Proximity and Innovation Through an "Accessibility to Knowledge" Lens

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Through an "Accessibility to Knowledge" Lens

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Abstract:

The aim of this paper is to improve our understanding of the spatial diffusion process of knowledge in terms of *accessibility,* and also to elaborate a new measurement and evaluation tools adapted to a concrete estimation of these phenomena.

This approach offers ways of giving an operational content to the concept of proximity. We enrich the "potential functions" used to measure geographical accessibility with the integration of the characteristics of knowledge diffusion, namely sources of externalities/knowledge, ways of transmission and absorptive capacity. We especially focus on the relational and strategic dimensions of proximity, using some developments from social networks analysis.

Such an approach leads to new empirical models for estimating the determinants of accessibility to knowledge.

Key words: knowledge diffusion, accessibility, geographical proximity, social proximity, networks

JEL classifications: O3, R12, R58

Résumé :

Le but de cet article est à la fois d'améliorer notre compréhension des processus de diffusion spatiale des connaissances et d'élaborer de nouvelles mesures et outils d'évaluation adaptés à une estimation concrète de ces phénomènes en termes *d'accessibilité*.

L'approche en termes d'accessibilité aux connaissances ouvre la voie à une opérationalisation du concept de proximité. Aux « fonctions de potentiel » utilisées pour mesurer la proximité géographique nous intégrons les caractéristiques de la diffusion des connaissances, à savoir les sources d'externalités/de connaissances ainsi que les moyens de transmission et la capacité d'absorption. En l'occurrence, nous mettons tout particulièrement l'accent sur les dimensions relationnelle et stratégique de la proximité en mobilisant certains développements de l'analyse des réseaux sociaux.

Une telle approche suggère de nouveaux modèles empiriques d'estimation des déterminants de l'accessibilité aux connaissances.

CRES-2006-0274.R1 (French abstract already provided)

Nähe und Innovation durch das Objektiv eines 'Zugangs zum Wissen'

Nadine MASSARD *and* Caroline MEHIER

Abstract:

Mit diesem Beitrag wird versucht, das Verständnis für den räumlichen Diffusionsprozess des Wissens im Hinblick auf den Zugang zu verbessern und neue

Mess- und Bewertungsinstrumente zu entwickeln, die sich für eine konkrete Schätzung dieser Phänomene eignen.

Dieser Ansatz bietet die Möglichkeit, dem Konzept der Nähe einen funktionalen Inhalt zu verleihen. Wir ergänzen die zur Messung des geografischen Zugangs verwendeten 'Potenzialfunktionen' durch die Integration der Merkmale der Wissensdiffusion, nämlich der Quellen von Externalitäten bzw. Wissen, der Übertragungswege sowie der Absorptionskapazität. Insbesondere konzentrieren wir uns auf die relationalen und strategischen Dimensionen der Nähe, wofür wir einige Entwicklungen aus der sozialen Netzwerkanalyse nutzen.

Ein solcher Ansatz führt zu neuen empirischen Modellen zur Schätzung der Determinanten eines Zugangs zum Wissen.

Key words:

Wissensdiffusion

Zugang

Geografische Nähe

Soziale Nähe

Netzwerke

JEL classifications: O3, R12, R58

Proximidad e innovación, vistas a través del objetivo de 'acceder al conocimiento'

Nadine MASSARD *and* **Caroline MEHIER**

Abstract:

El objetivo de este ensayo es conocer a fondo cuál es el proceso de divulgación espacial de los conocimientos en cuanto a la *accesibilidad,* y elaborar nuevas herramientas de medición y evaluación adaptadas para calcular concretamente estos fenómenos.

Este enfoque ofrece modos de aportar un contenido operativo al concepto de proximidad. Mejoramos las 'funciones potenciales' usadas para medir la accesibilidad geográfica con la integración de las características de la divulgación de conocimientos, es decir las fuentes de efectos

externos/conocimientos, los modos de transmisión y la capacidad absorbente. Prestamos especial atención a las dimensiones relacionales y estratégicas de proximidad usando algunos avances de los análisis de las redes sociales.
Esto nos lleva a nuevos modelos empíricos para calcular los determinantes del acceso al conocimiento.

Key words:
Divulgación del conocimiento
Accesibilidad
Proximidad geográfica
Proximidad social
Redes

JEL classifications: O3, R12, R58

I INTRODUCTION

It is now generally accepted that innovation has a strong locational component. Geographical knowledge externalities are at the heart of an understanding of the role of proximity in the innovation process. The association between externalities and proximity is however, far from obvious and deserves specification.

Various econometric studies on local externalities, assembled under the heading "geography of innovation"[1], have been developed aiming at the empirical estimation of the geographical dimension of technological externalities. A first assessment of the results obtained can show that geographical proximity as such is rarely sufficient to allow firms to benefit from knowledge spillovers. Firstly, innovation processes do not only involve local knowledge transfers. They mix together local and global exchanges. The model based on the strict dichotomy "tacit knowledge=local" and "codified knowledge=global" however, does not appear satisfactory. Secondly, geographical proximity is not the only one to play a role. Proximity effects can also pass through organisations or networks, so proximity can comprise a relational dimension. Nevertheless, the exact role of each of these forms of proximity and

the way they interact are not clear. Such ambiguities have given rise to theoretical returns aiming at highlighting the conditions under which knowledge (tacit or codified) can be exchanged at different geographical distances. The evolutionist literature, in particular, has focused on the "*local buzz-global pipeline*" issue. BATHELT *et al*. (2004, p. 38)[2] define the buzz as "*the information and communication ecology created by face-to-face contacts, co-presence and co-location of people and firms within the same industry and place or region*". Buzz does not require any particular investments. Actors continuously contribute to and benefit from the diffusion of information, gossip and news by just "*being there*" (GERTLER, 1995). On the contrary, the term "*pipelines*" refers to the channels used in distant interactions. Here, the establishment of relations with new partners takes time and involves costs. The advantages of global pipelines are associated with the openness of clusters which can feed the local buzz and avoid the lock-in or over-embeddedness phenomena. Nevertheless, the debate is not closed because this approach leads to another dichotomy which is open to criticism: "geographical proximity = buzz" and "relational proximity = global pipelines". AMIN and COHENDET (2005), by contrast, reconsider the local/global relation through a firm perspective and argue that buzz can take place at a great distance through virtual relations thanks to relational proximity. The corporate goal of "*being there*" is no longer a question of location, it is a question of mobilizing "*a network of both contiguous and non-contiguous relations of varying length, shape and duration, where knowing can involve all manner of spatial mobilizations*" (AMIN and COHENDET, 2005, p.465). According to this approach, relational proximity is what really matters.

ASHEIM *et al.* (2006) also consider that face-to-face (thereafter F2F) and buzz should not be conflated. They argue that "*face-to-face primarily refers to the multidimensional aspects of communications that require physical contact. It covers deliberate knowledge exchange in mainly formal collaborations, (while) buzz refers to rumours, impressions,*

recommendations, trade folklore and strategic information (so to non deliberate knowledge and information exchange propensities). Thus, it is predominantly about knowledge spillovers" (ASHEIM *et al.*, 2006, p.10). This allows them to distinguish between the relative importance of F2F and buzz for industries drawing on different knowledge bases and to show that the very spatial dimension of F2F as well as buzz can also vary according to this knowledge base.

At this point, and in order to disentangle the main conceptual arguments, it is clear that there is a lack of empirically sustained work on this topic. Most of the empirical studies in the geography of innovation have focused on the "buzz" considered as non deliberate and naturally emerging from the physical proximity over space. By contrast, very few elements have been provided concerning the role of relational proximity especially in its deliberate dimension in order to explain the geography of innovation[3].

In this paper our aim is to provide an alternative framework for the empirical study of knowledge diffusion over space. We propose to shift from a knowledge externality framework to an accessibility to knowledge one in order to take the micro-decision of actors (development of effective interactions which requires costly efforts) and social networks into account. That way, we go from a conception where the local environment is a source of unsolicited externalities from which firms may benefit by localizing nearby, to a conception of facilitated externalities arising from the actions of agents[4]. The Economics of Proximity (PECQUEUR and ZIMMERMAN, 2004), provides an interesting framework for the development of our perspective. The concern is an analysis of coordination by considering "situated agents", where situated means both where they are located in a geographical space but also how they are embedded in a system of relations that conditions their innovative activities. By using a multi-dimensional concept of proximity, including both geographical and non-geographical embeddedness, it is possible to analyze the way by which situated

agents access external knowledge. In this perspective[5], in accordance with ANDERSSON and KARLSSON (2004, p. 283) "*(…) we claim that the concept of accessibility can be used to provide meaningful and useful operationalization of proximity*" in the sense that it offers insights in the means of overcoming some of the difficulties we face when we try to measure knowledge externalities on one hand, and when we try to bridge the gaps between "proximities" on the other hand. Especially it will enable us to propose measurement tools that have two main advantages compared to the current methodology. Firstly, being "point-based" (actors-based) instead of "zone-based" (KWAN, 1998), these tools go beyond a strict local/global dichotomy and allow us to estimate the diversity of the spatial dynamics at play. Secondly, they permit us to assess the role of the different forms of proximity (geographical and relationnal) in order to give an empirical answer to the following question : is the effect of one form of proximity completely integrated into the other (the geographical proximity as a pure reflection of the relational one) or is it possible to distingish these two effects (geographical proximity, as such, keeps a specific role once the effect of relational proximity is taken into account) ?

The common approach to model and measure knowledge externalities has been to consider the stock of external knowledge as an augmenting variable of a knowledge production function (ANSELIN *et al.* 1997; AUTANT-BERNARD, 2001). As we will see in section II below, this literature shows many improvements during the last decade. Diverse and more flexible functional forms of the function are estimated, externalities are more and more finely modelled, and the improvement in the methodologies of estimation allows us to better take into account the data characteristics (notably, count data or/and panel data) and the environment characteristics (using techniques of spatial econometrics for instance to account for the spatial dependence or the spatial heterogeneity of the phenomena observed). Consequently, our objective is not to propose alternative methodologies but rather to pinpoint

the necessary changes in the production function when switching from the externalities perspective to the accessibility one.

The paper proceeds as follows. In section 2, we analyze the grounds for the transition from an issue of geographic knowledge externalities to one of the accessibility to knowledge. Section 3 outlines the use of the traditional potential function as a way of measuring geographical accessibility. It shows that, in order to improve our measurement of accessibility to knowledge, the potential function must be enriched by taking the characteristics of knowledge diffusion into account. In section 4, methodological proposals are presented for the estimation of the role of accessibility to knowledge within knowledge production functions. Conclusions are given in section 5.

II FROM EXTERNALITIES TO ACCESSIBILITY TO KNOWLEDGE

II.1 The Measurements of Knowledge Externalities and Their Limitations

Two questions remain subjects for discussion when it comes to assessing the spatial effect of externalities. What is the spatial dimension of this diffusion? Does the conception of externalities in the strict sense, that is to say free and unintentional diffusion, really allow us to grasp the spatial dynamics of knowledge flows?

The estimation of the knowledge production function is used to provide a measure for these spillover phenomena (GRILICHES, 1979). As well as the variables characterising a given firm (E_i) and the intra-firm research inputs (R_i), externalities are gauged according to the external research stock (R_i^*) which itself represents the amount of research activities carried out by the other firms, contributing to the production of internal innovations (I_i). The elasticity of performance in terms of innovation towards an evolution of this stock (β_3) measures the effects of this externality as intangible input for the corporation and ε_i is a random disturbance.

$$I_i = \alpha\,(E_i)^{\beta 1}\,(R_i)^{\beta 2}\,(R_i^*)^{\beta 3}\,\varepsilon_i \qquad (1)$$

Measuring the geographical dimension of knowledge externalities consists for the main part in introducing the spatial dimension into the estimated knowledge production function. Two methods are used.

The first method, which was introduced by JAFFE (1989) and then elaborated upon by ACS *et al.* (1992), consists of introducing a 'coefficient of geographic coincidence' into the knowledge production function. The underlying assumption here is that if innovation grows when the geographic coincidence between the research inputs is high, we may then believe that the R&D efforts of some are reflected locally on the innovation of others, thus that externalities are localized in the specific area.

The second type of method implies the reversion to a definition of externalities as an external stock of knowledge and testing the relevant geographic level for the constitution of this external stock. In order to gauge spillovers at different geographic levels, ANSELIN *et al.* (1997) include as explanatory variables the private (R) and public (U) research expenses invested in the periphery of the metropolitan area (50 or 75 miles). The underlying assumption being that if the estimated variables at the closest geographic level have a more significant effect on the level of innovation, then a concentration or location of the externalities may be inferred.

The econometric studies concentrating on the demonstration of the existence of local effects, which are carried out according to this "geography of innovation" trend, are not without ambiguity. Several explanations to these ambiguous results may be suggested:

- In these works, the geographical area within which the externalities phenomena are studied is often predefined. If the local dimension exists however, it is far from exclusive. Corporations from a same location are actually influenced simultaneously by local knowledge flows and global flows.

- Moreover, the mere observation of the externalities within the defined zones

raises spatial autocorrelation issues since the knowledge flows cross the administrative borders and the regions are consequently not independent. The use of spatial econometric techniques enables us to measure the weight and geographical dimension of these interdependences and to take them into account in the regressions. Let us note however, that few authors in the geography of innovation use these techniques, except for ANSELIN *et al.* (2000) and PARENT and RIOU (2005).

- The diversity of the results obtained also indicates that having a much more accurate understanding of the externalities, i.e. by better specifying the sources, ways and conditions of transmission, is essential. The analysis of the nature of knowledge and the distinction between tacit and codified knowledge constitute key arguments in the geography of innovation by founding the significance of geographical proximity for the transmission of knowledge (GERTLER, 2003). Some will note however, that knowledge is not tacit or codified as such. This cannot be classed as an attribute of knowledge but is in fact largely due to appropriation strategies developed by the actors around such knowledge (BRESCHI and LISSONI, 2001). It might seem that knowledge flows actually measure an effort level emanating from the players as they seek to develop interactions generating knowledge transfers rather than "externalities" which could be seen as homogeneous flows evenly covering localized corporations within a given zone. Consequently, geographical proximity as such cannot be sufficient to benefit from technological spillovers; it has to be articulated with relational proximity. Real interactions need to be developed and costly efforts expended.

On the whole, most of the ambiguities observed concerning the measurement of the geographical dimension of externalities, may therefore be explained by three main limits that stand out from the measures carried out: an excessive local/global dichotomy (one would only need to conclude on either the localized or global nature of the externalities), a lack of micro foundations of the knowledge flows, some methodological difficulties due to spatial

autocorrelation.

In our opinion, addressing these limitations requires a change of approach towards fundamental questions. Indeed, the overall question of such a measurement is no longer: What geographical distance does knowledge spread to?, but, rather, Which strategies should be implemented to identify sources of externalities, construct means of transmission and build the necessary absorptive capacities in view of the fact that all of this implies costs?

II.2 Accessibility to Knowledge

As far as measurement is concerned, switching from the externalities issue to the one of accessibility to knowledge helps us to go beyond the methodological difficulties we underlined above.

- *Lack of micro-economic foundations*. Many works present "transmission mechanisms" and absorptive capacities as necessary conditions for externalities to occur. Thus, in a perspective of accessibility, we can consider knowledge flows as resulting from deliberate actions of agents, aiming at having access to knowledge at the lowest cost. ANDERSSON and EJERMO (2003; 2004) determine the opportunity cost of access to knowledge. They suggest pinpointing the efforts made to attain research by describing the fact that each research unit of a firm *k* seeks to maximize profits from its innovations, those profits being considered as dependent upon university and firm research expenses:

$$max\, Y_k = \max_{U,Rk} U^{\alpha} R_k^{\beta} - \tau_u U - \tau_R R_k \qquad (2)$$

where: τ_u is the average time/distance cost of access to university research (U); τ_R is the average time/distance cost of access to firm research (R) ; τ_u and τ_R are the opportunity costs of access to knowledge.

- *Excessive local/global dichotomy*. As a result, the challenge cannot be reduced to locating the existence or non-existence of local externalities but is about understanding in greater detail the determinants of a geographical diffusion differentiated from knowledge

flows. Thus, we share CRESCENZI's (2005, p. 12) view that "*Defined as relative opportunity of interaction and contact (sources of knowledge transfer) across geographical space afforded by location in a particular town or region, accessibility could be relevant to measure the "easiness" not only of local interactions but also of those taking place on a wider spatial scale*".

– *Methodological difficulties due to spatial autocorrelation.* Using spatial econometrics constitutes a real advance for the measurement of knowledge externalities. In addition to the fact that these techniques correct the estimation bias due to the spatial interdependences, they permit a more precise modelling of these interdependences, going beyond a pure local vs global dichotomy, so as to obtain a valid estimation of the geographical range of externalities. Such an approach however, keeps the "black box" on the microeconomic foundations of interdependences. Another method consists of modelling these interdependences as resulting from strategies of accessibility to external knowledge implemented by the local participants.

On the whole, such methodological issues lead to a shifting from a "zone-based" spatial framework to a point-based one (KWAN, 1998). Indeed, as shown by KWAN (1998), the zone-based perspective is prone to problems of aggregation and of intra/inter zone delimitations (as we noticed for the measurement of externalities). It is also not suitable for evaluating an individual's efforts to access knowledge. As we aim to emphasise the strategic determinants of accessibility, we need a point-based approach that permits us to grasp the individual characteristics determining accessibility to knowledge.

III ACCESSIBILITY FORMULATIONS AND CHARACTERISTICS OF KNOWLEDGE DIFFUSION

Measuring accessibility is an appropriate method for interpreting proximity since it is related to concepts such as the ease of spatial interaction and the potential of opportunities for interaction (see inter alia WEIBULL, 1980).

III.1 Usual Potential Functions

In geography, accessibility does not only refer to the possibility of just reaching a given location but also translates the difficulty of travelling and getting in touch. Integral measures of accessibility (via gravity and "cumulative-opportunity" type of indices) are presented as follows:

$$A_i = \sum_j g(W_j) f(c_{ij})$$

Where A_i, is the accessibility of region I; $g(W_j)$ is a measure of the attractiveness or weight, W_j, is the activity W to be reached in region j – activity function and c_{ij}, is the generalised cost of reaching region j from region i (measurement of impedance factor: distance, time, cost etc.) –in the impedance or weight function, f, expressing the 'resistance function').

Referring to the law of gravitation, the attraction of a distance body is supposed to be equal to its mass weighted by a decreasing function of its distance. So, considering the activities to be reached as being attractors and the distance as the impedance function (friction of time, distance…), several accessibility indicators can be elaborated upon (SCHUERMANN *et al.*, 1997; VICKERMAN *et al.*, 1999). In particular a "potential" accessibility formulation can be proposed.

[Table 1 : Typology of Accessibility Indices]

Initially, the geography of innovation has almost exclusively modeled the local effect by confining externalities within a zone (using daily accessibility function where $f(c) = 1$ inside the zone and $f(c) = 0$ out of the zone). ANDERSSON and KARLSSON (2004) and ANDERSSON and EJERMO (2004) use a potential function with exponential decrease to measure the accessibility of intra-corporation knowledge, inter-corporation knowledge and the accessibility to university research influencing the number of patents.

Such a use of the "potential" functions is however, still far from perfect when it comes to accessibility to knowledge. Although these types of indicators permit a fine analysis of transmission mechanisms, we generally observe rather simplistic formulations of the function.

III.2 Conditions for knowledge transfers to occur…

Beyond the usual potential functions, we assume that the definition of an accessibility measure should take into account the necessary conditions for knowledge diffusion to occur. These conditions should be characterized and integrated : i) existence at a location of a capacity to produce knowledge and put knowledge externalities forward; ii) existence in another location of a capacity to absorb this knowledge; iii) existence of means of transmission enabling these knowledge externalities to spread.

The necessary existence in a place of a capacity to produce knowledge and put knowledge externalities forward raises the question of the identification of knowledge sources describing the opportunities of interaction or, in this case, the definition of the activity function *W*. Two relevant distinctions of potential knowledge sources are usually made according to origins of spillovers. In the literature on geography of innovation, the distinction between university research expenses and private corporation research expenses is made, considering that these knowledge sources are likely to answer to different transferability mechanisms. The distinction between intra- and inter-sectoral knowledge sources is also made, based on the importance of creative processes resulting from cross-knowledge originating from different disciplinary and sectoral fields.

But as emphasized by COHEN and LEVINTHAL (1989, 1990), acquiring the results of R&D spillovers from other firms requires effort by the recipient firm. On the one hand, the absorptive capacity of the firm could be the ratio of *usable* to *actual* external R&D carried out by other firms and institutions (LEAHY and NEARY, 2004). On the other hand, a vector of variables could be used to represent both the absolute and relative firms' absorptive capacity

(see VINDING (2002) for instance). Finally, if the determinants of absorptive capacity differ depending on the knowledge sources (public/private, intra/inter-sectoral), the weight of internal R&D have to be put into perspective compared to a more organisational type of determinants, namely organisational structures and practices, knowledge management (SCHMIDT, 2005).

Finally, in reference to the works from HÄGERSTRAND (1967) on spatial diffusion of innovations, we assume that accessibility is connected to the spatio-temporal constraints of human activity and of those interactions which facilitate knowledge diffusion. Thanks to the space-time framework, geographers measure accessibility (see inter alia KWAN *et al.*, 2003) considering this one as the geographical area or the number of opportunities individuals can reach knowing the spatio-temporal characteristics of their daily activities (taking the sequence of the duration of these activities into account) and the fixed locations (home, office...) (KIM and KWAN, 2003). But, the operationalisation of such a measure in the geography of innovation remains difficult however. A possible way of taking these space-time constraints into account in an accessibility function would be to distinguish the friction coefficient according to the time frame of the trips. By using the characteristics of the resources mobility (ANDERSSON and MANTSINEN, 1980) and putting the emphasis on human transfers thereby allowing physical contacts, we can define the spatio-temporal "units" and distinguish different spatio-temporal characteristics of the trips: trips within a city and intra-regional or inter-regional trips, for instance.

III.3 …Through Networks

Moreover, we share KWAN's (1998) conclusions that accessibility is a context-dependent notion. By focusing on the access to external knowledge stock, we must pay attention - beyond individual determinants of decision - to global frames surrounding the (situated) agents: the firm, social networks, institutional and cultural environment. Situated

agent interactions reveal, to a certain extent, the "limits" of geographical proximity due to possible "local" divisions and tensions between actors. Thus, from a strategic point of view, in order to circumvent these negative effects and thanks to mobility, a "temporary" geographical proximity (TORRE and RALLET, 2005) allowing effective knowledge exchanges can be privileged. Moreover, this phenomenon might be all the more significant since the development of Information and Communication Technologies permits unplanned remote relations based on relational proximity once the first connexion is established. This could justify a trade-off between localisation proximate to sources, on the one hand, and remote localisation associated with an intensive use of ICT and social proximity, on the other hand. Consequently, to describe the determinants of knowledge transfer a better assessment of the relational proximity is needed.

If we consider social proximity as that resulting from the structure of the network of relations betweens actors, the indicators developed by the social network's theoreticians[6] can allow us to grasp accessibility to resources via networks. This network point of view allows us to provide operational measures of social proximity. Such measures result from the relative positioning of the agents within the relevant network. They can simply account for the notion of social or relational proximity between two agents on the one hand, or, on the other hand, address the more complex question of the strategic positioning of agents within the global structure of networks.

The main advantage of such a network approach is to capture two important features of accessibility to knowledge: agents can deliberately create links with others agents in order to access their knowledge, such knowledge transfers are costly. Consequently, agents have to choose their partners so as to access knowledge efficiently. We must therefore consider the observed networks as reflecting the incentives faced by actors; the geographical distance being only one element of these incentives. The relational network between agents can be

represented by a graph, that is to say a set of nodes (agents) connected by links (relations). Considering the process of knowledge transfer through the emitters-transmitters-receivers perspective, we could at first glance distinguish two types of agents in the network according to their diffusion or receptive role. Here, we are interested in cooperative relations based on knowledge barter. Indeed, many instances of knowledge transfers are deliberate and reciprocal and involve agents that are simultaneously both sources and receivers of knowledge. Indeed, the value of knowledge is difficult to assess ex-ante, so knowledge barter is often the main incentive to cooperate (HELSLEY and STRANGE, 2004).

The simplest measure of distance through relational networks is the *geodesic distance* between two agents. A *path* is a sequence of links between two agents such as $g_{i1,i2} = g_{i2,i3} = \ldots g_{ik-1,ik} = 1$ where $i1=i$ *and* $ik=j$. The *geodesic distance* between two agents i and j is the number of links of the shortest path between them. The distance is considered as infinite when there is no *path* between two agents. If we consider the number of relations between i and j , we obtain a measure of the intensity of the link. And *tie intensity* can be transformed into *tie strength* using network proportions (BURT, 1992; UZZI, 1996). Network proportions define the strength of a tie within the context of the aggregate level of effect across an agent's network. Indeed, beyond the very existence of a link, the capacity to access knowledge is certainly dependant on the strength of this link. One can guess that, through learning by interaction, the higher the number of co-operations established between two agents; the better is the capacity to absorb the knowledge transferred.

The second way to consider network effects in the accessibility analysis consists of considering the overall resources available globally within a network and linking accessibility to the individual positioning within the network. This leads us to introduce the strategic perspective and in particular the existence of a trade-off between the objectives of maximizing the knowledge acquired on the one hand, and of minimizing the loss of appropriability of our

own knowledge, on the other hand. So the advantage of cooperation increases with the number of partnerships tied to a firm and also with the number of ties formed by its own partners. Firms are however, highly conscious of the problems of control or knowledge appropriability that can emerge from the diffusion of information amongst them. So, they generally face a trade-off between the necessity to increase the number of their direct and indirect partners in order to absorb new knowledge and the necessity to reduce this number so as to be able to control the dissemination of their own knowledge. This explains the star and small world structures of real networks that allow the multiplication of direct links, with partners themselves developing few links elsewhere. Consequently, measuring the accessibility to knowledge through network requires indicators capable of catching such strategic dilemma.

IV PROPOSALS

Let us now turn to more concrete proposals for the empirical estimation of the determinants of knowledge accessibility.

In order to describe the opportunities of interaction the *identification of knowledge sources* is needed. Here the definition of the activity function W has to take into account the "emitters" of knowledge.

The activity function W can then be written as follows:

$$W = U_i + R_i + U_e + R_e \qquad (3)$$

Where U and R are respectively university expenses and private research expenses external to the cluster in question, indices i and e indicate the intra- or extra-sectoral nature of these sources.

Moreover, rather than seeking to understand the knowledge-generating activities (U and R) via a research expenses indicator, suggesting a measure via knowledge-carrying human potential could be relevant. The tacit knowledge which is the hardest to transfer

implies personal contacts with the carriers of this knowledge. The opportunities for interaction are then directly dependent upon the quantity of personnel attached to these research activities.

These potentials of external knowledge are more or less accessible depending on transmission means and *absorptive capacities* of receivers. In the potential functions introduced above, the question of the difficulties caused by the existence or absence of knowledge absorptive capacities is merged with that of the transmission difficulties in the weight function. However, a distinction deserves to be done. From an accessibility problematic standpoint, two points must be underlined. First of all, the costs implied by the implementation of an absorptive capacity result in three types of internal requirements, namely having: a sufficient internal level of knowledge, a diversity of domains that increases the connection possibilities with outside knowledge and an organisation in favour of knowledge assimilation and learning. In terms of measurement in a knowledge production function, we may propose that the accessibility variable coefficient depends on the absorptive capacity, which comes to use cross-variables. Hence, the following type of knowledge production functions (in a log-linear form):

$$I_i = \alpha + \beta_1 RD_i + f(CA_i)A_i + \varepsilon_i \qquad (4)$$

where RD_i is the internal research and development of the firm, A_i is a function of the potential accessibility to external knowledge and CA_i is an absorptive capacity measure. Giving f a log-linear form amounts to including a cross-variable in the production function: $CA*Ai$.

Secondly, the absorptive capacity is not independent from the conditions of transmission. We may think that the transmission methods facilitating knowledge transferability enable the reduction of requirements as regards internal absorptive capacity or help to implement this capacity. Thus, both the characteristics of the local environment and

the connectivity to public or private external sources of knowledge (POWELL *et al.*, 1996; COCKBURN and HENDERSON, 1998) of a corporation have to be taken into consideration. In that case, absorptive capacity contributes to defining which part of the available activities *W* will be useful to the company; it follows that empirical modelling does not differ here from the definition of a weight function.

In order to define *the weight function*, following ANDERSSON and EJERMO (2003) and ANDERSSON and KARLSSON (2004), we retain the idea of distinguishing different levels of accessibility corresponding to different space-time units. Each space-time units defines itself according to the specific degree of sensibility of the accessibility to the distance: no role of the geographical distance in a space-time, for instance, lower than 15 mn travel (*l*), stronger sensibility depending on the frequency of the movements necessary for the transfer of knowledge beyond (*ir* = intra-regional ; *er* = external to the region)[7].

$$A_i = \sum_{i,h \in l} W_h + \sum_{i,j \in r} W_j e^{-\beta_{ir} c_{ij}} + \sum_{s \notin r}^{n} W_s e^{-\beta_{er} c_{is}} \qquad (5)$$

Where $\sum_{i,h \in l} W_h$ measures the accessibility at the local level, $\sum_{i,j \in r} W_j e^{-\beta_{ir} c_{ij}}$ measures the accessibility at the intra-regional level and $\sum_{s \notin r}^{n} W_s e^{-\beta_{er} c_{is}}$ measures the accessibility to knowledge produced outside the region.

As we insist upon earlier, the relational networks within which the actors are incorporated are means by which access to knowledge can be facilitated. Thus, in terms of measuring the accessibility to knowledge, this supposes that we identify the relevant network and define indicators of social proximity within the network.

We therefore consider that the identified sources of knowledge constitute the nodes of the network. There is a link between two nodes each time these nodes have set up an effective relation which is likely to enhance the knowledge transfers. Such relations can be identified through their outcomes (co-publications or co-patenting) or through the forms they take

(setting-up of a common R&D structure, commitment in a common R&D project…).The structure of the existing networks results from individual and bi-lateral decisions of link formation. Here, the *relevant network*, g, can be defined as a graph where the set of agents sources of knowledge are the nodes $N = \{1,2,\ldots,n\}$, and they are considered as connected if they have intentionally created a collaboration based on knowledge barter (links). So, $g_{i,j} = 1$ (and equivalently $g_{j,i} = 1$) if agents i and j have set a link with each other, otherwise $g_{i,j} = 0$. Once built up, these networks constitute the framework that can underline our measure of social proximity.

Coming back to the accessibility function, one can simply substitute or add this sort of *relational proximity measure* to the spatial proximity measure in the weight function. Coefficient c_{ij} would thus grasp relational distance rather than geographical distance between the studied units and the knowledge sources (measured via the geodesic distance, the relative intensity or the strength of the ties). As we pointed out earlier, we should pay attention to the institutional and cultural belonging environment of the (situated) agents. Due to very different practices, habits or communication languages, knowledge transfers are more or less complex according to the context. We can then assume that the sensibility of the knowledge accessibility to social proximity is thus higher for inter-institutional contacts than for intra-institutional ones.

Thus, the accessibility coefficient presented below can be used again, switching from the geographical context to the *relational context*.

$$A_i = \sum_j W_j e^{-\beta_{pp} d_{ij}} + \sum_s W_s e^{-\beta_{pupr} d_{is}} \qquad (6)$$

So, here, d represents the relational distance (geodesic or measured through the strength of ties), j represents an agent of the same type as i, s represents an agent of a different type to i, and we distinguish the *pp* and the *pupr* context as respectively the intra-institutional context (public-public or private-private) with low sensibility to the relational distance (β) and the

extra-institutional context (public-private) with a greater sensibility to relational distance.

The relational context given let us turn to *the strategic positioning in the networks*. The structural analysis of network allows us to define complex positioning indicators which are likely to account for the different strategic trade-offs that underline the problematic of accessibility to knowledge. From the point of view of one agent, different notions of *centrality* within a network have been proposed to account for this problematic (see BORGATTI, 2005, for a review). One can simply measure the *density* for an agent which is defined as the number of links set up by this agent compared to the total number of potential partners existing within this network[8]. Strategically, the notion of *Betweenness Centrality* is finer because this statistic measures how many times one agent is situated on the geodesic path (smallest path) between two other agents[9]. This indicator is based on a simple intuitive notion: the capacity of an individual to control (facilitate, prevent, hinder) the diffusion of knowledge between other individuals.

In a more complex approach, REAGANS *et al.* (2004) present two conceptions of the position advantage within a network. One follows the sociological and economic theories of exchange and considers positioning from the degree of control on the terms of exchange it provides to the agent. The other presents the position advantage from the differential of access to resources it allows. In his theory of structural holes, BURT (1992) shows that the same type of position ensures both advantages. The measure of the constraint weighing on the players captures this phenomenon[10].

In the BURT's perspective, the positioning ensuring the lowest constraint is the best and is achieved when the individual maximizes the size of his/her network by multiplying his/her relationships (in order to maximise our access to external knowledge in our perspective) and minimizes the connections between these relationships (in order to limit the risk of loss of appropriability), or in other words maximizes the number of structural holes around him/her.

To the contrary, REAGANS *et al.* (2004, p.1) describe arbitration situations according to the observation of the structurally equivalent or non-equivalent nature of the contacts: "*The key difference is that, while the absence of relations between structurally equivalent alters is essential for granting ego leverage when exchanging with these contacts, such a structural hole does little to widen ego's access to information. This implies that there is a trade-off between efforts at developing ties that expand access to information and those that augment control over the terms of exchange*". Altering the structural constraint measure is suggested in this sense.

Actors who maximise the number of structural holes around them also have another advantage with respect to accessing information. They are in a position to bring together otherwise disconnected sub-groups within the network. This allows them to benefit from the high density and transitivity of the connexions internal to their group (intra-group buzz and positive effect of information redundancy) as well as from a great diversity of new information and new ideas coming from other groups (inter-group pipelines and positive effect of non-redundancy) that can feed their knowledge base (BURT, 2000; BATHELT *et al.*, 2004).

Therefore, one can weigh the accessibility to intra-regional resources by the individual's degree of centrality or constraint within the scientific collaborations network within this region.

Thus the accessibility coefficient can be measured as follows:

$$A_i = W_n e^{-\beta c_{ni}}$$

where *Wn* measures the overall resources available globally within a network and c_{ni} is the degree of centrality (whatever the measure of centrality we choose) of *i* inside this network.

Theoretically, this can be applied to any geographical levels. The main obstacle we face then consists in finding data describing complete networks.

In fact, the data requirements constitute a problem for empirical application, for the

usual procedure of taking samples of firms is not appropriate when analysing networks and few systematic databases are available (CANTNER and GRAF, 2006). Consequently, many empirical applications which study networks of innovators or inventors make use of publications or patent data either by building citation or co-authorship networks. Even though this has the advantage of considering the very process of collaboration and not only the output in terms of publications or patents, very few papers use data on direct collaborative agreements in R&D. One can notice however, some recent works using social network analysis to describe the structure of the R&D collaboration established between firms[11], hence providing some empirical data to measure accessibility through networks.

V CONCLUSIONS

In order to provide a better understanding of the factors shaping the innovative and economic performances of territories or firms the "accessibility to knowledge lens" deserves to be widely developed in both theoretical and empirical ways. We can already outline some theoretical and empirical implications that the switching from an externality framework to an accessibility one has on the geography of innovation.

It has become obvious that the measurements carried out by economists to geographical dimension of knowledge externalities until now are insufficient. In fact, they are no real means for refuting economic theories as they hardly distinguish actual externalities from other forms of contract-based interactions. In order to mitigate the methodological difficulties encountered in measuring the geographical dimension of knowledge externalities, the adoption of the accessibility to knowledge lens leads us to assume the need to take into account both the potentials of "places" and the geographical and relational "space" of knowledge diffusion in the firm's location choice. By focusing on the conditions knowledge diffusion needs in order to occur, we formulate proposals consisting in the integration of: i) the quantity of personnel attached to knowledge generating activities (distinguished by their

intra or inter sectoral and private or public knowledge source); ii) an accessibility coefficient which depends on absorptive capacity; iii) the degree of sensibility of the accessibility to different space-time units; iv) the measure of the accessibility through social proximity resulting from the relative positioning of the agents within the relevant network.

Although there exists a wide theoretical literature concerning the articulation between geographical and social proximity; some considering social proximity as a substitute to geographical proximity for relations at distance, others considering the geographical proximity as a simple by-product of the more fundamental role of social proximity, existing empirical studies don't really confront these different effects. The operationalisation of proximity provided through accessibility can improve our understanding of the articulation between the role of geographical proximity and that of relational proximity in the exploitation of the external knowledge flows by the firms. To our knowledge, there are no works implementing such accessibility indicators via networks to assess knowledge production functions. The methodological approach presented in this paper constitutes a first step towards this objective. The operational implementation of such an approach for empirical estimations however, still faces two main obstacles. Firstly, this is a formal exercise through which the formulation of localized knowledge production functions can be enriched by including various measures of accessibility to knowledge. In order to reduce the well-known restricted nature of indicators and avoid misinterpretations however, estimations using these indicators have to be based on sound theoretical frameworks. This suggests paths using theoretical works on location, cooperation decisions and network formation[12], in order to develop more structural empirical models thereby enabling the endogeneization of the firms' location and cooperation choices. Secondly, for a better understanding of the fundamental links existing between innovativeness and accessibility to external knowledge we have shown that a new set of "relational" key indicators needs to be defined and data needs to be collected. In this

perspective, proposals to replace the science and technology regional scoreboards are under way. This should provide us with a better diagnostic on the accessibility to knowledge offered by a region.

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Table 1 : Typology of Accessibility Indices

Type of Accessibility	Activity function $g(W_j)$	Impedance function $F(c_{ij})$	Accessibility Formulation A_i
Travel cost : accumulated travel cost to a set of activities	$W_j \mid 1$ if $W_j \geq W_{min}$ 0 if $W_j < W_{min}$	c_{ij}	$A_j \mid c_{ij}$ if $W_j \geq W_{min}$ 0 if $W_j < W_{min}$
Daily accessibility: accumulated activities in a given travel time	W_j	1 if $c_{ij} \leq c_{max}$ 0 if $c_{ij} > c_{max}$	W_j if $c_{ij} \leq c_{max}$ 0 if $c_{ij} > c_{max}$
Potential: accumulated activities weighted by a function of travel cost	W_j^{α}	$\exp(-\beta c_{ij})$	$W_j^{\alpha} \exp(-\beta c_{ij})$

From SCHUERMANN *et al.* (1997).

[1] See FELDMAN (1994), FELDMAN and MASSARD (2002) and, for a review, ROSENTHAL and STRANGE (2004).

[2] Drawing their inspiration from STORPER and VENABLES (2004) and OWEN-SMITH and POWELL (2004).

[3] BRESCHI and LISSONI (2006) and SINGH (2005) are exceptions. They find that social proximity is more relevant than geographical proximity when evaluating the degree of knowledge transfers.

[4] Speaking about knowledge accessibility does not mean that we neglect spillover phenomena. It means that, contrary to the geography of innovation that insists on unintentional and "in the air" form of externalities, we wish to put the stress on the intentional (strategic) and embodied forms of spillover.

[5] Which falls within the scope of what BATHELT and GLÜCKLER (2003) name the "*relational economic geography*".

[6] See GRANOVETTER (1983), WASSERMAN and FAUST (1994).

[7] Following ANDERSSON and KARLSSON (2004) we choose here a negative exponential form ($-\beta c_{ij}$) to model the distance decay effect. For a discussion on the relevance of such a form see KWAN (1998). She shows that such a form (as well as the simple inverse power function ($c_{ij}^{-\alpha}$) tend to decay too rapidly close to the origin and suggest a modified Gaussian function.

[8] This corresponds to the *Degree centrality* simply defined by the number of direct connections of one summit with other summits. It measures potential associated to the topological distance threshold *l*, i.e. the number of direct relationship opportunities. To do so, we measure the distance of summit *i* by adding all its geodesic distances to the other summits:

$$C_{APi}^{-1} = \sum_{j=1}^{n} dij$$

From this absolute distance, a relative proximity index can be calculated by comparing it to the maximum centrality $C_{max} = n-1$:

$$C_{NPi} = \frac{n-1}{C_{APi}^{-1}}$$

[9] The *betweenness centrality* C_B of an individual *i*, is then given by:

$$C_{B(i)} = \sum_{j \neq i \neq k \in N} \frac{s_{jk}(i)}{s_{jk}}$$

where s_{jk} (i) number of shortest path from *j* to *k* that some individuals *i* lie on. s_{jk} the number of shortest paths from *j* to *k*.

[10] Measure for the *degree of constraint i*'s contacts posed upon it is:

$$C_i = \sum_{j \neq i}^{j} c_{ij},$$

where the constraint posed on *i* by a given *j* is:

$$c_{ij} = \left(p_{ij} + \sum_{q \neq i \neq j}^{Q} p_{iq} p_{qj} \right)^2$$

Here we find two elements, that is relationship intensity between *i* and *j* and the degree of triadic closure between *i*, *j* and third-parties *q*.

[11] See for instance, HAGEDOORN (2002) on the pharmaceutical industry, CLOODT *et al.* (2006) on the computer industry and BRESCHI and CUSMANO (2004) on EU framework programs.

[12] See for example GOYAL *et al.* (2006) or CARAYOL and ROUX (2004).