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Differentiated Knowledge Bases and the Nature of Innovation Networks

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Abstract

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Keywords: Knowledge bases, regional innovation systems, social capital, networks

1. Introduction - the geography of knowledge networks

The spatial concentration of innovation activities has been matter of extensive academic debate. Alfred Marshall (1920) began to explore the reasons for spatial clustering of small manufacturing companies in the late 19th century northern England, and suggested the decent economic performance of those companies to be the result of a favourable local "industrial atmosphere" composed of an intensive and often unintentional exchange of ideas in the region. Within an industrial district, he argued, the secrets of trade are available to everyone as if they were in the air. Once a new idea is launched by one company, it is taken up by others, combined with suggestions of their own and turns into the basis for further new ideas (Marshall 1920). Marshall's characterisation of industrial districts has strongly influenced our current understanding of the reasons and mechanisms behind geographical clustering of innovation activities. In the recent years, the notion of "new ideas" used by Marshall to refer to the driver of economic growth has been gradually replaced by the Schumpeterian term "innovation", i.e. a new idea that is brought to the market and is not only novel, but also expected to have a certain economic impact (Fagerberg 2005). Apart from this shift in terminology, the notion of industrial districts has been critically discussed by economic geographers questioning for instance the long-term stability of such cooperative forms (Harrison 1994, 1994), or stressing the importance of cooperation and knowledge exchange with non-local partners (Amin and Thrift 1992; Bathelt, Malmberg, and Maskell 2004). Other scholars argue that the possibility of industrial districts to promote innovation concerns mostly incremental novelty, i.e. gradual improvement of existing products or processes, and does hardly ever lead to radical innovation. For that reason, it is crucial for companies to cooperate and exchange knowledge also across the boundaries of the local milieu in order to come in contact with dissimilar thoughts and ideas that can eventually lead to fundamentally new products and processes (Bianchi and Giordani 1993).

The argument on the importance of the local milieu stressed by Marshall has been developed further in the literature on learning regions (Asheim 1996; Morgan 1997; Vinodrai 2009) and regional innovation systems (Braczyk, Cooke, and Heidenreich 2004; Asheim and Gertler 2005). In this stream of research, a recent shift in attention can be observed from specificities of the local industrial milieu towards strategies of individual companies, and how they obtain new knowledge and ideas required for successful innovation (Moodysson, Coenen, and Asheim 2008). There is agreement that an unintentional and frictionless roaming of ideas within the local milieu remains, at least when it comes to economically valuable novelty, a seldom exception. Even though there may be a higher probability that spatially collocated actors are exposed to knowledge flows amongst each other, spatial proximity is not a sufficient precondition for effective knowledge exchange. In fact, actors must be able to adopt and make use of the knowledge available in their surroundings, requiring a sufficient level of absorptive capacity for interactive learning to take place (Giuliani 2005, 2007). Such absorptive capacity involves a certain degree of cognitive similarity to enable mutual understanding, but also a certain degree of cognitive dissimilarity to evade redundancy and resemblance of thoughts and ideas (Nooteboom 1999). Consequently, knowledge is not equally accessible for all actors situated in the local milieu, innovation related knowledge is rather diffused and exchanged in a highly selective and uneven way (Giuliani 2007). Great parts of the innovation related knowledge is exchanged amongst business partners, i.e. between customers and suppliers or users and producers, and hardly ever by pure incidence and without intention. Rather, knowledge is sourced and exchanged through networks knitting together companies and other organisations inside and outside the region. A solid embeddedness in inter-firm networks is considered critical for the acquisition of new knowledge, and ultimately for a decent performance in terms of innovation. However, the existing literature remains unclear when it comes to the type of network embeddedness that is favourable for innovation to take place. Is it a large number of contacts that is most fruitful, or is an exclusive access to specific partners and thereby a strategic position the network that characterises successful innovators? Is it the intensive interaction and close cooperation within the regional milieu that matters, or is it capability to tap into global flows of knowledge that guarantees continuous innovation? Furthermore, it remains unclear whether knowledge networks are equally designed in all sectors of the economy, or whether the role and nature of innovation networks depend upon specific characteristics of an industry, such as the type of knowledge base that is critical for innovation.

This study deals with the question if and in what respect industries with different knowledge base vary with regard to the nature of innovation networks. On the level of industries, a distinction can be made between different types of knowledge bases, namely science based industries that rely on analytical knowledge, engineering based industries that rely on synthetic knowledge, and artistic based industries that rely on symbolic knowledge (Asheim and Gertler 2005; Asheim, Boschma, and Cooke 2011). On the level of networks, a distinction can be made between different dimensions, such as the structure of networks, the type of relations between network members, the geographical configuration of networks and their persistence over time. The paper begins with a conceptual discussion on social capital and network theory, followed by a theoretically informed discussion on differentiated knowledge bases and innovation networks, followed by an empirical analysis on patterns of cooperation and knowledge exchange in a number of regional industries situated in different parts of Europe[i].

2. Social capital and network theory

As touched upon above, innovation related knowledge is not traveling freely in the air and simply accessible to everyone, but is very often sourced and exchanged in defined networks between actors. In this context, networks are understood as socio-economic structures that connect people or companies to one another (Powell and Grodal 2005). A typical network consists of nodes and linkages, and while nodes represent actors (i.e. persons, companies and other organisations), linkages represent different types of relationships. Networks can be knit together by formal relationships, for example in the case of contract-based cooperation. Likewise, networks can be based on informal linkages, such as joint membership in a business association or a belonging to the same epistemic community or community of practice (Lave and Wenger 1991). The research on networks in economic geography is closely related to work in economic sociology and organisational theory, where networks are seen as a form of economic organisation through socio-economic relationships instead of price-setting mechanisms (i.e. markets), or the imposition of power (i.e. hierarchy) (Granovetter 1973; Powell 1990; Smith-Doerr and Powell 2005). One important body of literature that deals with a number of networks dimensions and may provide insights on the role and nature of innovation networks is related to social capital theory (Loury 1977; Bourdieu 1980; Coleman 1988; Rutten, Westlund, and Boekema 2010).

2.1. The structural and relational dimension of social capital

The term "social capital" occurs first in an article of Loury (1977), who criticises the dominant neoclassical theory to be incapable of taking social context into account, and therefore to be of little use for understanding many important socio-economic phenomena. A first systematic study on social capital is carried out by Bourdieu (1980, 1986), who defines the concept as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition (…)" (Bourdieu 1986, 51)[ii], and thereby explicitly refers to the notion of networks and their significance for economic activities . Coleman (1988) defines social capital by its function as "a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain action of actors - whether persons or corporate actors - within the structure" (Coleman 1988, 98).

Bourdieu (1986) and Coleman (1988) both agree that social capital is closely associated with the formation of networks, though they have different perspectives when it comes to the functioning of networks. Bourdieu regards social capital as a resource that is generated through the linkages to the nodes, whereas Coleman's standpoint is that social capital consists of the linkages between the nodes (Westlund 2006, 1). These different perspectives reflect a distinction between a structural dimension of networks on the one hand, where social capital is seen as the amount of connections that an actor possesses in a network, and a relational dimension of networks on the other hand, where social capital is seen as generated through the process of interaction, and particular attention is for that reason paid to the nature and quality of relationships. A structuralist approach to networks suggests that an actor with numerous connections has more social capital than an actor with few connections, since linkages provide potential access to valuable resources and opportunities. A relational approach to social capital, in contrast, implies that social capital is only the result of successful interaction. The value of a connection arises from its actual use, and accordingly, specific attention should be devoted to the nature, quality and frequency of interactions and to the institutions (e.g. norms, values, trust) that govern social interaction (Rutten, Westlund, and Boekema 2010).

The relational approach to networks has been, amongst others, influenced by Granovetter's (1973) work on the strength of weak ties. Originally referring to relationships between individuals, he distinguishes between strong ties connecting individuals that interact on a regular basis, and weak ties connecting remote acquaintances, or friends of friends. Strong ties are important as they deliver social or emotional support; nonetheless new and original ideas are typically transmitted through weak ties. This is explained by the fact that strong ties tend to be grounded on shared viewpoints and interests; therefore knowledge exchange through strong ties is likely to reinforce rather than to challenge existing views and opinions. Weak ties, in contrast, provide access to dissimilar thoughts and are more likely to introduce novelty in form of different ideas and thinking (Granovetter 1973).

Another notion linked to the relational, but also to the evolutionary dimension of networks, refers to the nature and emergence of relationships (Powell and Grodal 2005). Networks between economic actors can be created for a specific purpose and with the intention to carry out a particular task, or they can gradually grow out of previous and on-going social relationships based on social or cultural communality. Accordingly, they can be of strategic nature aiming at the realization of concrete business opportunities, or they can be of social nature and embedded in on-going inter-personal relationships. However, as networks evolve over time, it is unlikely that relationships remain always in one of these categories. Rather, strategic relationships will become increasingly embedded in social relationships, while social and trust-based cooperation can eventually lead to strategic and contract-based collaboration (Powell and Grodal 2005).

A notion that is linked to the structural dimension of networks is the one of bridges and structural holes (Burt 1992; Granovetter 1973; Walker, Kogut, and Shan 1997). A bridge can be thought of the node that joins two components of a network; removing a bridge will cause the network to divide into two unconnected parts. Individuals who act as bridge hold a strategic position in the network; they are the connecting elements in a network that would otherwise fall apart. While Granovetter (1973) argues that bridges are essential for networks as they generate weak ties, Burt (1992) develops the argument further by looking into network structures and how certain arrangements can create opportunities and benefits for economic actors. He stresses the role of structural holes, which are latent, non-existing connections between separate components of a network, which can deliberately be filled by an actor, also termed broker, who will then gain a strategic position in the network (Burt 1992; Moran 2005).

Bourdieu's (1980, 1986) and Coleman's (1988) treatment of the social capital concept emphasises the economic benefits or returns occurring to individuals by investing into networks. Networks are in this context not seen as predefined, but as outcomes of individual investments and efforts oriented to the institutionalisation of relationships that can be used in a later stage to generate additional benefits (Portes 1998). Different arguments can be brought forward to explain how investments into social networks can generate economic returns for individuals or organisations (Lin, Cook, and Burt 2001; Inkpen and Tsang 2005; Portes 1998). First, and particularly relevant in the context of innovation activities, network embeddedness facilitates the flow and access to information and knowledge. Connections with other actors, in particular when they are situated in strategic or hierarchical positions, can provide access to economically valuable knowledge, for instance about technologies or market opportunities that are elsewhere not available. Second, relationships can exert influence on decision making agents, e.g. managers in a company or policy makers in a government. Some relationships, due to their strategic position in the network, can transmit more and higher valued resources and accordingly exercise greater power on decision making agents. Third, embeddedness is often understood as sign of the social credentials or status of an actor, reflecting its access to resources through social networks and relationships. Individuals that are strongly embedded in networks can provide other actors with resources that go beyond their individual capital. Finally, embeddedness in social networks reinforces identity and common norms and rules, since membership in a group with similar interests and resources can provide acknowledgement on one's claim on specific resources (Lin 2001).

2.2. The geographical dimension of social capital

While these arguments mainly explain benefits from social networks gained by individuals or organisations, it is with Putnam's (1993; 1995) work that the concept of social capital became closely linked to performance of regional economic systems (Portes 1998). Putnam et al. (1993) study regional governments in Italy and argue that their relative success (or failure) depends on the existence of strong horizontal networks in the society, i.e. networks between individuals that are actively engaged in local clubs and associations. These networks encourage civic engagement, which goes hand in hand with more responsive regional governments and, eventually, with well-performing and prospering regional economies. In his study, he argues that northern Italian regions typically possess of active civic societies with people involved in associations, clubs and various types of collective activities, stimulating interaction amongst each other and with the regional administration and ultimately leading to good and effective governance. The south of Italy, as stylised contrast, is characterised by a virtual absence of social capital, going hand in hand with corrupt regional governments, organised crime and economic deprivation (Putnam, Leonardi, and Nanetti 1993). In Putnam's work, social capital, defined as networks between individuals governed by common norms and mutual trusts, is seen as necessary precondition for the economic prosperity of a regional economy.

Following Putnam's ideas, a large number of studies empirically examine the importance of social capital for economic growth (Westlund and Adam 2010), while some of them explicitly deal with regional innovation (Adam 2011). Apart from a few exceptions (Fromhold-Eisebith 2004; Lorenzen 2007), these studies apply econometric methods and, partly due to a lack of consensus on an operational definition of social capital, generate ambiguous results. Beugelsdijk and van Schaik (2005), for instance, study the effect of social capital on economic growth in European regions. They apply regression models using data from a large scale survey on basic human values and find that social capital does indeed explain differences in regional growth. It is however not the mere existence of network linkages, but the active involvement in these relations that matters (Beugelsdijk and van Schaik 2005). Hauser et al. (2007) use the same survey data to study the impact of social capital on regional patenting outcomes. They test the effect of various proxies for social capital on patenting activities and find that not all, but at least some dimensions of social capital can explain varieties in regional knowledge production. However, the authors recognize that a multidimensional concept such as social capital can hardly be captured in a number of econometric measures (Hauser, Tappeiner, and Walde 2007). Blume and Sack (2008) study patterns of social capital in Germany and combine data from different surveys to capture a number of social capital dimensions such as trust and the preference for markets, hierarchies or networks. They find that trust as well as the preference for markets have positive effects on regional growth, while the existence of strong political networks seem to have, unexpectedly, a negative effect on growth (Blume and Sack 2008). Barrutia and Echebarria (2010) study the impact of social capital on innovation outcomes in Spanish and Italian regions and compare two different approaches to social capital: a rational choice-driven approach where social capital is seen as investments into social relations of an individual, and a sociologically driven approach where social capital is seen as the amount of trust and reciprocity in a community. The two approaches provide contradictory results, while investments into social relations seem to have some explanatory power, trust and reciprocity does not explain the observed variance in innovation outcomes (Barrutia and Echebarria 2010).

Even though these empirical studies provide partly ambiguous results, they all point in the direction of positive effects on various measures of network embededdness on various measures for regional innovation outcomes (Westlund and Adam 2010; Adam 2011). The existing literature on social capital and regional innovation, however, has the tendency to treat regional economies as homogenous entities without looking deeper into the sectorial composition, with the result that little can be said about industry specific variation in the nature of innovation networks.

3. Differentiated knowledge bases and innovation networks

In the recent literature on regional innovation systems, increasing attention is paid to industry specific differences in the geography of knowledge. In this context, a distinction can be made between industries that build on different types of knowledge bases, namely (1) analytical, (2) synthetic and (3) symbolic (Asheim and Gertler 2005; Asheim, Boschma, and Cooke 2011). These knowledge bases differ in various respects such as the rationale for knowledge creation (Asheim, Coenen, and Vang 2007), the dominance of tacit and codified knowledge content (Polanyi 1967) and the dominance of different modes of innovation and learning (Johnson, Lorenz, and Lundvall 2002). Briefly summarised, an analytical knowledge base is prevailing in industries where scientific knowledge is important, and where innovation is mainly based on formal models, codified knowledge and rational measures. Typical analytical industries mentioned in the literature are biotechnology, life science and some segments of information and communication technology (ICT) (Plum and Hassink 2011; Moodysson, Coenen, and Asheim 2008). A synthetic knowledge base prevails in industries that innovate through use and recombination of existing knowledge, with the intention to solve concrete, practical problems. Examples mentioned in the literature are automotive, aviation and shipbuilding industry (Broekel and Boschma 2011; Plum and Hassink 2011). The symbolic knowledge base is a third category that is present within a set of cultural industries such as film, music, television, animation or video games, in which innovation is dedicated to the generation of aesthetic value, images and design (Martin and Moodysson 2011; Garmann Johnsen 2011; Sotarauta et al. 2011).

As put forward in this paper, industries with different knowledge base are likely to differ with respect to various network dimensions, such as the structure of networks, the type of relations between network members, important actors in the network, the geographical configuration of networks and their persistence over time. The characteristic differences and similarities in the nature of innovation networks are summarized in table 2 and described in the remainder of the paper.

Table 1: The nature of networks in different knowledge bases

	Analytical (Science based)	**Synthetic (Engineering based)**	**Symbolic (Arts based)**
Network structure	Small number of actors, high network density	Small number of actors, low network density	Numerous actors, low network density
Network relations	Epistemic communities, formal contracts	Communities of practice, Formal contracts	Temporary projects, Informal collaboration
Key actors	Universities and other research units	Suppliers and costumers	End-users, competitors
Network stability	Long-term	Medium-term	Short-term, flexible
Network geography	Global	National/regional	Regional/local

Source: Own draft

3.1. The nature of innovation networks in analytical industries

The defining feature of *analytical industries* is that they aim at the development of new knowledge about natural systems by applying scientific laws. Innovation and knowledge creation follow a deductive logic of reasoning through application of scientific knowledge and models. The type of knowledge involved in innovation processes is typically codified, abstract and universally valid (Asheim and Gertler 2005; Asheim, Coenen, and Vang 2007).

What does this imply for the nature of networks in those industries? Innovation typically involves a relatively small number of actors and an intensive collaboration between those actors. This can be explained by the dominant mode of innovation and learning in analytical industries, which is a science, technology and innovation (STI) rather than a doing, using and interacting (DUI) (Jensen et al. 2007). The prevailing mode of innovation is STI and formal R&D, often taking place in company-own research laboratories and with the explicit intention to protect research findings from possible competitors. Knowledge exchange takes place in a highly selective manner, through formal and contract-based research collaboration between research units in companies and universities, or within a community of scientists who are knowledgeable in a particular issue-area.

Analytical industries deal with scientific knowledge that is typically available in codified form, for instance printed in scientific journals and books or registered in patent databases. Results from public research at universities are usually disclosed in scientific publications and thus openly available to the public, while the results from private research carried out within companies are either kept secret and therefore inaccessible to others, or protected by patents and other copyrights, which makes them partly accessible to the public. Patents are the classic instrument to protect intellectual property in analytical industries, and at the same time they constitute a relevant source of information about innovation activities undertaken by competitors and other actors on the market. By registering a patent, the inventor receives a limited property right to exploit an invention, but only in exchange for sharing the details of the invention with the public. As described above, codified forms of knowledge accessible through publications and patent databases are particularly important for analytical industries, nonetheless obtaining and decoding these types of knowledge goes hand in hand with interactive learning and the exchange of more tacit forms of knowledge between scientists. Interactive learning and knowledge exchange with customers, suppliers and other actors is consequently not absent, but occurs in a highly selective manner.

In analytical industries, innovation is usually geared towards a very particular scientific field, in which only a limited number of professionals share the specific language and understanding relevant to the issue-area. Knowledge exchange and cooperation therefore take place within a relatively small community of knowledgeable actors, sometimes labelled as “epistemic community” (Haas 1992; Amin and Cohendet 2004; Knorr-Cetina 1999). The concept is usually used to refer to a network between scientists and professionals, who may well originate from a range of academic or professional backgrounds, but are linked by a set of unifying characteristics, such as a shared set of normative and principled beliefs, shared causal beliefs and shared notions of validity (Haas 1992, 3). Members of an epistemic community share similar patterns of reasoning, common causal beliefs and the use of a common discursive habit, as well as a shared commitment to the application and production of knowledge. They work on a commonly recognized subset of knowledge issues and accept some common procedural authority as essential to their knowledge-building activities (Moodysson 2008). While the notion of epistemic communities is not limited to science based industries, it is useful for understanding patterns of collaboration and knowledge exchange in those industries (Gittelman 2007; Moodysson 2008; Knorr-Cetina 1999). Moodysson (2008), for instance, shows for the biotech industry in southern Sweden that most of the interactive knowledge exchange is safely embedded in globally configured professional communities and attainable only by a small number of eligible professionals.

Relationships between members of epistemic communities are typically cultivated and maintained for an extended period of time, sometimes for a whole period of a professional career. This points in the direction of a long term stability of important parts of the knowledge networks in analytical industries. Innovation networks between companies are based on long term and contract-based cooperation between small numbers of specialized companies and research organisations, as well as on long term and trust-based cooperation between key individuals in epistemic communities. Cooperation and knowledge exchange takes place between research units and scientists that are widely dispersed across space. They deal with codified knowledge that is highly abstract and universally valid and therefore little bound to a specific geographical context, which implies that innovation and knowledge networks in analytical industries are globally rather than regionally configured.

3.2. The nature of innovation networks in synthetic industries

One of the inherent characteristics of *synthetic industries* is that innovation is driven by the use and recombining of existing knowledge and the application of engineering skills rather than scientific reasoning. Innovation and knowledge creation typically follows an inductive logic aiming at concrete problem solving and custom production. The types of knowledge involved are partially codified and partially tacit, and therefore primarily but not exclusively valid within a specific geographical context (Asheim and Gertler 2005; Asheim, Coenen, and Vang 2007).

Finding solutions to engineering problems in synthetic industries requires know-how and practical skills, while know-why, i.e. knowledge about scientific laws and principles, remains in the background. In search for solutions to concrete, technical problems, the dominant mode of innovation is DUI rather than STI. DUI subsumes three interrelated ways of learning, namely learning-by-doing, learning-by-using and learning-by-interacting (Lundvall 1988; Arrow 1962; Rosenberg 1982). The importance of learning-by-doing in engineering based industries has been emphasised by Arrow (1962), who argues innovation to be a result of practical experience and to take place by resolving concrete problems at the work place. Little later, Rosenberg (1982) developed the idea of learning-by-using to cater for the fact that learning not only occurs during the course of production, but also while a product is in use at the customer. His empirical illustration are air transport companies and the introduction of the latest jet engine aircrafts, where he argues that the viability of a complex product such as an airplane can often be assessed only during its actual use, and that feed-back loops between users and producers can help to incrementally improve the product (Rosenberg 1982).

Learning-by-doing and learning-by-using are primarily associated with innovation and learning inside the boundaries of a firm, and do not necessarily imply that companies need to cooperate with other actors in a network. However, the notion of learning-by-using suggests that learning processes do not take place in isolation, but very often in close connection between users and producers. As Lundvall (1988) points out, "(…) the knowledge produced by learning-by-using can only be transformed into new products if the producers have a direct contact to users" (p. 352). Thus, important forms of learning in synthetic industries occur in collaboration and close contact between users and produces. Such types of learning are consequently labelled as learning-by-interacting (Lundvall 1988). By means of cooperation, producers can benefit from insights into user needs and requirements and can adjust their products accordingly, while the users increase their understanding about the use-value characteristics of a new product (Lundvall 1988, 350-352).

Interactive learning along the supply chain between users and producers is not the only way in which synthetic industries engage into collaborative networks. Important forms of cooperation can evolve between individuals engaged with solving similar or interrelated technical problems. A concept that describes this form of cooperation is the idea of "communities of practice" (Lave and Wenger 1991; Hildreth and Kimble 2004). A community of practice refers to a group of people who share an interest, a craft, or a profession, and who communicate regularly with one another about their activities (Lave and Wenger 1991). The group can evolve naturally out of a common interest in a specific domain or area, or it can be created deliberately with the goal of gaining knowledge related to their issue-area. People in communities of practice share their expertise and knowledge, learn from each other and foster new approaches and solutions to problems. Communities of practice can exist within the boundaries of a firm, or they can develop between associates in different companies and different places. Communities can for instance emerge, as described by Wenger and Snyder (2000), between technicians who seek to improve a production flow within their company, or between engineers who cooperate between companies to improve a particular technology. Those persons are bound together by common expertise and passion for a joint undertaking, and they learn from each other by sharing knowledge about advancements and obstacles related to their work. This communication contributes to solving concrete problems and, at the same time, bridges the gap between theoretical and practical knowledge (Moodysson 2008).

Innovation networks in synthetic industries involve a relatively small number of actors, while most of the knowledge exchange relations occur between suppliers and customers along the supply chain, or between members of a community of practice with a mutual interest for a specific issue area. Interactive learning between customers and suppliers is likely to end after a certain period of time, for instance when a product is no more used by the customer or when the support contract between supplier and customer has ended. Communities of practice can be seen as more durable, as they involve a mingling of professional and personal relationships and are therefore likely to persist even after the end of the contract based collaboration. Companies deal to some extent with codified knowledge, while the most essential type of knowledge is tacit, since innovation is driven by leaning by doing, using and interacting. The importance of tacit knowledge and interactive learning implies that relatively little collaboration takes place across far geographical distance, while knowledge networks are primarily nationally or regionally configured.

3.3.The nature of innovation networks in symbolic industries

The defining feature of *symbolic industries* is that innovation is geared towards the creation of meaning, desire, aesthetic qualities, affect, intangibles, symbols and images. Innovation and knowledge creation is a creative process involving artistic skills and imagination. The types of knowledge involved are highly tacit and call for interpretation and cultural awareness, which implies a strong context specificity (Asheim and Gertler 2005; Asheim, Coenen, and Vang 2007).

Innovation in symbolic industries is dominated by creativity and artistic skills, while the prevailing mode of innovation is open and based on cooperation in temporary projects. In this context, a project is understood as "a temporary organizational arena in which knowledge is combined from a variety of sources to accomplish a specific task" (Grabher 2004, 104). Individuals come together and work in project teams that may dissolve after the particular problem is solved or redefined (Gibbons et al. 1994, 6). Innovation in symbolic industries is based on temporary projects since the trends and fashions that govern these industries tend to change rapidly, which leads to a continuous variation in the skills and competences required for innovation. Symbolic production typically involves a number of small companies and freelancers, i.e. independent contractors that join into a project for a limited period of time (Garmann Johnsen 2011). Individual producers need access to a range of potential cooperation partners, and therefore interpersonal networks and knowledge about possible partners for cooperation and knowledge exchange are particularly important. It is rather this particular know-who and to some extent also know-how that matter, while know-why is of minor importance. Although learning by doing, using and interacting is obviously important, it is argued that project-based industries are characterised by an alternative form of learning, sometimes labelled as "learning by switching ties" (Grabher 2004; Dornisch 2002; Grabher 2005). Innovative actors are tied together for the limited period of a project before they switch to other projects and another set of connections. Repeated collaboration is often based on the reputation that an actor gains (or loses) in earlier projects. Through collaboration in previous projects, actors progressively build up a pool of resources to draw on in future projects, and these connections can evolve into considerably large networks for cooperation and knowledge exchange. Most linkages in the network however remain latent and hidden for most of the time, until they come to be reactivated for the limited period of a project. The term latent network refers to such a pool of resources that is accumulated based on several project cycles (Grabher 2002).

Innovation in artistic industries is driven by creativity, interpretation and cultural awareness that can vary considerably between various regional and national settings. Companies tend to work with partners that have the same perception of the aesthetic qualities and design value of a product, which is typically the case for partners with the same socio-cultural background. The importance of cultural knowledge and sign values suggests that cooperation and knowledge exchange takes place first and foremost within the regional milieu, while national or international collaboration is less frequent. Innovation in symbolic industries is strongly governed by the local context, and therefore companies tend to cooperate primarily within regionally configured networks.

4. Empirical analysis - the nature of innovation networks

Some of the theoretically informed expectations regarding the different network dimensions can be challenged with empirical material collected in the European collaborative research project "Constructing Regional Advantage (CRA)". In the course of the project, research has been carried out on a number of regional industries located in different parts of Europe, which can typically be attributed to one of the three knowledge bases. Information has been collected on various characteristics of companies that constitute a regional industry, and in particular on their relations to other organisations in the industrial sphere. Managing directors or other firm representatives were interviewed about their company's strategies and practices for collaboration and knowledge exchange with other organisations. More concretely, they were asked with whom they cooperate and exchange knowledge with relevance for their company's innovation activities, either related to technological development or to market opportunities, and where these cooperation partners are located in relation to each other. The outcome of the interviews comprise detailed information about the companies that constitute a particular regional cluster, as well as information about networks of cooperation and knowledge exchange with other companies and amongst each other.

Analytical industries in the sample comprise biotechnology in North Rhine-Westphalia (Germany), space in The Netherlands and life sciences in Scania (Sweden). The synthetic industries in the sample comprise ICT in Moravia-Silesia (Czech Republic), electronics in South Moravia (Czech Republic), automotive in Southwest Saxony (Germany), food in Scania (Sweden), and aviation in The

Netherlands. The symbolic industries comprise video games in Hamburg (Germany) and moving media in Scania (Sweden).[iii]

4.1. The structure of knowledge networks

As pointed upon above, industries with different knowledge base are expected to differ with regard to the structural dimension of knowledge networks. In the following, particular attention is devoted to two network measures that are related to the structure of networks, namely degree centrality and component size. The first measure, degree centrality, reflects the number of *direct* contacts an actor has in a network. In this case, it reflects the number of cooperation partners a company can draw on in order to access new knowledge. Cooperation partners can include other companies in the same or related fields, suppliers, customers or competitors, public or private organisations engaged in research and education, or policy initiatives and other organisations with relevance for innovation activities. The measure provides an indication of the extent of immediate knowledge exchange between companies by capturing the number of actors that are directly connected to one another. The second measure, component size, goes beyond the previous by taking into account the direct and the *indirect* contacts an actor has in the network. It implies that companies can access knowledge not only through direct interaction with other organisations, but that they can also benefit from knowledge that is available and transmitted from one organisation to another through intermediate organisations acting as knowledge broker (Burt 1992; Granovetter 1973; Walker, Kogut, and Shan 1997).

Obviously, not all companies in a regional industry are directly linked to one another. Some companies have a large number of direct exchange partners but are weakly integrated in the overall network. They form network components that may be strongly connected amongst each other, but disconnected from the rest of the network. Other companies have only few direct exchange partners, but as those are strategically positioned in the network, they can connect different networks components and provide indirect access to a large number of organisations. Based on the theoretical discussion on the structural dimension of networks, one would expect knowledge exchange in analytical and synthetic industries to take place between a relatively small number of organisations, and symbolic industries to be constituted of a large number of collaboration partners.

Table 2: Structure of knowledge networks within analytical, synthetic and symbolic industries

Industry knowledge base		Degree centrality (direct linkages)	Component size (indirect linkages)
analytical	Median	8	202
	N	74	74
synthetic	Median	6	124

Industry knowledge base		Degree centrality (direct linkages)	Component size (indirect linkages)
	N	183	183
symbolic	Median	11	337
	N	57	57
Total	Median	7	178
	N	314	314

Source: Own calculations based on CRA database

The results from the overall network analysis go fairly well in line with these expectations (see table 2). Degree centrality, reflecting the number of direct contacts, is considerably higher in symbolic industries (11) compared to analytical (8) and synthetic (6) industries[iv]. This demonstrates that companies in symbolic industries rely on a larger number of partners for direct cooperation and knowledge exchange than companies in analytical and synthetic industries. Further insights can be gained by looking not only at the direct, but also at the indirect connections an actor possesses in the network. The component size is considerably lower in analytical (202) and synthetic (124) industries, while the largest component size can be observed for symbolic industries (337), confirming the theory led expectations regarding the structural dimension of networks.

Table 3: Structure of knowledge networks within different clusters

Regional industry		Degree centrality (direct linkages)	Component size (indirect linkages)
Biotech in North Rhine-Westphalia (DE)	Median	11	202
	N	23	23
Space in The Netherlands (NL)	Median	5	49
	N	21	21
Life Science in Scania (SE)	Median	8.5	242
	N	30	30
ICT in Moravia Silesia (CZ)	Median	6	17
	N	19	19
Electronics in South Moravia (CZ)	Median	4	124
	N	28	28
Automotive in Southwest Saxony (DE)	Median	11.5	545
	N	58	58
Aviation in The Netherlands (NL)	Median	3	84
	N	50	50
Food in Scania (SE)	Median	7.5	178
	N	28	28
Video Game in Hamburg (DE)	Median	11	189
	N	20	20
Moving Media in Scania (SE)	Median	11	337
	N	37	37
Total	Median	7	178
	N	314	314

Source: Own calculations based on CRA database

A more detailed picture can be gained by breaking up the aggregated values and concentrating on specific regional industries (see table 4). The lowest component sizes can be identified in the Dutch aviation industry (3), the electronics industry in South Moravia (4), the Dutch space industry

(5) as well as in the ICT industry in Moravia Silesia (6). These four industries are typical examples for a synthetic or analytical knowledge base. Component sizes in a middle range can be identified in the food industry in Scania (7.5), which is an example for a synthetic industry, and in the life science industry in Scania (8.5), an example for an analytical industry. The largest component sizes can be identified in the two symbolic industries, namely video games in Hamburg (11) and moving media in Scania (11), but also in biotech in North Rhine-Westphalia (11) and automotive in Southwest Saxony (11.5).

While the results from the overall network analysis go fairly well in line with our expectations regarding knowledge bases and different networks structures, the result from the industry specific analysis points in the direction that most, but not all of the observed variation can be explained by differences in the industrial knowledge base. While the general tendency confirms the expectation that regional industries with symbolic knowledge base rely on a larger number of cooperation partners than industries with other knowledge bases, there are cases where synthetic or analytical industries comprise a great number of interconnected organisations. As the discussion on the institutional characteristics of social capital implies, the extent and frequency of collaboration and networking is dependent on numerous factors such as the institutional setting in the respective regional innovation system (Tödtling and Trippl 2005; Tödtling et al. 2011), the characteristics of the national system of production, innovation and competence building (Asheim and Coenen 2006; Lundvall et al. 2002), and the stage of the development and evolution of the regional industry (Boschma and Frenken 2011; Martin and Sunley 2011). These dimensions need to be taken into account, but can hardly be captured in a comparative study comprising a number of regional industries situated in different regional and national settings and passing through different stages of development.

1.1. The geography of knowledge networks

Another notion of networks that can be challenged with the collected empirical material is the geography of knowledge networks. The companies where asked to indicate with whom they exchange knowledge and where these exchange partners are located. Accordingly, a distinction can be made between cooperation partners situated in the same regional milieu, cooperation partners located outside the region but within the national boundaries, and international cooperation partners situated outside the country. Based on the theoretical discussion on types of knowledge and modes of learning, industries with different knowledge base are expected to differ also with regard to the geographical configuration of knowledge networks.

Table 4: Geography of knowledge networks for different knowledge bases

			Contact location			Total
			regional	national	international	
knowledge base	analytical	Count	182	135	217	534
		% within knowledge base	34.1%	25.3%	40.6%	100%
	synthetic	Count	432	552	227	1211
		% within knowledge base	35.7%	45.6%	18.7%	100%
	symbolic	Count	334	167	159	660
		% within knowledge base	50.6%	25.3%	24.1%	100%
Total		Count	948	854	603	2405
		% within knowledge base	39.4%	35.5%	25.1%	100%

Source: Own calculations based on CRA database

The empirical results clearly support the theoretically informed expectations on the geography of knowledge networks (see table 4). In analytical industries, the largest share of all exchange relations are international (40.6%), while national (25.3%) and regional (34.1%) collaboration is less frequent. This illustrates the dominance of international collaboration and exchange of universally valid knowledge in science based industries. In synthetic industries, most of the exchange relations occur within the national boundaries (45.6%), followed by regional collaboration (35.7%), while international collaboration is less common (18.7%). This shows that engineering based companies interact and exchange knowledge mainly within the national or subnational context. In symbolic industries, the majority of all exchange relations occurs within the regional milieu (50.6%), while national (25.3%) and international (24.1%) collaboration is less frequent, demonstrating the essential role of the regional and local context for artistic based industries.

Table 5: Geography of knowledge networks for different regional industries

			Contact location			Total
			regional	national	international	
regional industry	Biotech in North Rhine-Westphalia (DE)	Count	105	58	79	242
		% within regional industry	43.4%	24.0%	32.6%	100%
	Life Science in Scania (SE)	Count	77	77	138	292
		% within regional industry	26.4%	26.4%	47.3%	100%
	ICT in Moravia-Silesia (CZ)	Count	60	45	10	115
		% within regional industry	52.2%	39.1%	8.7%	100 %
	Electronics in South Moravia (CZ)	Count	46	71	41	158
		% within regional industry	29.1%	44.9%	25.9%	100 %
	Automotive in Southwest Saxony (DE)	Count	241	368	124	733
		% within regional industry	32.9%	50.2%	16.9%	100 %

			Contact location			Total
			regional	national	international	
	Food in Scania (SE)	Count	85	68	52	205
		% within regional industry	41.5%	33.2%	25.4%	100 %
	Video Game in Hamburg (DE)	Count	113	69	75	257
		% within regional industry	44.0%	26.8%	29.2%	100 %
	Moving Media in Scania (SE)	Count	221	98	84	403
		% within regional industry	54.8%	24.3%	20.8%	100%
Total		Count	948	854	603	2405
		% within regional industry	39.4%	35.5%	25.1%	100 %

Source: Own calculations based on CRA database

A more detailed picture can be gained from distinguishing between regional industries (see table 5). The international level plays an important role in both of the analytical cases, in particular in the life science industry in Scania (47.3%), but also in biotechnology in North Rhine-Westphalia (32.6%). Among the synthetic cases, a clear dominance of the national level can be observed in particular in the electronics industry in South Moravia (44.9%) and the automotive industry in Southwest Saxony (50.2%), while cooperation networks in the ICT industry in Moravia-Silesia and the food industry in Scania are nationally and, to some extent, also regionally configured. The two symbolic cases video games in Hamburg (44.0%) and moving media in Scania (54.8%) are clearly dominated by regionalized cooperation networks, going very well in line with the theoretical argument of the dominance of the regional milieu for artistic based industries.

5. Concluding remarks

As stressed in this paper, important types of knowledge that are needed for innovation are not simply accessible to everyone in the local milieu, but sourced and exchanged within defined networks between economic actors. Insights from social capital and network theory suggest that innovation networks can differ in various aspects such as their structure and density, the nature of relationships, the type of actors holding a strategic position, their stability and their geographical configuration. Embeddedness into networks can have positive effects on innovation outcomes, as they facilitate the flow of information and knowledge and provide access to tacit forms of knowledge that are elsewhere not available. Moreover, networks can exert influence on decision making agents, for instance on regional or national governments, which can lead to economic benefits for the network members (Putnam, Leonardi, and Nanetti 1993; Lin 2001). A number of empirical studies demonstrate that social capital and networks indeed have positive effects on regional innovation outcomes (Adam 2011). However, most of the existing studies treat regional economies as homogenous entities without taking into account essential differences in the regional industrial composition. As put forward in this paper, the nature of innovation networks can vary substantially between industries that innovate on different knowledge bases (Asheim and Gertler 2005; Asheim, Coenen, and Vang 2007).

In analytical industries, cooperation and knowledge exchange typically takes place in a very selective manner between a small number of research units in companies or universities, as well as between scientists in globally configured epistemic communities. As networks are based on trust and reciprocity between experts in a very particular issue area, they tend to remain stable for a long period of time. Analytical industries deal with codified knowledge that is highly abstract and universally valid and therefore little bound to a specific geographical context. The importance of scientific principles and universally valid knowledge implies that innovation networks are globally, rather than nationally or regionally configured.

Innovation in synthetic industries is based on other principles. Cooperation and knowledge exchange occurs between users and producers along the supply chain or between members of communities of practice. Networks can remain stable for a considerable period of time, since communities of practice are based on a common personal or professional interest for a specific product or technology. Formal cooperation between users and producers, in contrast, can dissolve quickly when a product is no more in use or when a support contract between supplier and customer has ended. Companies in synthetic industries deal to some extent with codified knowledge, though, as innovation is driven by learning by doing, using and interacting, the most important type of knowledge is tacit. The importance of tacit knowledge and interactive learning suggests that relatively little collaboration takes place across far geographical distance, while knowledge networks are primarily nationally or regionally configured.

Innovation in symbolic industries is even more governed by the local context, and companies cooperate primarily within close geographical proximity and with a number of altering partners. Symbolic industries typically innovate within short-term projects, and companies change their cooperation partners frequently. They are tied together for the short period of a project before they switch to other projects and other sets of connections. Innovation in symbolic industries is driven by creativity, interpretation and cultural awareness that can vary considerably between various regional and national contexts. Companies exchange knowledge with associates that share a similar perception of the aesthetic qualities and design value of a product. The importance of cultural knowledge implies that cooperation and knowledge exchange takes place first and foremost within the regional milieu, while national or international collaboration is less frequent, which has been demonstrated in the empirical part of this paper.

As shown in this paper, the nature of networks can vary substantially between industries that are based on different types of knowledge. Such industry specific differences ought to be taken into account in order to reach a more nuanced understanding of the reasons and mechanisms behind the geographical clustering of innovation activities.

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[ii] This definition appeared initially in French in a short note in the journal “Actes de la recherche en sciences sociales” (Bourdieu 1980).

[iii] Studies on the individual cases are published, amongst others, in European Planning Studies “Special Issue: Constructing Regional Advantage: Towards State-of-the-Art Regional Innovation System Policies in Europe?” (Asheim, Moodysson, and Tödtling 2011)

[iviv] Numbers in brackets display median values. Median values are used in order account for the large number of outliers and high standard deviation in the network measures.