Geographical proximity and the diffusion of knowledge

(The case of SME's in biotechnology)

Delphine GALLAUD & André TORRE

UMR SAD-APT, INRA INAPG

16 rue Claude BERNARD

75231 PARIS Cedex 05

torre@inapg.inra.fr

D.Gallaud@wanadoo.fr

in Fuchs G., Shapira P. & Koch A. (eds), *Rethinking Regional Innovation*, Springer, USA, 2004.

Abstract :

Since the principle that the capacity for innovation is a driving force in the growth of firms or other productive systems has been acknowledged, public policies hold to the view that geographical proximity plays a part in the process of the circulation of technology and knowledge, by fostering the kind of face to face relationships needed to establish and maintain a common pool of knowledge. The aim of this article is to question the relevance of these ideas, and enquiring as to whether geographical proximity is really needed for the diffusion and exchange of knowledge. A body of literature (local systems of production and externalities) considers permanent geographical proximity as a necessary condition for the diffusion of knowledge (I) whereas the articles dealing with transmission channels for externalities, show that geographical proximity only influences the innovative performance of firms if there is effective interaction between the agents (II). We show that organisation is the first modality in the transmission of knowledge, and that geographical proximity can be temporary, particularly in the initial phases of the R&D processes. The smaller firms are then more acutely aware to fulfil the need of de geographical proximity (III). This pattern, applied to plant biotechnology (IV), reveals that SME's related to the AFI and to agriculture are part of a less diversified and more local innovation network than pharmaceutical SME's and are more involved in frequent and repeated contacts with the clients and the suppliers.

Key words : spatial interactions, geographical proximity, external knowledge, biotechnology, spillovers, absorptive capacity, co-operation.

INTRODUCTION

Since the principle that the capacity for innovation is a driving force in the growth of firms or other productive systems has been acknowledged, public policies hold to the view that geographical proximity plays a part in the process of the circulation of technology and knowledge, by fostering the kind of face to face relationships needed to establish and maintain a common pool of knowledge about companies or business concerns. It is therefore deemed necessary to encourage local interactions by promoting the setting-up of networks or local systems of innovation (clusters, technopoles...) where the circulation of knowledge is reinforced by the opportunity for frequent contacts, thanks to the common location of the actors (Porter 2000).

The aim of this article, in the filiation of Rallet and Torre (2000), is to question the relevance of these ideas, refusing all idealistic notions on the subject and enquiring as to whether geographical proximity is really needed for the diffusion and exchange of knowledge. In particular, we will ask ourselves about the spatial dimensions of technology interactions. The fundamental question we shall raise concerns the relation between geographical proximity and the different modes of external acquisition of technologies. More precisely, do firms need permanent geographical proximity in order to acquire the technological knowledge they need to innovate? Can they do without this variable? Or do they only need interactions mobilising geographical proximity more temporarily - that is only during certain stages of the R&D and innovation process?

Firstly, we shall briefly present the studies that uphold the idea of the importance of permanent geographical proximity in the diffusion of knowledge, regrouping of firms and spatial spillovers (I), before analysing the process of the transmission of knowledge, firstly by assessing the absorptive capacity of the firms (II), then by integrating the spatial dimension of the external acquisition of technology (III). This will allow us to highlight the possibility of satisfying the needs for geographical proximity through a temporary coming together of the actors of the innovation process. We will end with an evaluation of the localised nature of innovation interactions in the field of biotechnology in France, by comparing pharmaceutical activities to those related to agriculture and the agro-food industry (IV).

I. THE DIFFUSION OF KNOWLEDGE ON A LOCAL LEVEL : THE CONTRIBUTION OF CONTEMPORARY LITERATURE

Even if the concept of proximity as such, is not always directly referred to, contemporary literature regarding the transmission of knowledge in a spatial framework, continually alludes to this notion. Although everyone agrees on the importance of geographical proximity in the process of the diffusion of knowledge, the main aim of the systemic type of analyses is to highlight the real or assumed qualities of groupings of technology firms, and to define the LIPS (Localised Innovation Productive Systems) that hold the promise of a potential local technological development. A more econometric approach, on the other hand, aims to investigate the role of proximity in the process of the transmission of knowledge, based on the modeling of geographical externalities in regard to innovation and technology.

In the eighties and nineties, the relation between geography and technology became the focus of attention in regard to the institutional framework of the production of innovations, as differences had appeared between countries or regions that had a comparable level of development but were characterised by unequal innovation rhythms (Lung and al. 1999). Since then, research has been dedicated to various subjects such as innovative milieux (Ratti and al. 1997, Crevoisier 2001), technological districts (Antonelli 1986), technopoles or science parks (Monck and al. 1988, Longhi, 1999) and, in general, to localised systems of production and innovation (Lundvall 1992, Maskell and Malmberg 1999), so as to highlight the complex connection between spatial concentration and technological advantage, and then to reveal the organisational component underlying this type of local operation. These different approaches have two common characteristics : they postulate the effectiveness of local operations and highlight the importance of the organisational component. So it is, that studies concerning innovative milieux have underscored the importance of connections between the different local actors as regards the technological development of a given region or geographical area, particularly when they have technology supplier-user type relations that can help to reduce technology leakages and promote the implementation and development of local learning opportunities. Research concerning technopoles, which is often of a less theoretical nature, systematically attempts to highlight the advantages of grouping local high tech firms on the same territory, especially in regard to the production of innovations, not only because of the concentration of potential for research or innovation, but also because of the synergetic effects arising from the collaboration between local firms. Most of these characteristics can be found in the analyses of

regional innovation systems, that include the setting-up of a local network based on technological complementarities, as well as an institutional dimension illustrated by implementation policies undertaken by the public authorities in terms of support to innovation or the training of engineers or scientists, and where the relation between science and industry occupies a central position.

All in all, and as the most recent syntheses on innovation clusters have shown (Porter 2000), the idea that firms and productive systems benefit from the spatial concentration of their research and innovation activities, is widely accepted nowadays : permanent geographical proximity is seen as an essential condition for technological success, particularly in the case of SME's. Nevertheless, serious doubts are now being voiced, as to the characteristics themselves, or even the merits, of the process of spatial concentration that has been engaged in, particularly in regard to the ability to transfer knowledge that is often termed as tacit knowledge, without cost and without any particular effort (Rallet and Torre 2000)

Whereas this research takes it for granted that permanent geographical proximity plays a part in the process of innovation and the transmission of knowledge, studies on geographical externalities attempt to verify the role of this proximity in the transmission of knowledge by calculating the maximum distance that a technological externality could cover.

One of the characteristics of innovation is to produce externalities. Due to the peculiar nature of this activity, that is sometimes compared to the production of a (semi) public good, the results cannot be totally appropriated by the innovator, as part of the knowledge is diffused into the economy without the innovator being able to prevent it, or even being aware of it[1]. When innovation (or R&D) is likened to information, there is an unlimited leakage of results that concerns the overall economy, but the approach in terms of knowledge leads one to analyse the possibility of diffusing this knowledge, as well as the geographical area it covers. From an empirical point of view, the fact that there is a high concentration of innovative activities contradicts the hypothesis of a complete diffusion of R&D results, which would allow activities to be equally distributed throughout the territory. The over-concentration of innovative activities, which is even greater than the production activities (Audretsch and Feldman, 1996), is then often accounted for by the characteristics of the externalities, that are assumed to have a limited geographical extension.

Autant-Bernard and Massard (1999) have compiled four types of studies dedicated to calculating the externalities of knowledge (or spillovers) and to their spatial area, respectively based on :

- the use of patents as markers of externalities (Jaffé and al. 1993) ;

- the geographical concentration of innovations (, Audretsch and Feldman 1996) ;

- geographical coincidence (Jaffé 1986, Anselin and al. 1997) ;

- local interaction (Anselin and al. 1997, Wallsten 2001) ;

to which one may add (Feldman 1999) :

- knowledge incorporated in capital or investment goods.

All these approaches come to the conclusion that externalities exist and that their geographical extension is limited ; this explains the concentration of firms in certain areas and supports the idea that geographical proximity is an important factor in the diffusion of knowledge. However, there are two factors that limit the significance of this research : the measurement of the geographical extension is still much debated, and the analysis of the channels of transmission of externalities modifies the role of proximity. (Autant-Bernard et Massard 1999).

[1] We only take in account the common sense of the definition of the externalities, often presented in the literature on geography of innovation.

I.1. The measurement of geographical extension is still much debated

Some of the above-quoted studies do not really propose an estimation of spatial externalities : the authors use a predefined geographical area, which presupposes, but does not prove the existence of externalities. Thus, the first three methods (patents, concentration, coincidence) do not offer a true measurement of externalities (no calculation of the elasticity of R&D expenditure in relation to the innovation capacity of the company of reference) and even less of the distance they are supposed to cover. Assuming that externalities exist, they model their effects and, in actual fact, they measure agglomeration phenomena. These methods generally postulate the role of local dimensions by using pre-defined geographical areas : States (Jaffé 1989, Feldman 1994), metropolitan areas (Jaffé and al. 1993) and Counties (Anselin and al. 1997 in their first evaluation). Notions of distance, when they are introduced into the gravity and coverage indicators used by these authors, are pre-defined. For instance, according to Anselin and al (second measurement), R&D may have been carried out within a radius of 50 or 75 miles around the County of reference.

More recent studies, that make use of Geographical Information Systems (GIS) in order to model the range of technology spillovers, provide an indication for measuring distance. Thus, Wallsten (2001) makes use of GIS in order to analyse the probability for a firm whose neighbour received government support for innovation, of also benefiting from such assistance. It locates firms without using a pre-defined geographical zone and shows that firms receiving financial support are situated close to each other, in a radius of one tenth of a mile, often on the periphery of urban areas. Even if these are strategic externalities linked to information rather than R&D, and although participating in a government programme is liable to introduce a different angle, one sees nevertheless, that the distance retained, if it is not pre-defined, still varies noticeably from one author to another (from 50 miles to one tenth of a mile), which leaves room for many extrapolations. Lastly, it is not until the publication of Orlando's work (2000) that these methods present a simultaneous calculation of externalities and of distance.

I.2. The channels of transmission of externalities

Zucker and al. (1994) are the first to highlight the role of effective interaction in the diffusion of knowledge, by showing that geographical proximity is not sufficient to enable one to benefit from the externalities of technology, a finding also put forward by Cockburn and Henderson (1998), who consider that externalities can only be received if firms stay in contact with scientists (especially by co-authoring articles).Audretsch and Stephan (1996) continue in line with these studies, showing that 70 % of the contacts that are maintained between SME's and scientists are not local but vary according to the main tasks assigned to the scientists (transfer of knowledge, quality signal for investors, participation in the scientific committee of SME's). These results should be considered with caution, as it is only the transfer of knowledge that is concerned in the analysis of innovation networks.

Zucker and al (1998) measure the impact of relations with the most productive scientists (the « star-scientists », thus defined by the number of articles published) and the innovation ouput of firms, which is assessed by three indicators : the number of products being developed, the number of products on the market and the net growth of employment, that all express the stages in the process of innovation, from invention to economic performance (Autant-Bernard 1999). They conclude that only the influence of researchers linked to firms by research cooperation has a significant impact on innovation performance. It is therefore not enough for firms to be situated near the Universities, they must also effectively cooperate with the local scientists in order to capture the externalities and express them in terms of an increase in innovative results. Thus, the notion of interaction shows that the effectiveness of geographical proximity is limited, as it involves a certain organisation of the said proximity.

Thus, the analysis of the process of transmission of knowledge externalities , leads us to reconsider the supposed automatically positive role of geographical proximity, and to consider instead the role of an effective cooperative type of interaction between SME's and scientists. An

organisational constraint is added to the geographical factor, as the idea that firms could enjoy the results of R&D without costs is replaced by the organisation of its dissemination. Moreover, the definition of these externalities in itself, is problematic. If one considers that knowledge is in the very air, then externalities can be apprehended without cost and geographical proximity is enough ; knowledge becomes much less easily transferable on the other hand, when it is built into the human capital. Geographical proximity alone, is then an insufficient guarantee, and the (expensive) diffusion of knowledge will have to be organised. This is why it is necessary to investigate the actual interaction between agents, particularly in regard to the external acquisition of technology, even if this requires certain changes in the aforesaid definition of externalities and their content, in order to get into the black box of technology interaction.

II. GEOGRAPHICAL PROXIMITY AND ABSORPTIVE CAPACITY

Any company that wishes to benefit from external technologies must rely on its relations with agents who have that knowledge, whether they are markets for knowledge or more direct interactions. However, if this operation is to be fruitful, the firm must have sufficient internal ability to assimilate or reproduce this imported knowledge. Studies concerning the absorptive capacity of companies, analyse how a receiving firm may pick up a greater or lesser quantity of technology spillovers, the internal organisation of the said company enabling it to minimise its R&D investments in order to absorb available knowledge from its environment. Cohen and Levinthal (1989) show that, besides producing new information that can be used as input for innovation, R&D also facilitates the assimilation of external knowledge.

Thus, the absorptive capacity of a firm corresponds to the amount of external knowledge that it is able to use. This is a multiplying factor for sums invested in intra industrial R&D, and a stock of extra-industrial knowledge (mostly made up of University research), that does not take into account geographical distance ; only the technological distance between the transmitter and the receiver of the externality is considered.

This work can be continued through research on the connection between the internal characteristics of the firm and the type of external knowledge that is absorbed. Mangematin and Nesta (1999) have shown that the possibility of absorbing external knowledge gives rise to three series of specific problems :

- the distinction between applied and fundamental knowledge, that leads to the question of what type of knowledge companies import, and highlights two aspects of the absorptive capacity, respectively, research activities and development activities. This scientific skill enables one to discern the advance of knowledge leading to technological opportunities, and to reduce the uncertainty regarding the value of cooperation projects and of a technological component that would contribute to the development of innovation and to its introduction on the market (Arora and Gambardella 1994). Only a company that has a high absorptive capacity is in a position to absorb both types of knowledge ;

- the distinction between tacit and codified knowledge. Codified knowledge can be expressed through the use of a code and « embedded » in a medium that is not dependant on the person who possesses knowledge, whereas tacit knowledge cannot be expressed in a code or used by a third party independently of the possessor of that knowledge. Even if we distinguish knowledge that is predominantly tacit or predominantly codified, both forms of knowledge are complementary (Nonaka 1994), which is why firms invest in channels for the diffusion of knowledge that are more expensive than simply reading scientific and/or technical articles. Thus, a high absorptive capacity, due to the diversification of the means of access to knowledge, allows one to absorb codified and tacit knowledge through a greater number of different channels. On the other hand, a reduced absorptive capacity limits opportunities for cooperation ;

- the processes of recontextualisation. Knowledge is often generated in a particular context, specific to the company, laboratory or productive system that it originated from (and which aims to prevent this knowledge from leaking out). This specificity gives rise to some difficulty in the appropriation of knowledge, as the lack of certain elements of information that would help to clarify it, makes it difficult to use in a different context. The absorptive capacity of technology users must therefore resort to a process of recontextualisation of technology spillovers (Guilhon 2000), that is expensive and requires once again, specific absorption skills.

In view of these considerations, the potential complementary between internal and external R&D (without internal R&D, it is impossible to use knowledge that one has not generated oneself) brings us to the question of the role of external cooperation, an aspect that Cohen and Levinthal have not studied in any detail. However, although they have not explicitly broached the subject of space, their thesis is in opposition to the arguments promoting localised production and innovation systems (technopoles in particular). Whereas the LIPS approach assumes that geographical proximity can compensate for the shortcomings in the internal organisation of firms, particularly SME's, the analysis in terms of absorptive capacity, recommends that internal organisational abilities within the firm be used for the assimilation of external knowledge, even if the latter originates from close neighbours.

Thus, whereas studies on the diffusion of knowledge at local level (whether it be the geographical knowledge externalities or the LIPS) consider the geographical proximity of the actors as the most important factor (although they relativise it sometimes), research on the absorptive capacity of firms gives greater precedence to the internal organisational capabilities of firms, or to the organisational proximity, as referred in the Economics of Proximity (Gilly and Torre 2000)[2], and above all it makes it possible to raise the question concerning the stages of the innovation process during which geographical proximity is necessary.

III : THE SPATIAL DIMENSION OF THE EXTERNAL ACQUISITION OF TECHNOLOGY

Although they explicitly refer to an external acquisition of knowledge, Cohen and Levinthal's works hardly discuss the way in which this acquisition process takes place, and in particular the types of interaction between firms. But these interactions are extremely important, as no firm possesses internally all the knowledge it needs for its production process.

A firm that wishes to acquire external knowledge can get information made public through conferences, trade fares, publications, symposia, exhibitions… but most knowledge it wishes to acquire is private (or semi public) and can only be acquired from other firms or organisations. These acquisitions range from commercial transactions (the markets of technology) to research cooperation. The latter can be more or less formalised, whether it concerns the relations with public research organisations (contracts between universities and industries) or with other enterprises (vertical cooperation, that corresponds to the relations with clients or suppliers, and horizontal cooperation with the competitors (a rare form which concerns less than 10% of R&D agreements)). In cases where knowledge is public, geographical proximity has no impact because knowledge can be acquired wherever the innovating firm is located in relation to the productive source of knowledge. Things are different when the information is not divulged : it can be beneficial for the firm that seeks to acquire it to be located in the proximity of the productive organisation, especially if it does not have a monopoly on this information.

The different types of interactions made in order to obtain external knowledge can be classified according to their relation to space and to the need for geographical proximity.

[2] We define organisational proximity as the membership to the same group of economic entities, linked with interactive processes.

- *informal relations for the exchange of technological knowledge :* these require a permanent and high level of geographical proximity, because of the tacit and contextualised nature of the knowledge in question, and the need to continually validate and enrich this knowledge ;
- *research collaboration :* the joint accumulation of knowledge is facilitated by a relation of geographical proximity ;
- *exchange of researchers :* geographical proximity is required in the case of an exchange of tacit knowledge, but can be obtained by temporarily importing a skill ;
- *purchase of patents and licences :* it is useful to distinguish between licence agreements that do not provide any technical assistance and those that do. The former represent a spot transaction on the knowledge market : geographical proximity does not exist. Where the licence agreement does make provision for technical assistance, the patentee must organise the transmission of technical know-how defined within the field of the patent, which implies the transmission of both the codified and tacit knowledge needed for the industrial utilisation of the invention. Geographical proximity facilitates the transmission of this knowledge, and also lowers the costs involved, particularly when the agreement provides that the patentee shall personally undertake the start-up of production and training sessions for the licensee's staff. (Gaudin 1993) ;
- *Industry-University research contracts* : when the content of this research is tacit it requires geographical proximity, particularly in the urban areas or within specific geographical zones (Grossetti and Nguyen 2001). However, as soon as the results are acquired and presented in a codified form, the need for geographical proximity disappears ;
- *vertical or horizontal cooperation :* although geographical proximity is frequent in client-supplier relations, its role in horizontal cooperation is not that obvious. Here too, temporality is significant, as there are temporary moments where proximity is necessary. In the case of relations involving competing companies, it is advisable to try and obtain organisational proximity at a distance in order to retain access to local markets.

The process of acquisition of external competencies in its spatial dimension may be described as follows. When a technical object or a technology are introduced, it is essential to implement a decoding and/or recontextualisation phase (or even a decontextualisation phase in the case of an imitation procedure) with the help of the absorptive capacity of the firm. The purchase of external technologies on the markets for knowledge is a point in case. But this also holds true for other types of interactions, and particularly for relations of a cooperative nature ; meetings between people must take place, in order to decodify or to decontextualise knowledge and to establish protocols for the distribution of tasks between the participants in the operation, whether they are people inside the firm or outside contributors or newly arrived on the scene. Cooperative relationships often require geographical proximity, even if it is temporary, because of the frequency and the intensity of the interactions that we have just noted. The following phase of internal recodification or recontextualisation requires a lesser degree of geographical proximity in the relationships within the network, as it involves a considerable amount of exchanges of codified knowledge within the company and an integration of the absorptive capacity of the latter. The type of learning referred to is mostly internal, and the starting-up of the production process relies extensively on codified knowledge, which becomes the major element in the process, as external support and contributions can be realised by means of long distance communication.

It is possible to specify the needs for geographical proximity in the particular case of cooperation which was studied byveque et al (1996) who analysed the link between the forms of internal organization of R&D and the types of external cooperation. This study proposes three main

archetypes that, in the case of firms, correspond to an equal number of R&D forms[3]: they are respectively:

- the exploration of ways to implement an enduring technical transformation, by seeking to acquire new knowledge and finding out how to use it in the innovative process. *Exploration R&D*, which allows new knowledge to be produced and internalised, generates cooperation that in turn increases learning opportunities. The high level of uncertainty attendant on this activity is matched by the large number of agreements entered into with partners (especially scientists) who are in a position to generate new knowledge;

- the exploitation of a relatively well-known innovation technique. *R&D exploitation* is the expression of a routine way to produce innovation. Cooperation, that includes a higher proportion of agreements between clients and suppliers than exploration R&D, occurs when both parties seek to develop identical skills but the products and the markets are complementary ;

- the imitation of innovative processes initiated by competing firms. *Imitation R&D*, that requires rapidity and flexibility, is generally completely internalised.

The number of external relations drops with the shift from exploration (that can be distributed between several sites) to exploitation (characterised by the use of relatively commonplace sources of external technology) and then to imitation (a situation in which external models are reproduced, often because the firm does not have the internal skills needed to produce innovation).

This pattern, which enables us to connect the internal organization of R&D (and hence its absorptive capacity) to a certain type of external relations, applies for the most part to differentiated oligopolies, in other words, to relatively big firms. It has to be amended by taking into consideration the size of the firms. SME's for instance, trapped between their innovation rationale and the insufficiency of their own skills in regard to the creation of technology, are not in a position to so easily develop certain modalities of internal R&D.

Based on these considerations, and taking into account the fact that organisational proximity is consubstantially necessary for the overall process of acquiring external knowledge, the relation between the different types of R&D and geographical proximity (defined as the opportunity for frequent face to face meetings between agents, according to Lung and al. 1997 and Rallet and Torre 2000) can be defined as follows (see Table I) :

Process of exploration R&D	Permanent geographical proximity
Process of exploitation R&D	Temporary geographical proximity
Process of imitation R&D	Secondary geographical proximity

Table I: Temporary and permanent geographical proximity in technological co-operation processes

In this instance, the term 'permanent or temporary geographical proximity' applies to the process, and must on no account be confused with the location of firms, which differs according to their size. It means that there exists a need for geographical proximity that can be met through a temporary coming together of the actors of the cooperation process.

Put very simply, big firms, subsidiary groups or Universities, can avoid the constraint of a permanent location in the initial phase of exploration by using devices such as sending out research teams or doctors, a solution that is allowed because of they have such a large pool of human resources

[3] Dans la réalité peu de firmes n'utilisent qu'une de ces formes et peuvent passer de l'une à l'autre en fonction de la période considérée et selon les types de concurrence auxquelles elles se trouvent confrontées.

to draw from. In smaller firms, on the other hand, the coincidence of the need for an exploration R&D with the need for permanent geographical proximity during this process, is often a factor that determines the locality of the firm, as tasks related to the different phases of the R&D process are assigned to the same person. So these firms have to be located close to other firms or laboratories, even if geographical proximity is only needed during one of the phases of the R&D process. Geographical proximity and the location of firms should on no account be assimilated, as the existence of permanent geographical proximity during the exploration R&D process does not in any way require the company to be located nearby, except in the case of smaller companies, where permanent geographical proximity does entail this kind of constraint in terms of their location.

Finally, it should be noted that the role of geographical proximity, of greater or lesser import according to the phases and types of innovation project involved, decreases over a period of time. Geographical proximity can be either :

- permanent and complementary to organizational proximity during the phase of the joint production of fundamental, tacit and contextual knowledge ;

- temporary and complementary to organizational proximity during the phase of the absorption of knowledge developed during the scientific phase, which means that this knowledge must be recontextualised in order to test it in various situations ;

- totally dominated by organizational proximity, as in the case of coordination at a distance, which does not require face to face interactions. This is often the case during the development phases of prototypes and clinical trials, or when the findings of research are being codified ;

Thus, the thesis according to which the need for geographical proximity in the process of external acquisition of knowledge leads to a co-localisation of firms or organisations in one same area proves erroneous. Indeed, the great number of modes of external acquisition allows firms to obtain techniques or knowledge even if they are not localised in the proximity of the enterprise or laboratory that has produced them. The more commercial interactions are, the less necessary geographical proximity becomes. On the other hand, the closer one gets to cooperation, the more important it becomes. However, the need for geographical proximity can be met in a temporary manner through the mobility of qualified staff, in particular by organisations that possess the necessary resources to carry out this type of operations.

IV. EXTERNAL ACQUISITION OF KNOWLEDGE AND PROXIMITY IN THE FIELD OF BIOTECHNOLOGY.

The agricultural food-processing industry has undergone major changes over the last thirty years, and in particular, there has been a complete reversal of France's position, which has shifted from being an importer to being an exporter. The AFI now contributes overwhelmingly to the positive trade balance, following the modernisation and extension of farms, the rapid increase in the output, the intensification of breeding, etc… these factors generate productivity gains that are reflected in profound institutional modifications. Today, thanks to the boost in France's international trade, it has become the second country in the world after the USA, with a competitivity based on several strong points : food grains, sugar, dairy products, wine and beverages. However, although the growth in these activities has been extremely significant, the AFI still comes last in the field of research. In France, due to the lack of researchers and of funds available for R&D, relatively little research has been carried out in the private sector (1% of the GDP) ; moreover, the level of research in the private sector differs considerably according to the type of company concerned. Thus, big groups in the agricultural food-processing industry enjoy many R&D activities (often organised worldwide), and this is also the case for about 300 French SME's. Most of the small companies, on the other hand, do not have formal access to R&D, and, in the best of cases, they make use of transfer centres or intermediation institutions. Public research plays an important part in this context, and the INRA in particular, has a

pivotal role, as contracts passed between firms and public laboratories are often presented as a substitute for the lack of internal R&D.

Several explanations can be given in order to resolve this apparent paradox :

- the dynamics of this sector is not based on innovations, or only incremental ones;

- this situation arises because of knowledge and know-how that are already present, but have not been fully exploited and that, as soon as they are used, become engines of productivity;

- agronomic innovations are not linked to research in this sector ; this explanation substantiates the hypothesis of a diffusion arising from other industries. Joly and Lemarié (2000) note that Pavitt (1984) classifies the AFI in the category of industries where innovation is almost entirely due to technical progress that has been built into the capital goods purchased by them, and very little to their own research;

- lastly, the social return on research is particularly high in the fields of agriculture and the food trade. Huffman and Evenson (1993) show that the impact of research is particularly significant in the AFI, more for agriculture than for breeding and more for scientific research than for applied research. This result justifies the many studies carried out in the seed sector, because genetic engineering and improvements represent an important area of innovation and contribute massively to the increased yield of the large-scale farming industry.

Biotechnologies are defined as a number of techniques and knowledge related to the use of the living in the industrial processes of production (Ducos and Joly 1988). This is not enough to define a sector (Porter 1990) even though certain firms have specialised in these activities. These techniques are used in the pharmaceutical industry, agriculture, the agro-food industry and the environment (they are still in the experimental stage in the latter case). In France, an economic environment is emerging that constitutes a production sector composed of biotechnology firms and firms offering complementary activities: manufacturing of specific instruments and equipment, consulting and technical expertise (Lhuillery 2002).

Chemical firms remain the main suppliers of innovation in the agro-food industry. It is the case, in particular, of the production of flavourings - additives produced by a few firms in the agro-food industry, but essentially manufactured by the chemical industry. There are currently about one hundred flavourings obtained thanks to biotechnologies. This activity is therefore still developing. The market is not much internationalised and SMEs as well as groups are present on the market. Whereas pharmaceutical and chemical firms produce techniques related to biotechnologies, agricultural and agro-food firms are essentially users. The market is internationalised in the chemical and pharmaceutical industries (there is world oligopoly), but a few SMEs have specialised in specific products. However, in the long term, one can wonder if they will be able to maintain these activities. These firms have to innovate constantly in order to create markets on which they obtain a temporary monopoly.

Lemarie et al (2001) have highlighted the specific characteristics of these companies as far as France is concerned :

- very few of them operate on final consumer markets ; they are mostly suppliers for other enterprises, whether in the field of health or of the AFI. Their main business is to design, develop and manufacture custom-made genetic or biological material. The main business of SME's of the AFI (a third of the sample) is the perfecting of diagnostic kits in order to determine, for instance, if GMO are present- most of them are situated in the Ile de France, a region that specialises in pharmacology, as well as in five other regions: Alsace, Auvergne, Aquitaine, Brittany (regions that specialise in the AFI) and Rhône-Alpes (a region that specialises in pharmacology) ;

- their development is related to different models of cooperation networks. Companies with a fast growth rate (a minority, mostly involved in pharmacology) have a dense network of cooperation with Universities and public research organisations. Geographical proximity has very little relevance for these firms, that are used to recruiting skills through their international scientific network and who

therefore favour organisational proximity. Lastly, firms with a parent company include mainly SME's connected to agricultural markets, that have been created by groups with a view to flexibility and decreased risks, and that are situated near the customers.

Catherine et al. (2002) also highlight the recourse to local networks, by connecting their development to the founders' profile. Companies are usually established in the area where its founders had already worked previously, particularly in the case of scientists, which would seem to indicate that this human capital is more specific and less transferable than the capital of the managers. Thus, successful SME's combine local skills (particularly in the scientific field) and global skills (mostly in the managerial field).

Thus, we can distinguish (Catherine and Corolleur, 2001) two main types of companies :

- firms with a low level of technological complexity and small exploitation and imitation R&D budgets, that lead to incremental innovations, and rely on internal skills that stem from the core business of the firm. These SME's, that make up 2/3 of the total number of SME's and whose outlets are mainly in the AFI and agriculture sectors, are often suppliers for big groups and operate on markets with a narrow niche. They have an essentially local network, and rely on funding within a demarcated geographical area. They can either be classified as service providers or as manufacturers of generic products as the case may be, and these activities enable them to rapidly become operational and to make a considerable profit ;

- firms that have a higher level of technological complexity and a big volume of exploratory R&D, whether they are leaders on their market and make radical innovations, or research providers. These companies, with outlets mainly in the pharmacology sector, take on the risks and uncertainty of programmes that big groups consider too risky, and they look for wider markets. They can combine purchases of licenses that imply a very limited geographical proximity, with means such as co-developments in partnership which necessitate greater geographical proximity

Cooperation between SME's linked with agricultural outlets that tend to practise exploitation R&D, is often a customer-supplier type relationship (Léveque and al. 1996) that requires ties of geographical proximity, (Cf. III, below), particularly in the initial phases of research and development. Nevertheless, the modalities of cooperation in R&D are liable to change over time due to the influence of the dynamics of competition. The initial phases of the innovation process require extensive application to external collaboration, or even joint contracts in order to carry out the exploratory R&D, the number and variety of contracts decreasing at a later stage, and becoming more like the supplier-customer types of cooperation (Léveque and al. 1996). The theory suggesting that networks are more extensive and diversified in pharmacology than for SME's connected to agriculture and the AFI, has to be relativised, because they all generally go through a phase of exploratory R&D when they enter the market.

The information (very scarce) about SME's in this sector, shows that big integrated networks (Depret and Hamdouch 2000), that include different organisations and are developed by big groups from the pharmaceutical industry, often create a plant biotechnology sector outside of their core business. This is the case for Aventis, for example. It is important not to confuse these networks with the networks formed by SME's, that have specificities in terms of their objectives and/or constraints (survival through access to the network, for instance) and are more motivated to create an area of expertise (specific skills) for themselves (and thus to develop a strategy of niches).

The strategy of the groups leads one to believe that a certain number of techniques, initially perfected in pharmacology, can then be transferred to the AFI. But the gap between the results of research and the market, is more significant in the case of plant biotechnology than for biotechnology in the pharmacology sector, that is almost continually linked to the advance in fundamental research. Whereas pharmacology is marked by a series of discoveries converted as quickly as possible into innovations, plant biotechnology is often characterised by a lesser volume of scientific discoveries and a slower renewal of skills. Moreover, as these techniques are generally relatively older, the life cycle of the industry can more frequently correspond to the phase of exploitation R&D, where the

agreements are less in number, involving extensive sub-contractual relations, the aim of which is to reduce the cost of developing innovations. Consequently, the recourse to scientific cooperation could be more selective and be used as a means to complete the data base of the SME on certain specific issues, in order to carry out a particular project instead of maintaining a diversified absorptive capacity. The interactions mobilised within this framework would then only require a temporary geographical proximity, that has however, proved fatal to SME's in terms of locality.

CONCLUSION

What is the role of geographical proximity in setting-up and operating of external acquisition of technology? Is it fundamental, as public policies that favour the interaction between science and industry at local level in the hope of obtaining a better circulation of knowledge, seem to imply ? Our article shows that a body of literature (local systems of production and externalities) considers permanent geographical proximity as a necessary condition for the diffusion of knowledge (I) whereas the articles dealing with transmission channels for externalities, show that geographical proximity only influences the innovative performance of firms if there is effective interaction between the agents (II). In order to benefit from externalities, firms have to make costly efforts of organisation.

Our research is based on the hypothesis that organisation is the first modality in the transmission of knowledge, and that geographical proximity can be temporary, particularly in the initial phases of the R&D processes. The smaller firms are then more acutely aware to fulfil the need of de geographical proximity (III). This pattern, applied to plant biotechnology (IV), reveals that SME's related to the AFI and to agriculture are part of a less diversified and more local innovation network than pharmaceutical SME's and are more involved in frequent and repeated contacts with the clients and the suppliers. The localised nature of their technological interactions can be explained by different variables, but not by a need for permanent geographical proximity in the process of knowledge circulation. It stems more from the lack of human abilities and financial means, that forces them to choose a close to companies and laboratories, which are a source of knowledge, in the hope of benefiting from the transmission of knowledge that, however, only concerns short term projects.

REFERENCES

Anselin L., Varga A. and Acs Z. (1997) Local geographic spillovers between University research and high technology innovations; *Journal of Urban Economics*, 42, 422-448.

Antonelli, C. (1986), Technological Districts and Regional Innovation Capacity, *Revue d'Economie Régionale et Urbaine*, 5, 695-705

Arora A. and Gambardella A. (1994) Evaluating technological information and utilizing it. Scientific knowledge, technological capability and external linkages in biotechnology, *Journal of Economic Behaviour and Organization*, 24, 91-114.

Audretsch D. and Stephan P. (1996), Company scientist locational links : the case of biotechnology, *American Economic Review*, 86, 3, 641-651.

Audretsch D. and Feldman M. (1996), R&D spillovers and the geography of innovation and production, *American Economic Review*, 86, 3, June, 630-640.

Autant-Bernard C. and Massard N. (1999), Econométrie des externalités technologiques locales et géographie de l'innovation : une analyse critique, *Economie Appliquée*, LII, 4, 35-68.

Catherine D. Corolleur F., Coronini R. (2002), Les fondateurs des nouvelles entreprises de biotechnologies et leurs modèles d'entreprise. Une approche par les compétences and les ressources illustrée sur le cas français, *Revue Internationale des PME,* 15, 2, 63-92..

Cockburn I. and Henderson R. (1998), Absorptive capacity, coauthorship behaviour and the organization of research in drug discovery, T*e Journal of Industrial Economics*, XLVI, 2, 157-182.

Cohen W. and Levinthal W. (1989), Innovation and learning : the two faces of R&D, *The Economic Journal*, 99, september, 569-596.

Crevoisier O. (2001), L'approche par les milieux innovateurs : état des lieux et perspectives, *Revue d'Economie Régionale and Urbaine,* 1, 153-165.

Depret M and Hamdouch A . (2000), Pharmacie et biotech l'ère des réseaux, *Biofutur,* 203, septembre, 44-48.

Ducos C. et Joly PB. (1988), *Les biotechnologies*, La découverte, Repères, 128p.

Feldman M. (1999), The new economics of innovation, spillovers and agglomeration : a review of empirical studies, *Economics Innovation and new technology*, 8, 5-25.

Gaudin JH. (1993), *Guide pratique de l'ingénierie des licences et des coopérations industrielles,* LITEC, 415 p.

Gilly J.P. and Torre A. (2000) (dir), *Dynamiques de proximité*, L'harmattan, Paris, 301p.

Grossetti G. and Nguyen D. (2001), La structure spatiale des relations science-industrie en France : l'exemple des contrats entre les entreprises et le laboratoires du CNRS, *Revue d'Economie Régionale et Urbaine*, 2, 311-326.

Guilhon B. and al. (2000), *Technology and markets for knowledge*, Kluwer Academic Publishers.

éHuffman W. and Evenson R. (1993), *Science for Agriculture : a long term perspective*, Ames, Iowa State University Press.

Joly P.B. and Lemarié S. (2000), Cinquante ans d'innovation en Agriculture, *Economie Rurale*, Janv.-Avr., 86-97.

Jaffé A. (1986), Technological opportunity and spillovers of R&D : evidence from firms patents, profits and market value, *The American Economic Review*, 76, 5, 984-1001.

Jaffé A. (1989), Real effects of academic research, *The American Economic Review,* 79, 5, 957-970.

Jaffé A. Trajtenberg M. and Henderson R. (1993), Geographic localization of knowledge spillovers as evidenced by patents citations, *The Quarterly Journal of Economics,* august, 577-598.

Lemarié S., Mangematin V. and Torre A. (2001), Is the Creation and Development of Biotech SMEs Localized ? Conclusions drawn from the French Case, *Small Business Economics,* 17, 61-76.

Léveque F., Bonazzi C. and Quental C. (1996), Dynamics of cooperation and industrial R&D : first insights into the black box 2, in Coombs R. (eds), *Technological cooperation*,Cheltenham, Eduard Elgar.

Lhuillery S. (2002), *Panorama des entreprises françaises de biotech*, séminaire REPERES, MENRT, 4 p.

Longhi Ch. (1999), Networks, collective learning and technology development in innovative high technology regions : the case of Sophia-Antipolis, *Regional Studies*, 33, 4, 333-342.

Lundvall, B.A. (1992), Relations entre utilisateurs et producteurs, systèmes nationaux d'innovation et internationalisation, in Foray, D. and Freeman, Ch. (eds), *Technologie et Richesse des Nations,* Economica, Paris.

Lung Y. and al. (1997), *Organisation spatiale et coordination des activités d'innovation des entreprises*, Rapport pour le Commissariat au Plan.

Lung, Y., Rallet, A., Torre, A. (1999), Connaissances et Proximité Géographique dans les processus d'innovation, *Géographie, Economie, Société*, 1, 2, 281-306.

Mangematin V. and Nesta L. (1999), What kind of knowledge can a firm absorb ?, *International Journal of Technology Management*, 18, 3-4, 149-172.

Maskell, P., Malmberg, A. (1999), Localised learning and industrial competitiveness, *Cambridge Journal of Economics*, 23, 167-185.

Monck, C.S., Porter, S.P., Quintas, P. and Storey, D.J. (1988), *Science Parks and the Growth of High Technology Firms,* Croom Helm, London.

Nonaka I. (1994), A dynamic theory of organizational knowledge creation, *Organization Science,* 5, 1, 14-37. .

Orlando M. (2000), *On the importance of geographic and technological proximity for R&D spillovers: an empirical investigation*, WP Federal Reserve Bank of Kansas, Kansas City.

Pavitt K. (1984), Sectoral patterns of technical change : towards a taxonomy and a theory, *Research Policy,* 13, 343-373.

Porter M. (1990), *The competitive advantage of nations*, , Mac Millan, London.

Porter M. (2000), Locations, clusters and company strategy, in Clark and al. (eds), *The Oxford handbook of economic geography*, Oxford U. Press, Oxford.

Rallet A. and Torre A. (2000), Is Geographical Proximity necessary in the Innovation Networks in the Era of Global Economy ?, *GeoJournal*, n°49, 373-380.

Ratti, R., Bramanti, A., Gordon, R. (1997), *The Dynamics of Innovative Regions*, Ashgate Publishing, Aldershot.

Wallsten S. (2001), An empirical test of geographic knowledge spillovers using geographic information systems and firm-level data, *Regional Science and Urban Economics,* 31, 571-599.

Zucker L., Darby M. and Armstrong J. (1994), *Intellectual capital and the firm : the technology of geographically localised knowledge spillovers*, WP NBER 4946.

Zucker L., Darby M. and Brewer M. (1998), Intellectual human capital and the birth of US biotechnology enterprises, *The American Economic Review*, 88, 1, 290-305.