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# Differentiated Knowledge Bases and the Nature of Innovation Networks

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**WP 2013/14**
**Differentiated Knowledge Bases and the Nature of Innovation Networks**

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## ABSTRACT

It is argued in this paper that the nature of innovation networks can vary substantially with regard to the type of knowledge that is critical for innovation. Subject to the knowledge base of an industry, networks between companies can differ in various aspects, such as their geographical configuration, their structure, the type of actors holding a strategic position and the type of relations between actors. The paper comprises a conceptual discussion on social capital theory and networks, followed by a theoretically informed discussion on differentiated knowledge bases and innovation networks, which is subsequently illustrated with empirical material. The empirical analysis is based on social network analysis in association with exclusive data about patterns of cooperation and knowledge exchange in a number of regional industries located in different parts of Europe. The findings suggest that networks in analytical industries are not much constrained by geographical distance; knowledge is exchanged in a highly selective manner between research units and scientists in globally configured epistemic communities. Synthetic industries source knowledge within nationally or regionally configured networks between suppliers and customers, and within communities of practice. Symbolic industries rely on knowledge that is culturally defined and highly context specific, resulting in localised networks that are temporary and flexible in nature.

**JEL Code:** B52, O25, P51, R11, R12, R58

**Keywords:** differentiated knowledge bases; regional innovation systems; social capital; social network analysis; knowledge networks

**Title:**

# Differentiated Knowledge Bases and the Nature of Innovation Networks

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**Abstract:** It is argued in this paper that the nature of innovation networks can vary substantially with regard to the type of knowledge that is critical for innovation. Subject to the knowledge base of an industry, networks between companies can differ in various aspects, such as their geographical configuration, their structure, the type of actors holding a strategic position and the type of relations between actors. The paper comprises a conceptual discussion on social capital theory and networks, followed by a theoretically informed discussion on differentiated knowledge bases and innovation networks, which is subsequently illustrated with empirical material. The empirical analysis is based on social network analysis in association with exclusive data about patterns of cooperation and knowledge exchange in a number of regional industries located in different parts of Europe. The findings suggest that networks in analytical industries are not much constrained by geographical distance; knowledge is exchanged in a highly selective manner between research units and scientists in globally configured epistemic communities. Synthetic industries source knowledge within nationally or regionally configured networks between suppliers and customers, and within communities of practice. Symbolic industries rely on knowledge that is culturally defined and highly context specific, resulting in localised networks that are temporary and flexible in nature.

**Keywords:** differentiated knowledge bases; regional innovation systems; social capital; social network analysis

# 1. Introduction - networks and the geography of innovation

The spatial concentration of innovation activities is a matter of extensive academic debate, where increasing attention has recently been devoted to the notion of networks. The origin of this discussion refers back to Marshall (1920), who began to explore the spatial clustering of small manufacturing companies in northern England in the late 19th century and argued that their considerable economic performance results from a favourable local industrial atmosphere composed of an intensive and often unintentional exchange of ideas in the region. Within an industrial district, Marshall (1920, IV.X.7 §3) states, “[t]he mysteries of the trade become no mysteries; but are as it were in the air”. The argument on the importance of the local milieu has been developed further in several territorial innovation models (Moulaert and Sekia 2003), notably in the literature on regional innovation systems (RIS) (Cooke et al. 1998; Cooke et al. 2004; Asheim and Gertler 2005). In this stream of literature, a recent shift in attention can be observed from characteristics of the local industrial milieu towards strategies of innovating companies and how they can acquire new knowledge (Moodysson et al. 2008). There is agreement that the unintentional roaming of ideas described by Marshall (1920) remains a seldom exception, at least when it comes to economically valuable knowledge. 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 (Torre and Gilly 2000; Gertler 2003; Boschma 2005). 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 (Cohen and Levinthal 1990; Giuliani 2005). 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 to all actors in the local milieu, innovation related knowledge is rather diffused and exchanged in a highly selective and uneven way (Giuliani 2007). Large parts of innovation related knowledge are exchanged amongst business partners (i.e. between customers and suppliers or users and producers), but hardly ever by pure incidence. Rather, knowledge is sourced and exchanged through *networks* that knit together companies and other organisations at different geographical locations (Gertler and Levitte 2005; Powell and Grodal 2005). The embeddedness in inter-firm networks is considered as critical for successful innovation in all sectors of the economy, and this holds for analytical, synthetic and symbolic industries (Asheim et al. 2011a). However, it remains unclear in the literature whether knowledge networks are equally designed in all sectors, and, more specifically, why and in what respect the nature of networks differ between industries that rely on different types of knowledge bases.

This study deals with the questions if and in what respect the nature of innovation networks varies between industries which are based on different types of knowledge. On the level of networks, a distinction is made between three dimensions, namely the structure, the type of relations and the geographical configuration of networks. On the level of industries, a distinction is made between three types of knowledge bases, namely analytical (also called 'science-based'), synthetic (also called 'engineering-based') and symbolic (also called 'art-based') industries (Asheim and Gertler 2005; Asheim et al. 2011a). The paper begins with a conceptual discussion on networks grounded in social capital theory, followed by a theoretically informed discussion on differentiated knowledge bases and innovation networks. This conceptual framework is subsequently illustrated with empirical data on patterns of cooperation and knowledge exchange in a number of regional industries situated in different parts of Europe.[1]

## 2. Social capital and the nature of networks

Innovation related knowledge is neither travelling freely in the air nor simply accessible to everyone, but is very often sourced from, and exchanged in, defined networks of actors. 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 of a business association or belonging to the same knowledge community (Lave and Wenger 1991). Networks 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. They can be of a strategic nature and aim at the realisation of concrete business opportunities, or they can be of a social nature and be embedded in on-going inter-personal relationships. However, as networks evolve over time, it is unlikely that relationships will always remain in one of these categories. Rather, strategic relationships can 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 central body of literature which stresses the importance of networks for innovation is related to the notion of social capital. The literature on social capital offers on the one hand a theoretical argument on the role of networks for innovation, and provides on the other hand a

[1] The data are drawn from an EU collaborative research project entitled ‘Constructing Regional Advantage (CRA)’. All project partners are gratefully acknowledged for collecting and providing the data.

number of network dimensions that can be taken into consideration when studying the geography of innovation (Loury 1977; Bourdieu 1980; Coleman 1988; Rutten et al. 2010).

### 2.1. The structural and relational dimension of social capital

According to Bourdieu (1980, 1986) and Coleman (1988), two of the main protagonists in social capital theory, social capital is closely associated with the formation of networks.[2] Bourdieu (1986, 51) defines social capital as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalised relationships of mutual acquaintance or recognition", and thereby explicitly refers to networks and their significance for economic activities. Coleman (1988, 98) 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”. Although both agree on the importance of networks, each takes a different perspective when it comes to the functioning of networks. Bourdieu regards social capital as a resource which 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). These different perspectives reflect a distinction between a structural dimension of networks on the one hand, where social capital is seen as the number 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 being generated through the process of interaction, and particular attention is for that reason devoted 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 fewer connections, since linkages

[2] The term ‘social capital’ occurs first in an article by Loury (1977), who criticises the dominant neoclassical theory to be incapable of taking social context into account.

provide potential access to valuable resources and opportunities. A relational approach, 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 et al. 2010).

Bourdieu’s (1980, 1986) and Coleman’s (1988) treatment of the social capital concept emphasises the economic benefits occurring to individuals by investing in networks. Networks are in this context seen 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 benefits for individuals or organisations (Portes 1998; Lin et al. 2001; Inkpen and Tsang 2005). 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. Second, relationships can exert influence on decision making agents, e.g. managers in a company or policy-makers in a government. Some agents, 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 a sign of the social credentials or status of an actor, reflecting its access to resources through social networks and relationships. Individuals who 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 was 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, that is, 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 their study, they argue that northern Italian regions typically possess 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 and economic deprivation (Putnam et al. 1993). In Putnam's work, social capital, defined as networks between individuals governed by common norms and mutual trusts, is seen as a necessary precondition for the economic prosperity of a regional economy.

Following these ideas, a number of studies empirically examine the importance of social capital for economic growth (Westlund and Adam 2010). Some of these explicitly deal with regional innovation (Adam 2011). With a few exceptions (e.g. Fromhold-Eisebith 2004; Lorenzen 2007), these studies tend to apply econometric methods that generate rather ambiguous results, partly due to a lack of consensus on an operational definition of social capital. 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 recognise that a multidimensional concept such as social capital is difficult to capture in a small set of econometric measures (Hauser et al. 2007). 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 do not explain the observed variance in innovation outcomes (Barrutia and Echebarria 2010).

Even though they provide partly ambiguous results, these empirical studies all point in the direction of positive effects on various measures of network embeddedness on various measures for regional innovation outcomes (Westlund and Adam 2010; Adam 2011). The existing literature on social capital and regional innovation offers a detailed insight into various network dimensions, but it has a 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. Knowledge bases and the nature of innovation networks

In the recent literature on regional innovation systems, increasing attention has been paid to industry specific differences in the geography of innovation. In this context, a distinction can be made between industries that build on different types of knowledge bases, namely analytical, synthetic and symbolic (Laestadius 1998; Asheim and Gertler 2005; Cooke and Leydesdorff 2006; Asheim et al. 2011a). These knowledge bases differ in various respects, such as the rationale for knowledge creation, the dominance of tacit and codified knowledge content and the dominance of different modes of innovation and learning. In this paper, it is argued that industries with different knowledge bases differ not only with regard to the type of knowledge which is involved in innovation activities, but also with regard to the nature of innovation networks, that is, their structural, relational and geographical dimension. In the following paragraph, the theoretical arguments underlying the differentiated knowledge bases concept are synthesised with regard to the notion of networks, which leads to a number of theoretically informed postulations on the nature of networks in analytical, synthetic and symbolic industries. Some of these expectations are subsequently illustrated with survey data on knowledge networks in different regional industries in Europe.

### 3.1. The nature of innovation networks in analytical industries

An analytical knowledge base prevails 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) (Moodysson et al. 2008; Plum and Hassink 2011a). A defining feature of these 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 (Asheim et al. 2011a).

What does this imply for the nature of networks in analytical industries? It is argued in the following that innovation 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 science, technology and innovation (STI) (Jensen et al. 2007). The prevailing type of innovation is formal R&D, often taking place in company-owned research units and with the intention to protect (rather than to share) new research findings. Knowledge exchange is however not absent, but occurs very selectively, either through formal collaboration between organisations, or, less formalised, within communities of scientists knowledgeable in a particular issue-area.

Analytical industries deal with scientific knowledge which is typically accessible in codified form, for instance, in scientific publications or 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 or protected by patents or other copyrights. Patents are the classic instrument used to protect intellectual property in analytical industries, while at the same time constituting a source of information relating to innovation activities undertaken by competitors and other actors in the market. Codified forms of knowledge accessible through publications and patent databases are particularly important for analytical industries; nonetheless, obtaining and decoding the information often goes hand in hand with interactive learning and exchange of more tacit forms of knowledge between scientists. Interactive learning and knowledge exchange with customers, suppliers and other actors is accordingly not absent, but occurs in a very selective manner.

In analytical industries, innovation is usually geared towards a very particular field, in which only a limited number of professionals share the specific language and understanding relevant to the issue-area. Knowledge exchange, therefore, takes place within small communities of knowledgeable individuals sometimes labelled as 'epistemic communities' (Haas 1992; Knorr-Cetina 1999; Amin and Cohendet 2004). Epistemic communities can be seen as networks between scientists and other professionals, who may well originate from a range of academic backgrounds, but are associated 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). Members of an epistemic community share similar patterns of reasoning, common causal beliefs and common discursive habits, as well as a shared commitment to the application and production of knowledge. They work on a commonly recognised subset of knowledge issues and accept 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 (Knorr-Cetina 1999; Gittelman 2007; Moodysson 2008). Moodysson (2008), for instance, shows that the biotech industry in southern Sweden that most of the interactive knowledge exchange is embedded in globally configured epistemic 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, which points in the direction of a long term stability of networks. Innovation networks are either based on long term and trust-based cooperation between key individuals in epistemic communities, or on long term and contract-based R&D cooperation between small numbers of specialised companies and research organisations. As analytical industries deal with scientific knowledge that is not dependent on a particular geographical or social-cultural context, cooperation and knowledge exchange can take place between scientists and research units that are widely dispersed across great distances. This implies that innovation networks can be globally configured, and that intensive knowledge exchange is not always restricted to a specific geographical area.

### 3.2. The nature of innovation networks in synthetic industries

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 (Broekel and Boschma 2011; Plum and Hassink 2011b). One of the main characteristics of synthetic industries is that innovation is driven by the recombining of existing knowledge and the application of engineering skills. Innovation and knowledge creation are typically aimed at concrete problem solving and custom production (Asheim et al. 2011a).

What does this imply for the nature of knowledge networks? It is argued in the following that networks involve a relatively small number of actors who cooperate along the supply chain or exchange knowledge in communities of practice. These networks are predominantly nationally or regionally configured. Synthetic industries are constantly engaged in resolving engineering problems, which require know-how and practical skills. In search for solutions to concrete technical problems, the dominant mode of innovation is doing, using and interacting (DUI) (Jensen et al. 2007). DUI subsumes three interrelated ways of learning, namely learning-by-doing, learning-by-using and learning-by-interacting (Arrow 1962; Rosenberg 1982; Lundvall 1988). The importance of learning-by-doing for engineering based industries is stressed by Arrow (1962), who argues innovation to be a result of practical experience and to take place by resolving concrete problems in the work place. Then again, essential forms of learning do not only occur during the course of production, but also while a product is in use by the customer, which leads to the notion of learning-by-using (Rosenberg 1982). Learning-by-doing and learning-by-using do not necessarily imply a need for knowledge sharing with other actors. However, the notion of learning-by-using suggests that learning does not take place in isolation, but very often in close connection between users and producers. As Lundvall (1988, 352) 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”. Important forms of learning occur in collaboration and close contact between users and producers and 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 can increase their understanding about the use-value characteristics of a new product (Lundvall 1988, 350-352).

Interactive learning between users and producers is not the only way in which synthetic industries collaborate in networks. Important forms of cooperation can evolve between individuals engaged in solving similar or interrelated technical problems. A concept that describes this form of cooperation is ‘community of practice’ (Lave and Wenger 1991; Hildreth and Kimble 2004). Communities of practice refer to groups 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). Individuals 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. They 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 (Moodysson 2008).

Innovation networks in synthetic industries involve a relatively small number of actors, while most of the knowledge exchange occurs between suppliers and customers along the supply chain, or between the members of a community of practice with a mutual interest for a specific product or technology. Interactive learning between customers and suppliers is likely to end after a limited period of time; for instance, 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. Although companies deal to some extent with codified knowledge, 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 ways of learning implies that spatial proximity plays an important role for collaboration and knowledge exchange. Although international cooperation is not absent and knowledge exchange may well happen over longer geographical distances, companies are more likely to engage in intensive cooperation with suppliers and customers which are located within the regional or national milieu, where a common institutional framework facilitates interactive learning and knowledge exchange (North 1990; Johnson 1992). Consequently, knowledge networks in synthetic industries are expected to be primarily nationally or regionally configured.

### 3.3. The nature of innovation networks in symbolic industries

The symbolic knowledge base is a third category which is present within a set of cultural industries, such as film, music, television, animation or video games, in which innovation is based on creativity and cultural knowledge (Garmann Johnsen 2011; Martin and Moodysson 2011; Sotarauta et al. 2011; van Egeraat 2012). The defining feature of symbolic industries is that innovation is geared towards the creation of meaning, desire, aesthetic qualities, effects, symbols and images. Innovation and knowledge creation are creative processes involving artistic skills and imagination (Asheim et al. 2011a)

What does this imply for the nature of knowledge networks? It is argued that networks in symbolic industries involve a large number of actors engaged in knowledge sharing and project-based cooperation within highly localised networks. Innovation in symbolic industries is dominated by creativity and artistic skills, while the dominant mode of innovation is flexible and based on temporary and project-based cooperation. In this context, a project can be 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 is based on temporary projects because trends and fashions tend to change rapidly, which leads to a continuous variation in the skills and competences required for innovation. Product development often involves a large number of small companies and freelancers, that is, independent contractors who join into a project for a limited period of time (Garmann Johnsen 2011). Individual producers need access to a range of potential cooperation partners, so that interpersonal networks and knowledge about possible partners for cooperation and knowledge exchange are particularly important. Know-who and to some extent also know-how are highly relevant, while know-why is of minor importance. Although learning by doing, using and interacting does obviously play a role, it is argued that project-based industries are characterised by an alternative form of learning, sometimes labelled as ‘learning by switching ties’ (Dornisch 2002; Grabher 2004, 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 which an actor gains (or loses) in earlier projects. Through collaboration in previous projects, actors build up a pool of resources to draw on for future projects, and these connections can evolve into considerably large networks of cooperation and knowledge exchange. Most linkages in the network remain latent and hidden for most of the time, until they come to be reactivated for the limited period of a project (Grabher 2002).

Apart from cooperation between companies within projects, knowledge is also sourced and exchanged between individuals who share similar interpretation of the aesthetic properties of a product (Scott 2006). A group of individuals who share a common way of understanding a cultural product can be labelled as an ‘interpretive community’ (Fish 1980). Fish (1980) argues that a cultural product such as literary work will be interpreted differently by different persons; however, there exist communities of like-minded individuals who share similar perceptions about how a text should be read. Members of the same interpretive community are likely to use the same interpretive strategies. Conversely, disagreement about the interpretation of a cultural product is more likely to arise among members of different interpretive communities (Dorfman 1995). Interpretive communities are not necessarily bound to a specific location, though they tend to concentrate in places where people share similar socio-cultural experiences and backgrounds. Regions, and in particular metropolitan regions as centres for cultural production, can host a number of interpretive communities whose members interact and exchange knowledge on a regular basis (Berkowitz and TerKeurst 1999).

Innovation in symbolic 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 who have the same perception of the aesthetic qualities and design value of a product, which is typically the case for partners with a similar 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 companies tend to cooperate primarily within regionally or locally configured networks (Martin and Moodysson 2011).

## 4. Empirical illustration – the nature of knowledge networks

The theoretical arguments made on the nature of innovation networks can be illustrated with empirical material collected in the European collaborative research project 'Constructing Regional Advantage (CRA)'. Over 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 the companies that make up a regional industry, in particular on their relations to other organisations in the (regional) innovation system. Managing directors or other firm representatives were interviewed about their companies' strategies and practices to collaborate and exchange knowledge with other organisations. More specifically, they were asked with whom they cooperate and exchange knowledge with relevance for their companies' innovation activities, either related to technological development or to market opportunities, and where these cooperation partners are located in relation to each other. The resulting survey data includes information about the companies that constitute a particular regional cluster and about their patterns of cooperation and knowledge exchange, which can be analysed by means of social network analysis. In the following network analysis, the nodes in the network represent companies in a regional industry and their cooperation partners, while the linkages in the network represent actual knowledge flows, that is, previous and on-going knowledge exchange relations.[3]

The 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 include 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).[4]

### 4.1. The structure of knowledge networks

As described above, industries with different knowledge bases are expected to differ with regard to the structural dimension of knowledge networks. In the following, particular attention is devoted to two network measures which are related to the structure of networks, namely degree centrality and component size (Wasserman and Faust 1994). The first measure, degree centrality, reflects the number of *direct* contacts an actor possesses in the network.[5] 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

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[3]Van Egeraat and Curran (2012) use a similar approach to study knowledge exchange in the Irish biotechnology industry, and find that neither formal R&D networks, nor informal directorship networks do fully reflect the actual scale and scope of knowledge flows between companies.

[4] Studies on the individual cases are published, amongst others, in the European Planning Studies special issue ‘Constructing Regional Advantage: Towards State-of-the-Art Regional Innovation System Policies in Europe?’ (Asheim et al. 2011b)

[5] Degree centrality is a concept in graph theory and calculated using Freeman’s (1979) approach. The degree of a vertex is the number of vertices adjacent to that vertex in a graph. For a given graph $G \coloneqq (V, E)$ with $|V|$ vertices and $|E|$ edges, the degree centrality of vertex $v$ is defined as $C_D(v) = \deg(v)$.

innovation activities. The measure provides an indication of the extent of immediate knowledge exchange between companies by capturing the number of actors who are directly connected to one another. The second measure, component size, goes beyond the previous by taking into account the direct and *indirect* contacts an actor has in the network.[6] This implies that companies can access knowledge not only through direct interaction with other organisations, but that they can also indirectly benefit from knowledge that is available and transmitted from one organisation to another through intermediate organisations which act as knowledge brokers (Granovetter 1973; Burt 1992; Walker et al. 1997). These two measures reflect characteristics of individual companies and their ego-networks, and at the same time, they provide information on the structural dimension of the overall network. A small average number of cooperation partners is a sign for a low density of the overall network, while a high average number of cooperation partners points towards a generally high network density (Wasserman and Faust 1994; Hanneman and Riddle 2005).[7]

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 a few direct exchange partners; however, as those are strategically positioned in the network, they can connect different components of the network and provide indirect access to a large number of organisations. Based on the theoretical discussion on the structural dimension of

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[6] A component of a graph is a sub-graph in which any two vertices are connected to each other by paths. The component size of a vertex is the number of vertices directly or indirectly connected to that vertex in a graph (Wasserman and Faust 1994).

[7] In graph theory, network density reflects the total number of edges divided by the total number of possible edges, that is, the percentage of all possible edges that are actually present in a network (Hanneman and Riddle 2005).

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.

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Table 1: Structure of knowledge networks in analytical, synthetic and symbolic industries

The results from the overall network analysis are fairly well in line with these expectations (see table 1). Degree centrality, reflecting the number of direct contacts, is considerably higher in symbolic industries (11) compared to analytical (8) and synthetic (6) industries.[8] 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 argument on the structural dimension of networks.

Please insert here:

Table 2: Structure of knowledge networks in different regional industries

A more detailed picture can be gained by breaking up the aggregated values and concentrating on specific regional industries (see table 2). The lowest component sizes can be identified in the Dutch aviation industry (3), the electronics industry in South Moravia (4), the Dutch space

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[8] Numbers in brackets display median values. Median values are used in order to account for the skewed distribution of the network measures.

industry (5) as well as in the ICT industry in Moravia Silesia (6). These four industries are typical examples of a synthetic or analytical knowledge base. Component sizes in the 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 closely match the expectations regarding knowledge bases and network structures, the industry specific analysis reveals that not all variation in the network structure can be explained by differences in the industrial knowledge base. The extent and frequency of collaboration and networking is not only dependent on the knowledge base of an industry, but also on other 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 (Lundvall et al. 2002; Asheim and Coenen 2006) and the stage of the development and evolution of the regional industry (Boschma and Frenken 2011; Martin and Sunley 2011). As this analysis encompasses a variety of industries situated in different regional and national settings and passing through different stages of development, the result points in the direction that the knowledge base is one important determinant among several factors which can explain the structural dimension of innovation networks.

### 4.2. The geography of knowledge networks

Another notion of networks which can be illustrated with the 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.[9]

Please insert here:
Table 3: Geography of knowledge networks in analytical, synthetic and symbolic industries

The empirical results are in line with the discussion on the geographical dimension of innovation networks (see table 3). In analytical industries, the largest share of all exchange relations is international (40.6%), while national (25.3%) and regional (34.1%) collaboration is less frequent. This illustrates the dominance of international collaboration and globally configured networks 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 regional and localised nature of networks in artistic based industries.

Please insert here:
Table 4: Geography of knowledge networks in different regional industries

A more detailed picture can be gained from distinguishing between regional industries (see table 4). The international level plays an important role in both analytical cases, in particular

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[9] The space and aviation industries in the Netherlands were excluded from the geographical analysis, as the research design did not distinguish between regional and national collaboration.

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, which are video games in Hamburg (44.0%) and moving media in Scania (54.8%), are clearly dominated by regionalised cooperation networks, supporting the theoretical argument on the importance of the regional milieu for artistic based industries.

# 5. Conclusion - knowledge bases and the nature of networks

As stressed in this paper, important forms of knowledge which are required for innovation are not simply accessible to everyone in the local milieu, but are sourced and exchanged within defined networks between economic actors. Insights from social capital theory suggest that innovation networks can differ in various dimensions, such as their structure, the nature of relationships 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 which are elsewhere not available. Most of the existing studies on social capital and innovation networks treat regional economies as homogenous entities without taking into account essential differences in the regional industrial composition (Lin 2001; Westlund 2006; Adam 2011). In this respect, a distinction between knowledge bases is useful in order to conceptualise industry specific differences in the geography of innovation by referring to the nature of knowledge that underlies innovation activities.

As put forward in this paper, the structural, relational and geographical nature of innovation networks can vary substantially between industries which innovate based on different types of knowledge (see table 5).

Please insert here:
Table 5: Knowledge bases and the differentiated nature of innovation networks

In analytical industries, cooperation and knowledge exchange takes place in a highly selective way between small numbers of research units as well as between individual scientists in globally configured epistemic communities. Because 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, which implies that innovation networks are globally, rather than nationally or regionally configured.

In synthetic industries, cooperation and knowledge exchange occurs between users and producers or between members of communities of practice. Networks can remain stable for a period of time, since communities of practice are based on a common personal or professional interest for a specific product or technology, while formal cooperation between users and producers can dissolve quickly when a product is no longer in use, or when a support contract between supplier and customer has ended. Companies 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 implies that relatively little collaboration takes place across greater 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 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 in interpretive communities who 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 regionally configured networks, while national or international collaboration is less frequent.

The literature on social capital provides valuable insights into the notion of networks by explaining the economic benefits generated by engagement into networks. Furthermore, it stresses a number of network dimensions, such as structure, relations and geography, all of which are important in understanding the differentiated geography of innovation. Then again, the literature on regional innovation systems and in particular on differentiated knowledge bases emphasises the need to consider industry specific differences in innovation, as the nature and geography of innovation can vary substantially between industries which are based on different types of knowledge. These industry specific differences are well reflected in the structural, relational and geographical dimensions of networks. Combining a nuanced view on networks with a differentiated perspective on knowledge bases can help to further advance our understanding of the nature and geography of innovation.

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# Tables

Table 1: Structure of knowledge networks in analytical, synthetic and symbolic industries

| | | | Direct linkages (degree centrality) | Indirect linkages (component size) |
|---|---|---|---|---|
| Knowledge base | Analytical | Median | 8 | 202 |
| | | N | 74 | 74 |
| | Synthetic | Median | 6 | 124 |
| | | N | 183 | 183 |
| | Symbolic | Median | 11 | 337 |
| | | N | 57 | 57 |
| Total | | Median | 7 | 178 |
| | | N | 314 | 314 |

*Source*: own calculations

Table 2: Structure of knowledge networks in different regional industries

| | | | Direct linkages (degree centrality) | Indirect linkages (component size) |
|---|---|---|---|---|
| Regional industry | 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

Table 3: Geography of knowledge networks in analytical, synthetic and symbolic industries

| | | | Contact location | | | Total |
|---|---|---|---|---|---|---|
| | | | regional | national | international | |
| Knowledge base (KB) | Analytical | Count | 182 | 135 | 217 | 534 |
| | | % within KB | 34.1% | 25.3% | 40.6% | 100% |
| | Synthetic | Count | 432 | 552 | 227 | 1211 |
| | | % within KB | 35.7% | 45.6% | 18.7% | 100% |
| | Symbolic | Count | 334 | 167 | 159 | 660 |
| | | % within KB | 50.6% | 25.3% | 24.1% | 100% |
| Total | | Count | 948 | 854 | 603 | 2405 |
| | | % within Total | 39.4% | 35.5% | 25.1% | 100% |

*Source*: own calculations

Table 4: Geography of knowledge networks in different regional industries

| | | | Contact location | | | Total |
|---|---|---|---|---|---|---|
| | | | regional | national | international | |
| Regional industry (RI) | Biotech in North Rhine-Westphalia (DE) | Count | 105 | 58 | 79 | 242 |
| | | % within RI | 43.4% | 24.0% | 32.6% | 100% |
| | Life Science in Scania (SE) | Count | 77 | 77 | 138 | 292 |
| | | % within RI | 26.4% | 26.4% | 47.3% | 100% |
| | ICT in Moravia-Silesia (CZ) | Count | 60 | 45 | 10 | 115 |
| | | % within RI | 52.2% | 39.1% | 8.7% | 100% |
| | Electronics in South Moravia (CZ) | Count | 46 | 71 | 41 | 158 |
| | | % within RI | 29.1% | 44.9% | 25.9% | 100% |
| | Automotive in Southwest Saxony (DE) | Count | 241 | 368 | 124 | 733 |
| | | % within RI | 32.9% | 50.2% | 16.9% | 100% |
| | Food in Scania (SE) | Count | 85 | 68 | 52 | 205 |
| | | % within RI | 41.5% | 33.2% | 25.4% | 100% |
| | Video Game in Hamburg (DE) | Count | 113 | 69 | 75 | 257 |
| | | % within RI | 44.0% | 26.8% | 29.2% | 100% |
| | Moving Media in Scania (SE) | Count | 221 | 98 | 84 | 403 |
| | | % within RI | 54.8% | 24.3% | 20.8% | 100% |
| Total | | Count | 948 | 854 | 603 | 2405 |
| | | % within total | 39.4% | 35.5% | 25.1% | 100% |

*Source*: own calculations

Table 5: Knowledge bases and the differentiated nature of innovation networks

| | Analytical | Synthetic | Symbolic |
|---|---|---|---|
| *Structural dimension* | Small number of actors; high network density | Small number of actors; low network density | Numerous actors; low network density |
| *Relational dimension* | Knowledge exchange in epistemic communities; long term cooperation between research units | Knowledge exchange in communities of practice; cooperation along supply chain | Knowledge exchange in interpretive communities; cooperation in short-term projects between companies |
| *Geographical dimension* | Knowledge exchange in globally configured networks | Collaboration in nationally and regionally configured networks | Prevalence of regionalised/localised networks |

*Source*: own draft

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