European Planning Studies
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ceps20

The Geography and Structure of Global Innovation Networks: A Knowledge Base Perspective

Ju Liu [a] , Cristina Chaminade [a] & Bjorn Asheim [a]
[a] CIRCLE, Lund University, Lund, Sweden
Version of record first published: 29 Jan 2013.

European Planning Studies, 2013
http://dx.doi.org/10.1080/09654313.2012.755842

Routledge
Taylor & Francis Group

The Geography and Structure of Global Innovation Networks: A Knowledge Base Perspective

JU LIU, CRISTINA CHAMINADE & BJORN ASHEIM

CIRCLE, Lund University, Lund, Sweden

(Received August 2012; accepted September 2012)

ABSTRACT *This paper explores the geography and structure of global innovation networks (GINs) of two multinational companies belonging to industries with different knowledge bases. It contributes to the existing literature on knowledge bases, by studying both intra-firm and inter-firm GINs. By means of social network analysis based on primary data, we identify two different forms of GINs, namely the globally organized model and the locally organized model. The paper finds that, in addition to influencing the geographic spread of a GIN, the knowledge base also influences the way that a GIN is organized.*

1. Introduction

Innovation is a networked phenomenon. Firms and other organizations innovate in continuous interaction with other organizations in their near but sometimes also distant environment (Freeman, 1987; Lundvall, 1992). The geography of innovation has long been discussed by economic geographers in the literature on innovative clusters (Audretsch & Feldman, 1996; Feldman, 2000; Giuliani, 2007; Lissoni, 2001; Moodysson *et al*., 2008), regional innovation systems (Asheim, 2002; Asheim & Isaksen, 1997; Cooke, 1996) and innovation networks (Boschma & Frenken, 2001; Cooke, 1996; Love & Roper, 2001; Sternberg, 2000). Economic geographers have argued that due to the tacit nature of knowledge and its sticky character, innovation networks tend to be bounded to certain territories. Geographic proximity often enhances trust and thus facilitates the exchange of knowledge among organizations co-located in a certain territory.

Since the mid-1990s, economic geographers have been increasingly concerned with the global spread of innovation activities (Chen, 2004; Coe & Bunnell, 2003; Dankbaar,

Correspondence Address: Ju Liu, CIRCLE, Lund University, PO Box 117, 22100 Lund, Sweden. Email: ju.liu@circle.lu.se

2007; Ernst, 2002; Fifarek & Veloso, 2010; Gertler & Levitte, 2005). The increasing globalization of economic activities has not diminished the role of the region (Dickens, 2007; Gertler, 2008). Instead, regions have become knowledge hubs in global innovation networks (GINs) (Chaminade & Vang, 2008; Gertler & Levitte, 2005). As knowledge continues to be bounded to certain territories, these areas become poles of attraction for agents involved in knowledge intensive activities. For example, multinational companies (MNCs) are attracted to certain regions in the world that have accumulated specific competences that are difficult to acquire (Cantwell & Piscitello, 2005, 2007; Lewin *et al*., 2009; Narula & Zanfei, 2004). Furthermore, clusters that are able to maintain high levels of local buzz and simultaneously create channels that tap into global flows of knowledge show higher levels of growth and dynamism (Bathelt *et al*., 2004). Local and global linkages are, therefore, complementary.

Asheim and Coenen (2005) extended the local–global debate by arguing that the extent to which an industry becomes more localized or globalized is highly contingent on its knowledge base. Firms in industries dominated by the synthetic knowledge base tend to exchange knowledge with geographically close partners while firms in industries dominated by the analytical knowledge base may tap more often into geographically distant sources of knowledge (Asheim & Coenen, 2005; Martin & Moodysson, 2011a, 2011b; Moodysson *et al*., 2008). Synthetic knowledge tends to differ from place to place, while analytic knowledge is more codified, abstract and universal. As a consequence, innovation networks that rely on synthetic knowledge tend to be more local, while innovation networks built on analytic knowledge tend to be more global.

Despite its value, the existing literature is based exclusively on the analysis of inter-firm networks, almost completely neglecting intra-firm relationships (Coe *et al*., 2008) which play a critical role in how global networks operate and impact (Dicken & Malmberg, 2001). The interaction between the intra-firm and inter-firm networks influences the geographic pattern of a GIN as well as its structure. Structure is defined here as the pattern of relations in the network. The structure of a network reflects how the network is organized and suggests "possible ways in which we could exploit it to achieve certain aims" (Newman, 2003, p. 180). Thus, when studying the geography and structure of GINs, it makes sense to conceive of the firm as a relational intra-firm network embedded in wider networks of external actors (Coe *et al*., 2008).

The aim of this paper is to address this research gap by investigating the influence of knowledge bases on the geography and structure of the innovation networks in two MNCs whose internal and external innovation networks are both globally spread. Using social network analysis, we analysed the primary relational data of the case firms' GINs and identified their relational patterns to see how their GINs are organized. The evidence shows that the knowledge base influences the way that MNCs organize their innovation networks in a global scope.

The rest of the paper is presented in four sections. Section 2 includes the literature review and theoretical framework. Section 3 is the analytical and methodological framework, which includes the case study design, selection of case firms, the data collection methods and analysis of the data. Section 4 presents the main findings. Section 5 provides a discussion of the findings and concludes the article.

2. Theoretical Framework

In this section, we will review the literature on the geography of innovation networks and introduce the theoretical framework based on the knowledge base approach of economic geography.

Innovation is the result of the continued interactions between firms and other organizations (Freeman, 1987; Lundvall, 1992; Nelson, 1993) as well as between different individuals and departments within one organization (Grant, 1996). It is through interactions that tacit and explicit knowledge is transferred and new knowledge is created. Networks are, therefore, the basis for interactive learning and innovation.

Contemporary economic geography aims at understanding the geography of these networks, particularly by studying the nature of the knowledge being transferred. Traditionally, it has been argued that when knowledge was mainly tacit, innovation networks were likely to be geographically bounded because proximity with other members of the network facilitated the exchange of non-codified or tacit knowledge (Storper, 1992; Storper & Venables, 2004). Only codified knowledge could be transferred across geographic distances. Tacit knowledge was "sticky" and was therefore difficult to transfer across large spatial distances. This led to an overemphasis on the importance of co-locality for innovation. The literature on industrial districts (Becattini, 1990; Markusen, 1996) and clusters include good examples of this (De Bresson, 1986; Nadvi & Schmitz, 1999; OECD, 2001; Porter, 1998).

The gradual decline of some traditional industrial districts in Europe due to lock-in as well as the increasing evidence of clusters in developing countries with very strong international linkages (Giuliani *et al.*, 2005; Loebis & Schmitz, 2005; Schmitz, 2000) brought to light the importance of global "pipelines" and the interaction between global and local networks of innovators (Bathelt *et al.*, 2004). This "international turn" runs in parallel with a wider critique by economic geographers and innovation scholars to the rather dichotomous way of looking at types of knowledge (tacit-local versus codified-global), its transferability and its geography. Both tacit and codified knowledge are necessary for the innovation process or, more generically, for the process of knowledge creation (Nonaka & Takeuchi, 1995). The co-existence of tacit and codified knowledge in both organizations and individuals (Nightingale, 1998) makes the separation between them virtually impossible in practice. Furthermore, both tacit and codified knowledge can be transferred within networks and across spatially distant locations (Gertler, 2008); notably when the lack of geographic proximity is compensated by other dimensions of proximity (Boschma, 2005).[1]

Some scholars in this line of thought argue that, due to the different nature of their knowledge bases, industries are likely to differ in the degree of globalization of their innovation networks. The local–global interaction also differs across industries (Asheim & Coenen, 2005; Asheim & Gertler, 2005; Moodysson *et al.*, 2008) and activities (Moodysson, 2008) and depends on the type of knowledge base that is dominant in that particular industry. Asheim *et al.* (2007a) distinguish between three types of knowledge bases: the analytical, synthetic and symbolic knowledge base. In this paper, we will focus only on the first two types of knowledge bases, namely analytical and synthetic.

Analytic knowledge refers to industrial settings where scientific knowledge is highly important and where knowledge creation is often based on deductive rational processes and applications of scientific laws. It is the equivalent of science-based knowledge creation. Collaboration usually takes place between research organizations or research units. Knowledge is often highly abstract, universal and often codifiable in the form of formulas and scientific laws. Due to these characteristics, knowledge creation can take place across distant locations compared with firms in other knowledge-based industries which rely more on local sources of knowledge (Martin & Moodysson, 2011b). Knowledge can be transferred through communication technologies like the Internet. Typical examples of these industries include the bio-medical industry (drug development) and sub-sectors of the information and communication technologies sector.

Synthetic knowledge refers to industrial settings wherein innovation takes place mainly through the application of existing knowledge or through new combinations of knowledge. It is the equivalent of an engineering-based learning process. In contrast to the analytical knowledge base, synthetic knowledge is built through inductive processes often based on solving specific problems. Knowledge is context-specific and has a strong tacit component. In this case, collaboration typically takes place with suppliers and users, who provide the product specifications. Face-to-face interaction is very important in these industries and, as a consequence, so is spatial proximity. Firms in these industries tend to establish collaborations with other organizations in close geographic proximity (Asheim *et al*., 2007b, Asheim & Coenen, 2005). In addition, synthetic knowledge bases are often subject to specific national norms or regulations which vary significantly from region to region or country to country (Martin & Moodysson, 2011a, 2011b). Typical examples of these industries include food processing, automotive components and, in general, mechanical engineering.

The main characteristics of these two types of knowledge are summarized in Table 1.

The analytic–synthetic taxonomy has three main merits. First, it integrates the tacit-explicit tandem and the science-engineering distinction. Second, it moves away from the tacit-explicit dichotomy that is prevalent in economic geography by introducing a much more nuanced explanation of the geography of knowledge interactions in specific industries and the motivations for localization/globalization, in particular. Third, it provides researchers with an analytical tool to predict and explain why certain industries are more globalized than others, with regard to their external knowledge sourcing.

Table 1. The main characteristics of analytic and synthetic knowledge base

Analytic (science-based)	Synthetic (engineering-based)
Innovation by creation of new knowledge	Innovation by application or novel combination of existing knowledge
Importance of scientific knowledge often based on deductive processes and formal models	Importance of applied, problem-related knowledge (engineering)
Research collaboration between firms and research organizations and between research units	Interactive learning with clients and suppliers
Dominance of codified knowledge due to documentation in patents and publications	Dominance of tacit knowledge due to more concrete know-how, craft and practical skill
More radical innovation	Mainly incremental innovation
More globally spread	More national and regionally spread

Source: Asheim and Gertler (2005) and Martin and Moodysson (2011a).

With few exceptions (e.g. Moodysson, 2008), scholars in the knowledge-base approach focus their analysis on inter-firm relationships, ignoring almost completely the internal linkages of the firm. Such remissness mainly results from the major focus of economic geographers on small-and-medium-sized enterprises whose internal connections are mainly local and excludes the MNCs, particularly those that have multiple plant sites. This is a critical missing component in the analysis of the structure and geography of innovation networks. MNCs are some of the most important agents in internationalization. Innovation networks that involve MNCs are different in at least one respect: knowledge creation encompasses the use of both internal and external networks that span across different geographic areas (Barnard & Chaminade, 2011; Castellani & Zanfei, 2006; Zanfei, 2000). Knowledge sourcing thus takes place through inter-firm as well as intra-firm networks.

If knowledge bases influence the geographic patterns of knowledge creation in inter-firm networks, we may expect that they also exert influences on the pattern of intra-firm network relations. Thus, knowledge bases should influence the way GINs are organized as a whole. In order to explore this, we focus on the GINs of two MNCs belonging to industries dominated by the analytical and the synthetic knowledge base, respectively.

The method used in our study will be described next.

3. Research Method

In this section, we introduce the design of the case study, the selection of case firms, the data collection methods and the analysis of data.

3.1 *Design of the Comparative Case Study*

This paper attempts to analyse the geography and structure of the GINs of two MNCs and the influence of knowledge bases, namely the analytic and synthetic knowledge base, on the pattern of relations within the GINs .With this intention, we conduct a social network analysis on two MNCs operating in the analytic and synthetic knowledge-based industries, respectively. We adopted a structural approach of social network analysis to explore the relational pattern of the GINs. The structural approach neglects the content of the relations and the attributes of the actors in a network but puts emphasis on the pattern of interactions among the actors (Borgatti & Foster, 2003). The structural approach allows a closer examination of how the case firms' GINs are organized by focusing on the social relations among actors rather than the value-adding functions (R&D, production, financing, marketing, etc.) of the actors, which are mostly similar in the two case firms.

3.2 *Selection of Case Companies*

Case company selection was based on four criteria, namely, the firm's global location, firm's production and innovation capabilities, firm size and the knowledge base of the industry within which the case firms operate. Based on these four criteria, we selected a company in the telecommunication industry and a company in the automobile safety product industry. For confidentiality reasons, we refer to these two firms as TELE and AUTO.

Both companies are headquartered in Scandinavia and have a strong global presence in Europe, Asia-Pacific, North and South America and Africa. Both firms have strong innovation capabilities. TELE is a world-leading provider of telecommunications equipment and related services to automotive and fixed network operators. TELE's patents comprise one of the industry's strongest portfolios. AUTO is also a world-leading company, specialized in airbags, seatbelts, safety electronics, steering wheels and seat components. AUTO's patent portfolio is very extensive, ranking at the top of the automobile components industry, particularly regarding safety. Both firms are large companies with more than 1000 employees.

Even though the knowledge base of an industry is always a complex mixture of both analytic and synthetic knowledge, one can still identify the dominant knowledge base of an industry according to the characteristics of its main technology group. In this paper, TELE is selected as a case firm from an analytic-knowledge-based industry (Asheim & Gertler, 2005). In the telecommunication industry, as suggested by Asheim *et al*. (2007a) and verified by the vice president (VP) of TELE during our interview, formal R&D plays an important role. In 2005, the world's biggest telecommunication company ranked fourth in terms of international patent applications with the World Intellectual Property Office (WIPO). The automobile safety company is selected as a case firm from a synthetic-knowledge-based industry (Asheim & Gertler, 2005). In automobile industry, R&D plays a smaller role relative to analytic-knowledge-based industries. As pointed out by the VP of AUTO, this industry typically responds to the need to solve specific problems that come up in the firm's interaction with customers and suppliers. In 2005, the world's biggest automobile safety product manufacturer was ranked 171st in terms of international patent applications with the WIPO, a much lower ranking than the world's biggest telecommunication company. Automobile safety products are often one-off products which are produced in a relatively small series in order to fit into a specific car model for a specific market. Knowledge creation is often an inductive process based on testing, experimentation, computer-based simulation or practical work. Innovation is more geared towards reducing cost and increasing efficiency and reliability of new solutions. These characteristics of the automobile safety industry exhibit the characteristics of synthetic-knowledge-based industry suggested by Asheim and Gertler (2005).

3.3 *Collection of Data*

Data sources used in this study include interviews, questionnaires, websites, corporate internal reports and documents and press news. The questionnaire was developed and administered to elicit responses from the VPs for research from the two case firms. In total, four interviews were conducted. Each interview lasted between 1 and 3 h and all interviews were recorded and transcribed. The interviews were conducted between the years 2010 and 2011 and took place at the headquarters of the case firms and one of their international branches.

The interviews included questions on the background of the company and the industry, such as the history of the company, the organizational structure of the company, their strategy of innovation, the technology nature and competition in the industry, etc. The questions then focused on the relationship between the internal actors, namely the headquarters' functional departments/groups and the subsidiaries at three geographic levels and the relationships between the internal actors and the outside organizations. The informants were reminded constantly that all the relationships should be relevant to the companies' technological innovation activities in order to avoid any confusion of mixing daily operations and innovation.

Potential informant bias is addressed in three ways. First, we triangulated information with multiple data sources such as internal documents of the company, annual reports, websites and specialized journals in the sector. The use of multiple sources provides more accurate information and improves the robustness of the results (Jick, 1979). Second, we selected highly knowledgeable informants. The VPs for research or R&D operation have a deep and wide-ranging understanding of the innovation activities in the company at all levels. Third, we used the "courtroom questioning" technique to focus on factual accounts (Huber & Power, 1985; Lipton, 1977). We asked the informants to specify the activities involved in each specific relationship.

3.4 *Analysis of Data*

GIN in this paper refers to a set of relationships of the case company aiming at technological innovation, both product and process innovation. Service innovation is excluded in this research.

The study distinguishes two groups of GIN actors, the intra-firm group and the inter-firm group. The *intra-firm network* refers to the set of relations among the functional departments or groups within a company's headquarters and its subsidiaries. Following Porter's (1985) taxonomy, this study identified the following headquarters' functional departments: production, R&D, marketing, finance, human resource and purchasing/sourcing. As to the subsidiaries of the case companies, the study distinguishes between subsidiaries for R&D, production and marketing. The intra-firm network captures the relationships among the different departments at the headquarters as well as between the headquarters' departments and the subsidiaries around the world. Those subsidiaries include R&D centres and laboratories, manufacturing plants and sales offices. The *inter-firm network* refers to the set of relations among the case company (headquarters and subsidiaries) and the outside collaborators. The outside collaborators include universities and research institutes, customers, suppliers, competitors and government agencies.

In both intra-firm and inter-firm networks, we identified three geographic levels: local, national and international. The local level refers to the region where the case companies are headquartered. The national level refers to the rest of the country excluding the region of the headquarters. The international level refers to the rest of the world.

The names and abbreviations of the actors of the GINs are shown in Table 2. Geographic locations are identified as L (local), N (National and I (International). For example, the actor LCST refers to Local CuSTomers in the headquarters region. NGOV refers to National GOVernment agencies. ISRD refers to International Subsidiaries for R&D which locate in other countries.

The relations in the innovation networks are both formal and informal relationships for:

(1) accessing openly available information at a low cost, such as membership in trade associations, attendance at conferences and subscriptions of journals;
(2) acquiring technology and knowledge without active cooperation with the source, such as purchasing machinery, equipment, hiring people or using contract research and consultant service and
(3) actively participating in joint innovation projects.

Table 2. Names and abbreviation of intra-firm and inter-firm network actors of the GINs

Intra-firm network actors		Inter-firm network actors	
R&D	R&D department	CST	Customers
PRD	Production coordinator	SPL	Suppliers
HR	Human resource department	CPT	Competitors
MKT	Marketing department	GOV	Government agencies
FIN	Financial department	U&R	Universities and research institutes
PCH/SOC	Purchasing department/sourcing department		
SPD	Subsidiaries for production		
SRD	Subsidiaries for R&D		
SMK	Subsidiaries for marketing		

The relational data on these ties were collected through a roster recall method (Wasserman & Faust, 1994). Each case company was presented with a complete list (roster) of the actors in the network and was asked the following questions:

Q1: Do the following actors contact each other for your company's production/innovation activities?
Q2: If they do, are these connections for production, for innovation, or for both?
Q3: What is the strength of these connections in terms of the intensity[2] of their collaboration and the frequency with which they contact each other? The strength was measured in a five-point Likert scale, where 5 denotes "very strong" and 1 denotes "very weak". 0 denotes "no connection".

We mapped the GINs of the two case companies by using the NetDraw tool of multi-dimensional scaling (MDS) with a principal component layout. MDS is a set of techniques that is used in network analysis to assign locations to nodes in multi-dimensional space.

To explore the geography and the structure of the case firm's GINs, we conducted two network analyses, namely key connection analysis and structural equivalence analysis. In addition, we used quotations from the interviews to provide a more detailed insight and understanding of the geography and structure of the GINs.

Key connection analysis identifies the most important connections of the GINs. The key connections carry the most important networking activities in the networks. Key connection analysis reveals information about how the network is mainly organized and by whom. A connection or a group of connections are considered to be important if the whole network is disrupted when this connection or the group of connections were to be removed. Conversely, the connection is deemed unimportant if the absence of this connection or these connections do not create any disruption to the whole network. By distinguishing the geographic location of the actors involved in key connections, we obtain an insight into the geographic pattern of the connections that are playing important roles in the network. For identifying the key connections, we adopted a lambda set approach which ranks each of the relationships in the network in terms of importance by evaluating how much of the flow among actors in the network goes through each link of the GIN. We select three connections with the highest cut-off value in the hierarchical lambda set partitions. These three connections are the top three most important connections which, if disconnected, would greatly disrupt the flow between all of the actors.

Structural equivalence analysis identifies actors belonging to categories according to their pattern of relations with other actors. The structural equivalence in a social network results from similar patterns of relations among actors and from similar social roles or social behaviour in the network (Lorrain & White, 1971). It is an indicator of the actors' social roles in the network.[3] Two actors are structurally equivalent if they have identical relations with the other actors. Thus, they are considered to be in the same category and embedded in the same social environment. They are, therefore, expected to yield the same outcome; for example, to adopt the same attitude, behaviour or performance (Burt, 1987) regarding decisions for transferring knowledge to other actors. In short, structurally equivalent actors play the same social role in GINs. The social roles of different categories of actors reflect the way a GIN is organized as a social network. By analysing the geographic location of the actors who are structurally equivalent, we reveal the structure and geography of GINs.

4. Geography and Structure of Innovation Networks: Evidence and Discussion

In this section, we will first present the main empirical findings of the paper and then identify two models of the structure of GINs. Finally, we will discuss the different nature of the knowledge bases of the case firms' industries and their relation with the two different GIN structure models.

4.1. *GIN of a Case Firm in an Analytical-Knowledge-Based Industry*

When inspecting the most important connections of TELE's GIN, we find that the R&D department and subsidiaries constitute the most important connections at all geographic levels (Figure 1). The most important connection consists of relations among the headquarters' R&D department and local R&D subsidiaries. The second important connection

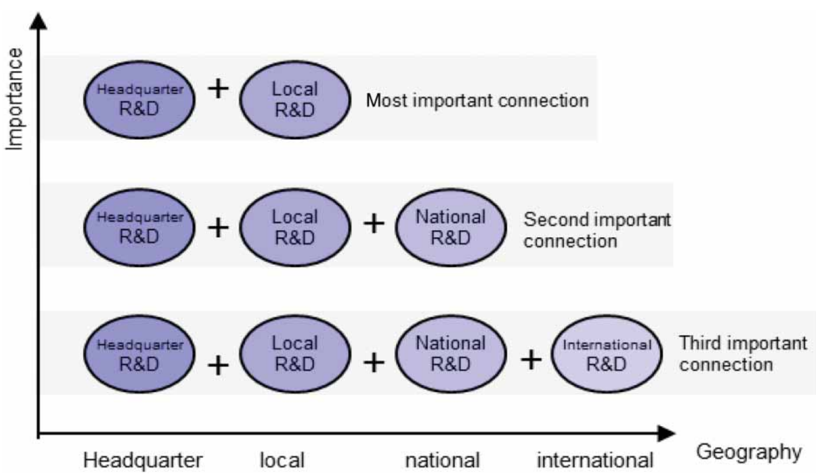

Figure 1. TELE's top three most important connections in its GIN.

consists of relations among headquarters' R&D department, local R&D subsidiaries and national R&D subsidiaries. The third important connection in the GIN of TELE consists of relations among all the four levels of R&D organizations, namely the headquarters' R&D department and local, national and international R&D subsidiaries. In other words, relationships involving different R&D units within the firm carry the greatest communication flow. This means that if we remove R&D, the structure of TELE's GIN will be most disrupted. This holds at all geographic levels. It seems that R&D actors play the biggest and most important role in the TELE's GIN. The strong presence of R&D units in the important connections in the network reflects a model of knowledge creation based on research and scientific discovery, such as the one that characterizes analytical knowledge bases.

To understand the structure and geography of the network, we use the structural equivalence analysis described earlier. The sociogram of the GINs are plotted with NetDraw MDS with a principal component layout. In these sociograms, when a group of nodes are close to each other, it means they have a similar pattern of relations; that is, they are connected by the same nodes and they have a similar number of connections and distance to all other nodes. These nodes are structurally equivalent. As we introduced before, structurally equivalent actors are considered to play the same social roles and embedded in the same social environment which reflects the way that a GIN is organized as a social network.

In TELE's GIN, structurally equivalent actors belong to the same function. As shown in Figure 2, the actors aggregated together are for the same value-adding function (R&D,

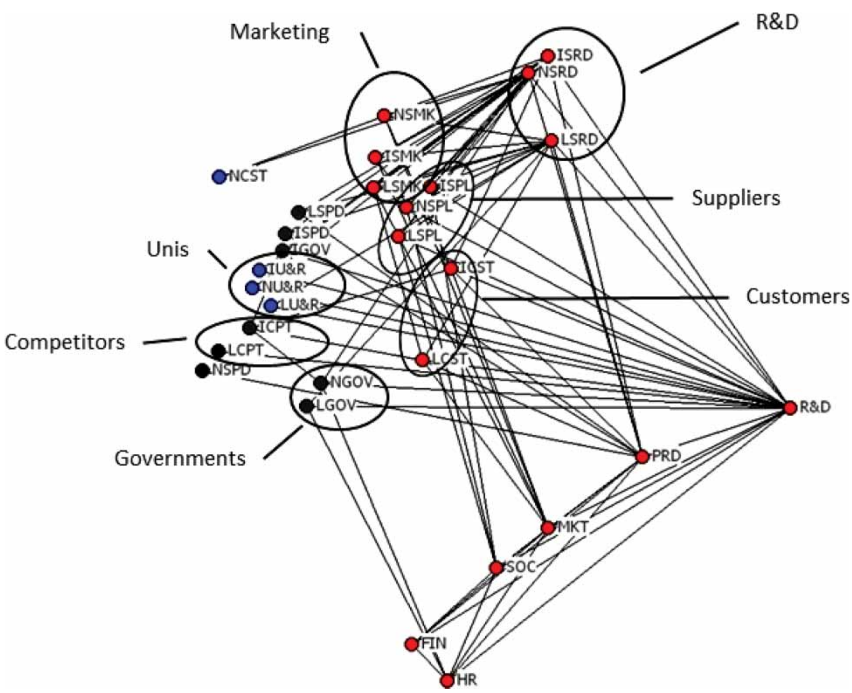

Figure 2. Structure of TELE's GIN.

marketing, production, etc.), independent of their location. They are linked to each other and also to other actors of their internal and external network, also independent of their location.

This means, TELE's GIN is more globally organized. The globally organized characteristic of TELE's GIN is explained by its VP.

> Taking the relationship between R&D and the suppliers as an example, our suppliers are global. So it is "all-talk-to-all". An R&D branch in the headquarters will talk to all levels of suppliers within their product line. If they are responsible for that machine, then they need to form their own network (. . .) it becomes the same thing for any R&D site regardless if it is in the European headquarters or in Beijing. If they are responsible for product development, they need to talk to, for example, all the marketing units at all levels who can provide relevant information. That's why it becomes a global "mess".

4.2. *GIN of a Case Firm in a Synthetic-Knowledge-Based Industry*

In the case of AUTO, the most important connections are within or with the headquarters' departments (Figure 3). The most important connection consists of relations among the headquarters' production department and marketing department. The second important connection consists of relations among headquarters Production, Marketing and R&D department, as well as international subsidiaries for production. The third important connection consists of relations among headquarters production, marketing, R&D and financial department, as well as national and international subsidiaries for production. Thus, we can see that the headquarters is the most important communication hub in the AUTO's GIN, in general, and the production and marketing departments are the most well connected actors in the GIN. The fact that production and marketing are the key functions in the innovation network (and not R&D) reflects the nature of the knowledge base in

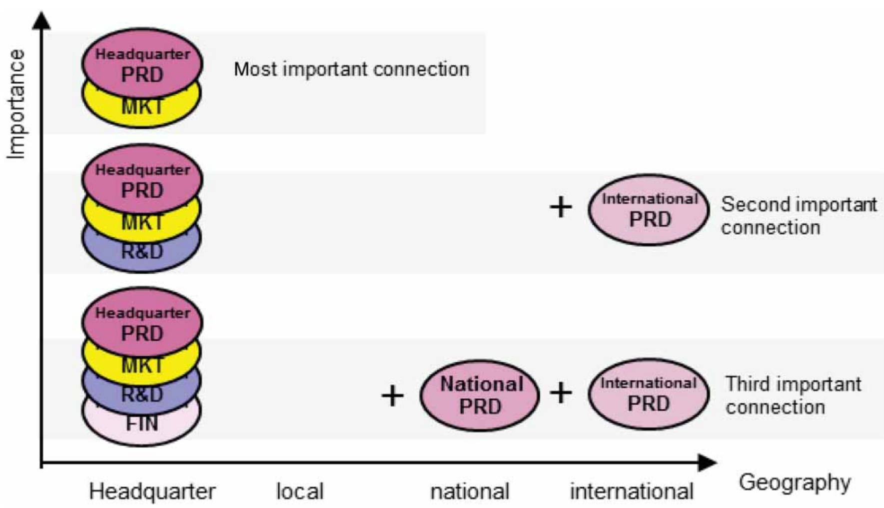

Figure 3. AUTO's top three most important connections in its GIN.

that particular industry. Knowledge is highly tacit and customer-specific and it is created through interactions with customers and suppliers, which, functionally, are mediated by the marketing and production departments of the organization.

Geographically, AUTO's GIN is organized in a completely different manner from TELE's GIN. Structurally equivalent actors are those who locate within the same geographic scope (Figure 4), such as headquarters and local, national and international levels. These results suggest a great overlap between the geography and structure of the innovation and production networks in this particular industry. Both follow what Dickens (2007, p. 356) labels as "regionalized networks", in which operations at a global scale are organized regionally, with distinctive marketing and production networks in each market.

The locally organized characteristic of GINs and the great overlap between GINs and global production networks (GPNs) in the case firm from a synthetic knowledge base industry is also verified by the VP of AUTO. He gave an example of such localization of the global operation of AUTO.

> We have an internal supply chain. For example, a seat belt has different parts, the metal parts, the plastic parts, (and) the fabric parts. We have our own weaving facilities where we weave them. There are other internal suppliers working for seat belt production. The same is for the air bag. We have our own facilities for weaving the

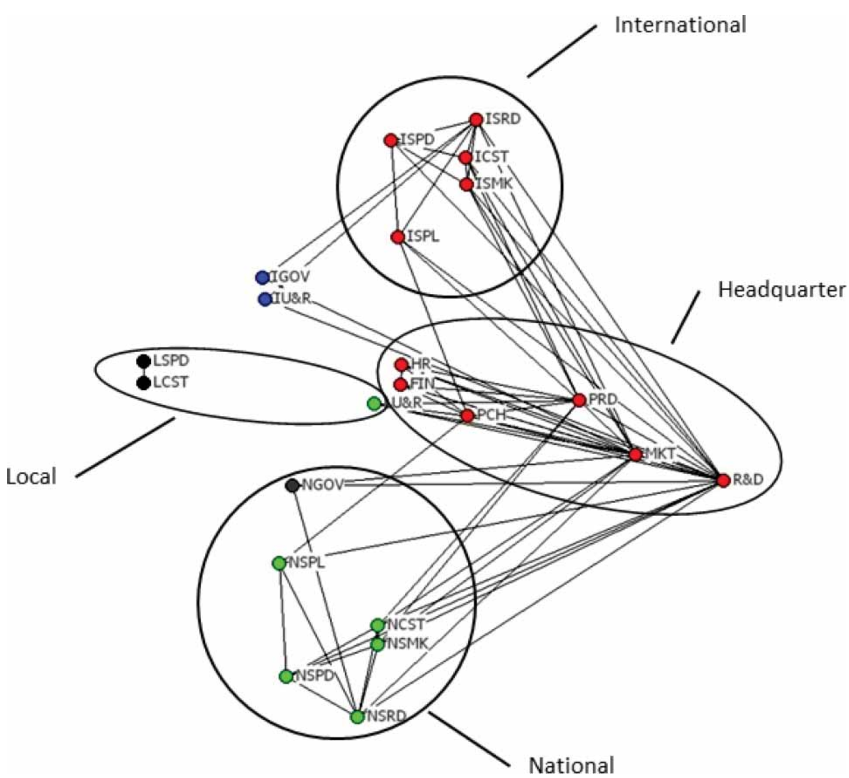

Figure 4. Structure of AUTO's GIN.

> bag and for making the inflator. These connections are mainly in some regions. If you look into the map of our locations, you will see we have a bag facility in North America which supplies the needs of North America. We have a bag facility in China and Taiwan. They supply their region. We have the same in Europe. One is in UK and one in Poland. Then we have production facilities for different customers in Germany, France, Sweden, and some in Spain. They are buying from their internal suppliers in their regions. We have more consolidated production for the key components. There are subsidiaries for production which are also in a vertical line organized as tier one, tier two, and tier three. The tier one suppliers are our main supplier and they are the closest to the customers.

This statement suggests that due to the nature of the knowledge base of this industry, even globalized networks (such as those of MNCs) reproduce, in the different locations, the same patterns of geographically close relations. That is, the R&D unit in a region internationally collaborates with the production and marketing unit co-located in that region, and also with the suppliers and customers of that particular region (Figure 4).

4.3. *Models of the Structure of GINs*

With the results of the social network analysis (key connection analysis and structural equivalence analysis) and the evidence from the interviews conducted with the case companies, we identified two different models of structure of GINs, as shown in Figure 5, the globally organized model of TELE's GIN and the locally organized model of AUTO's GIN.

We explain differences in the structure of GINs by the different knowledge bases of the two industries within which the two case companies operate. The telecommunication industry is characterized by the analytic knowledge base. In an analytic-knowledge-based industry, innovation is generated by radically new knowledge creation. R&D plays a big role in the firm's operation. As the knowledge created in the industry is more standardized, codified and transferable, it makes it possible to organize innovation globally as the new knowledge is appropriate and applicable to innovation in different geographic locations. The automobile safety industry is more synthetically knowledge-based.

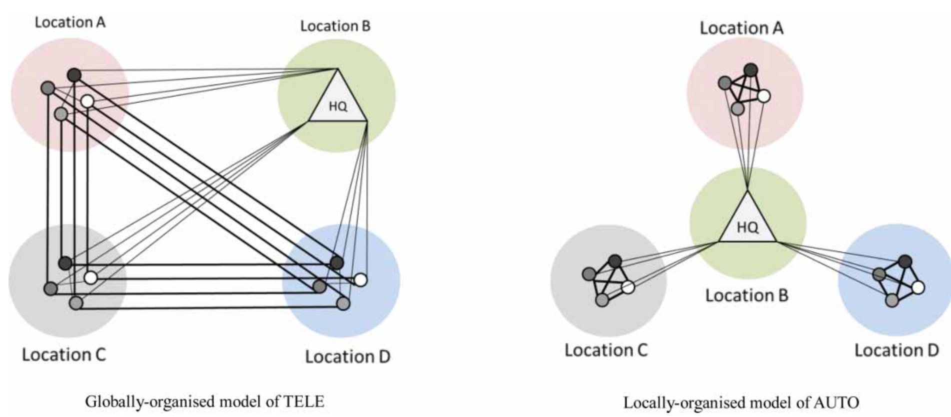

Figure 5. Illustration of the different structures of GINs.

In such industries, innovation usually comes from an application or novel combinations of existing knowledge. Applied and problem-solving-related knowledge is more important. That is the reason why in AUTO they distinguish between research (4–6 years to production), development (3–4 years to production) and engineering (2 years to production). In that respect, they talk about R&D&E rather than simply talk about R&D as most do. In addition, R&D usually refers to a small "r" and a big "D". Tacit knowledge, based on experiences, concrete know-how, craft and practical skills, seem to be more important to this industry than codified knowledge. This may be because innovative solutions generated in one location may not be applicable to another location. Innovation designed for a certain group of local customer based on their driving habits, the local road condition and traffic regulation may not be accepted by another group of customer in another country or region. Hence, it is sensible to organize innovation at a more local level but with strong controls from the headquarters. The last issue is also verified by the VP of AUTO:

> We have development which is generic development of new concepts and new systems. All of these developments we finance centrally. (...) Even though the development is done in Japan, in the US, in Europe, or in China and India, it is still under the coordination and order from our VP of engineering. The reason is that we want to avoid developing the same product in different places at the same time. We also want to strategically control what kind of product we want to develop and when it should come up to the market. So they are useful for all our markets even though they are developed in one market or one region. With all these generic products completed we can go out to the customer and quote. We would be asked what kind of seat belt we can offer to this new vehicle and then we would quote them our latest technology or what we think is the most suitable for both production and technical needs. After this we would run this application and engineering work. And we start the production.

5. Conclusion

The knowledge base literature, underpinning this paper, argues that due to different knowledge bases, industries will show different geographic patterns of knowledge sourcing. Firms in industries dominated by the analytical knowledge base will be more globally spread than firms in industries dominated by the synthetic knowledge base. We take this argument one step forward by investigating how MNCs (which by default are already globally spread) organize their innovation networks. We found that although innovation networks are similarly globally spread, the networks are organized very differently.

Our main argument is that the knowledge base dominating the industry in which a firm is operating strongly influences the geography and structure of its GIN. Firms in industries dominated by analytical knowledge base organize their innovation activities on a global scale, while firms in industries dominated by synthetic knowledge base regionalize their GINs.

Despite the increased globalization, regions continue to be critical for innovation networks. But their role in GINs varies according to the nature of the knowledge base in that particular industry. GINs in analytical knowledge-based industries are attracted to regions that have accumulated certain competences that are required for their research processes and that can only be acquired by "being there". But their embeddedness in the host region may not be as strong as in synthetic knowledge-based industries, as it does not imply other functions than R&D. On the other hand, GINs in synthetic knowledge bases involve close linkages with production, suppliers and clients and are strongly organized at regional levels, even on a global scale. Although it is not explicitly addressed in this paper, the results also provide some insights on the interplay between GPNs and GINs. GINs in analytical-knowledge-base industries are driven by and organized around R&D. Production departments are not part of the most important connections in the GIN which suggests that GINs may not necessarily overlap with GPNs in these industries. On the other hand, GINs in synthetic-knowledge-base industries are organized around production departments, clients and suppliers, suggesting a clear overlap between GPNs and GINs.

One should be careful in generalizing the results presented here. The way that firms organize their GINs is influenced by several determinants; the knowledge base is just one of them. In order to fully understand the structure and geography of firms' GINs, more research is needed on the determinants of the geography and structure of GINs as well as the interplay between GINs and GPNs.

Finally, one important policy implication of the increased importance of globally distributed innovation networks over the last decade is that it becomes more than ever vital for national and regional policy-makers to understand how the global context interacts with the region- and sector-specific conditions in affecting innovativeness, competitiveness and economic growth.

Acknowledgements

Research for this paper was partially funded by the European Community's Seventh Framework Programme (Project INGINEUS, Grant Agreement No. 225368, www.ingineus.eu). The authors alone are responsible for its contents which do not necessarily reflect the views or opinions of the European Commission, nor is the European Commission responsible for any use that might be made of the information appearing herein. Additionally, financial support from the Swedish Research Council (Linneaus grant) is acknowledged. All errors remain exclusively of the authors.

Notes

1. Cognitive, organizational or social proximity may compensate the lack of geographic proximity creating the conditions for the transferability of tacit knowledge across different geographic scales.
2. Intensity refers to the degree of scale and scope of the collaboration. In this paper, the scale depends on the financial and human resources invested in the collaboration. The scope depends on the form of collaborative activities such as shared membership in the trade association, contract research and joint research project.
3. In sociology, the most commonly used example of structural equivalent actors is parents. A parent is a social role defined by the relation with at least one partner and one child. It does not matter what the name of the partner or child is. Once we find out the structural equivalent actors in the family network, we understand how the family network is organized.

References

Asheim, B. T. (2002) Temporary organisations and spatial embeddedness of learning and knowledge creation, *Geografiska Annaler: Series B, Human Geography*, 84(2), pp. 111–124.

Asheim, B. & Coenen, L. (2005) Knowledge bases and regional innovation systems: Comparing Nordic clusters, *Research Policy*, 34(8), pp. 1173–1190.

Asheim, B. T. & Gertler, M. S. (2005) The geography of innovation: Regional innovation systems, in: J. Fagerberg, D. Mowery & R. Nelson (Eds) *The Oxford Handbook of Innovation*, pp. 291–317 (Oxford: Oxford University Press).

Asheim, B. T. & Isaksen, A. (1997) Location, agglomeration and innovation: Towards regional innovation systems in Norway? *European Planning Studies*, 5(3), pp. 299–330.

Asheim, B., Coenen, L., Moodysson, J. & Vang, J. (2007a) Constructing knowledge-based regional advantage: Implications for regional innovation policy, *International Journal of Entrepreneurship and Innovation Management*, 7(2–5), pp. 140–155.

Asheim, B., Coenen, L. & Vang, J. (2007b) Face-to-face, buzz, and knowledge bases: Sociospatial implications for learning, innovation, and innovation policy, *Environment and Planning C: Government and Policy*, 25(5), pp. 655–670.

Audretsch, D. B. & Feldman, M. P. (1996) R&D spillovers and the geography of innovation and production, *The American Economic Review*, 86(3), pp. 630–640.

Barnard, H. & Chaminade, C. (2011) Global innovation networks: Towards a taxonomy, CIRCLE Electronic Working Papers. Available at http://www.circle.lu.se/upload/CIRCLE/workingpapers/201104_Barnard_Chaminade.pdf (accessed 22 February 2012).

Bathelt, H., Malmberg, A. & Maskell, P. (2004) Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, 28(1), pp. 31–56.

Becattini, G. (1990) The Marshallian industrial district as a socio-economic notion, in: G. Becattini (Ed.) *Industrial Districts and Inter-Firm Co-Operation in Italy*, pp. 37–51 (Geneva: International Institute for Labor Statistics).

Borgatti, S. P. & Foster, P. C. (2003) The network paradigm in organisational research: A review and typology, *Journal of Management*, 29(29), pp. 991–1013.

Boschma, R. (2005) Proximity and innovation: A critical assessment, *Regional Studies*, 39(1), pp. 61–74.

Boschma, R. & Frenken, K. (2001) Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. Papers in Evolutionary Economic Geography, Utrecht University.

Burt, R. S. (1987) Social contagion and innovation: Cohesion versus structural equivalence. *American Journal of Sociology*, 92(6), pp. 1287–1335.

Cantwell, J. & Piscitello, L. (2005) Recent location of foreign-owned research and development activities by large multinational corporations in the European regions: The role of spillovers and externalities, *Regional Studies*, 39(1), pp. 1–16.

Cantwell, J. & Piscitello, L. (2007) Attraction and deterrence in the location of foreign/owned R&D activities: The role of positive and negative spillovers, *International Journal of Technological Learning, Innovation and Development*, 1(1), pp. 83–111.

Castellani, D. & Zanfei, A. (2006) *Multinational Firms, Innovation and Productivity* (Cheltenham: Edward Elgar).

Chaminade, C. & Vang, J. (2008) Globalisation of knowledge production and regional innovation policy: Supporting specialized hubs in the Bangalore software industry, *Research Policy*, 37(10), pp. 1684–1696.

Chen, S.-H. (2004) Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network, *Research Policy*, 33(2), pp. 337–349.

Coe, N. M. & Bunnell, T. G. (2003) "Spatializing" knowledge communities: Towards a conceptualization of transnational innovation networks, *Global networks*, 3(4), pp. 437–456.

Coe, N. M., Dicken, P. & Hess, M. (2008) Introduction: Global production networks—Debates and challenges, *Journal of Economic Geography*, 8(3), pp. 267–269.

Cooke, P. (1996) The new wave of regional innovation networks: Analysis, characteristics and strategy, *Small Business Economics*, 8(2), pp. 159–171.

Dankbaar, B. (2007) Global sourcing and innovation: The consequences of losing both organizational and geographical proximity, *European Planning Studies*, 15(2), pp. 271–288.

De Bresson, C. (1986) *Technological Clusters: Poles of Development* (Paris: OECD).

Dicken, P. & Malmberg, A. (2001) Firms in territories: A relational perspective, *Economic Geography*, 77(4), pp. 345–363.

Dickens, P. (2007) *Global Shifts: Mapping the Changing Contours of the World Economy* (New York: Guilford).

Ernst, D. (2002) Global production networks and the changing geography of innovation systems. Implications for developing countries, *Economics of Innovation and New Technology*, 11(6), pp. 497–523.

Feldman, M. (2000) Location and innovation: The new economic geography of innovation, spillovers, and agglomeration, in: G. Clark, M. Feldman & M. Gertler (Eds) *The Oxford Handbook of Economic Geography*, pp. 373–394 (Oxford: Oxford University Press).

Fifarek, B. J. & Veloso, F. M. (2010) Offshoring and the global geography of innovation, *Journal of Economic Geography*, 10(4), pp. 559–578.

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

Gertler, M. (2008) Buzz without being there? Communities of practice in context, *Community, Economic Creativity, and Organization*, 1(9), pp. 203–227.

Gertler, M. S. & Levitte, Y. M. (2005) Local nodes in global networks: The geography of knowledge flows in biotechnology innovation, *Industry and Innovation*, 12(4), pp. 487–507.

Giuliani, E. (2007) The selective nature of knowledge networks in clusters: Evidence from the wine industry, *Journal of Economic Geography*, 7(2), pp. 139–168.

Giuliani, E., Rabelotti, R. & Van Dijk, M. P. (2005) *Clusters Facing Competition: The Importance of External Linkages* (Aldershot: Ashgate Publishing).

Grant, R. (1996) Toward a knowledge-based theory of the firm, *Strategic Management Journal*, 17(winter special issue), pp. 109–122.

Huber, G. P. & Power, D. J. (1985) Retrospective reports of strategic-level managers: Guidelines for increasing their accuracy, *Strategic Management Journal*, 6(2), pp. 170–180.

Jick, T. D. (1979) Mixing qualitative and quantitative methods: Triangulation in action, *Administrative Science Quarterly*, 24(4), pp. 602–611.

Lewin, A. Y., Massini, S. & Peeters, C. (2009) Why are companies offshoring innovation: The emerging global race for talent, *Journal of International Business Studies*, 40, pp. 901–925.

Lipton, J. P. (1977) On the psychology of eyewitness testimony. *Journal of Applied Psychology*, 62(1), pp. 90–95.

Lissoni, F. (2001) Knowledge codification and the geography of innovation: The case of Breschia mechanical cluster, *Research Policy*, 30(9), pp. 1479–1500.

Loebis, L. & Schmitz, H. (2005) Java furniture makers: Winners or losers from globalisation? *Development and Practice*, 15(3–4), pp. 514–521.

Lorrain, F. & White, H. C. (1971) Structural equivalence of individuals in social networks. *Journal of Mathematical Sociology*, 1(1), pp. 49–80.

Love, J. H. & Roper, S. (2001) Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants, *Research Policy*, 30(4), pp. 643–661.

Lundvall, B.-A. (Ed.) (1992) *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning* (Londres: Pinter).

Markusen, A. (1996) Sticky places in slippery space: A typology of industrial districts, *Economic Geography*, 72(3), pp. 294–314.

Martin, R. & Moodysson, J. (2011a) Comparing knowledge bases: On the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden, *European Urban and Regional Studies*. doi: 10.1177/0969776411427326.

Martin, R. & Moodysson, J. (2011b) Innovation in symbolic industries: The geography and organization of knowledge sourcing, *European Planning Studies*, 19(7), pp. 1183–1203.

Moodysson, J. (2008) Principles and practices of knowledge creation: On the organization of “Buzz” and “Pipelines” in life science communities, *Economic Geography*, 84(4), pp. 449–469.

Moodysson, J., Coenen, L. & Asheim, B. (2008) Explaining spatial patterns of innovation: Analytical and synthetic modes of knowledge creation in the Medicon Valley life-science cluster, *Environment and Planning A*, 40(5), pp. 1040–1056.

Nadvi, K. & Schmitz, H. (1999) Industrial clusters in developing countries, *Special Issue of World Development*, 27(9), pp. 1605–1626.

Narula, R. & Zanfei, A. (2004) Globalization of innovation: The role of multinational enterprises, in: J. Fagerberg, D. Mowery & R. Nelson (Eds) *The Oxford Handbook of Innovation*, pp. 318–347 (Oxford: Oxford University Press).

Nelson, R. (Ed.) (1993) *National Innovation Systems. A Comparative Analysis* (New York: Oxford University Press).

Newman, M. E. J. (2003) The structure and function of complex networks, *SIAM Review*, 45(2), pp. 167–256.

Nightingale, P. (1998) A cognitive model of innovation, *Research Policy*, 27(7), pp. 689–709.

Nonaka, I. & Takeuchi, H. (1995) *The Knowledge-Creating Company* (New York: Oxford University Press).

OECD (2001) *Innovative Clusters. Drivers of National Innovation Systems* (Paris: OECD).

Porter, M. E. (1985) *Competitive Advantage* (New York: The Free Press).
Porter, M. E. (1998) Clusters and the new economics of competition, *Harvard Business Review*, 76(6), pp. 77–90.
Schmitz, H. (2000) Does local co-operation matter? Evidence from industrial clusters in South Asia and Latin America, *Oxford Development Studies*, 28(3), pp. 323–336.
Sternberg, R. (2000) Innovation networks and regional development—evidence from the European regional innovation survey (ERIS): Theoretical concepts, methodological approach, empirical basis and introduction to the theme issue, *European Planning Studies*, 8(4), pp. 389–407.
Storper, M. (1992) The limits to globalization: Technology districts and international trade, *Economic Geography*, 68(1), pp. 60–93.
Storper, M. & Venables, A. (2004) Buzz: face-to-face contact and the urban economy, *Journal of Economic Geography*, 4(4), p. 351.
Wasserman, S. & Faust, K. (1994) *Social Network Analysis. Methods and Applications* (Cambridge: Cambridge University Press).
Zanfei, A. (2000) Transnational firms and the changing organisation of innovative activities, *Cambridge Journal of Economics*, 24(5), pp. 515–542.