Moreover, often it is supposed a high context specificity regarding the empirical validation these two concepts (Gudmundsson and Lechner 2006). The impressive study of Reagans and McEvily (2003) indeed is showing that social cohesion and network range ease knowledge transfer. But there is not inter-organizational context. Therefore results are constricted to the intra-organizational perspective and are not simply adoptable to an inter-organizational context. Moreover, as McEvily and Zaheer (1999) notice, the concepts of weak ties and structural holes were used to explain individual career mobility on the one hand and industry profitability on the other. However, little research exists that has considered theses theories in explaining firm-level outcomes. Especially there exists a lack of empirical work that analysis the impact of network structure as well as a firms' network position on inter-organizational information and knowledge exchanges.

3 Hypotheses, data and measurement

3.1 Hypotheses

Our study mainly is concerned with the following three topics:

(1) **Strong tie benefits outweigh the returns resulting from weak ties with respect to the regional innovation networks studied here (hypothesis 1).** In contrast to the findings of Granovetter we suppose: In the context of regional innovation networks weak ties neither are conducive to knowledge exchange nor to information exchange. Conversely we assume that especially strong ties enable the circulation of information and knowledge when interactions and outcomes are accompanied by a high degree of risk and uncertainty and knowledge with tacit dimensions is involved. One could argue that this is likely in the case of knowledge exchange but not in the case of information exchange to the same degree. However beyond the "tacit knowledge argument" there is another reason for the advantage of strong ties: Exerting an information selecting function for a network partner is determined to a high extent by information of the potential transmitter about the potential receiver and his needs and shortcomings. But firms typically don't disclose such firm sensitive information without having strong ties. Therefore, the information selection function works better if based on strong ties.

(2) **Moreover, we assume that (instead of non-redundancy) network cohesion (the overall connectedness of the network members) has a positive effect on information and knowledge transfer (hypothesis 2)** for two reasons: (a) Network cohesion will ease the circulation of information and knowledge in reason of practical advantages that short distances between interacting parties are entailing. Short distances (in terms of crossing only few persons) transmit information accurately and in a timely way, while long distances are stretching the space that has to be crossed, what decelerates diffusion and possibly distorts the information (Cross, Parker et al. 2002). Thus, cohesion results in a higher degree and accuracy of information and knowledge transferred. (b) Moreover, decreasing network fragmentation (increasing cohesion) is leading to socially embedded relations in which a "reputation effect" is working. This means that any kind of information pathology, like closure, distortion, or delay (Müller, Wiechmann et al. 2002) as well as undesired knowledge flows (that are critical to the competitiveness of the firm the knowledge dropped from) into the hands of third parties (possibly competitors) is more likely to be noticed and sanctioned (by third parties) compared to a more fractioned ego network. In fear of reputation losses every actor has strong incentives to transfer information fully, accurately, and timely and to handle business secrets as cautious as necessary. Thus, the argument (b) is referring to the transmitters' behavioural constraints resulting from embedded interactions whereas the argument (a) refers to aspects of interaction in a more technical sense.

(3) Within the discussion on structural holes mostly there is not taking into account that benefits resulting from bridging a structural hole can be attained in many respects. As Nooteboom (2003) points out, problems of „asymmetric information" ("revelation problem" in selling information) can be reduced if there are bridging or mediating agents (so called „go-betweens" or "broker"). Furthermore broker probably can act as arbitrators of simple contracts or holder of hostages, eliminate misunderstandings (e.g. a lack of observed project performance might be attributed to opportunism, while in fact it is due to lack of competence) and reducing Arrow's paradox of information, provide reputation mechanism, control spillover risk and mediate in the building and maintenance of trust and therefore can be seen as a part of the institution-based trust (Zucker 1986; Shapiro 1987; Nooteboom 2003; Daskalakis and Kauffeld-Monz 2007). But with respect to the notion of Burt (1992) it is firstly the brokers itself that take profits from its position. **Following the social capital argument associated with broker roles and taking into account that organization involved in networks are self interested and therefore seeking for profit, we suppose that**

not only social returns but also private returns derive on the basis of such broker positions (hypothesis 3).

3.2 Data

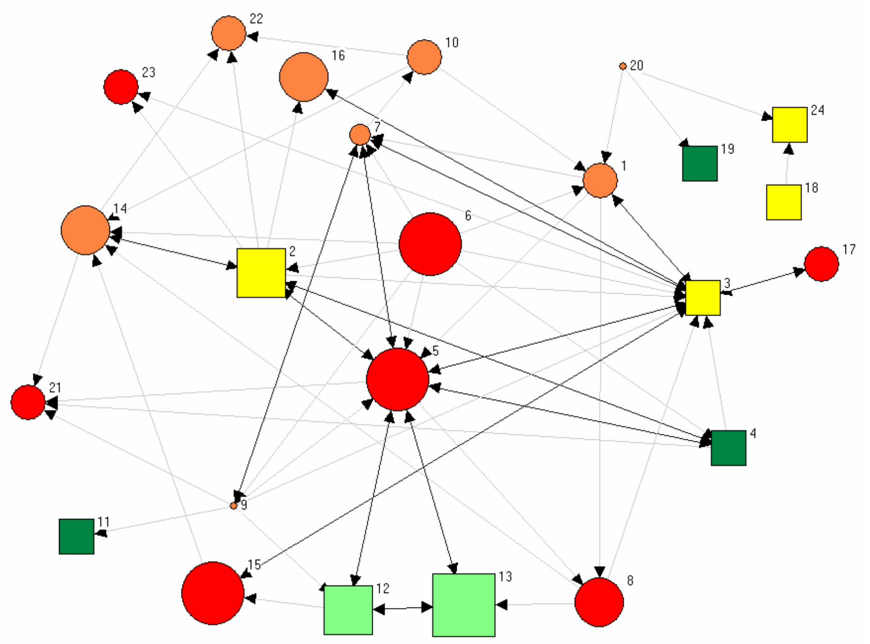
As some studies points out (e.g. Ahua, 2000) the ideal network structure depends on the context of the respective network as well as on the goal(s) the network is instrumented for. We are far away from analysing an ideal network structure in the context of regional innovation networks when studying the impact of network structure on information and knowledge exchange. But following Ahua (2000) and another researchers (e.g. Sydow 2003) we consider this argument due to our selection of data.

Data used in this analysis derives from 16 German regional networks of innovation starting their activities in 1999. Promoted by policy these networks were initiated to improve the regional innovation systems they are located in. Instrumental object of the policy program (Eickelpasch, Kauffeld et al. 2002; Kauffeld and Wurzel 2003, bmbf 2005, Eickelpasch and Fritsch 2005, Kauffeld-Monz 2005) was first of all collaborative R&D involving both, science and business. In reason of this the networks studied tend to be similar concerning their objectives, groups of agents involved, and “organizational restrictions” going along with the promotion initiative. But the networks show differences concerning the industries as well as the number of agents involved. The networks are neither restricted to horizontal nor to vertical network relations. The firms involved in the networks predominantly are small or of a medium size.

3.3 Measurement

All data applied in this study was gathered by postal questionnaire of the network actors in 2004. Each actor of the networks we examined was requested to name his “most important partners in the network” (this name generator technique typically is employed; Burt and Minor 1983; Marsden 1990). On average the actors listed between 3 and 4 partners. On the basis of these links we generated 16 co-operation matrixes, one for each network. Because in the name generating process the agents referred to organizations (and not to individuals employed in these organizations) we got the co-operation matrix at organizational level. These matrixes result in directed graphs that allow for discern between reciprocated and non-reciprocated links (outgoing links of an organisation are called “outdegree”, incoming links “indegree”). A lot of links we found – unlike often assumed in the network theory - to be not reciprocated. In line with Freeman (1979) and Tsai (2001) which argue that the degree centrality is a relatively suitable measure for capturing an actor's information- and knowledge access, we assume that along these links (or rather in reverse direction) the processes of information and knowledge exchange takes place. Figure 1 illustrates the resulting graph for one of the innovation networks studied.

Figure 1: Cooperation Graph (size of symbols represents extent of knowledge absorption)



O = Firm; □ = Science;

Arrowheads = direction of knowledge flow; bold arrows = reciprocal ties; semi-bold arrows = non-reciprocal links
Red = Manufacturing Firm; Orange = Service Firm; Yellow = University; Green = Public Research Institute

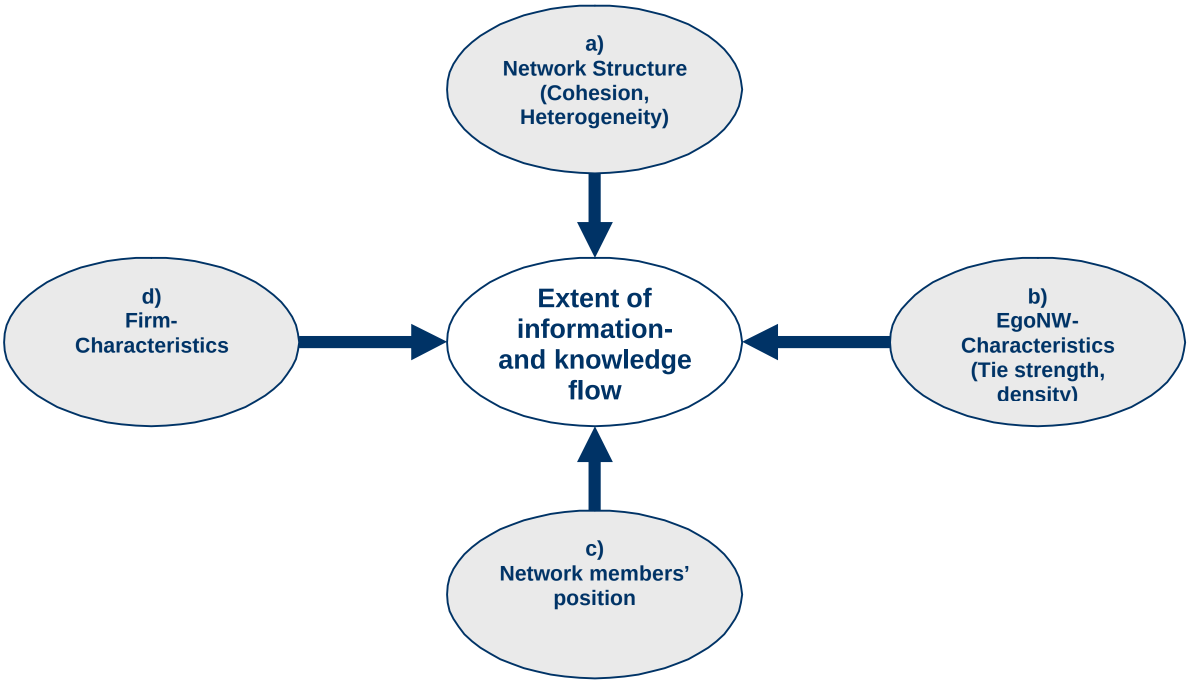
Similarly we aggregated the dependent as well as the independent variables at organizational level (in terms of means per organization) before analysing. Mainly we are referring only to the firms in our analyses, when studying the network outcome in terms of information and knowledge flow. But with respect to some aspects we additionally conducted analyses that contrast the results for the different groups of actors (e.g. firms versus public research organizations) which represent key elements of the systems of innovation approach (Cooke, Uranga et al. 1998, Evangelista, Iammarino et al. 2002; Asheim and Coenen 2005).

Following studies on economics of knowledge (e.g. Cowan, David et al. 2000) we take into consideration that there are many types and dimensions of knowledge rather than one. Our analysis mainly focuses on the technological know-how exchanged between the organizations (measured by "technological support" provided or received). To some degree there is indeed also "know-what" (declaratory/factual knowledge) as well as "know-why" (scientific knowledge) subject of the flows. Concerning all flows of knowledge together a certain extent of tacitness surely is involved, that refers to the implicit nature of knowledge (Polanyi 1967). The information flow hadn't been defined more fine grained in the questionnaire. Due to information we assume a major extent of codification what means that information rather is featured with diffusion characteristics and therefore is "travelling" easier along the network links. The following four indicators are created and used as dependent variable in order to assess differences between information and knowledge as well as differences between the transferring and the absorbing perspective of exchanges: (1) The extent of information transferred to network partners, (2) The extent of knowledge transferred to network partners, (3) The extent of information absorbed from network partners, (4) The extent of knowledge absorbed from network partners. We also assume that the indicators measuring the absorption are more suitable to reflect the real value of the flows.

The independent variables, whose influence on the information and knowledge flows we are studying, can be ascribed to four spheres of influence (fig. 2): (a) The characteristics of the whole network (network cohesion, heterogeneity of competences), (b) every firms' ego network characteristics (ego network density, tie strength), (c) Positions a single firm is occupying in its ego network (broker positions that bridging structural holes) and (d) firm characteristics we control for (firm size and R&D-cooperation experience).

With respect to (a) we not only refer to the mere structure of the network relations (cohesion) that is indicating the degree of redundancy (Burt 2001b) and is calculated by a distance based measure (geodesic distances). We also refer to an often mentioned implication of technological change within innovation economics literature: the diversity of competences and resources (heterogeneity). Thus, heterogeneity we suppose to be an extension of the more structural concept of (non-)redundancy. But we don't follow the assumption "the more persons on board the higher the diversity" like Rost (2006) does while assuming the size of a network indicates heterogeneity. Instead of we draw the heterogeneity indicator directly from the postal questionnaire asking for as "the scope of the network partners' competencies"). Concerning (a) it is essential that the direct ties a network member is holding as well as the transitive, indirect ties (e.g. A is linked indirectly to C because A is linked directly to B and B directly to C) play a crucial role. The respective network members' position (c) arises from its kind of involvement into this structure. The aspects of (b) however (tie strength) focus on the capacity of the direct relations which a network member is holding at the time of examination.

Figure 2: Determinants of information- and knowledge flow by different areas



As McEvily and Zaheer (1999) noticed concerning the measurement of “tie strength”, “despite the explicit use by Granovetter (1973) infrequency of interaction may not be the best measurement of weak ties” (tie strength). They consider alternative dimensions of tie strength, such as bandwidth of communication, emotional intensity, or reciprocity. Following McEvily and Zaheer (1999) we assume that frequency of interaction (as Granovetter in his study employs) is a very rough measurement for tie strength. In innovation context, especially with respect to collaborative R&D, it would be more adequate using the scope (multiplicity) or the depth (intensity) of a relationship. Therefore we employ the degree of trust a network member is granted towards his network partners (measured on a 5-point Likert scale) for indicating “tie strength”. By this means we also prevent that different network aspects becoming mixed/compounded. For example it should be better avoided to equate automatically density with tie strength, because even a dense network could be exhibit many links that aren’t really resilient. However the main reason that should prevent from the pitfall of indicating strong ties on the basis of density is the network size sensitivity of density. If considering that strong ties need (specific) investments and its number is constraint by resource availability of a firm it is logical that the capacity of every actor due to holding strong ties is restricted to a small number of partners. Thus, large networks tend to show relative low densities while nevertheless exhibit lots of strong ties.

Analysing network density at all therefore needs to be normalized to the network size or restricted to the ego-network of an actor. An actors' ego network contains all actors (alters) the actor (ego) is directly connected with. The ego-network density is constructed as the number of realized ties in an ego network divided by the number of possible pairs. The data has been dichotomized for calculating this kind of density (undirected graphs – reciprocated as well as non-reciprocated ties - are used). Otherwise it would be conflicting with the measure that is indicating the structural holes spanners, namely the broker. This second ego network measure refers to the number of broker roles an actor is holding in his ego-network. Brokerage is counting the connection of two alters which directly not are connected but are connected via ego indirectly. The calculation of the number of broker positions an actor holds in his ego network is counting how many times the actor is linking two other actors of his ego network indirectly which otherwise wouldn't be connected. This indicates to what degree an actor is bridging structural holes in his ego-network. So we strongly separate the structural holes measure from the tie strength. Avoiding size effects of an ego network we normalized this attribute of an ego (number of accounted broker roles divided by the number of potential ties in an actors' ego network).

Finally we control for firm size (classified into five classes) and as well for absorptive capacity. Concerning the latter we recognized recent results showing that R&D-intensity as well as the share of high skilled labour, while effects positively the exploitation of knowledge generated by public research institutions, doesn't significantly influence the absorption of intra- and inter-industry knowledge (Schmidt 2005). For this reason we applied a different indicator. A study of knowledge transfer in strategic alliances based on a cross sectional sample of 147 multinational firms shows (focussing on dyadic relationships without a broader network context) that positive effects on technological knowledge transfer are moderated by the firm's level of collaborative know how (Simonin 1999, Simonin 2004). In line with those results we use the "former existence of R&D with partners external to the firm" to differentiate between those firms that are well trained in exploiting external resources and the others that recently started to built up resource- and competence pooling beyond their boundaries.

4 Results

Strong ties and R&D-cooperation experience we found to be important factors with regard to the processes of information and knowledge exchange within the innovation networks examined here. But R&D-cooperation experience isn't decisive respectively sufficient due to the absorption of knowledge (table 1, models 1 - 4).

Regression Analysis

Independent Variables \ Regression Models	Information				Knowledge			
	Transfer (1)		Absorption (2)		Transfer (3)		Absorption (4)	
	Koeff.	T	Koeff.	T	Koeff.	T	Koeff.	T
Constant	***	6.136	**	2.224	***	4.766	**	2.045
Tie Strength	.168**	2.336	.249***	3.433	.135*	1.903	.285***	3.961
Ego Network Density	.151*	1.934	.096	1.219	.088	1.146	.139*	1.770
Network Cohesion	.176**	2.482	.129*	1.807	.176**	2.518	.015	.214
Heterogeneity	-.116	-1.627	.112	1.558	.039	.549	.085	1.185
nBroker	.175**	2.250	.063	.804	.112	1.458	.048	.621
R&D Cooperation Experience	.280***	4.079	.149**	2.148	.308***	4.554	.123*	1.792
Firm Size	-.101	-1.469	-.023	-.323	-.179***	-2.635	.091	1.314
N	194		194		192		192	
Adj. R^2	0.135		0.160		0.122		0.136	

*** = significant at 0,01 level ** = significant at 0,05 level * significant at 0,10 level

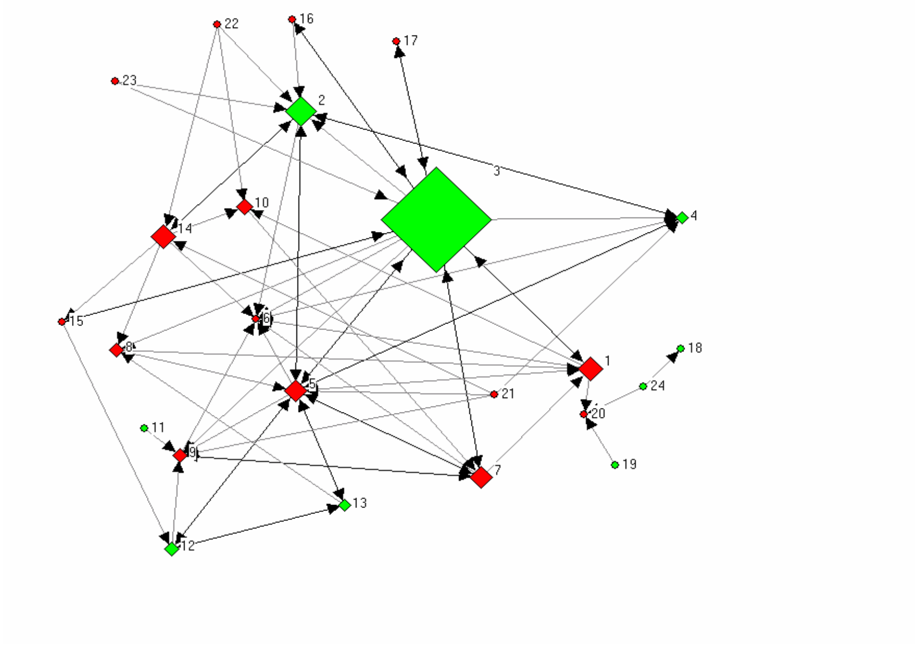
At first glance one could conclude that the argumentation of Granovetter (non-redundancy acts as a promoter concerning the circulation of new information and knowledge within a network) doesn't apply to the networks studied here when looking at the impact of network cohesiveness (connectedness of a network as a whole; indicating the degree of redundancy, Burt 2001b) on information exchanged within the course of interaction. Cohesiveness (that indicates redundancy) is affecting the information exchange in a diametrical opposition to the supposition of Granovetter (models 1 and 2). But considering the knowledge exchange our results differ. Whereas cohesiveness seemingly is conducive with respect to knowledge addressed to network partners (model 3), those partners obviously aren't interested in its absorption (model 4). Thus, a certain amount of knowledge is worthless because it is not exploited in the networks. This we can take for the confirmation of the supposed effect of redundancy. But possibly there are other reasons for a missing correlation resulting from insufficient absorption capacities or a low degree of complementarities.

Ego-network density positively effects information and knowledge flow, but once with respect to transfer and the other time with respect to absorption (model 1 and 4). On the basis of a less detailed analysis that doesn't differentiate between transfer and absorption one would conclude that both, the information flow and the knowledge flow positively correlate with the density of a network.

The extent of heterogeneity between the network partners (extending the more structural concept of non-redundancy to aspects like recombination of competences and resource as well as innovative labour division) turns out to be insignificant if considering only the firms (model 1 – 4). But additional analyses in which we include further groups of agents the regional system of innovation approach is differentiating have shown that heterogeneity is crucial for public science due to the absorption of information and knowledge. Probably firms are more interested in exploitation than exploration but possibly they gain advantages in the long run resulting from network partners' heterogeneity.

As the analyses brought out actors which are well positioned in broker roles (spanning a bridging tie over a structural hole in their ego network; figure 3) neither are able to gain advantages due to the absorption of information nor to the absorption of knowledge (models 2 and 4). But as the results indicate bridging structural holes is enhancing the information transferred to network partners (model 1). If the brokering actor belongs to public science he is enriching the transfer of knowledge as well. Thus, our results indicate that there is no possibility or no necessity for gaining private returns resulting from the number of broker roles an actor holds. But we got strong evidence that those organizations spanning a structural hole are generating social returns especially in terms of information transfer.

Figure 3: Broker Positions



Size of symbols represents extent of brokerage between firms, which not are linked directly

Green diamonds = public research is exerting a broker function between two firms

Red diamonds = a firm is exerting a broker function between two other firms

Circles = no broker function

Furthermore our results are supporting what the policy programme the networks come from was striving for: First of all the firms take profits within the course of knowledge exchange. But absorption of information is not influenced by the firm dummy in the same manner. This means that public science was realizing profits due to information that was absorbed as well. Obviously there has not been a strong linear innovation process but rather a cycling one in which reverse technological transfer occurred in terms of feedbacks from business to science.

Firm size comes out to be significant only with respect to the knowledge transfer. But surprisingly the smaller the firm the more it was transferring to their network partners. Obviously smaller firms were more engaged due to the transfer processes that took place within the network. More important than the pure size of a firm seems to be its absorptive capacity in terms of experience in conducting R&D with partners external to the firm.

5 Conclusions and discussion

It becomes clear that, contrary to the standpoints of transaction cost economists[1], strong ties (measured in terms of trust) are one of the most important prerequisites due to knowledge exchange in economic contexts. That we found strong evidence for the advantageous of strong ties in the context of innovation networks therefore don't rule out the argument of Granovetter. It simply shows the importance of the context when analysing the impact of certain network characteristics. We tried to consider this context specificity as examining networks that, in spite of all differences they show, are emerging under similar conditions.

The argument, strong ties (in terms of "closed shops" of homogenous agents) constrain economic exchange relationships with potential transaction partners outside the network and involve the danger of cognitive lock-in (Grabher, 1993) or entropic death (Camagni, 1991) is a relevant aspect and should be taken into account in longitudinal network studies. But since networks are in an early stage of evolution (like in our case), this reasoning is of less importance. The optimal balance between heterogeneity of agents and a common knowledge base of those (which is necessary for knowledge exchange) is an aspect that first of all has to be answered on the firm level. Uzzi (1996) in a manufacturer-supplier context brought out that embeddedness (essentially measured in terms of a high concentration of a manufacturer on few suppliers/contractors) "yields positive returns (in terms of the suppliers survival) up to a threshold point. Once this threshold is crossed, returns from embeddedness become negative" (Uzzi, 1996).

In reason of our differentiation between the transfer and the absorption of knowledge we can show further that each of the two arguments, often stated as conflicting ones, get its relevance: Social capital (in terms of relatively high network cohesion) indeed has a positive impact on information exchange and the amount of knowledge that a firm is placed at a partner's disposal (the knowledge tried to be transferred to network partners). But if looking at the ingoing side of the examined knowledge exchange processes it becomes clear that the knowledge made available in reason of a high cohesiveness isn't really valuable for the partners it was addressed to. So we found both of the two theses have to be refined: (i) Non-redundancy (in terms of low network cohesion) by no means does going along with circulation of a higher amount of knowledge (respectively more valuable knowledge). (ii) But social capital (in terms of high network cohesion), although enhancing the information flow, doesn't really affect the knowledge circulation positively: the evaluated transmission of

[1] Concepts such as trust and reciprocity only muddy the clear waters of economic analysis (Williamson 1994).

knowledge is increasing, but its absorption doesn’t. Concerning these results we can assume that there is redundancy at work. Thus, in some respects social capital seems to be conducive due to the emergence of inefficiencies and in other respects social capital is enhancing exchange processes.

Obviously the future discussion on knowledge exchange processes could be enriched while differentiating between information and knowledge as well as between the transferring and the absorbing aspect of the exchange relations, an issue that is missing in most of the existing theoretical as well as empirical studies. In many cases it turns out to be valuable to split up the economics of knowledge exchange into economics of knowledge transmission and knowledge absorption.

As we have shown the number of broker positions an organization holds in its ego network has a positive influence on the transfer of information and the transfer of knowledge, although the latter refers only to the organizations of public science (including universities). But, contrarily to our supposition, broker roles neither result in a higher absorption of information nor in advantages with regard to knowledge absorption of the brokering organizations. But why do firms not drawing private returns from their broker position whereas they are able to generate social returns? We suppose that particularly high attractive firms in terms of competencies and capacities attain such positions which are well equipped and therefore less reliant on information circulating in those networks. Our results by all means don’t indicate that firms posit themselves within regional innovation networks in such broker roles because of strategic considerations (in contrast to suppositions often encountering in the literature).

For further discussion it seems to be fruitful to take into consideration the different incentive systems the agents belonging to (firms and public research organisations). Concerning this we found for example that the social returns seemingly turn out to be higher if organizations belonging to the public sphere are well positioned in knowledge broker roles.

To conclude in line with Lin (1999) it would be theoretically more viable to conceptualize for what kind of outcomes which network structures might generate a better return. The postulation of deduced hypotheses possibly brings out that there are different structures at work which improve knowledge sharing and knowledge creating. Moreover, it would be more fruitful to adopt an evolutionary perspective that reflects changing needs of a firm over time. For example (Hite and Hesterly 2001) suggest that firms especially are able to exploit network benefits that derive from structural holes when they shift to advanced stage of their development. While in an early stage of their development firms gain higher benefits from a more cohesive network. But actually there is lacking longitudinal data for verifying this suggestion.

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Appendix

Appendix 1: Measurement of the variables

Variable	Description	Indicator	Measurement
Information transfer	Information a network member is transferring to his partners	Did your network partner(s) take profit in reason of your information or suggestions?	5-point Likert-Scale; very few – very much
Information absorption	Information a network member is absorbing from his partners	Did you get information and suggestion/stimulation from your network partner(s)?	5-point Likert-Scale; very few – very much
Knowledge transfer	Knowledge a network member is transferring to his partners	Did your network partner(s) take profit in reason of your technical/professional assistance?	5-point Likert-Scale; very few – very much
Knowledge absorption	Knowledge a network member is absorbing from his partners	Did you get technical/professional assistance from your network partner(s)?	5-point Likert-Scale; very few – very much
Tie strength	Trust of a partner (A) towards his direct/immediate network partners	Between the partners there is fairness and trust	5-point Likert-Scale; Not at all – very much
Ego NW Density	Density of a network members' ego-network.	An actors (A) ego network is covering all network partners, that are linked directly to A, either because nominated by A or because nominating A.	Number of realized ties divided by the number of potential links
Cohesion	Degree of network cohesion	Based on geodesic distances (the length of the shortest path that is connecting two nodes) between the actors.	Based on mean geodesic distances of all actors to each other
Heterogeneity	Diversity of Competences/Resources within a network	In the network there is a wide range of partners with complementary competences	5-point Likert-Scale; not at all – very much
nBroker	Information and knowledge broker	Number of broker functions a network member is exerting between two network partners which not are linked directly	Standardized for the size of the respective ego network
R&D Cooperation Experience	Existence of partners in R&D external to the organization	Has your firm undertaken R&D with partners external to the firm in the last two years?	Yes/no
Firm Size	Size of the Firm	Number of employees in 2003	Ranked into five classes

Appendix 2: Descriptive Statistics

	N	means	Std.Dev.	Min.	Max.
NW-Größe (RL)	231	27,6277	13,19782	7,00	51,00
Info-Absorption	230	3,5285	1,05961	1,00	5,00
Wissens-Absorption	229	3,5706	1,08786	1,00	5,00
Info-Transfer	232	3,4068	0,84897	1,00	5,00
Wissens-Transfer	232	3,2920	0,91750	1,00	5,00
Beziehungsstärke	214	3,9827	0,81844	1,00	5,00
Größe EgoNW	230	2,9000	1,76415	0,00	9,00
EgoNW-Dichte	229	41,4461	36,23220	0,00	100,00
Broker	230	3,1500	7,93576	0,00	94,00
Kohäsion	232	0,2908	0,07620	0,19	0,52
Heterogenität	213	3,9622	0,92190	1,00	5,00
Reziprozität	232	0,4186	0,12833	0,20	0,82
Beschäftigte2004	221	56,4098	109,7345	1,00	1250,00
FuE-KoopErf.	233	0,5753	0,49240	0,00	1,00

Appendix 3: Correlation matrix

	Info Transfer	Info Absorption	Knowledge Transfer	Knowledge Absorption	Trust	EGO-NW Density	NW Cohesion	Hetero-geneity	nBroker	R&D Exp.	Firm Size
Info Transfer	1	,223(**)	,772(**)	,161(*)	,149(*)	,097	,185(*)	,022	,098	,287(**)	-,020
		,002	,000	,025	,039	,181	,010	,766	,176	,000	,778
Info Absorption	,223(**)	1	,136	,618(**)	,281(**)	,103	,141	,227(**)	,033	,199(**)	,050
	,002		,059	,000	,000	,154	,050	,002	,646	,005	,486
Knowledge Transfer	,772(**)	,136	1	,132	,140	,071	,184(*)	,165(*)	,062	,337(**)	-,104
	,000	,059		,067	,052	,325	,011	,022	,389	,000	,149
Knowledge Absorption	,161(*)	,618(**)	,132	1	,337(**)	,142(*)	,043	,195(**)	,000	,166(*)	,149(*)
	,025	,000	,067		,000	,049	,556	,007	,998	,021	,039
Trust	,149(*)	,281(**)	,140	,337(**)	1	,040	-,112	,263(**)	,076	,074	,143(*)
	,039	,000	,052	,000		,579	,122	,000	,297	,304	,048
EGO-NW Density	,097	,103	,071	,142(*)	,040	1	,132	,075	-,482(**)	,018	,048
	,181	,154	,325	,049	,579		,066	,301	,000	,803	,506
NW Cohesion	,185(*)	,141	,184(*)	,043	-,112	,132	1	,109	,030	,112	,180(*)
	,010	,050	,011	,556	,122	,066		,130	,679	,119	,012
Heterogeneity	,022	,227(**)	,165(*)	,195(**)	,263(**)	,075	,109	1	,016	,179(*)	,007
	,766	,002	,022	,007	,000	,301	,130		,821	,013	,927
nBroker	,098	,033	,062	,000	,076	-,482(**)	,030	,016	1	-,051	,013
	,176	,646	,389	,998	,297	,000	,679	,821		,478	,857
R&D-Experience	,287(**)	,199(**)	,337(**)	,166(*)	,074	,018	,112	,179(*)	-,051	1	,054
	,000	,005	,000	,021	,304	,803	,119	,013	,478		,455
Firm Size	-,020	,050	-,104	,149(*)	,143(*)	,048	,180(*)	,007	,013	,054	1
	,778	,486	,149	,039	,048	,506	,012	,927	,857	,455	

** Die Korrelation ist auf dem Niveau von 0,01 (2-seitig) signifikant.
* Die Korrelation ist auf dem Niveau von 0,05 (2-seitig) signifikant.
a Listenweise N=193