CESIS

Electronic Working Paper Series

Paper No. 09

The Role of Accessibility for the Performance of Regional Innovation Systems [1]

Martin Andersson and Charlie Karlsson

(JIBS, CESIS)

August 2004

---

[1] Status of the paper: This paper will be published as a chapter in the peer-reviewed book: Karlsson, C., P. Flensburg & S.-Å. Hörte (2004) (eds.) *Knowledge Spillovers and Knowledge Management*, Edward Elgar, Cheltenham (Forthcoming.

The Role of Accessibility for the Performance of Regional Innovation Systems

Martin Andersson[⊗]

Charlie Karlsson[⊕]

August 18, 2004

Abstract

The link between proximity and innovation has been dwelled upon extensively in the literature. A regional economic milieu characterized by proximity between relevant actors is maintained to be suitable for establishing and maintaining successful regional innovation system. In this paper it is proposed that the relevant link to be studied is rather that between accessibility and innovation. Although accessibility is a key factor in facilitating the processes stressed to be important for innovations, the relationship between accessibility and innovation is surprisingly unexploited. Scrutinization of the relationship between accessibility and innovation is necessary in order to fully comprehend regional innovative capacity. Furthermore, such scrutinization will shed further light in the issue of the importance of knowledge spillovers.

[⊗] Martin Andersson,, Economics, JIBS, Box 1026, 551 11 Jönköping
[⊕] Charlie Karlsson, Economics, JIBS, Box 1026, 551 11 Jönköping

1. INTRODUCTION

In recent years, an embryo of a new approach to regional economic development has been advanced. This strand of literature is based on a systemic approach to innovations and regards innovations as the result of ongoing and prolonged collaboration and interaction between firms and a variety of other actors, (see *inter alia* Lundvall, 1995; Edquist, 1997b; Fischer, 2001). These actors include customers, subcontractors, consultants, governmental institutions, research institutes, universities, etc. Regional constellations in which such interaction takes place have been labeled regional innovation systems.

The literature in the field stresses the importance of interaction between actors and proximity is seen as an important aspect of regional innovation systems. As will be accentuated, proximity is in the literature regarded as a core characteristic of regions with a successful regional innovation system, (see e.g. Asheim & Isaksen, 1996)[1]. However, earlier research has failed to provide meaningful operationalizations of the proximity concept in the context of innovation processes. In this chapter we claim that the concept of accessibility can be used to provide meaningful and useful operationalization of proximity. Surprisingly, there is essentially nothing in the literature that explicitly discusses the relationship between accessibility and the performance of regional innovation systems. In view of the fact that accessibility is strongly related to opportunities of interaction, we find this to be a drawback of the existing literature.

In this chapter it is maintained that there is a close link between accessibility and the performance of regional innovation systems. It is well established that knowledge is crucial in innovation processes. In particular, the generation of regional innovations is to a large extent a function of (1) the speed at which new knowledge is introduced to the actual region from other regions and (2) how easily knowledge is exchanged within the region. In the current chapter it is argued that the way these two processes work is a function of the regional accessibility. Recent research suggests that much of the knowledge relevant in innovation processes is hard to codify. This kind of knowledge is usually labelled tacit and does not exist in explicit forms, e.g. printed on paper, (Leonard & Sensiper, 1998). This implies that exchange of tacit knowledge generally requires direct contacts, i.e. face-to-face (FTF) contacts, (see e.g. Teece, 1996). The opportunities of FTF-contacts are in turn determined by a region's accessibility to personal contacts. With reference to (1) and (2) above, it is fruitful to make a distinction between different types of accessibility. This chapter distinguishes between three kinds of accessibility: (i) local accessibility, (ii) intraregional accessibility and (iii) interregional accessibility. Such a distinction makes it possible to analyze what kind of accessibility is most important for different regional innovation systems and, hence, allows for formulation of clear policy guidelines.

The purpose of the chapter is to make a strong case for the hypothesis that there is a close link between regional accessibility and the performance of regional innovation systems. Of course, accessibility can be looked upon from different perspectives. The starting point is that accessibility is a measure of potential opportunities. We focus upon how variations between regions in terms of accessibility to different opportunities affect processes especially important for successful innovation processes, such as R&D and product development.

The remainder of the chapter is organized in the following fashion: Section 2 provides an overview of the systemic approach to innovation focusing upon the rationale for proximity as a critical factor in innovation processes. A short presentation of some empirical findings is also given. The section ends by stressing the link between accessibility and innovation. In Section 3, accessibility is formally defined. A structured method of how to divide regional accessibility into different categories and how to differentiate between causes of a change in accessibility is presented. The section also contains a discussion of the type of opportunities relevant to have accessibility to for different regions. Section 4 concludes the chapter.

2. REGIONAL INNOVATION SYSTEMS AND ACCESSIBILITY

Interaction, Knowledge and Innovations

The systemic approach to innovation is founded upon the interactive (non-linear) model of innovation and regards innovations as a result of ongoing collaboration and interaction between different economic actors, (Andersson & Karlsson, 2002). These actors can, for example, be buyers, sellers, suppliers, local and national authorities and intermediate organizations, such as universities and R&D institutes, (see e.g. Meeus et al., 1999). The emphasis on interaction stems from the conception that there is a strong relationship between learning and innovation. In order to innovate, a firm must learn, (Lagendijk, 2001). This view presupposes that knowledge is both produced and diffused through interaction. For learning to take place, interaction must generate knowledge exchange. Lundvall (1995) point out that learning is mainly a social process since it involves interaction between people, implying that knowledge exchange is essentially an interpersonal doing.

The requirements, as regards regional economic milieu, to make knowledge exchange and subsequently innovation activities successful, have been widely debated in the literature. After all, the only requirement for knowledge exchange is some form of communication channel, e.g. telecommunications. However, the exchange of different types of knowledge demands different communication channels. Currently, there seems to be a consensus among researchers that the kind of knowledge necessitated for innovation depends on the industry in question as well as on the type of innovation made. Hence, the knowledge base demanded for innovation differs

across industries, (Breschi & Malerba, 1997) and between types of innovations, (Asheim & Isaksen, 1996). Innovations are normally divided into (i) radical, (ii) major (adaptive) and (iii) incremental, (Jonsson et al., 2000; Rothwell, 1992). Radical innovations constitute new products or processes that may result in a new line of business or even a new technological paradigm whereas major innovations refer to new products (processes) or their improvements within established businesses. Incremental innovations, on the other hand, constitute marginal changes or improvements of existing products and processes.

A number of different categorizations of knowledge are available in the literature. Many of these are highly specific and only applicable in certain contexts. The distinction used here is general and follows Karlsson & Manduchi (2001, p.104) who distinguish between three broad kinds of knowledge: (i) scientific, (ii) engineering and (iii) entrepreneurial. According to the authors, scientific knowledge refers to basic scientific principles, which requires a formal training to access, whereas engineering knowledge is equivalent to blueprints, i.e. inventions directly applicable in production. Entrepreneurial knowledge stems mainly from learning-by-doing and incorporates knowledge about business concepts, markets, customers and so forth. It is also common to make a distinction between tacit and explicit knowledge. The role of tacit knowledge for regional innovativeness has recently gained much research interest and the concept seems to emanate from organizational science. In contrast to explicit knowledge, i.e. easily codified and "disembodied" knowledge, tacit knowledge is semi- and unconscious knowledge that does not exist in explicit printed forms, (Leonard & Sensiper, 1998). Skills and routines are examples of tacit knowledge, (Lorenzen, 1998). Lubit (2001) maintains that while explicit knowledge is related to 'know-that', tacit knowledge is related to "know-how". Table 2.1 broadly describes the differences between them.

The degree of tacitness and explicitness of the knowledge required for innovation is a major factor in determining the prerequisites for an enhancing milieu. The reason lies in that explicit and tacit knowledge differ substantially in terms of the communication channels needed for knowledge exchange. Lorenzen (1996) maintains that explicit knowledge (evolving from education and formal training and is thus universal) can be transmitted via communication technologies. But, it is necessary for the receiver to have relevant training in order to be able to absorb the knowledge being transmitted. Tacit knowledge, on the other hand, is transmitted via employee mobility, informal personal relations and supervision. It is commonly argued that exchange occurs mainly through knowledge spillovers, which in turn require direct contacts, i.e. face-to-face (FTF) contacts, as asserted by Breschi & Lissoni (2001a, 2001b). Transmission of new knowledge, for instance, often requires the creators' presence, (Teece, 1996).

Table 2.1 Types of knowledge and learning by interacting

Knowledge type	Intra-firm learning	Pool	Learning by interacting	Channel	Code Keys
Explicit	Education & formal training	Formalizing records & procedures	Transmitting information signals	Communication technologies	Formal qualification
"Less" explicit	Apprenticeship & trial and error	Following routines & scripts	Sharing experiences	Discussions, conferences & visits	Skills & experiences
Tacit	Socialization	Understanding norms & mental models	Communicating understanding & sharing norms	Employee mobility & informal personal relations	Culture

Source: Lorenzen (1996, p.9)

An important question concerns the linkage between the different types of innovations and the different kinds of knowledge. Understanding such linkages is essential for the identification of the innovation potential in different regions as well as for formulation of policy guidelines. In this framework, it seems sensible to put forward that radical innovations demand a 'wall-to-wall' knowledge base. To generate a radical innovation, a firm is most likely enforced to employ scientific, engineering and entrepreneurial knowledge. Development of new technologies certainly demands an education in engineering, R&D competence and so forth. In turn, both engineering and entrepreneurial knowledge are needed in order to get a new technique applicable on the market. Hence, lack of market-oriented knowledge may leave a firm left with an invention. In contrast, incremental innovations may be generated on the basis of entrepreneurial knowledge only. The development of a new design for an old product, for example, should only require entrepreneurial knowledge. With similar reasoning for major innovations, a general relationship between knowledge types and innovations may be presented as in Figure 2.1.
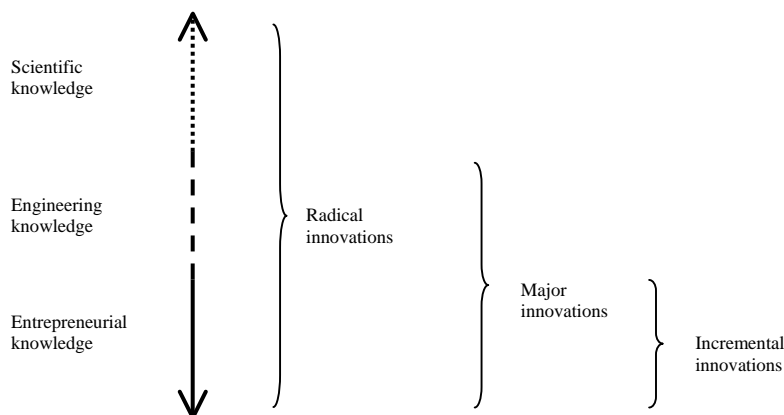
Figure 2.1 Depiction of the link between knowledge types and innovations

As pointed out earlier, tacit knowledge and its role in innovation processes is a subject that has been dwelled upon immensely in recent years. A good deal of what has been written avers that much knowledge germane to innovations is indeed tacit, (Karlsson, 2001). This is not to be perceived as implying that formal education and R&D, etc, are of minor importance for innovations. On the contrary, tacitness and explicitness should be looked upon as more generic in the sense that part of an agent's knowledge may be more or less tacit regardless of what kind it is. Tacit knowledge tends to coexist in very different activities such as scientific research and traditional manufacturing production, (Grimaldi & Torrisi, 2001). This can be explained by the fact that knowledge is inclined to always be partially tacit in the minds of the creators, (Saviotti, 1998). Hence, the importance of formal education does not oppose a significant role of tacit knowledge. Lawson & Lorenz (1999) affirm that tacit knowledge has a role to play for innovation processes in high technology sectors, which generally use formal knowledge and R&D extensively.

The reasons given for the role tacit knowledge plays are many. Firstly, it is suggested that experiences, skills and know-how, which by definition represent tacit knowledge, are without doubt important inputs in an innovation process, (see e.g. Lubit, 2001). Secondly, tacit knowledge seems to induce firms to be up to date, as regards new ideas, etc. The rationale for such an approach is that new knowledge is not devised codified, (Fischer & Varga, 2001; Saviotti, 1998). The degree of explicitness is low in the development stage of new knowledge. Lawson & Lorenz (1999) discuss the relative importance of tacit knowledge in different phases of an innovation process. They differentiate between four stages. The first entails sharing of tacit knowledge, the stage in which many of the new ideas are generated. In the second, the ideas become articulated and can be formulated more precisely, i.e. the ideas are made explicit. After the second stage, the explicit ideas are combined with other known technologies and methods and it is in this third stage that prototypes are made. The third stage stands for the process in which explicit knowledge is combined. In the fourth, a new product is produced. New routines and skills, i.e. new tacit knowledge, are developed upon which new knowledge may be created. Thus, the knowledge used in the early phases of an innovation processes is mostly tacit and is important in order to keep up with other firms' developments, such as new ideas on technical solutions and so forth. Marshall (1948, p.271), though referring to technological spillovers, had quite a similar way of thinking: '…if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further ideas'. Thus, it can be argued that Marshall implicitly recognized the importance of tacit knowledge.

Of course, a firm is most likely reluctant to share new ideas with competitors. However, as is usually maintained in the literature, the mode of exchange for tacit knowledge is most often spillovers, which may be defined as positive externalities rather than planned activities. This implies that exchange occurs implicitly. As such, it can to some extent be considered as public good, mutually beneficial for all firms receiving it. Furthermore, as previously mentioned, exchange of tacit knowledge necessitates that both the receiver and the transmitter are familiar with the 'code' of the tacit knowledge. Reciprocal understanding of codes demand prolonged interaction between the transmitter and the receiver. Lawson & Lorenz (1999) maintain that such elements may be developed through strong local institutions, intensive collaboration between firms or labor mobility. Hence, the former objection does put demands on the regional economic milieu.

Proximity and Innovations

The current literature emphasizes the vital role that geographical proximity between the actors in a regional innovation system plays for the functioning of the system, (see e.g. Asheim & Isaksen, 1996; Wiig & Wood, 1995). In particular, regional clusters are argued to create superlative suppositions for a well-functioning regional innovation system.

When dealing with the role of proximity, most research emphasizes the linkage between proximity and likelihood of knowledge spillovers. It generally asserts that knowledge spillovers have clear spatial boundaries since the communication between workers depends on their geographical proximity, (see, for instance, Echeverri-Carroll & Brennan, 1999; Feldman & Audretsch, 1999). The main message is that spillovers and transfers of knowledge are likely to be smooth in the presence of proximity. Baptista (2000) provides empirical evidence that innovations diffuse faster within clusters. In addition to geographical proximity it is also acknowledged that common conventions and rules shared by actors, i.e. informal institutions, are important for the smoothness of knowledge transfers and spillovers, (see e.g. Storper, 1995; Maillat, 1995; Maillat & Kebir. 2001). In principle, this strand of literature tries to give an in depth explanation of the emergence and importance of local cultural institutions, which according to Lawson & Lorenz (1999) may generate shared tacit knowledge. It is maintained that not only geographical proximity but also relational proximity play a prominent role. The latter encompasses relations developed by integration of firms and socio-cultural homogeneity, (Capello, 2001), and can be related to Storper's (1995) untraded interdependencies and Maillat's (1995) atmospheric externalities. Thus, common rules and conventions bring about mutual trust, which diminish uncertainties and stimulates and facilitates interaction. As Harrison (1996, p.235) writes:

'[B]y increasing the likelihood of familiarity, proximity reduces the incidence of opportunistic behavior by suppliers, customers and even competitors, thus facilitating learning'.

A large amount of research effort has been devoted to find evidence for knowledge spillovers and determine whether they are localized or if distance plays only a minor role. Albeit knowledge spillovers are hard to measure, as notoriously noted by Krugman (1991, p.53): "…knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked", there seems to be a consensus that knowledge spillovers exist and are important for innovation processes. Jaffe et al. (1993) found compelling evidence for both the existence of knowledge spillovers and their boundedness in space. They studied to what extent citations to patents, to both universities and corporations, were spatial phenomena from 1972 to 1980 in the U.S. They showed that citations to patents were more likely to come from the same region as the patents to which the citations were made. It was also found that localization of patent citations fades over time. Similar patterns are found by Maurseth & Verspagen (1998) for European regions, using patent citations as proxy for knowledge spillovers. Their findings indicate that distance between regions matters and that spillovers are more prevalent within sectors. They concluded that the European innovation system should be regarded as a polarized system with many centers rather than a single system. Moreover, Feldman (1994) shows that (product) innovations are indeed concentrated in space in the U.S. Similar patterns are observed by Shefer & Frenkel (1997) who find that the rate of innovation is higher in agglomerations for the electronics industry in Israel. Thus, both theory and empirical findings point in the direction that geographical proximity is critical for innovations. It needs to be mentioned, however, that many of the studies of knowledge spillovers do not explicitly model *how* knowledge is exchanged. Breschi & Lissoni (2001a, p.976) are indeed critical to the current research and claim:

…the concept of LKS [localized knowledge spillovers] is no more than a black box, whose contents remain ambiguous. On the one hand, its frequent mentioning serves merely an evocative purpose, i.e. it helps signaling a strong interest in coupling geography and innovation as research themes; on the other hand it helps researchers to avoid studying the specific mechanisms through which the two phenomena are linked".

In spite of the criticism and the fact that the specific mechanisms should be more fully studied, the concept of knowledge spillovers is a pleasant and intuitively appealing explanation for the strong relationship between innovation and proximity.

The role of universities and other knowledge providers is another issue that has been focused upon in the literature, where universities are believed to play an essential role for the functioning of regional innovation system, (Etkzkowitz & Leydesdorff, 2000). Koschatzky (2001, p.3) stresses that Higher Research Institutes (HEIs) generally fulfill two main functions in a region. According to the author, they:

- manage the common knowledge base of a region by producing and diffusing knowledge through education, by distributing scientific and technological information and by demonstrating and transferring technological or scientific solutions.

- provide expertise knowledge by training, consulting, contract research and development, or by the transfer of services, taking into account the specific needs of single actors.

Since HEI's keep regional firms up to date regarding scientific solutions, etc, they facilitate necessary industrial transformations when new technologies are introduced. Hence, they counteract lock-in situations and lower the risk of structural unemployment. In addition, Koschatzky (2001) maintains that HEIs do not only act as knowledge providers, they are also incubators for new firms since they qualify and support potential entrepreneurs. HEIs, thus, help to transform new scientific knowledge into commercialized products and create new businesses.

Empirical observations support the view that universities are important for regional innovativeness. For example, Varga (1998) shows that universities promote regional economic growth and that their presence affects regions' attractiveness as location for firms. Firms regard universities as a source of new knowledge and technologies, (ibid.). Anselin et al. (1996) find that regional university research stimulates regional high-technology firms' innovative activities in the U.S. Blind & Grupp (1999), studying regions in Germany, find that regional public R&D infrastructure is a source of knowledge input in the innovative activities of regional businesses. Similar observations are made by Varga (2001) in a study of regions in the U.S.

3. ACCESSIBILITY AND THE PERFORMANCE OF A REGIONAL INNOVATION SYSTEM

The Unexploited Link between Innovation & Accessibility

As the title of this section suggests, the relationship between accessibility and innovation is indeed unexploited[2]. This is surprising since the accessibility concept is directly connected to many of the functions stressed to be important for innovation in the systemic approach.

The concept of accessibility can be coupled to Hägerstrand's (e.g. 1970) time-geography. Hägerstrand stressed the importance of constraints for the possibility to interact and viewed time as one of the fundamental constraints. Weibull (1980, p.54) proclaims that measures of accessibility relates to:

- nearness
- proximity
- ease of spatial interaction
- potential of opportunities of interaction
- potentiality of contacts with activities or suppliers

This implies that a high accessibility value (to some relevant opportunity) eases the processes essential for innovations. The above points are also valid for proximity, though it is a much wider concept than accessibility. Focusing upon the latter allows for extension and preciseness of the conventional view on the role of geographical proximity for innovations, (Bertuglia & Occelli, 2000). The advantages of accessibility are best understood by stressing two distinct features of the concept. Firstly, accessibility purveys a link between the functional and the spatial component of an urban system, (ibid.). This is because it defines the range and temporal organization of economic activities available in space as well as the cost of overcoming space in order to explore opportunities at different locations. Accessibility accounts for the size of an attraction in a location and discounts the accessibility value with distance in a way that reflects the willingness to explore that attraction given its size and distance. Secondly, accessibility is a robust operational measurement tool and allows for a thorough methodology, (see e.g. Occelli & Gallino, 1992). Thus, computing accessibility makes proximity operational.

Concurrently with an emphasis on accessibility, the relevant type of distance should be discussed. The well-known axiom in regional economics, namely that "interaction decreases with distance", (Beckman, 2000), is widely spread. But what is relevant is the type of distance. In the context of knowledge exchange and communication between individuals, the appropriate treatment of distance is most certainly by means of time distance. Geography matters not because of the physical distance, but because traveling is time and resource consuming. Accordingly, Beckman (2000) is of the opinion that travel time is the most appropriate measure of distance when dealing with knowledge networks. He also maintains that this was the measure used in several studies on knowledge networks and scientific collaboration. Figure 2.1 appears in Hugosson (2001) and shows the cumulative frequency (in percent) of Swedish aggregate domestic interregional business trips[3]. As is evident from the figure, the share of business trips declines very rapidly as the travel-time distance increases. This confirms the critical role of time distances for spatial interaction. Moreover, Törnquist (1996) point out that there is a palpable relationship between European metropolitan regions' accessibility and the frequency of

Swedish business contacts with these regions. Time distances are also critical when it comes to spatial borders of labor markets and business collaboration trips. By studying commuting between municipalities in Sweden, Johansson & Klaesson (2001) show that there is a threshold time distance for commuting, approximately around 45 minutes[4]. Commuters seem to be highly reluctant to commute if the time distance for a single trip exceeds 45 minutes. Thus, it is possible to identify regions with a high potential for knowledge spillovers by computing, for example, regional accessibility to jobs. Within such an area, interaction is inexpensive in relative terms. This increases the probability of FTF-contacts, both planned and unplanned.

Another important reason for using time distance is that it takes differences in regional infrastructure capacity and quality into account. The inability to reveal such disparities is a major drawback of ordinary geographical distance. Two regions may have the same distance to some opportunity but unequal time distances, which is the most important factor. A clear connection between accessibility and innovation provides a thoroughly operational way of evaluating the effect on innovation by construction and improvements of infrastructure. This stems from the fact that time distance is dependent upon the quality of the infrastructure. Hence, it enables, at least in one aspect, for rather straightforward evaluations of public investments in infrastructure.
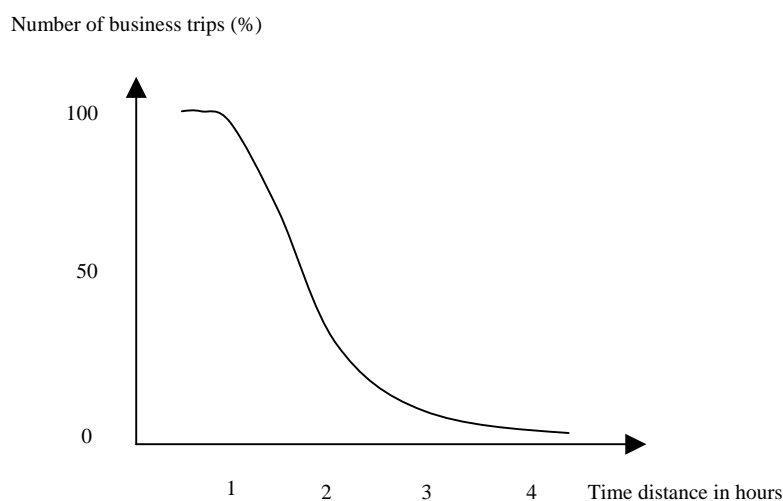

Figure 3.1 The cumulative percentages of interregional business travel over time distances, (Hugosson, 2001)

Acknowledging the link between accessibility and innovation underlines the strong connection between the transportation network and the human interaction network. The former partly determines the borders of the former. Table 3.1 compares the two networks. Kobayashi & Fukuyama (1998) stress that the two networks are essential in the realization of communication. Ideas, both scientific and others, flow in the human interaction network. Individuals function as nodes that absorb ideas and the meetings as 'arenas' in which ideas are exchanged. Hence, learning, believed to be crucial in the systemic approach, is not only heavily dependent upon

human interaction networks, but also upon the transportation networks. The accessibility concept incorporates both elements. The accessibility value itself measures the potential of interaction and hence the potential of human interaction networks. The transportation networks are reflected in the time distance used to calculate the accessibility value.

Table 3.1 The Comparison of Network Characteristics

	Transportation Network	**Human Network**
Node	Origin, destination	Individual
Link	Roads, railways	Meeting, Communication
Input	Trip demand	Idea, friendship, etc
Output	Realized trips	Evolution of ideas, deepening of friendship
Observable variable	Transportation trip	The number of meeting state
Variable(s)	Transportation conditions	Function of ideas, friendship and others
Objective variable(s)	Travel time, costs	Exchange of knowledge and ideas
Medium	Transportation methods	Discussions

Source: Kobayashi & Fukuyama, (1998, p.241)

The discussion above suggests that there is a paramount link between accessibility and the performance of regional innovation systems. It is possible to claim *ceteris paribus* that a region characterized by high accessibility to FTF-contacts is likely to produce and diffuse new knowledge at a higher speed than a similar region with lower accessibility. Such a region is able to develop a dense human interaction network. Also, frequent contacts between regional actors imply that they are prone to developing common norms and bilateral understanding. The regional actors are likely to develop reciprocal understanding of codes essential for the sharing of tacit knowledge. Taken together, regions with high accessibility to relevant opportunities should, ceteris paribus, have a higher innovation potential and a higher innovation rate.

Accessibility Defined

Having discussed the link between accessibility and innovation, a formal definition of accessibility and a discussion of the effect of changes in the parameters might be in order. Consider a set of *n* of municipalities. The accessibility of municipality *i* to itself and to the *n*-1 surrounding municipalities can be defined as follows:

$$A_i^D = D_i f(c_{ii}) + D_1 f(c_{i1}) + D_2 f(c_{i2}) + ... + D_n f(c_{in}) \qquad (3.1)$$

where A_i^D is the total accessibility of municipality i. D is a measure of opportunities in each municipality, which can be opportunities such as suppliers, customers, producer services, educated labor, universities and R&D institutes, etc, (see *inter alia* Klaesson, 2001). A municipality's accessibility is defined as the sum of its internal accessibility to a given opportunity D and its accessibility to the same opportunity in all the other municipalities in the set {1,...,n}. $f(c)$ is the distance decay function that determines how the accessibility value is related to the cost of reaching the opportunity. Different researchers have used different specifications of this relationship, (Seng, 1996). One of the most common approximations is made by means of an exponential function, (Johansson & Klaesson, 2001). Applying an exponential function, the distance decay function takes the following form:

$$f(c_{ij}) = \exp\{-\lambda t_{ij}\} \tag{3.2}$$

where t_{ij} is the time distance between municipality i and j and λ is a sensitivity parameter w.r.t. t. Hence, λ determines how the accessibility responds to changes in t. Combining Equation (3.1) and (3.2), the accessibility of municipality i to opportunity D is defined in Equation (3.3).

$$A_i^D = \sum_{j=1}^{n} D_j \exp\{-\lambda t_{ij}\} \tag{3.3}$$

The accessibility measure of the type in Equation (3.3) satisfies criteria of consistency and meaningfulness. This is shown by Weibull (1976), who approach the construction of an accessibility measure by formulating requirements that lead to desired properties and then derives an appropriate mathematical form consistent with such requirements. Specifically, the author sets up six axioms that a meaningful measure of accessibility should fulfill. The mathematical form in Equation (3.3) is consistent with these axioms.

Defining the Region & Division of Accessibility

Following the recommendations in Andersson & Karlsson (2002), a region is here referred to as a functional region. This implies that the borders of a region are composed of the intensity of economic interaction, consisting of nodes, such as municipalities, connected by economic networks and networks of infrastructure, (Johansson, 1992). Local labor market regions are synonymous with functional regions. Given that regions have these properties, it is possible to divide a (functional) region's total accessibility to some opportunity D (A_R^D) into three parts, as shown in Equation (3.4) below:

$$A_R^D = A_{RL}^D + A_{RI}^D + A_{RE}^D \tag{3.4}$$

where A_{RL}^{D}, A_{RI}^{D} and A_{RE}^{D} express local accessibility, intraregional accessibility and interregional accessibility respectively. Table 3.2 lists and describes the different categories of accessibility. As seen in the table, local accessibility is relevant for unplanned contacts. The time distance is sufficiently low to make it possible for persons to carry out several contacts within a day. Intraregional accessibility, on the other hand, is relevant to contacts and travels made on a regular basis, such as commuting. The time distance is too large for several unplanned contacts during one day. For interregional accessibility, the time distance is too large for commuting. The contacts made in this range are therefore likely to constitute planned activities, such as business meetings.

Table 3.2 Three types of accessibility, their approximate time distance and range

Accessibility	*Approximate time distance*	*Range*
Local	5-15 minutes	several unplanned contacts per day
Intraregional	15-50 minutes	contacts and travels made on regular basis (commuting), once per day
Interregional	>50 minutes	planned contacts, low frequency

The task is now to give a more detailed specification of the accessibility measures in Equation (3.4). In doing so, we start by referring to a paper by Johansson, Klaesson & Olsson (2002), which shows that the time sensitivity parameter λ is different for intramunicipal, intraregional and interregional interaction. More precisely, the type of interaction considered in the chapter is commuting between municipalities. The authors find that for interaction inside a municipality λ^1 applies, inside the region λ^2 applies and λ^3 applies for contacts outside the region. The three parameters differ in the following manner: $\lambda^2 > \lambda^3 > \lambda^1$, which means that the time friction is greater for time intervals 15-50 minutes, smaller for intervals longer than 50 minutes and smallest for very short time distances. In order to formally define the three types of accessibilities set out in Equation (3.4), we will use the following notation[5]:

W = {1,…,n}, the set of all municipalities (nodes) in the economy.
R = a functional region constituted by nodes in W, so that $R \subset W$.
i,j = nodes (municipalities).
R_{-i} = $R \setminus \{i\}$, the set of nodes in region R excluding node i.
W_{-R} = $W \setminus R$, all nodes in the economy, except those in R.

We start at the municipality level and focus on municipality i in region R, hence $i \in R$. The average time distance between zones in municipality i is denoted by t_{ii} and the size of opportunity D in the same region is denoted by D_i. This given, the intramunicipal accessibility to opportunity D can be expressed as in Equation (3.5).

$$A_{iM}^D = D_i \exp\{-\lambda^1 t_{ii}\} \tag{3.5}$$

The economic actors in municipality i also have accessibility to the same opportunity in all other municipalities in the region. Thus, we can also establish municipality i's intraregional accessibility.

$$A_{iR}^D = \sum_{j \in R_{-i}} D_j \exp\{-\lambda^2 t_{ij}\} \tag{3.6}$$

Finally, all the actors in the municipality can also access the opportunity D in all municipalities outside the region. This gives the interregional accessibility of municipality i.

$$A_{iE}^D = \sum_{j \in W_{-R}} D_j \exp\{-\lambda^3 t_{ij}\} \tag{3.7}$$

Having specified municipality i's ($i \in R$) three types of accessibility, it is easy to establish the local, intraregional and interregional accessibility of functional region R. Let θ_i be a weight expressing the relative importance of municipality i in functional region R, the three types of regional accessibility can be defined as below.

Local accessibility
$$\Rightarrow A_{RL}^D = \sum_{i \in R} D_i \exp\{-\lambda^1 t_{ii}\}\theta_i = \sum_{i \in R} A_{iM}^D \theta_i \tag{3.8}$$

Intraregional accessibility
$$\Rightarrow A_{RI}^D = \sum_{i \in R} \sum_{j \in R_{-i}} D_j \exp\{-\lambda^2 t_{ij}\}\theta_i = \sum_{i \in R} A_{iR}^D \theta_i \tag{3.9}$$

Interregional accessibility
$$\Rightarrow A_{RE}^D = \sum_{i \in R} \sum_{j \in W_{-R}} D_j \exp\{-\lambda^3 t_{ij}\}\theta_i = \sum_{i \in R} A_{iE}^D \theta_i \tag{3.10}$$

The equations reveal that local accessibility, A_{RL}^D, refers to the weighted sum of each nodes' intramunicipal accessibility in region R. Intraregional accessibility, A_{RI}^D, refers to the weighted sum of all nodes' accessibility to all other nodes within region R. Interregional accessibility, A_{RE}^D, is the weighted sum of R's municipalities' accessibility to opportunity D in all municipalities outside region R.

Given the approximate time distances set out in Table 3.2, it is worthwhile noting that the relevant mode of transport may differ between the three accessibilities. Referring to local accessibility, car and local busses are likely to be the relevant modes of transport. For intraregional accessibility, regional trains should be added. At least three transport modes should be important here. In the time distance corresponding to interregional accessibility, it is likely that busses and cars are, to a high degree, substituted in favor of high-speed trains and

air travels. These observations have implications with regard to the measurement of time distances and are also important from a policy perspective.

Consulting the former equations, it is evident that there are two ways in which the accessibility value may be improved. It can be made either by a reduction in the time distances or by an increase in the size of the opportunity. Johansson & Klaesson (2001) propose a method to decompose a change in regional accessibility into (i) 'a time distance effect' and (ii) 'a localization effect'. This method allows for an evaluation of the relative size of the two effects. It also gives an opportunity to effectively evaluate the effect of improvements of intra- and interregional infrastructure. The following example only concerns the intraregional accessibility of a functional region but the method can be applied to any type of accessibility.

Suppose that over time, the time distance between nodes within a functional region decreases while the size of a relevant opportunity in the nodes grows. The impact of both will increase the accessibility value. How can the relative size of their impact be calculated? Let Equation (3.11a) and (3.11b) symbolize the intraregional accessibility of municipality i in R at time (t) and $(t + \tau)$, respectively. The change in the accessibility value from time (t) to time $(t + \tau)$ can then simply be described as in Equation (3.12)[6].

$$A_{iR}^{D}(t) = \sum_{j \in R_{-i}} D_j(t) \exp\left\{-\lambda^2 t_{ij}(t)\right\} \tag{3.11a}$$

$$A_{iR}^{D}(t + \tau) = \sum_{j \in R_{-i}} D_j(t + \tau) \exp\left\{-\lambda^2 t_{ij}(t + \tau)\right\} \tag{3.11b}$$

$$\Delta A_{iR}^{D} = A_{iR}^{D}(t + \tau) - A_{iR}^{D}(t) \tag{3.12}$$

The causes of the change $\Delta A_{iR}^{D}(t + \tau)$ can be divided into (i) $\Delta t_{ij} = t_{ij}(t + \tau) - t_{ij}(t)$ and (ii) $\Delta D_j = D_j(t + \tau) - D_j(t)$ for each node in R. The decomposition can then be made as in Equation (3.13).

$$\Delta A_{iR}^{D} = \underbrace{\sum_{j \in R_{-i}} D_j \exp\left\{-\lambda^2 t_{ij}(t + \tau)\right\} - A_i^{D}(t)}_{\text{time effect}} + \underbrace{\sum_{j \in R_{-i}} \Delta D_j \exp\left\{-\lambda^2 t_{ij}(t + \tau)\right\}}_{} \tag{3.13}$$

localization effect

Finally, it may be noted that the total change in functional region R's intraregional accessibility can be expressed as in Equation (3.14).

$$\Delta A_{RI}^{D} = \sum\nolimits_{i \in R} \Delta A_{iR}^{D} \theta_{i} \qquad\qquad (3.14)$$

The method suggested by Johansson & Klaesson (2001) reveals that accessibility has many desired properties. Primarily, the exercise clearly shows that accessibility is operational. Having defined the region and the accessibility concept, the next step is to discuss what types of opportunities are relevant for a region to have accessibility to in order to have an efficient regional innovation system and what type of regional accessibilities are important for different types of regions.

Opportunities Important to have Accessibility to

There is no explicit concurrence in the literature regarding which relations between which actors are essential for an innovation system to be well functioning. It is, for example, maintained that an innovation system: '…is constituted by the elements and relationships which interact in the production, diffusion, and use of new, and economically useful, knowledge', Lundvall (1995, p.2) or that it is: '…a set of institutional actors that, together plays the major role in influencing innovative performance', Nelson & Rosenberg (1993, p.4). Such definitions lack the preciseness needed to draw clear conclusions as regards the actors and relations one should focus upon in both research and policy. Fischer (2001) acknowledges the deficiency of the literature and suggests that an innovation system capable of encompassing a whole innovation process should consist of four key building blocks. This is shown in Figure 3.2, where the four building blocks are: (i) the manufacturing sector, (ii) the scientific sector, (iii) the sector of producer services and (iv) the institutional sector. According to Fischer (2001) the central actors in an innovation system are manufacturing firms. The manufacturing sector includes these firms as well as their research activities. The scientific sector provides both training and research and includes all actors that fund and carry out research or supply education, (ibid.). The third sector, producer services, is constituted by organizations that supply supporting services to firms. The institutional sector contains both formal and informal institutions. These four sectors should be present in a coherent regional innovation system, as shown in the figure. The components are interrelated with each other and their interaction generates new knowledge into the innovation system through knowledge exchange. Formal as well as informal institutions, whose borders are defined by the borders of the region, facilitate such exchange. Each component can be seen as a sub-system in which the relations between the actors of that sub-system transform knowledge gained from other sub-systems into new knowledge and vice versa. As indicated by the dashed circle, some of the actors in each component are located within the region while some are located outside. However, this picture varies from one region to another.
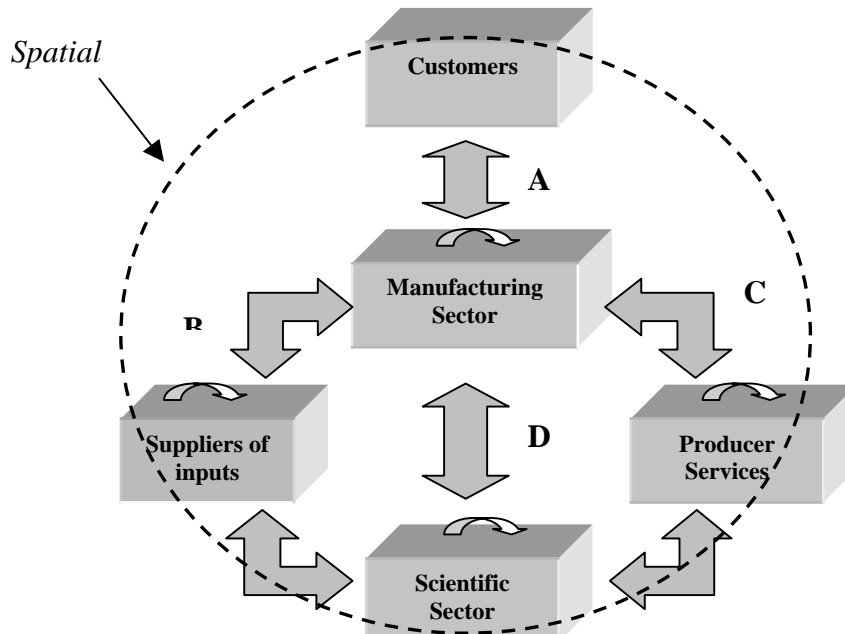
Figure 3.2 Main components and relationships in a coherent regional innovation system, (adapted from Fischer, 2001)

From the figure above, it is evident that there are four essential relationships in a coherent regional innovation system. These are (1) customer-producer relations (**A**), (2) supplier-producer relations (**B**), (3) service supplier-producer relations (**C**) and (4) science-producer relations (**D**). These are essentially the same as those listed by Fischer (2001). Karlsson (1997), though referring to relevant actors in innovation networks, arrives at similar conclusions. From the present discussion it can be concluded that the following actors are strategic in the innovation process:

- Producing firms.
- Subcontractors.
- Producer service suppliers.
- Customers.
- Knowledge handlers, i.e. skilled labor.
- Universities with a suitable research agenda.
- R&D institutes.

Interaction within and between these actors enhances the creation and dissemination of new knowledge. In addition to the actors listed above, meeting arenas such as local communities, etc, most likely play an important role. Such opportunities of personal interaction ought to play a major role in shaping informal institutions such as conventions and rules. A region hosting the actors above and where the composition of the industry and

infrastructure generates a high accessibility value, will have the requirements needed to develop a successful regional innovation system. However, not all regions host a sufficient set of these actors.

The Role of Different Accessibilities in Different Regions for the Potential of a Coherent Regional Innovation System

To be able to develop a coherent regional innovation system a region must have a rich regional economic milieu. A region should, for example, be large enough to host a university. However, not all regions are of the size needed for such a diverse economic landscape. To elucidate the role of different accessibilities in different regions, it is necessary to distinguish between the regions according to the characteristics presented in Figure 3.3. In the figure, region A and B can be considered as two extremes. Region A has an expedient initial position. It is large, central and dense implying that it has a strong potential of hosting the actors needed for successful regional innovation systems as well as a strong potential for developing high accessibility within and between the actors. Region B, on the other hand, is at the other extreme. It is small, peripheral and sparse. This implies that its chances of developing a coherent regional innovation system are weak. Its smallness and peripheralness make it hard to attract the necessary actors. The fact that it is sparse makes it costly to establish high accessibility within and between those strategic actors the region eventually hosts.

The subsequent text will not only discuss which of the aforementioned types of accessibility is likely to be most important for different regions defined according to Figure 3.3, but also the appropriate method to achieve a high accessibility value for different regions, i.e. is it most productive to increase the size of the opportunities or decease the time distance?

Consider again the figure above. On reasonable grounds, it can be assumed that the smaller the size of a region, the harder it is to attract the necessary actors for a coherent regional innovation system. Interregional accessibility is therefore likely to be of critical importance for such regions. High accessibility to other regions creates good suppositions to tie the actors within the region to strategic ones in other regions. This shows that the relevant means to improve the accessibility is by decreasing the interregional time distance[7]. Obviously, tying the regional actors to actors in other regions is a harder task for a small peripheral region than for a small central region. It is doubtful whether a small peripheral region is able to achieve sufficiently high accessibility to develop the intensity of interaction needed for successful knowledge creation and diffusion since FTF-contacts are, as illustrated earlier, essential in such processes. A small central region, on the other hand, is likely to reach the necessary diversity as regards strategic actors within sufficient time ranges. Centrality implies that a region is located close to a large region and/or close to a set of smaller regions. Improving the accessibility to a nearby

large region hosting the actors or to a number of smaller surrounding regions with diverse industry structures should make it possible to develop a successful innovation system. In the latter case, small regions may develop network-like relations to be able to develop a coherent innovation system. A small sparse region ought to improve its intraregional accessibility, independently of whether it is central or peripheral.
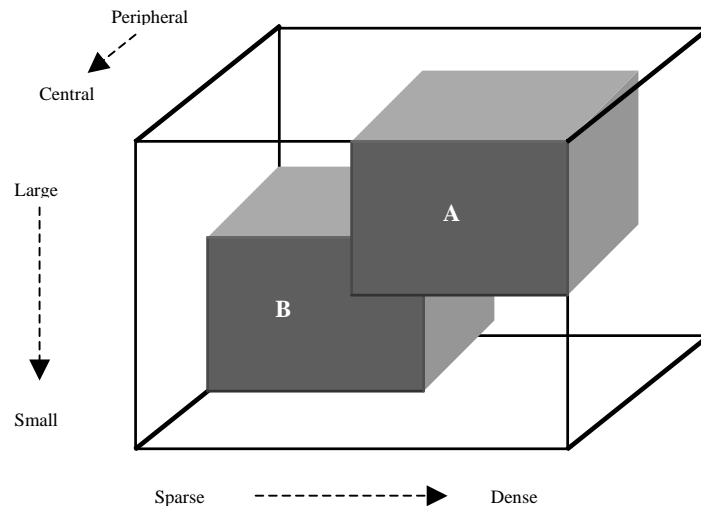

Figure 3.3 Characterization of regions

Unlike small regions, large regions are able to host a larger number and set of the strategic actors and are also able to attract actors to a greater extent. Intraregional accessibility is most likely to be the relevant accessibility for these regions. It can be improved by either attracting more strategic actors or decrease the intraregional time distances or both. Clearly, it is of advantage to use both means. However, if a region already hosts all the strategic actors, it should focus on improving the time distance within the region. This is especially important if the region is sparsely populated. Interaction between the actors is the driving force behind the creation of new knowledge and the relation between the intensity of interaction and time distances is well established. The above is true for both large central and large peripheral regions. However, it should be mentioned that large central regions have greater opportunities to develop successful innovation systems than peripheral ones. Since smaller regions are likely to try to link their actors to actors in larger regions, a large central region will always have access to a more diverse set of actors than large peripheral regions. Given that the accessibility to the surrounding smaller regions gets sufficiently low, the innovation systems of large central regions may eventually converge with that of smaller surrounding regions. Here it is possible to talk about regional enlargement since the borders of a region, as defined in this chapter, are determined by the intensity of interaction. Thus,

cumulative effects are possible to take place. These outcomes are not achievable in large peripheral regions since the accessibility to other regions is not likely to reach sufficient levels.

The role of local accessibility has not been addressed so far. Referring to Table 3.2, local accessibility is relevant in the time span in which people are willing to travel to take part in different sorts of communities, etc, after working hours. Local accessibility is therefore likely to have a role to play for the functioning of the meeting arenas discussed earlier.

An important observation to be made from this section has to do with the borders of the regional innovation systems in different regions. In the framework presented here, it is evident that a small region cannot develop a coherent innovation system if it is to be constrained to the resources within its own borders. Therefore, a coherent innovation system of a small region should not be termed 'regional'. Rather, the actors of a small region may be part of a coherent innovation system constituted by a network between a set of smaller regions and/or links to a larger region. Small regions are strongly dependent upon external resources and subsequently on interregional accessibility. Coherent regional innovation systems seem to be the case for large regions able to host a diverse set of strategic actors.

4. CONCLUSIONS

The role of proximity for innovations has been the subject of an extensive amount of research in recent years. This chapter has proposed that proximity should be replaced by the more concrete and operational concept of accessibility. The aim has been to make a strong case for the hypothesis that there is a close link between regional accessibility and the performance of regional innovation systems. To simplify the analysis, regional accessibility has been decomposed into local, intraregional and interregional accessibility. The analysis suggests that the current state-of-the-art research on regional innovation systems can be improved by incorporating the accessibility concept.

It has been advanced that the successfulness of the processes stressed to be important in the systemic approach to innovation is to a large extent likely to be determined by the accessibility to FTF-contacts. Therefore, much empirical research remains to be done to explicitly scrutinize the relationship between regional accessibility and regional innovation performance. Moreover, the analysis demonstrates that such studies should employ time distance instead of geographical distance, since the former is the relevant factor in determining the willingness to make a trip. Empirical studies show that there is a palpable relationship between time distance as regards commuting intensity and the intensity of business interaction.

It has been maintained that the distinction between local, intraregional and interregional accessibility ought to be important to be able to reveal differences across regions as regards the relative importance of a region's external and internal resources. Against the background of the distinction between different types of accessibilities, a case has been made that the size and location of a region have important implications for its suppositions to develop a coherent regional innovation system. In particular, the chapter questions the ability of a small region to develop a coherent regional innovation system.

NOTES

1. We define a successful innovation system as an innovation system in which the actors are engaged in frequent interaction and which is able to create innovations. This definition will be used throughout the chapter.
2. Since a search on ECONLIT with "innovation" and "accessibility" as keywords only generates 10 matches, this statement is justified. The search was made in October 2002.
3. The figure is based on observed travel-time distances during the period 1990-1997 for 1 979 different travel links. The time distance is the shortest travel time over the modes car, train and air. For more details about the data, see Hugosson (2001).
4. In Johansson et al (2002), it is also shown that the time sensitivity w.r.t commuting is different between females and males, as well as that there are differences between education categories. Specifically, females are more time sensitive than males and well-educated people are less sensitive than people with lower education. Also, the difference between males and females is present for education categories.
5. We are grateful to an anonymous referee for this suggestion.
6. Observe that in the above equations, it is implicitly assumed that the time sensitivity parameter for intraregional interaction, $\lambda 2$, is constant over time. It is of course possible, both empirically and theoretically, to let it be time-dependent.
7. A small region is not likely to be able to affect the location of actors in other regions in any significant way.

REFERENCES

Andersson, M. and C. Karlsson (2002), *Regional Innovation Systems in Small & Medium Sized Regions - a Critical Review & Assessment*, JIBS Working Paper Series No. 2002-2.

Anselin, L., A. Varga and Z. Acs (1996), 'Local Geographic Spillovers between University Research and High Technology Innovations', *Journal of Urban Economics*, **42**, 422-448.

Asheim, B. and A. Isaksen (1996), *Location, Agglomeration and Innovation: Towards Regional Innovation Systems in Norway*, Oslo: STEP Report R-13.

Baptista, R. (2000), 'Do Innovations Diffuse Faster within Geographical Clusters?', *International Journal of Industrial Organization*, **18**, 515-535.

Batten, D., C. Bertuglia, D. Martellato and S. Occelli (eds) (2000), *Learning, Innovation and the Urban Evolution*, London: Kluwer Academic Publishers.

Beckman, M. (2000), 'Interurban Knowledge Networks', in Batten, D. et al (eds) (2000), *Learning, Innovation and the Urban Evolution*, London: Kluwer Academic Publishers.

Beckman, M., B. Johansson, F. Snickars and R. Thord (eds) (1998), *Knowledge and Networks in a Dynamic Economy,* Berlin*:* Springer-Verlag.

Bertuglia, C. and S. Occelli (2000), 'Impact of New Information Technologies on Economic-Spatial Systems: Towards an Agenda for Future Research', in Batten, D. et al (eds) (2000), *Learning, Innovation and the Urban Evolution*, London: Kluwer Academic Publishers.

Blind, K. and H. Grupp (1999), 'Interdependencies between the Science and Technology Infrastructure and Innovation Activities in German Regions: Empirical Findings and Policy Consequence', *Research Policy*, **28**, 451-468.

Breschi, S. and F. Malerba (1997), 'Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics and Spatial Boundaries', in Edquist, C. (ed). (1997), *Systems of Innovation: Technologies, Institutions and Organizations*, London: Pinter.

Breschi, S. and F. Lissoni (2001a), 'Knowledge Spillovers and Local Innovation Systems: a Critical Survey', *Industrial and Corporate Change*, **10**, 975-1005.

Breschi, S. and F. Lissoni (2001b), 'Localized Knowledge Spillovers vs. Innovative Milieux: Knowledge Taciteness Reconsidered', *Papers in Regional Science*, **80**, 255-273.

Capello, R. (2001), 'Urban Innovation and Collective Learning: Theory and Evidence from Five Metropolitan Cities in Europe', in Fischer, M. and J. Fröhlich (2001), *Knowledge, Complexity and Innovation Systems*, Berlin: Springer-Verlag.

Echeverri-Carroll, E. and W. Brennan (1999), 'Are Innovation Networks Bounded by Proximity?', in Fischer, M., I. Suarez-Villa and Steiner, M. (1999), *Innovation Networks and Localities*, Berlin: Springer-Verlag.

Edquist, C. (ed). (1997a), *Systems of Innovation: Technologies, Institutions and Organizations*, London,: Pinter.

Edquist, C. (1997b), 'Systems of Innovation Approaches – their emergence and characteristics', in Edquist, C. (ed) (1997), *Systems of Innovation: Technologies, Institutions and Organizations*, London: Pinter.

Etkzkowitz, H. and L. Leydesdorff (2000), 'The dynamics of Innovation: from National Systems and Mode 2 to a Triple Helix of University-Industry-Government Relations', *Research Policy*, **29**, 109-123.

Feldman, M. (1994), *The Geography of Innovations*, Boston: Kluwer Academic Publishers.

Feldman, M. and D. Audretsch (1999), 'Innovation in Cities: Science-Based Diversity, Specialization and Localized Competition', *European Economic Review*, **43**, 409-429.

Fischer, M., L. Suarez-Villa and M. Steiner (1999), *Innovation Networks and Localities*, Berlin: Springer-Verlag.

Fischer, M and A. Varga (2001), *Production of Knowledge and Geographical Mediated Knowledge Spillovers from Universities: a Spatial Econometric Approach*, Mimeograph, JIBS.

Fischer, M. and J. Fröhlich (2001), *Knowledge, Complexity and Innovation Systems*, Berlin: Springer-Verlag.

Fischer, M. (2001), 'Innovation, Knowledge Creation and Systems of Innovation', *The Annals of Regional Science*, **3**, 199-216.

Grimaldi, R. and S. Torrisi (2001), 'Codified-Tacit and General-Specific Knowledge in the Division of Labor among Firms: a Study of the Software Industry', *Research Policy*, **30**, 1425-1442.

Harrison, B. (1996), 'Innovative Firm Behavior and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects and Technological Change', *Economic Geography*, **72**, 233-258.

Hugosson, P. (2001), *Interregional Business Travel and the Economics of Business Interaction*, JIBS Dissertation Series No. 009, Jönköping International Business School.

Hägerstrand, T. (1970), 'What about people in regional science?', *Regional Science Association Papers*, **24**, 7-21.

Jaffe, A., M. Trajtenberg and R. Henderson (1993), 'Geographic Spillovers of Knowledge as Evidenced by Patent Citation', *The Quarterly Journal of Economics*, **8**, 577-598.

Johansson, B. (1992), *Ekonomisk Dynamik i Europa* (Economic Dynamics in Europé), Malmö: Liber-Hermods.

Johansson, B. and J. Klaesson (2001), *Förhandsanalys av Förändringar i Transport- och Bebyggelsesystem*, JIBS.

Johansson, B., J. Klaesson and M. Olsson (2002), 'Time Distances and Labor Market Integration', *Papers in Regional Science*, 305-327.

Johansson, B., C. Karlsson and R. Stough (eds) (2001), *Theories of Endogenous Regional Growth – Lessons for Regional Policies*, Berlin: Springer-Verlag.

Jonsson, O., H. Persson and U. Silbersky (2000), *Innovativitet och regionen – Företag, Processer och Politik*, Swedish Institute for Regional Research.

Karlsson, C. (1997), 'Product Developments, Innovation Networks, Infrastructure and Agglomeration Economies', *The Annals of Regional Science*, **31**, 235-58.

Karlsson, C. (2001), *Klusters Betydelse för Industriell & Regional Utveckling* (The Role of Clusters for Industrial & Regional Economic Development), Mimeograph, JIBS.

Karlsson, C. and A. Manduchi (2001), 'Knowledge Spillovers in a Spatial Context', in Fischer, M. and J. Fröhlich (2001), *Knowledge, Complexity and Innovation Systems*, Berlin: Springer-Verlag.

Klaesson, J. (2001), *Spatial Interaction Models and Concepts: a Review of the Gravity Theory*, Mimeograph, JIBS.

Kobayashi, K. and K. Fukuyama (1998), 'Human Contacts in Knowledge Society: an Analytical Perspective', in Beckman, M. et al (eds) (1998), *Knowledge and Networks in a Dynamic Economy,* Berlin: Springer-Verlag.

Koschatzky, K. (2001), *Regional Development through Entrepreneurship Promotion? The Role of Higher Education Institutes for Stimulating Firm Foundations*, Paper presented at the 41st Congress of the ERSA, Zagreb, Croatia.

Krugman, P. (1991), 'Increasing Returns and Economic Geography', *Journal of Political Economy*, **99**, 483-499.

Lagendijk, A. (2001), 'Scaling Knowledge Production: How Important is the Region?', in Fischer, M. and J. Fröhlich (2001), *Knowledge, Complexity and Innovation Systems*, Berlin: Springer-Verlag.

Lawson, C. and E. Lorenz (1999), 'Collective Learning, Tacit Knowledge and Regional Innovative Capacity', *Regional Studies*, **33** (4), 305-317.

Leonard, D. and S. Sensiper (1998), 'The Role of Tacit Knowledge in Group Innovation', *California Management Review*, **40** (3), 112-131.

Lorenzen, M. (1996), *Communicating Trust in Industrial Districts*, Mimeograph, JIBS.

Lorenzen, M. (1998), *Localized Learning – Why are Inter-Firm Learning Patterns Institutionalized within Particular Localities?*, Mimeograph, JIBS.

Lubit. R. (2001), 'Tacit Knowledge and Knowledge Management: the Keys to Sustainable Competitive Advantage', *Organizational Dynamics*, **29** (4), 164-178.

Lundvall, B., E. (1995), *National Systems of Innovation - Towards a Theory of Innovation and Interactive Learning*, London: Biddles Ltd.

Maillat, D. (1995), 'Territorial Dynamic, Innovative Milieus and Regional Policy', *Entrepreneurship & Regional Development*, **7**, 157-165.

Maillat, D. and L. Kebir (2001), 'The Learning Region and Territorial Production Systems', in Johansson, B., C. Karlsson and R. Stough (eds) (2001), *Theories of Endogenous Regional Growth – Lessons for Regional Policies*, Berlin: Springer-Verlag.

Marshall, A. (1948), *Principles of Economics* 8ed 6th Print, New York: The Macmillian Company.

Maurseth, P. and B. Verspagen (1998), *Knowledge Spillovers in Europe and its Consequence for Systems of Innovations*, ECIS Working Paper No. 98.1.

Meeus, M., L. Oerlemans and J. van Dijck (1999), *Regional Systems of Innovation from within – an Empirical Specification of the Relation Between Technological Dynamics and Interaction Between Multiple Actors in a Dutch Region*, ECIS Working Paper No. 99.1.

Nelson, R. and N. Rosenberg (1993), 'Technical Innovation and National Systems', in Nelson, R. (ed) (1993), *National Innovation Systems – a Comparative Analysis*, New York: Oxford University Press.

Occelli, S. and T. Gallino (1992), *Un'analisi dell'accessibilità in Piemonte: note metododologiche ed applicazione empirica di alcuni indicatori*, Atti della XIII conferenza Italiana de Scienze Regionali, Ancoa, 337-68.

Rothwell, R. (1992), 'Successful Industrial Innovation: Critical Factors for the 1990s', *R&D Management*, **22**, 3, 221-239.

Saviotti, P. (1998), 'On the Dynamics of Appropriability of Tacit and of Codified Knowledge', *Research Policy*, **26**, 843-856.

Seng, S. (1996), 'Some Tests of Alternative Accessibility Measures: a Population Density approach', *Land Economics*, **72**, 4, 474-482.

Shefer, D. and A. Frenkel (1997), *Local Milieu and Innovations: Some Empirical Results*, Paper presented at the 37th European Congress in Rome, Italy, 26-29 August 1997.

Storper, M. (1995), 'The Resurgence of Regional Economies, Ten Years Later: the Region as a Nexus of Untraded Interdependencies', *European Urban and Regional Studies*, **2** (3), 191-215.

Teece, D.J. (1996), 'Firm Organization, Industrial Structure and Technological Innovation, *Journal of Economic Behavior & Organization*, **31**, 193-224.

Törnquist, G. (1996), *Sverige i Nätverkens Europa: Gränsöverskridandets Former och Villkor*, Malmö: Liber-Hermods.

Varga, A. (1998), *University Research and Regional Innovation – a Spatial Econometric Analysis of Academic Technology Transfers*, Massachusetts: Kluwer Academic Publishers.

Varga, A. (2001),'Universities and Regional Economic Development: Does Agglomeration Matter?', in Johansson, B et al (eds). (2001), *Theories of Endogenous Regional Growth – Lessons for Regional Policies*, Berlin: Springer-Verlag.

Weibull, J. (1976), 'An Axiomatic approach to the Measurement of Accessibility', *Regional Science & Urban Economics*, **6**, 357-379.

Weibull, J. (1980), 'On the Numerical Measurement of Accessibility,' *Environmental Planning A*, 12, 53–67.

Wiig, H. & Wood, M. (1995), *What Comprises a Regional Innovation System? – An Empirical Study*, STEP Working Paper R-01, Oslo