The Role of Accessibility for Regional Innovation Systems

by

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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 claimed 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 on the issue of the importance of knowledge spillovers.

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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 system. 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). However, earlier research has failed to provide meaningful operationalizations of the proximity concept in the innovation process. In this paper we claim the concept of accessibility can be used to provide meaningful and useful operationalizations of the proximity concept. Surprisingly, there is essentially nothing in the literature that explicitly discusses the relationship between accessibility and the performance of regional innovation systems. This is a major flaw since accessibility is strongly related to ease of interaction. Against this background, it is maintained in this paper that there is a close link between accessibility and the performance of regional innovation systems. It is, for example, 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 paper 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 labeled 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 determined by a region's accessibility to personal contacts. The accessibility to interact with other actors is critical for knowledge exchange between firms within and between regions.

In the context of accessibility, it is necessary to make a distinction between different types of accessibility. This paper 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 clear policy guidelines to be formulated.

The purpose of the paper 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. In particular, 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 this paper is organized as follows; 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 paper.

2 Regional Innovation Systems & Accessibility

This section explains the close link between accessibility and the functioning regional innovation systems and examines the extent their performance of regional innovation systems is dependent upon accessibility.

2.1 Interaction, Knowledge & 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, 2001). 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, as noted by Karlsson & Manduchi (2001), 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 demand different communication channels, (see inter alia Wallsten, 2001). 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, (see e.g. 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 (op. cit., p.104) who distinguish between three broad kinds of knowledge, namely (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 both 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 & Lionni (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 of different regions as well as the 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 3.1.

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, i.e. 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.

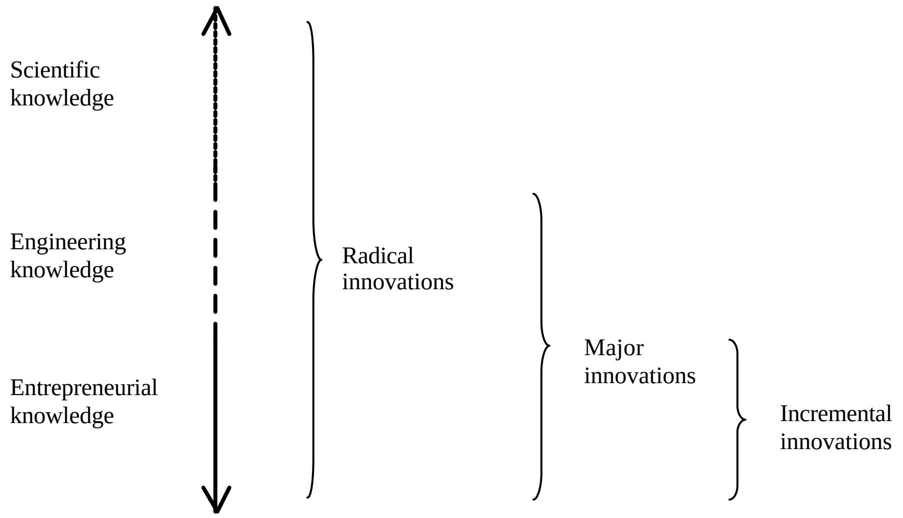

Figure 2.1. Depiction of the link between knowledge types and innovations.

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, op. cit.). 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, op. cit.). The degree of explicitness is low in the development stage of new knowledge. Lawson & Lorenz (op. cit.) 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.

Two objections may however be raised against this line of reasoning. First and foremost, a firm is most likely reluctant to share new ideas with competitors. A counterargument against this is that the mode of exchange for tacit knowledge is spillovers, which are positive externalities rather than planned activities. This implies that exchange occurs implicitly. As such, it can be considered as public good, mutually beneficial for all firms receiving it. Furthermore, exchange of tacit knowledge necessitates that both the receiver and the transmitter are familiar with the "code" of the tacit knowledge, (see Saviotti, op. cit.). Reciprocal understanding of codes demand prolonged interaction between the transmitter and the receiver. Lawson & Lorenz (op. cit.) 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.

From this overview it follows that a regional economic milieu characterized by proximity between actors and arenas for interaction is suitable for establishing and maintaining successful regional innovation systems. Since exchange of tacit knowledge demand FTF-contacts, time distance is a major factor in determining its intensity and frequency. Moreover, it has also been concluded that scientific knowledge is important for firms' ability to generate more radical innovations. This suggests that the presence of universities, research institutes and other knowledge providers in a region should play an important role in boosting the capabilities of the regional innovation system.

2.2 Proximity & 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, 1998). In particular, regional clusters are argued to create superlative suppositions for a well-functioning regional innovation system, (see e.g. Asheim & Isaksen, op. cit.).

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; Wiig & Wood, op. cit.). 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 (loc. cit.) 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 (op. cit.) untraded interdependencies and Maillat's (op. cit.) 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;

> "…by 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), for example, 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 between 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, empirical evidence does suggest that knowledge spillovers and innovation output coincide in space. 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 that "…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, (see e.g. Etkzkowitz & Leydesdorff, 2000). Koschatzky (2001, p.3) stresses that Higher Research Institutes (HEIs) generally fulfill two main functions in a region since 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, (see e.g. Etkzkowitz & Leydesdorff, op. cit.). Hence, they counteract lock-in situations and lower the risk of structural unemployment. In addition, Koschatzky (loc. cit.) 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 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.

It can be concluded that the current research on innovation regards proximity as vital for a successful innovation performance at the regional level, mainly because knowledge exchange requires FTF-contacts. It is commonly argued that clusters constitute exceptional bases for innovative activities. Meantime, several empirical studies claim to have found evidence for knowledge spillovers.

3 Accessibility & the Performance of a Regional Innovation System

3.1 The Unexploited Link between Innovation & Accessibility

As the title of this section suggests, the relationship between accessibility and innovation is indeed unexploited[1]. 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. For example, 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 (op. cit.) 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. Time distances are also critical when it comes to spatial borders of labor markets and intense business collaboration, i.e. business trips. Johansson & Klaesson (2001) show that there is a threshold time distance for commuting, approximately around 45 minutes. 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. Similar threshold time distances can be found for business travels. For example, 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. Hugosson (1998) derives a relationship such as shown in Figure 2.2. between interregional business FTF-

[1] Since a search on ECONLIT with "innovation" and "accessibility" as keywords only generates 10 matches, this statement is justified. (The search was made in January 2002).

contacts and time distances. It clearly shows that frequency is dependent upon time distance and that there is a critical time distance interval between 60 and 180 minutes[2].

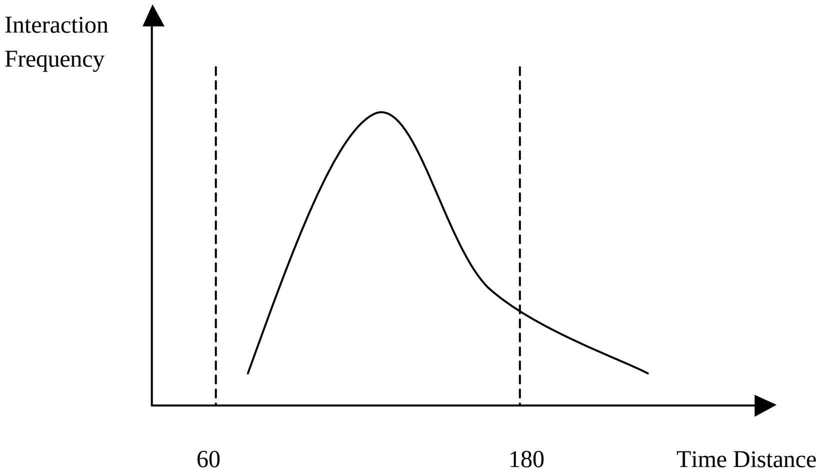

Figure 2.2. The relationship between time distance and the frequency of long-distance interregional business FTF-interactions, (Hugosson, 1998)

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.

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 2.2. below 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. The individuals function as nodes that absorb ideas and the meetings as “arenas” in which ideas are exchanged, (ibid.). 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.

2 The figure is based on data covering business trips longer than 100 kilometers. This is the reason for the lower frequency at short time distances.

Table 2.2. 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 shows that there is a paramount link between accessibility and the performance of regional innovation systems. Firstly, 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.

3.2 Accessibility Defined

Having made the link between accessibility and innovation clear, 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 regions. The accessibility of region i (within the n regions) to itself and to the n-1 surrounding regions can be defined as follows,

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

, where T_i is the total accessibility of region i. D is a measure of opportunities in each region, which can be opportunities such as suppliers, customers, producer services, educated labor, universities and R&D institutes, etc, (see inter alia Klaesson, 2001). A region'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 regions in the set n. $f(c)$ is the Distance Decay function that determines how the accessibility value is related to the cost of reaching the opportunity, (see e.g. Andersson & Johansson, 1995). Different researchers have used different specifications of this relationship, (Seng, 2001). One of the most common approximations is made by means of an exponential function, (Johansson & Klaesson, op. cit.; Johansson et al, 2001). Applying an exponential function, the distance decay function takes the following form,

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

, where t_{ij} is the time distance between region i and j and λ[3] 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 region i to opportunity D is defined in Equation (3.3).

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

3.3 Defining the Region & Division of Accessibility

Following the recommendations in Andersson & Karlsson (op. cit.), a region can be defined 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 and relevant to divide a region's total accessibility to some opportunity D (A_R^D) into three parts, as shown in Equation (3.4) below,

(3.4) $$A_R^D = A_{RL}^D + A_{RI}^D + A_{RE}^D$$

, where A_{RL}^D, A_{RI}^D and A_{RE}^D express local accessibility, intraregional accessibility and interregional accessibility respectively. Table 3.1. lists and describes the different categories of accessibility.

Table 3.1. Categories of accessibility.

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

As seen in Table 3.1, local accessibility is relevant to 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.

Letting i denote a specific node (e.g. a municipality) within a functional region R, j denote all other nodes within R, q_i node i's weight, (for example the share of region R's population) and r a functional region other than R, the three categories of accessibility can formally be expressed in the following way (D is an unspecified opportunity);

(i). Local accessibility $\Rightarrow A_{RL}^D = \sum_{i \in R} D_i \exp\{-\lambda t_{ii}\} q_i$

(ii). Intraregional accessibility $\Rightarrow A_{RI}^D = \sum_{i \in R} \sum_{j \in R} D_j \exp\{-\lambda t_{ij}\} q_i$

[3] λ can be estimated by means of a doubly constrained gravity model.

(iii). Interregional accessibility $\Rightarrow A_{RE}^{D} = \sum_{r \notin R} D_r \exp\{- l t_{Rr}\}$

The equations reveal that local accessibility refers to the sum of each nodes' weighted accessibility to itself in region *R*. Intraregional accessibility refers to the sum of all nodes' weighted accessibility to all other nodes within region *R*. Interregional accessibility is the sum of a region *R*'s accessibility to all regions *r* outside region *R*.

Given the approximate time distances set out in Table 3.1., 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 are 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 (op. cit.) 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 (3.5a) and (3.5b) symbolize the accessibility value to other nodes, (located in the same region), at time (t) and $(t + t)$, respectively, of a representative node within a functional region *R*. The change in the accessibility value from time *(t)* to time $(t + t)$ can then simply be described as in Equation (3.6)[4].

(3.5a) $$A_i^D(t) = \sum_{j \in R} D_j \exp\{- l t_{ij}(t)\}$$

(3.5b) $$A_i^D(t + t) = \sum_{j \in R} D_j \exp\{- l t_{ij}(t + t)\}$$

(3.6) $$\Delta A_i^D(t + t) = A_i^D(t + t) - A_i^D(t)$$

The causes of the change $\Delta A_i^D(t + t)$ can be divided into (i) $\Delta t_{ij} = t_{ij}(t + t) - t_{ij}(t)$ and (ii) $\Delta D_j = D_j(t + t) - D_j(t)$ for each node in region *R*. The decomposition can then be made as in Equation (3.7).

(3.7) $$\Delta A_i^D = \sum_{j \in R} D_j \exp\{- l t_{ij}(t + t)\} - A_i^D(t) + \sum_{j \in R} \Delta D_j \exp\{- l t_{ij}(t + t)\}$$

In Equation (3.7) the expression, $\sum_{j \in R} D_j \exp\{- l t_{ij}(t + t)\} - A_i^D(t)$, shows the total the time effect and $\sum_{j \in R} \Delta D_j \exp\{- l t_{ij}(t + t)\}$ is the localization effect. The change in the

[4] q is dropped in the example for simplicity.

intraregional accessibility of the functional region R would then be (n is the total number of nodes in the functional region),

(3.8) $$\Delta A_{RI}^{D} = \frac{1}{n}\sum_{i=1}^{n}\Delta A_{i}^{D}$$

, i.e. simply the average of the change in each nodes' accessibility to other nodes within the functional region. Similarly, the localization effect (ΔAl_{RI}^{D}) and the time effect $\left(\Delta At_{RI}^{D}\right)$ of the whole functional region R can be expressed as in Equations (3.9) and (3.10), respectively.

(3.9) $$\Delta Al_{RI}^{D} = \frac{1}{n}\sum_{i\in R}\sum_{j\in R}\Delta D_{j}\exp\left\{-l t_{ij}(t+t)\right\}$$

(3.10) $$\Delta At_{RI}^{D} = \frac{1}{n}\left(\sum_{i\in R}\sum_{j\in R}D_{j}\exp\left\{-l t_{ij}(t+t)\right\} - A_{i}^{D}(t)\right)$$

The method suggested by Johansson & Klaesson (op. cit.) reveals that the 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.

3.4 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 (op. cit., 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; (i) the manufacturing sector, (ii) the scientific sector, (iii) the sector of producer services and (iv) the institutional sector. According to the Fischer, 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 Figure 3.1. The components are interrelated with each other and their interaction generates new knowledge into the innovation system through knowledge exchange. Such exchange is facilitated by formal as well as informal institutions, whose borders are defined by the borders of the region. Each component can be seen as a sub-system, (ibid.), 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. This picture, however, from one region to another.

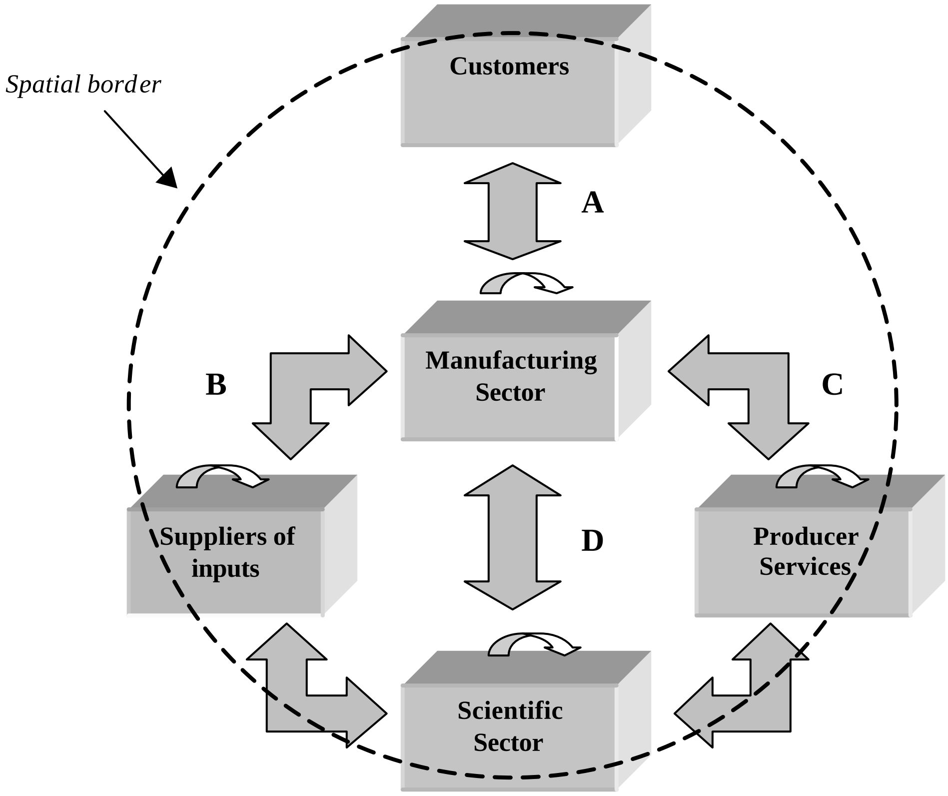

Figure 3.1. Main components and relationships in a coherent regional innovation system, (adapted from Fischer, 2001).

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 (op. cit.). Similar conclusions are made by Karlsson (1997), though referring to relevant actors in innovation networks. This makes it possible to be more precise as regards the important actors firms need to have accessibility to. 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. Opportunities of personal interaction like these, 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.

3.5 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 3.2. 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.

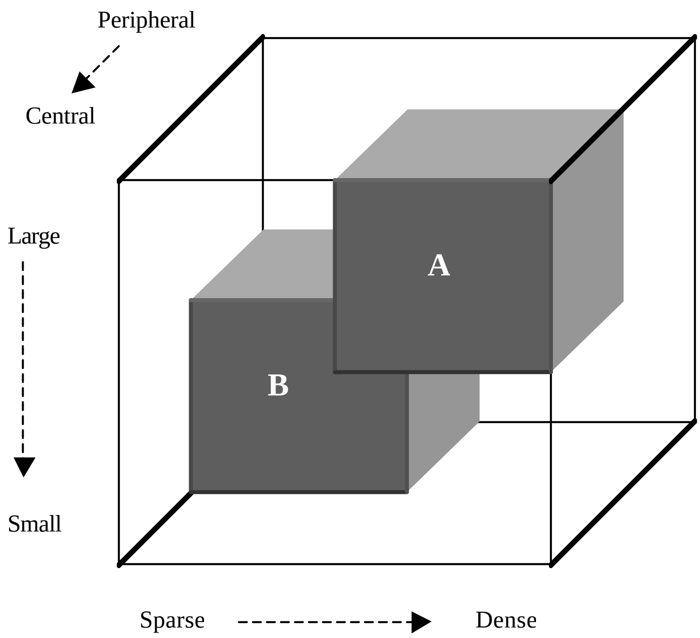

Figure 3.2. Characterization of regions

There are two ways to improve the accessibility value, either by (1) an increase of the size of the opportunity in destinations or by (2) a decrease in the time distance between the locations in question. With this in mind, the subsequent text will not only discuss which of the accessibilities are likely to be most important for different regions defined according to Figure 3.2 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 mean to improve the accessibility is by decreasing the interregional time distance[5]. Obviously, tying the

[5] A small region is not likely to be able to affect the location of actors in other regions in any significant way

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.

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 paper, 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 3.1., 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 Concluding Comments

The role of proximity for innovations has been the subject of an extensive amount of research in recent years. This paper 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 makes it clear that the current state-of-the-art research on regional innovation systems can be improved by incorporating the accessibility concept.

It has been shown that the successfulness of the processes stressed to be important in the systemic approach to innovation is to a large extent 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.

The distinction between local, intraregional and interregional accessibility has been shown to be essential 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 paper questions the ability of a small region to develop a coherent regional innovation system.

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