

**Knowledge access and location decisions in biotechnology:
the spatial dimension of social networks**

Margarida Fontes

*(INETI & DINAMIA)
margarida.fontes@ineti.pt*

Cristina Sousa

*(INETI & DINAMIA)
cristina.sousa@ineti.pt*

Pedro Videira

*(DINAMIA)
p_videira@yahoo.com*

Abstract

This paper addresses the spatial dimension of knowledge sourcing strategies, investigating the role played by social networks on the access to scientific and technological knowledge by new biotechnology firms. Our approach takes into consideration the impact of various forms of proximity - geographical, social, cognitive and organisational - on the development of key relationships, as well as on their use for knowledge acquisition. It enables us to assess the relative importance of local and distant knowledge sources and to explain the entrepreneurs' decisions in terms of network mobilisation.

Gateway: Regions as Innovative Hubs ?

Knowledge access and location decisions in biotechnology: the spatial dimension of social networks¹

1. Introduction

Biotechnology is frequently presented as an example of an industry whose mode of organisation spans several spatial levels. In fact, research has shown that biotechnology firms tend to cluster around major centres of knowledge production and “star scientists”, or key clients or, in the case of the US, venture capital organisations (Audretsch and Stephan, 1996; Cooke, 2006; Powell et al., 2002, Zucker et al., 1998). But, on the other hand, research has also shown that biotechnology firms are frequently highly internationalised, engaging in a variety of relationships with organisations located in different regions around the world (Owen-Smith e Powell, 2004).

The knowledge intensive nature of these firms is one of the drivers behind this mode of organisation. In fact, dedicated biotechnology firms are frequently based on the exploitation of scientific and/or technological knowledge produced in research organisations or in large science-based firms and, therefore, they will tend to locate, at least in their early years, in the vicinity of their knowledge sources (Lemarié et al. 2001). But, because their competitiveness depends on the ability to constantly develop and renew their knowledge base, these firms will also need to search for relevant knowledge and for knowledge related partnerships, wherever these can be found (Davenport, 2005; Fontes, 2005). Evidently, search for other resources (particularly capital) and also for markets for their sometimes highly specialised technologies and products, will also have an important impact on their location and networking strategies (Stuart and Sorenson, 2003). But search for knowledge tends to be determinant in the early stages and to remain an important element of those strategies through time (Bagchi-Sen, 2007).

This paper addresses the spatial dimension of knowledge sourcing strategies, investigating the role played by social networks on the access to scientific and technological knowledge by new biotechnology firms, focusing specifically on the relationships between these firms and research organisations. It takes into consideration the process of firm agglomeration around major centres of knowledge production and investigates the effective relevance of such location in firms’ early knowledge acquisition strategies. The objective is to understand the relative importance of knowledge networks connecting firms to these centres, as compared with the ones involving more distant knowledge sources. It is argued that social networks – both those resulting from the entrepreneurs’ previous trajectory and those intentionally created during firm formation - play a key role in knowledge access and transmission. Moreover, since such networks can span spatial boundaries, it is argued that their role is not confined to the local/regional level - which is often the focus of network research – but may be even more critical when firms need to search beyond their local/regional environment.

The paper is organised as follows: in the next section we review the relevant literature, combining contributions from literature on technological entrepreneurship and on the role of social networks in the entrepreneurial process, with recent debates on the nature and

¹ Research conducted in the context of the project ENTSOCNET “Entrepreneurs' social networks and knowledge access: the case of biotechnology” (POCI/ESC/60500), funded by the Fundação para a Ciência e Tecnologia, whose support is gratefully acknowledged.

implications of proximity. In section 3 we discuss, at a theoretical level, the role played by social networks on knowledge access, taking into consideration the impact of various forms of proximity on entrepreneurs' decisions regarding network mobilisation for knowledge access during the process of firms' creation and early development. A number of propositions are put forward regarding knowledge sourcing decisions, which are subsequently explored in Section 4, using the case of Portuguese new biotechnology firms as empirical setting. For this purpose we develop and apply a new methodological approach that permits to reconstruct the entrepreneurs' social networks mobilised for knowledge access and to analyse the different types of proximity relatively to centres of knowledge production to which firms are connected through these networks.

2. Entrepreneurship, proximity and social networks

2.1. Entrepreneurship in biotechnology

The entrepreneur is someone who exploits an opportunity that was not previously recognized and who decides to engage in something new, involving risk and uncertainty. The entrepreneurial process entails the confluence of two events: the emergence of an opportunity and the presence of individuals who are able to identify and explore it (Shane and Venkatraman, 2000). The exploitation of such opportunity requires obtaining a number of resources, whose nature depends on the nature of the opportunity (Joahannisson, 1998). New firm creation is a complex and dynamic process, that is influenced by a variety of factors of a very diverse nature (economic, social, cultural): entrepreneurship is a learning process that is strongly embedded in the environment in which it takes place and requires a constant information exchange with other actors present in that environment.

Entrepreneurship in biotechnology presents some specificity, related with the nature of this industry. Biotechnology is characterised by the proximity between scientific research and the market, which creates opportunities for transforming the results from this research into technologies, products and services (Orsenigo, 1989). Knowledge associated with new scientific discoveries can have a high tacit component, derived from its very novelty that endows it with "natural excludability" (Zucker et al, 1998). This means that only those who were involved in the development of the knowledge will possess the know-how necessary to replicate it, at least until the discovery diffuses sufficiently. Thus, scientific entrepreneurs are likely to have some advantages in what concerns the identification and exploitation of new business opportunities. Likewise, relationships with research organisations, namely those conducting frontier research, can be critical for their development (Murray, 2004; Bagchi-Sen, 2007), not only for developing the first technologies / products, but also for maintaining their competitive edge through time (Witt and Zellner, 2007). Given the variety of fields that contribute to biotechnology development and the distributed nature of knowledge production, firms may need to resort to a variety of organisations in a diversity of locations, in order to obtain the required knowledge mix (McKelvey et al, 2003; Owen-Smith e Powell, 2004).

The need to gain access to external knowledge resources, particularly in the early stages of firm development, when firms' knowledge base is still being built and largely dependent on the competences possessed or accessed by the founding team, leads entrepreneurs to try to mobilise or develop a set of knowledge-related relationships that can facilitate access to key knowledge sources (Elfring and Hulsink, 2003).. Research on social networks can therefore provide an important contribution to an understanding of this process.

2.2. The role of social networks on entrepreneurship

2.2.1 Social networks and entrepreneurship

Research on the sources of entrepreneurship underwent a profound transformation in the last decades. The exclusive focus on the entrepreneurs personality traits, psychological factors and demographic variables, was replaced by a more systemic perspective, which abandons the traditional view of the entrepreneur as an “heroic” isolated individual, and addresses entrepreneurship as a socio-economic process (Granovetter, 1985), embedded in social structures (Aldrich and Zimmer, 1986; Johannison, 1988; Carsrud and Johnson, 1989; Uzzi, 1997). According to this view, the concepts of social capital and social network are fundamental to an understanding of the entrepreneurial process. Firm formation and development is therefore presented as strongly influenced – facilitated or constrained - by the social networks of its founders (personal networks) and by the social environment in which the process takes place (inter-organisational networks). These networks permit to circumvent some of the constraints faced by the entrepreneurs along the formation process, facilitating access to relevant resources.

Research on the role of social networks on entrepreneurship has frequently focused on the case of new technology intensive firms, whose survival and development depends on their capacity to expand and renew their knowledge base (Liebeskind et al, 1996; Yli-Renko et al, 2000). Given the fast pace of technological development in the fields where they tend to operate and given their inevitable resource limitations, these firms often end up being strongly reliant on knowledge originating from external sources (Baum et al, 2000; McMillan et al, 2000). According to some authors, knowledge access and exploitation are social processes (Kogut and Zander, 1992) and thus social networks can be crucial, permitting to increase the scope, depth and efficiency of knowledge exchanges (Lane and Lubaktin, 1998). On the other hand, since these firms are often commercialising technologies/products whose value is not fully demonstrated and since the firms themselves tend to be too young to have built a reputation that supports their marketing efforts, social networks are also regarded as sources of scientific and market credibility (Powell et al, 1996).

2.2.2 Properties of social networks

A social network can be defined as a set of nodes or actors (that can be persons or organisations) connected by a social relationship (or tie) of a specified type (Castilla et al., 2000). It is usual to distinguish between direct ties (a direct relationship between two nodes) and indirect ties (a link between two nodes that is established through other nodes).

Relations can be characterised by the type of interaction (e.g. formal vs. informal), the intensity of the tie and the content of the relation (e.g. the type of resource(s) that circulate through it).

The literature on social networks distinguishes between strong and weak ties, stressing that strong ties are related with higher levels of reciprocity and social proximity. According to Granovetter (1973), the strength of ties can be analyzed using a combination of aspects like frequency/duration of the tie, emotional intensity, intimacy and reciprocity. In order to develop strong ties, actors need to make efforts and to interact in a regular basis. This regular interaction is favored by the physical proximity of actors, which stimulates face-to-face contacts (McEvily e Zaheer, 1999), non-planned contacts (Fornahl, 2005) and the emergence

of trust (Bönte, 2008; Johannisson, 1998) between them. However, the development and maintenance of strong ties entails considerable costs (in terms of time and money), and thus actors tend to have them in a limited number.

The balance between strong and weak ties affects the knowledge transfer process (Maskell and Malmberg, 1999), as well as the cost of accessing knowledge (Coleman, 1988). According to some authors, densely embedded networks with many strong ties - “closed networks” - are more beneficial. They generate trust and cooperation between the actors (Ahuja, 2000), facilitate the exchange of high quality information (Gulati, 1998; Van Geenhuizen, 2008) and of complex (Hansen, 1999) and tacit knowledge (Lundvall, 1993), being particularly important to access scarce resources (Lovas and Sorenson, 2008). According to other authors, however, more “open” networks with many weak ties (Granovetter, 1973) and structural holes (Burt, 1992) have more advantages, which derive from the fact that individuals can build relationships with multiple unconnected actors and explore brokerage opportunities (Burt, 1992). So, in this network configuration, actors use these connections to obtain non redundant information, which can be particularly important in the identification of new opportunities (McEvily and Zaheer, 1999; Low and Abrahamson, 1997).

2.2.3 Networks, proximity and the transmission of knowledge

According to the social network literature, the creation of a direct social tie requires at least one face-to-face interaction between two actors. However, social networks are usually characterised by a more intense and frequent pattern of interactions between agents, since without them, the ties risk to dissolve. Given this need for frequent interactions, several authors defend the importance of proximity between the nodes. However, the literature offers several concepts of proximity that are relevant for social networks. For instance Boschma (2005) distinguishes five types of proximity: geographic/spatial; social; cultural/institutional; cognitive/technological/knowledge-based.

Geographic proximity has been object of the greatest attention in the economic and sociological literature. Its relevance is namely associated with the idea that, as pointed out above, both entrepreneurship and innovation and knowledge creation are collective processes, deeply embedded on social/institutional structures. As a result, there is a strong emphasis on the advantages of co-location, both for established companies and for new entrants (Stuart and Sorenson, 2003; Saxenian, 1994). Geographic proximity is thought to have an important role on innovation and learning. The concept of “economies of agglomeration” (Marshall, 1919), in particular, is rooted on the view that co-location between firms brings them advantages concerning the access to resources, which are translated in cost reductions associated with economies of localisation and economies of urbanisation. Economies of localisation, which are described as one of the factors behind the emergence of industrial districts, consist of economies of scale in intermediate inputs, knowledge externalities and labour market advantages. The concept of economies of urbanisation focuses on the advantages associated with urban milieus, namely in terms of centralisation of government and other public institutions and a variety of specialised services (Castells, 1989).

One of the motives advanced for the agglomeration or “clusterisation” of firms, particularly in more technology intensive sectors, is the presence of local/regional concentrations of knowledge (Audretsh and Feldman, 1996). The literature usually distinguishes between codified and tacit knowledge and puts particular emphasis on the importance of co-location,

mobility and social interaction for the transmission of the latter (Feldman, 1999). The concept of “localised learning” emerged to describe the advantages, for the process of knowledge creation, of co-location between actors conducting related activities (Maskell et al., 1998). Similarly, the literature on knowledge spillovers is based on the assumption that firms co-located with sources of scientific and technological knowledge are favoured, since the presence of social and professional ties and the frequent informal contacts enabled by these, facilitate the access to new knowledge and to problem solving capabilities (Jaffe et al., 1993; Audretsch and Feldman, 1996; Autant-Bernard, 2001). Globally, this literature argues that learning processes are strengthened by the geographic proximity between organisations that exchange information and knowledge. Access to qualified human resources is an additional advantage pointed out by the literature on agglomeration: the presence, diversity and quality of higher education organisations and, more generally, the existence of a critical mass of qualified workers facilitates recruitment in the region and may also foster the creation and/or development of new firms (Wolfe and Gertler, 2001).

2.2.4 Social networks and different types of proximity

Despite the emphasis on geographic proximity, several authors have called the attention to the fact that the simple co-location between actors is not sufficient for knowledge transmission (Breschi and Lissoni, 2001; Boschma, 2005). On the other hand, some authors have shown that relationships established with geographically distant actors can be as (or more) relevant than the ones established with the ones close by and that, frequently, firms combine the benefits from networks spanning various spatial levels (Cooke, 2006; Stahlecker and Koschatzky, 2004; Lagendijk and Lorentzen, 2007). In the case of Portugal, Fontes (2005) analysed the conditions in which new biotechnology firms obtain the knowledge required for their formation and development, concluding that they combine close and distant relationships and that, in the case of the latter, they resort to a variety of mechanisms to overcome the disadvantages of geographic distance.

An explanation of firms’ capacity to benefit from knowledge obtained from geographically distant organisations, calls for the other forms of proximity defined by Boschma (2005). Among these, social, cognitive and organisational proximity appear as particularly relevant, when considering the role of social networks on knowledge access.

Social proximity is a central element in this approach, since it is a basic premise of social networks. Social proximity is related with the presence of social ties between actors, which derive from sharing the same origin or affiliation, and that give rise to social attributes such as trust and the facility of communication. Trust is strongly related with friendship and kinship and with ties linked with the personal experience of actors (Casson and Della Giusta, 2007). Facility of communication is supported by sharing a common language and culture. Thus, social proximity works through actor cohesiveness, facilitating knowledge exchange (McPherson et al, 2001).

Cognitive proximity, which is associated with the sharing of a knowledge base, is also relevant for knowledge exchanges. This is particularly evident in the case of emerging fields, due to the often “exclusive” and “localised” nature of the knowledge being produced and shared (Antonelli, 1995; Zucker et al, 1998). But in any case, effective comprehension and absorption of the knowledge being acquired, always requires that the receiver’s cognitive structure does not differ significantly from the sender’s (Cohen and Levinthal, 1990). “Epistemic communities”, that is, groups of scientists sharing the same knowledge base, as

well as common codes of behaviour and communication, combine cognitive and social proximity (Steinmueller, 2000). Knowledge is “openly” exchanged within the community, but external actors, who are not acquainted with the codes, even when co-located, are unable to decode knowledge that is only apparently available (Breschi and Lissoni, 2001)

Finally, organisational proximity is associated with relationships that take place on an organisational basis, being related with the hierarchical governance structure of those relations, namely in terms of autonomy and degree of control (Boschma, 2005). It is possible to relate this governance structure with the configuration of ties in a given social network: stronger organisational proximity translates into stronger ties between independent actors. Following Boschma, both social and organisational proximity are associated with strong ties, but with different mechanisms (hierarchy and trust, respectively).

The above discussion shows that the literature puts a great emphasis on the role of physical proximity in processes involving knowledge transmission, due to the nature of these processes. Physical proximity is regarded as particularly relevant when knowledge being transmitted has a strong tacit component, e.g. in the case of new scientific discoveries or in cases where “know-how” is critical; when knowledge is of a sensitive nature and therefore its access is restricted; or when knowledge is highly complex, in which case even a process of codification may not guarantee complete comprehension and/or reproduction in a different context (Sorenson, 2005).

However, what can also be implied from some of this literature is that, underneath the importance attributed to physical proximity in knowledge transmission, lies the role played by co-location in the creation of other forms of proximity, that *effectively* facilitate such transmission: namely social, cognitive and organisational proximity. In fact, as is increasingly recognised, simple physical proximity does not guarantee knowledge access and acquisition. Social proximity is important because it generates trust and can facilitate entry into more exclusive knowledge communities. Cognitive proximity is necessary to assess the value of the knowledge produced by a given source and to fully understand it (namely when its diffusion takes place in the context of epistemic communities), as well as to absorb and apply it effectively. Finally, organisational proximity (previous or actual) facilitates interaction, since it enables an understanding of the rules, hierarchies and codes of behaviour that prevail in the source organisation. But, it is also a fact that these forms of proximity tend to be more difficult to develop or maintain when there is no physical proximity, and that they are often the result from the frequent face to face interaction and experience sharing enabled by co-location (Torre and Rallet, 2005). Co-location also generates opportunities for the identification of common interests and encourages the development of closer relationships in order to exploit them and, when pursued through time, favours the co-evolution of the actors.

While instances of co-location are recognised as important for the *creation* of social, organisational and cognitive proximity, the capacity to *develop and benefit* from these types of proximity does not necessarily require continued physical proximity. Temporary co-location can, in certain conditions, substitute for it, namely when the relevant knowledge cannot be found (or is more complex to access) in the context where the actor is usually located. The implication is that knowledge access networks can involve both ties with individuals/organisations that are geographically close – which will tend to be stronger, given the greater opportunity for frequent interaction - and ties with individuals/ organisations geographically more distant – which will tend to be more difficult to obtain and maintain and

are likely to be more frequently associated with access to knowledge particularly important for the firm and/or more difficult to obtain in the geographic vicinity (Gittelman, 2007).

The social network literature brings an additional contribution for the understanding of these multi-spatial interactions process, by addressing the process of network building and, namely, by calling the attention to the role played by individual trajectories in that process. Applying these contributions to the case of new firm formation, it is possible to argue that, while the building up of personal networks that facilitate knowledge access rarely occurs without co-location, such co-location may take place at different points of the entrepreneur's trajectory and does not need to be contemporary to the creation of the new firm. Mobility is at the root of this multi-spatiality (Williams et al, 2004). In the particular case of science-based fields such as biotechnology, the growing inter-organisational and international mobility of scientists (Ackers, 2005) creates the conditions for these processes to become increasingly frequent. It is to be expected that scientific entrepreneurs establish relationships characterised by cognitive and/or social and/or organisational proximity in the various locations they move through, and that at least some of these relationships are kept when co-location finishes (Saxenian and Hsu, 2001). Advances in information and communication technologies, that make access to information at a distance easier and affordable (Amin and Cohendet, 2006) and new opportunities for temporary co-location (e.g. short-term mobility for training or joint work; project meetings or even presence in at international events that join the main actors in a given field (Wink, 2008)), that provide the setting for nurturing the social relationship and also create the conditions for maintaining co-production of knowledge and thus cognitive proximity (Torre and Rallet, 2005; Sapsed et al, 2005), are the ingredients that enable the continuity of these close relationships. Considering that international mobility, particularly from more peripheral regions, is frequently associated with search for advanced knowledge that is not available in the region, it is not surprising that the individuals/ organisations with whom these relationships were established end-up assuming an important role as knowledge sources for the new organisations being created.

The social networks that are determinant for knowledge access by the firm being created can thus have different structures and origins and encompass several spatial levels (Coe and Bunnell, 2003; Gittelman, 2007). They can be based on entrepreneurs pre-existing personal network, involving: actors that are in the geographic proximity of the firm being created; actors that were in the physical proximity of the entrepreneur at some point of his/her previous academic or professional path and, while not being in that position anymore, still belong to his/her social network and are regarded as important source of knowledge relevant for the new firm. But they can also result from a purposeful effort to develop new relationships (and create cognitive or social proximity) with individuals from organisations that possess knowledge regarded as important for the firm. If sources of this knowledge are available in the vicinity, it is to be expected that efforts are put into gaining access to them: as pointed out above geographic proximity favours a greater intensity of interactions and facilitate the development of trust. If not, they may be oriented to more distant sources, namely through the search for opportunities of temporary co-location. In both cases, the members of the existing network can have a critical role as mediators (Wink, 2008).

The nature of the scientific and technological infrastructure present in the context where the firm is created influences its decisions regarding the establishment of knowledge-oriented relationships. If knowledge sources are numerous, diversified and of high quality the firm will have less incentive to establish distant networks. But there are exceptions. For instance, when pre-existing ties with distant sources are perceived as important, the effort necessary for

their preservation may be lower than the one required for searching and establishing new ties with local scientific communities. It is also possible that local communities are closed and difficult to access or that it is not possible to achieve locally a similar level of trust. On the other hand, local sources may not be able to provide the required knowledge and, in that case entrepreneurs are likely to try to resort, first of all, to distant members of their personal networks, mobilising ties whose origin was co-location in some point of their trajectory, but who involve individuals who are now geographically distant from the place where the firm is established. These situations can also occur when the local/ regional environment offers variety and quality of knowledge sources - which may even be used by the firms - but which cannot provide knowledge that is more specialised or more novel and is only available in some particular locations. This supports the idea that firms may have knowledge networks with different spatial structures, in which close and distant relationships can have different weights or be balanced. Such differences in spatial structure can be related to the nature of the knowledge being searched and its relevance to the firm, as well as to the nature of the relationships.

In summary, the above discussion enables us to conclude that geographic proximity (i.e., co-location of individuals, either permanent or temporary) favours the development of relationships characterised by other types of proximity - social, cognitive and/or organisational – that facilitate transmission of scientific and technological knowledge. While continued geographic proximity favours the persistence through time and the strengthening of the networks thus formed, and also facilitates interaction and collaboration among its members, the functions played by these networks in knowledge access are not geographically bounded. Thus, while it may be easier, and eventually more effective, to resort to network members that are located in the vicinity, it is equally possible – and often necessary - to use distant ties, which can play a critical role when it comes to gain access to knowledge that is not available in nearby organisations.

This has implications for our approach to the question addressed in this paper: the location of biotechnology firms in the vicinity of centres of knowledge production and the effective position of these centres in their knowledge networking strategies. Drawing on the above reasoning, we put forward the following propositions concerning the access to scientific and technological knowledge (assuming similar conditions regarding the access to other critical resources and disregarding entrepreneurs' personal circumstances²):

- a) In the formation period, the new firms will tend to be located in the vicinity of those knowledge sources that entrepreneurs regard as more relevant for their activity and with which they have more intense relationships.
- b) When firms can mobilise their network to gain access to knowledge sources that are geographically close, they will have less incentive to mobilise relationships with more distant knowledge sources.
- c) When firms need to gain access to distant sources of knowledge, they will tend mobilise the geographically distant elements of the social networks they build along their trajectory, profiting from the social, cognitive or organisational proximity created to facilitate such access.

² It should be noticed that the process of firm creation involve mobilising other resources - such as capital, laboratory and other facilities, specialised services, and complementary competences at the production, commercialisation or regulatory level (Colombo et al, 2006) – whose access may also have an influence on location decisions (Egeln et al, 2004). On the other hand, entrepreneurs' family, professional and other personal motivations can also constrain such decisions.

4. Empirical research: the case of Portuguese biotechnology firms

The questions raised in the previous section are investigated using the case of Portuguese biotechnology industry as empirical setting. For this purpose we have selected a specific subset of the Portuguese dedicated biotechnology firms: the molecular biology companies, involving 23 firms and 61 entrepreneurs. The choice of this sub-group was based on the fact that molecular biology firms configure the most science-based biotechnology subset and thus search for knowledge is likely to assume particular relevance, namely in the early years. On the other hand, the use of a group that is relatively homogenous, at least in terms of the core knowledge base, and therefore of the type of source organisations, avoids an additional source of variety concerning the availability of the latter.

In this section we present a brief characterisation of the sector and propose a research methodology.

4.1 Brief characterisation of Portuguese biotechnology firms

The development of a biotechnology industry is a recent phenomenon in Portugal. In fact, after a period of relative stagnation, during which very few firms were created, there was a sudden entrepreneurial upsurge around 2003, which has been maintained until this day. Nevertheless, the number of dedicated biotechnology firms is still relatively small: there are currently 79 firms formally in operation³ (to which can be added a growing number of firm projects in a more or less advanced stage of development), but about 80% were created from 2003 onwards. Thus several firms are still in an embryonic stage of development and only a small group of pioneers have developed their technologies/products and started introducing them into the market. As a result, the sector is still very incipient and populated by very small firms.

The upsurge registered in mid-2000 was associated with a combination of favourable factors, described in detail in Fontes (2007). They include: the growing quality and maturity of research in some public research organisations (PROs) and the presence of a pool of highly qualified and internationalised (but often under-employed) young scientists, combined with changes in the institutional environment (involving both public and private actors), that led to a sudden increase in the incentives and support to technology-based entrepreneurial initiatives, particularly those involving the commercial exploitation of knowledge from public research organisation (PROs)⁴. However, most institutional changes were directed towards the process of firm formation, and there are still serious obstacles to an effective take-off of the sector, namely in what concerns the access to resources that are critical for firms' subsequent development.

The conditions in which firm formation took place can partly explain their characteristics: the majority were direct or indirect spin-offs from research (Fontes, 2007) and a substantial proportion involved or were created through the initiative of young scientists. Their location

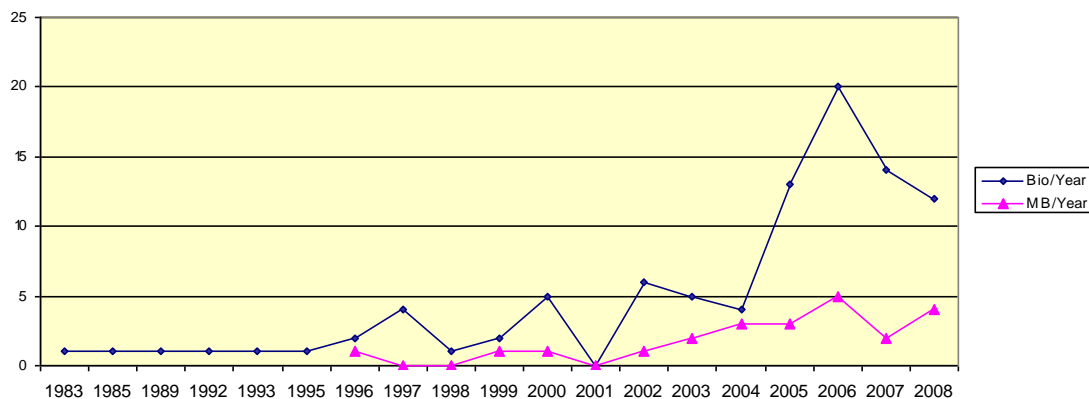
³ Firms identified up to December 2008. It includes the whole population of dedicated biotechnology firms, to the best of our knowledge. Information on these firms is stored in an INETI proprietary data-base.

⁴ There has been a low interest/investment of large developed companies in this field, which can be partly explained by the country's specialisation in sectors that are not drivers of biotechnology development. So there was a limited impact of industry-related actors in this process. One notable exception were the biotechnology entrepreneurs themselves, namely those from "pioneer" firms, who have been particularly proactive in political action on behalf of the industry and who have also shared their experience with the younger firms.

also reflects their origin, since it follows the main metropolitan areas where the main PROs are located and where incubation and other support infrastructures and key services are increasingly available. Thus biotechnology firms are basically distributed along a “littoral strip”, being more concentrated on and around the major towns of Lisbon and Porto, which account for half of the firms (respectively 35% and 20%), although there is a growing number of firms being created around smaller towns with research universities. The small size of the country and the good level of accessibility along this strip make contacts between these locations relatively easy and frequent. The main areas of application include: health (human and animal) (45%), agriculture and food production (respectively 30% and 16%) and environment (9%). It is interesting to notice that the health sector weight is a relatively recent phenomenon and that it includes a high proportion of firms oriented to clinical applications, although there are a growing number of firms in biopharmaceuticals.

The group of 23 firms that are the focus of this research – the molecular biology firms - belongs almost exclusively to the younger generation (again 80% were created from 2003 onwards), as becomes evident from Figure 1, that compares the year of firm creation in this group with that of biotechnology firms in general⁵. They tend to follow the above pattern although, as would be expected given the nature of the technologies being exploited, their activities tend to concentrate in the health sector (20 out of 23), with a greater predominance of clinical applications (as opposed to pharmaceuticals). All firms were created by entrepreneurs coming from universities or research organisations; although in several cases non-academic individuals joined the team (e.g. graduates with managerial competences, entrepreneurs, and practitioners in the applications field). The teams are mostly composed of young entrepreneurs, although in some cases there is also a senior researcher in the team (who tends to retain the post in the university).

Figure 1: Firm creation per year: comparison between molecular biology firms and biotechnology firms in general

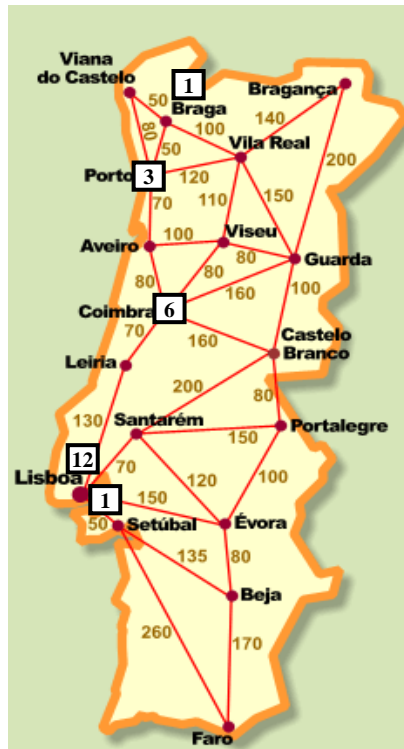


A further specificity of this group of firms is the fact that they tend to be clustered in two main metropolitan areas: in the Greater Lisbon (50%), which is responsible for the highest R&D investment in the country and around the town of Coimbra (27%), a region that has developed some competences in the health sector and which appears to be starting to

⁵ Note that the number of dedicated biotechnology firms created per year, presented in the Figure, includes firms that are now out of business (15 firms).

specialise in this field⁶. The remaining 2 firms are located in medium-sized towns that, in practice, belong to the “metropolitan area” of one of the major towns. Figure 2 presents the geographic distribution of these firms, also displaying the geodesic distances (in kilometres) between the towns where this set of firms – and the majority of the main biotechnology research centres - are located.

Figure 2: Location of the molecular biology firms analysed



This choice of geographic location may signify that there was a decision to create the firms in the vicinity to the main centres of knowledge production in scientific fields relevant to their activity. However, we cannot discard the existence of other reasons, associated to personal motives as well as to access to other resources. Therefore, it is relevant to evaluate whether the location option is effectively associated with the presence and/or development of scientific and technological relationships with local research organisations, what is the origin of such relationships and also, what is their importance to the firm, when compared with other knowledge sources. One interesting particularity of this group of firms is that, in almost all cases, there was at least one entrepreneur who had an international trajectory, often entailing graduate training or research work in biotechnology centres of excellence. This suggests that personal networks established with scientists of these organisations could assume an important role in the new firm search for knowledge.

4.2 A methodology to analyse the role of social networks in knowledge access

The objective of the empirical research is to investigate the structure and origin of the relationships established by these firms to gain access to scientific and technological

⁶ This can be explained by a tradition of research in the health area, associated with the presence of a major university hospital, an important research centre in the molecular field and, more recently, the creation of an incubator that acts as an attractor to firms in this field.

knowledge, in order to uncover and explain the spatial dimension of their knowledge access strategies. Departing from the observation that, in the Portuguese case (as elsewhere), firms tend to cluster around the main centres of knowledge production, we try to understand the role effectively played, on knowledge access, by the networks connecting entrepreneurs/firms to the centres located nearby and by networks involving more distant knowledge sources.

Our approach takes into consideration: i) that scientific and technological knowledge is a key resource for these firms; ii) that physical proximity is an important factor in knowledge acquisition, though not being generally sufficient to guarantee effective access and absorption, which may require the presence of other forms of proximity: social, cognitive, organisational; iii) the role played by personal networks, built by the entrepreneurs along their academic and professional trajectories, in the development of these types of proximity; iv) the fact that location decisions taken by new firms will also be influenced by a series of other factors, including access to additional resources and entrepreneurs' personal conditions. Having in mind these assumptions we investigate:

- a) the influence of geographical proximity to knowledge sources in the location of the firms, during the period of firm formation;
- b) the role played by social networks in the match between knowledge access and location strategies: either reinforcing the tendency to locate in the vicinity to knowledge sources with which entrepreneurs have developed key relationships; or enabling firms to get established in locations that are more or less geographically distant from these knowledge sources, but that eventually present other types of advantages for the new firm.

We will therefore investigate, on the one hand, how important for the firms in our sample is physical proximity with knowledge sources, namely whether it is effectively synonymous with extensive use of these sources; and whether physical proximity is associated with other forms of proximity. On the other hand we investigate the relative importance of distant knowledge sources and whether their access requires other forms of proximity that compensate for the physical distance.

In order to address this problem we developed a two-step methodology. The first step entails the (re)construction of social networks that are mobilised by the entrepreneurs during firm formation, with a view to understand their composition and origin. "*Firm formation*" is regarded as a process that includes the pre-start-up period, the year of formal creation and the two subsequent years of activity. The second step involves an analysis of proximity relatively to centres of knowledge production that were mobilised.

4.2.1 (Re)construction of the networks

As was pointed out above, the academic and professional trajectory of the entrepreneurs is a key element in the formation of the new firm social network. In fact, the entrepreneurs' career trajectory not only contributes to configure their competence base and what they perceive as key sources of information and ideas, but it also shapes the composition of their personal networks in terms of actors and their potential contributions (Burton et al., 2002). In the early stages, the firms' knowledge base and social network will correspond quite closely to the entrepreneurs' (Hsu, 2007).

The set of personal relationships established by the entrepreneurs before they engage on the entrepreneurial process can thus be regarded as a latent social capital, which will be partially

mobilised during the process, thus becoming part of the new firm's social network. In addition to their existing set of ties, the entrepreneurs also establish, during the process of firm formation, a new set of relationships - frequently formal, or formalised at some point – which already have the firm as explicit goal and should therefore be considered as part of the network that is mobilised by it.

Information on the networks that were mobilised by the entrepreneurs for knowledge access was collected using a combination of complementary methods, involving both search for documentary information and in-depth face-to-face interviews with the founders, conducted during 2008. This combination of methods represents a novel approach that puts together methods usually applied independently (Balconi et al. 2004; Breschi e Lissoni, 2004; Casper, 2007; Dietz et al, 2000; Murray, 2004; Singh, 2003) and that not only provides a richer set of information, but also offers the possibility of confronting different sources and perspectives, thus improving the robustness of the data.

Documentary information included: the Curriculum Vitae (CV) of the entrepreneurs, published data about formal collaborative projects, patent data, and a variety of information, from diverse sources about the entrepreneurs' personal trajectories and firm formation histories (including also data collected along previous research on some of the firms)⁷. The interviews were based on a semi-structured questionnaire, composed by two parts. The first focused on the entrepreneurs' personal network and on the importance of that network for firm formation, allowing the collection of more systematic and fine grained information about the people who were important during the formation period, including the origin of the relationships and the type, nature and relevance of their respective contributions. The second addressed the firm activities, strategy and performance, with particular emphasis on innovation and technological development and on formal cooperation arrangements with other firms and research organisations.

These sources enabled us to obtain information at three levels. Documentary analysis (complemented where necessary by the interviews), permitted to reconstruct the paths of all members of each firm's founding team and to map the organisations where they had developed training or professional activities and, thus, where personal relationships might have been established through time. This approach was based on the assumption that, when an individual works in a given organisation, he/she develops some ties that are maintained after he/she leaves, becoming part of their social network (Burton et al, 2002)⁸. This permitted us to build individual trajectory networks that, put together, composed the latent set of ties that could be mobilised during firm creation and early development: the "*potential network*".

Subsequently, the interviews permitted to identify the members of these potential networks who were *effectively mobilised* by the firms in the access to scientific and technological knowledge during the formation process – the "*trajectory networks*" – and also to have a more precise idea of the origin of the tie, the purpose(s) for which it was used, the location of the actor(s) and the intensity of the interaction. This permitted us to have a perception of the

⁷ Data on publications was also collected and will be used on a subsequent stage

⁸ Our interviews confirm it for these entrepreneurs, at least for relationships abroad, which are usually regarded as more difficult to maintain through time (Dhalander and McKelvey, 2005).

extent to which entrepreneurs resorted to their pre-existing relationships, as well as to characterise the nature of the relationships underpinning them⁹.

Finally, the interviews, combined with documentary analysis, permitted to identify the networks intentionally built to access scientific and technological knowledge, during the firm formation process: the “*intentional networks*”. Interviews equally provided information on the origin¹⁰, purpose, location and intensity of these new relationships, while documentary analysis – using data on joint R&D projects and patents submitted by the firm – provided more detailed information on formal relationships established by the firm in their early stages.

The *mobilised network* of each firm was built by considering both the ties from the potential network that were mobilised - i.e. the *trajectory networks* - and those intentionally established – i.e. the *intentional networks*. Because the objective of this research was to investigate the relationship between the firms and centres of knowledge production, we used the organisation as the unit of analysis, which entailed making a correspondence between the individual ties and the organization(s) in which the individuals were working.

The data were organised in a way that enables us to distinguish between mobilised ties that are part of trajectory networks and those that are part of intentional networks; and between formal (related to projects and patents) and informal ties. We also took into consideration tie strength and actor location.

4.2.2 Analysis of proximity

The literature presents several measures of geographic proximity. In this research we opted by defining several spatial levels, recognising the multi-spatial nature of the biotechnology industry. The following scale of proximity between biotechnology firms and research organisations was defined: *local* (co-located in the same address or in the same municipality); *national* (located in a different municipality but within country borders)¹¹; *international* (in a foreign country).

Other forms of proximity are more difficult to operationalise. In this research, we opt for simply distinguishing between physical proximity and other forms of proximity - social, organisational or cognitive - which were taken globally¹². Then we assume that at least one form of non-physical proximity existed with organisations whose members were part of the entrepreneurs’ trajectory network. The rationale behind this assumption is that, at some point of their academic or professional trajectory there was a period of co-localization between

⁹ In a subsequent stage this may enable us to define more precisely the type (or types) of proximity that characterise them. At this stage we simply assume that, given their origin, these ties entail at least one of the three types of non-geographic proximity described above.

¹⁰ This permitted namely to identify some members of the potential networks that were not directly mobilised for knowledge access but acted as “structural holes”, granting access to critical actors who could not be easily mobilised without proper references.

¹¹ The option of considering exclusively local and national distance, thus not introducing a intermediary “regional” level, is based on the recognition that Portugal is a relatively small country, whose main transportation lines run along the littoral strip, where the molecular biology firms and the relevant research organisations are located, and that, therefore, physical distances between organisations located in the “regions” along this strip are indeed very relative (maximum 3 hours travel), as becomes evident from Figure 2,

¹² In subsequent research we will try to disaggregate the non-geographic forms of proximity and to understand more clearly their individual role.

individuals from those institutions and the entrepreneurs, during which links were established and therefore social, cognitive or organisational proximity was developed.

We analyse the proximity between the firms and the organisations they mobilised through their networks, to access scientific and technological knowledge, during the formation period. We assume that the organisations mobilised were *relevant knowledge sources*. Some might have proven to be more useful for the firm than others but all these organisations had, at least potentially, some knowledge which the new firm regarded as relevant for its activity. Some other potentially relevant knowledge sources would certainly have existed even geographically close but for a number of reasons, namely the existence of other types of proximity, the selection of the institutions perceived as more useful, or lack of information about the work being developed, have led the entrepreneurs to establish relations with these. Therefore, when we speak about the *absence* of relevant sources of knowledge, we mean that the firms being analysed have found no local sources in their vicinity or have elected - by reasons of necessity or preference - to establish relations with geographically more distant institutions.

The analysis involved assessing the number, strength and origin of the ties established at the different spatial levels: local, national, international.

The strength of the ties was measured according to two criteria: the frequency of the contacts and the existence of more than one type of relation (formal or informal) between our firms and other institutions. According to these criteria a *strong tie* is one where an informal (personal) relationship is sustained at least through one monthly contact (though these can obviously be more frequent on a weekly or daily basis) or where there is more than one type of relationship (i.e. a formal and an informal relation, more than one formal relation, or more than one informal relation). Conversely, a tie will be considered *weak* when it is supported by a sporadic informal relation and when there is only one type of relation (e.g. when the two institutions only participate jointly in one project). Stronger (individual) ties reflect higher social proximity and thus this measure reinforces the presence of other forms of proximity.

The origin of ties is based on the previous characterisation of networks. Thus *trajectory ties*, are derived from the entrepreneurs' personal networks, being established with organisations that are part of their previous trajectory. According to the definition presented above, these ties are assumed to involve some form of non-physical proximity. *Intentional ties*, are the ties purposefully established by the entrepreneurs. They are assumed to be new ties connecting firms to organisations not previously part of the network, even though in some cases there may have been an indirect link to the organisation, through a friend, acquaintance or former colleague. The role played by existing network members as mediators – i.e. the presence of indirect ties - was not included in this research, because although some interviews permitted to identify their presence, the data available on them was not necessarily exhaustive.

Finally, it should be pointed out that, while the focus of our attention is on research organisations, we did not exclude other organisations that firms regarded as sources of knowledge. However, it was found that PROs accounted for the vast majority of ties, other firms being very rarely present and almost exclusively at the international level (namely in formal relationships through projects). Therefore, the conclusions reached concern basically research organisations.

4.3. Results from the empirical research

4.3.1 – The knowledge access networks

Two tie matrices were created on the basis of the variables described above: one including the whole set of ties established by each firm at the three spatial levels and discriminating between trajectory-ties and intentional ties; another including only the strong ties, according to the same distribution. The analysis of these matrices permitted to discern a number of patterns in terms of the combination of variables: distance between firms and knowledge sources, tie strength and tie origin (as a proxy to other forms of proximity). The patterns enabled us to define five main categories of firms in what concerns the modes of knowledge access. Table xxx presents the network data, already organised according to these five groups, which are characterised below.

Table 1 – Mobilised networks for knowledge access (all ties)

Firms		NUMBER OF TIES					
		Trajectory ties mobilised			Intentional ties mobilised		
		local	national	international	local	national	international
Group 1	A	1	1	1	3	1	9
	B	2	3	0	0	3	4
	C	2	0	1	1	1	18
Group 2	D	2	0	1	1	0	1
	E	1	1	1	1	0	0
Group 3	F	1	0	0	0	0	0
	G	1	0	0	0	0	0
	H	1	0	0	0	0	0
	I	1	0	0	0	1	0
	J	1	1	0	0	1	0
	K	1	0	0	0	0	0
	L	1	0	0	0	0	0
	M	2	0	0	0	2	0
	N	1	0	0	3	1	0
	O	1	0	0	0	3	0
P	1	0	0	1	0	1	
Group 4	Q	0	0	0	1	2	0
	R	0	0	1	0	2	0
	S	0	0	1	0	0	0
	T	0	2	1	1	0	0
	U	0	1	1	0	0	0
	V	0	0	1	0	0	2
Group 5	W	0	0	0	0	5	7

Table 2 – Mobilised networks for knowledge access (strong ties)

Firms		NUMBER OF <i>STRONG</i> TIES					
		Trajectory ties mobilised			Intentional ties mobilised		
		local	national	international	local	national	international
Group 1	A	0	0	1	1	2	0
	B	2	1	0	0	0	0
	C	1	0	1	0	0	0
Group 2	D	1	0	1	0	0	0
	E	1	1	1	1	0	0
Group 3	F	1	0	0	0	0	0
	G	1	0	0	0	0	0
	H	1	0	0	0	0	0
	I	1	0	0	0	0	0
	J	1	0	0	0	0	0
	K	1	0	0	0	0	0
	L	1	0	0	0	0	0
	M	1	0	0	0	1	0
	N	1	0	0	1	1	0
O	1	0	0	0	0	0	
P	1	0	0	1	0	0	
Group 4	Q	0	0	0	1	2	0
	R	0	0	1	0	0	0
	S	0	0	1	0	0	0
	T	0	0	1	1	0	0
	U	0	1	1	0	0	0
	V	0	0	1	0	0	2
Group 5	W	0	0	0	0	2	0

Group 1 – Firms in this group are characterised by having ties that span all spatial levels, both deriving from the entrepreneurs' trajectory and intentionally created. The latter are more extensively mobilised than in any other group (excepting of the very particular case described in group 5), especially in what concerns access to international sources of knowledge.

Group 2 – This group is very similar to group 1 regarding the mobilisation of trajectory tie networks, which also span all spatial levels, but differs on that firms mobilise few intentional ties. The majority of ties established by these firms are strong ties.

Group 3 – Includes the largest group of firms. Firms are characterised by mobilising one key tie from the entrepreneur's trajectory to access knowledge from a local source, with which they have a strong relationship (indeed, with which are often co-located, in the same premises), as well as for not mobilising international ties (with only one exception, not derived from the trajectory). Trajectory networks are exclusively mobilised at local level, while intentional ones are mobilised at local and at national level.

Group 4 – Firms in this group are characterised by only mobilising entrepreneurs' trajectory networks to access non-local sources of knowledge. Few firms mobilise ties with local sources and always new ties, intentionally created. Some firms also establish new ties for accessing national sources, but in only one case there is mobilisation of this type of ties for accessing international sources. International knowledge access is basically conducted through trajectory ties, thus is based on previous co-location with the organisation or some of its members. Interestingly, both trajectory and intentional ties tend to be strong ties.

Group 5 – Includes in fact only one firm, whose behaviour is atypical in this set of firms: it does not mobilise any local tie (trajectory or intentional) and it does not resort to the entrepreneurs' potential network. Thus all ties are with sources of knowledge that were not part of the entrepreneurs' trajectory and that are located in a different municipality or country. The fact that this company was a pioneer in this field in Portugal and therefore was created at a time when the local scientific and technological capabilities in the field were less developed (and possibly the local knowledge sources were less prepared to interact with a company) may contribute to explain its singularity among the generality of molecular biology companies¹³.

4.3.2 – *The role of proximity for knowledge access*

In this section we address our theoretical propositions at the light of the empirical evidence collected.

Proposition 1 states that, in the formation period, firms will tend to be located in the neighbourhood of relevant knowledge sources and that the ties they establish with these will tend to be more intense than the ones established with more distant sources.

Following the rationale defined in section 4.2.2 we assume that when entrepreneurs mobilise a tie with a knowledge source, this source is regarded as *relevant* and therefore we use the mobilised networks as unit of analysis and measure the number and intensity of ties established with each knowledge source.

The comparison, for the totality of firms, of the networks mobilised by the entrepreneurs at the three spatial levels (Table 3), supports Proposition 1. Table 3 shows, in the first column, the relative weight of local, national and international ties, measured as the mean of the percentage of each type of tie on the totality of ties, calculated for each firm. In the second column it shows a similar measure, but only for the strong ties. It is clear from the data presented that local ties are generally more expressive and more intense than national or international ones. Thus, there is a tendency for co-location with relevant knowledge sources, with which firms tend to establish more intense relationships (in terms of frequency of interaction and/or continuity).

¹³ The behaviour of this firm is consistent with that of other pioneer biotechnology firms, studied by Fontes (2003). Since the majority of molecular biology firms belong to a younger generation of firms, they have already been established in a more favourable environment.

Table 3 – Mean percentage of mobilised ties by spatial level

	Total mobilised ties	Strong mobilised ties
Local ties	46%	60%
National ties	27%	18%
International ties	27%	22%

However, if we look in more detail at the five groups of firms identified, we realise that there are differences between them regarding the relative importance of geographic proximity. In fact, some firms (the firm in Group 5 and four firms from Group 4) do not mobilise ties to any nearby knowledge sources, being exclusively connected with geographically distant ones. That is, entrepreneurs from these firms did not find any *relevant sources* in the location where they decided to create their firms – location being thus based on other reasons that prevailed over knowledge access - and had to resort to more distant ones.

When we remove this group of firms, we observe an even stronger weight of local ties for the remaining ones, which are the majority in the sample. Among these, there is even a group of firms (all from Group 3) that only mobilise local ties, which basically connect them to the research organisation that was at the origin of the technology and of some of the entrepreneurs.

So we have in fact two types of situations, either firms do not mobilise local ties at all, or, when they mobilise them the relationships established are strong. The latter situation appears to be the most frequent, thus confirming that co-location to relevant knowledge sources – which they frequently (but not always) combine with mobilisation of more distant, national or foreign sources - is the preferred strategy for Portuguese molecular biology firms, at least in their early years. The former situation may be associated with the nature of the knowledge being searched or with the characteristics of the local knowledge communities in the firms' specific area of activity.

Proposition 2 states that if firms mobilise local actors from their network they will have less propensity to mobilise relations that are geographically distant.

To address this issue we evaluate the impact of mobilising local ties on the propensity to mobilise distant ones (national or international). We find support for our proposition only for the case of international ties. In fact, if we compare firms that mobilise and firms that do not mobilise local ties, relatively to the mobilisation of international ties (Table 4), we conclude that *all firms* that do not mobilise local ties will mobilise international ones, while only 39% of the firms that mobilise local ties will simultaneously mobilise international ones. Thus firms that resort to local knowledge sources have a lower tendency to resorting to knowledge sources located abroad, than those that cannot find relevant sources in the vicinity.

Table 4 – Degree of mobilisation of international ties

	% Firms
Firms that mobilise local ties	39 (a)
Firms that do not mobilise local ties	100 (b)

(a) % was calculated on the basis of all firms that mobilise local ties (18)

(b) % was calculated on the basis of all firms that do not mobilise local ties (5)

Given this result, we have tried to understand the relative importance of national and international ties in the search for knowledge beyond the local space. Table 5 presents the relative weight of each spatial level, for firms that have and for firms that do not have local ties. It shows that, effectively, when firms do not mobilise local ties, the non-local ones they mobilise are predominantly international (68%). On the contrary, when firms mobilise local ties, the non-local they mobilise are predominantly national (62%). That is, for this last group of firms, country-level knowledge sources (both at local and national level) are the most important, while for the first group, international sources are definitively more relevant.

Table 5 –Proportion of international ties on non-local ties

	International ties (%)	National ties (%)
Firms that mobilise local ties	28	72
Firms that do not mobilise local ties	68	32

One possible explanation for this dichotomy concerns the nature of knowledge production at country level. It is possible that there was limited activity in some specific fields, while in others occurred the development of stronger capabilities, which may be located in one specific organisation, but may also be distributed by several research organisations throughout the country. The period when the companies were formed will have some impact on this capability development, as we referred above. Thus some firms will be forced to look abroad for knowledge given the absence of sources at country level, whereas others may find a variety of sources, not only nearby but also in other organisations located elsewhere in the country. The fact that intentional ties were found to predominate among the national ties mobilised (over 2/3), suggests that the latter may result from a search for complementary sources, while the interviews show that sometimes the building up of these intentional ties is often based on the links between the pre-existing local organisation and the new national ones. On the other hand, the extensive (or even exclusive) use of international ties, may be related to personal choice: entrepreneurs who, along their international trajectory, developed close relationships with scientists/organisations possessing knowledge relevant for their firms, may prefer to resort to this source, at least in the early stages of firm development, irrespective of the presence of potentially relevant sources at country level (even if not locally). Further research may be required to understand the eventual strategies behind these decisions.

The case of firms whose stronger ties are with foreign sources of knowledge also brings an additional insight into location strategies. Since, in order to locate in the vicinity of key sources, entrepreneurs would have to change country - which is always a complex decision for various reasons, namely the potentially local/national nature of the network required for accessing other types of resources – their choice might have indeed been guided by the advantages of a major metropolitan area, where capital and specialised services tend to be concentrated and where they can benefit from the access to international airports.

Proposition 3 states that, when firms need to resort to distant sources of knowledge they will tend to mobilise their trajectory networks, that is, they will tend to resort to knowledge sources with which they have other types of proximity, resulting from previous co-location (permanence in the organisation or co-location with members of that organisation);

To address this proposition we evaluate the importance of trajectory networks in the access to international sources, since these can be regarded as more complex to access at distance, and also since we already identified a certain tendency for a dichotomization between local and international trajectory ties, leaving a secondary role to national ties. We calculate, for the whole sample, the relative weight of the ties based on the trajectory and of those intentionally created, on the total number of ties mobilised at international level (measured as the mean percentage of each type of tie origin on the total ties, calculated for each firm). We then repeat the calculation only for the case of strong ties (Table 6)

Table 6 - Origin of ties mobilised at international level (%)

	All ties mobilised at international level	Strong ties mobilised at international level
Ties based on trajectory	16%	80%
Ties intentionally created	84%	20%

Contrariwise to what we expected, the weight of the international ties intentionally created exceeds substantially those originating from the trajectory, although the result is exactly the opposite when it comes to the strong ties. Considering that we use the origin of the tie as a proxy to non-geographic proximity originating from previous co-location (as explained above), our first conclusion would be that this was not determinant for the access to international knowledge sources.

However, the striking difference in the results for strong ties – which are associated with continuity in the relationship or with frequency of interaction, denoting a greater importance attributed to these particular ties - led us to observe in greater detail the results. We found that the weight of intentionally created ties derived essentially from the involvement of a few firms (particularly from group 1 and 5) in large European projects. These projects usually involve a large number of partners that are not part of the trajectory network (thus the weight of intentional ties), but the actual interaction with most of them is very limited (explaining the absence of strong ties)¹⁴. Thus, without disregarding the effective need felt by some firms to search for new knowledge that could not be accessed through their pre-existing networks and which required them to resort to building new intentional ties also at distance, it is possible to suggest that these situations may be relatively less frequent than reflected in the above results. This points to the need of separating, in the next step of this research, the informal and formal ties and assess the relative role of each.

It is also important to notice that we equally find differences between groups of firms regarding the use of ties based on the trajectory to access international sources. In particular, we find that firms in Group 4 - that practically do not resort to local sources and never mobilise trajectory ties for that purpose - will typically mobilise trajectory ties to access international sources, all of these ties being strong. A similar behaviour is found in firms from Group 2, but in this case firms also mobilise ties based on the trajectory to access local sources. Conversely, the mobilisation of intentional ties based on projects (that are always weak ties) is typical of the firm in Group 5 and of the firms in Group 1 – but the latter also mobilise trajectory-based ties for that purpose. So once again strategies are not homogeneous: the importance of other types of proximity appears to be strong for the majority of firms that resort to distant knowledge, although some of them will also need to gain access to distant

¹⁴ For instance, in one case two projects involved 18 different partners, in another one project involved 9 partners. This biases strongly the results, considering that the average number of ties in this sample is 5.

knowledge sources that do not seem to be part of the entrepreneurs networks and will not (in principle) benefit from these types of proximity.

In addition, it was also found from the interviews that, in many cases, the creation of “new intentional” ties with distant organisations, was mediated by members of the trajectory networks. Some of these were not directly mobilised by the firm, thus remaining potential according to our criteria. Others were members of the trajectory networks geographically co-located and thus considered as local ties. This information points to the need of exploring in more depth the case of indirect ties.

The above result leads us to add and test a clause to proposition 3: When firms need to resort to distant sources of knowledge they will tend to mobilise their trajectory networks, also *by using these networks indirectly to gain access to relevant knowledge sources*.

Finally, we are also interested in understanding how relevant was non-geographic proximity for accessing the local sources. For this purpose we conduct a similar calculation as above, but for the local ties (Table 7).

Table 7 - Origin of ties mobilised at local level

	All ties mobilised at local level	Strong ties mobilised at local level
Ties based on trajectory	62,5%	73%
Ties intentionally built	37,5%	27%

The results show that not only a substantial proportion of all ties result from the entrepreneurs trajectory but that, in this case, these are also the strongest ties. This finding confirms the idea that, even when there is geographic proximity, other forms of proximity are also relevant for gaining access to knowledge sources and that, therefore, firms resort extensively to the entrepreneurs’ pre-existing relationships and continue developing them.

5. Conclusions

This paper aimed at contributing to a better understanding of the knowledge access strategies of new science-based firms, such as biotechnology, focusing on the role played social networks and, namely, on their influence on firms’ ability to gain access to this key resource at different spatial dimensions.

The case of new biotechnology firms in Portugal – a country where a reasonable knowledge base was developed in this field and where we observe a growing number of entrepreneurial initiatives, but that is still far from displaying important “biotechnology clusters” – is an interesting setting to raise some questions about firms’ location strategies and their relationship with knowledge access strategies. These questions reflect on-going debates in the literature about the biotechnology industry, which either discusses the tendency for clustering around major centres of biotechnology knowledge and business, thus stressing the role of geographic proximity; or calls the attention to the fact that these firms tend to develop an extensive set of geographically distant relationships.

The approach adopted in this paper, combining contributions from social network literature with recent debates on proximity, enables us to go beyond a linear reasoning based on a

“proximity vs. distance” dichotomy. The social network literature – through the consideration of the influence of entrepreneurs’ trajectory in the formation of their social network – and the literature on proximity - stressing the role of social, cognitive and organisational proximity – enabled us to develop a conceptual framework to address the variety of knowledge acquisition strategies, which departs from the simple logics of physical proximity. According to this framework geographic proximity (i.e. co-location between individuals) is important in knowledge transmission mainly because it creates the conditions for the development of the other forms of proximity, which are determinant to facilitate such transmission. Thus, such co-location does not need to be contemporary with firm creation – it can take place at some point in the entrepreneurs’ trajectory and still enable them to mobilise the relationship established when they decide to create a firm (within limits: ties that are not nurtured tend to disappear).

Following this rationale, it is argued that while it will usually be easier and more effective to mobilise relationships with individuals located in the vicinity, in some circumstances it may be indispensable (or at least judged more effective), to mobilise more distant relationships who possess relevant knowledge assets, their access being facilitated by the presence of social, cognitive or organisational proximity. Decisions on the sources of knowledge depend on a complex combination of availability, accessibility and relevance. But, it is argued, at least in the early stages of firms’ development, social networks – in particular entrepreneurs’ personal networks – by offering the type of proximity that facilitate knowledge transmission, and by allowing knowledge mobilisation at different spatial levels, improve the conditions for gaining access to relevant knowledge, in some cases permitting to overcome the availability constraints of the specific location where the firm ends up being created.

Social network analysis provided us with an analytical tool to address empirically this question, supporting the development of a methodology that enabled to reconstruct the networks effectively mobilised for knowledge access by a group of Portuguese biotechnology firms – the molecular biology firms - and to investigate the location and origin of the various ties. This permitted to assess the actual use of geographically close sources and that of geographically distant ones; and provided some evidence towards the role of non-physical proximity on the access to both.

The empirical analysis was guided by a number of propositions regarding location and knowledge access decisions, which were partly supported.

First of all, it was found that, for the majority of firms, local knowledge sources are important: local ties are extensively mobilised and tend to be strong. Moreover, a substantial proportion of local ties result from the entrepreneurs’ trajectory – thus being characterised by social, cognitive or organisational proximity. However, there are exceptions: a small group of firms do not use local sources and, in their search for alternative ones, they tend resort to international sources more than to other national. Their access to these more geographically distant sources is largely based on ties derived from the entrepreneurs’ trajectory. Thus firms compensate for the absence of relevant sources in the vicinity, with the use of other forms of proximity to access geographically distant ones.

It was also found that firms that use local sources have less tendency to mobilise distant sources and that, when they do, they are more likely to mobilise them within the country borders than abroad. On the contrary, the group of firms that do not use local sources are more likely to mobilise international ties. Thus, we can conclude that not only geographical

proximity, but also the national context, is important for the majority of firms, while, once again, it appears to matter less for a small group.

The use of local sources does not deter the majority of firms from also accessing distant ones, namely at international level. Here the exception is a group of firms, closely connected with a local research organisation (from which they often spun-off), which appears to provide them with a substantial part of the knowledge required at this stage, since they display relatively few additional ties. The remaining firms combine ties deriving from the entrepreneurs' trajectory and new intentional ties, to gain access to knowledge from these distant sources. However, new intentional ties with international sources are more typically established in the context of large European projects and there are some indications that entrepreneurs pre-existing ties are often used as mediators in these processes.

Globally, it can be concluded that geographical co-location between the firm and the knowledge sources – when relevant sources are available - is indeed important, but even in this case knowledge access appears to be facilitated by the presence of other forms of proximity. This generic conclusion should not obscure the fact that, even in the very early stages of development, most of these firms also mobilise distant sources of knowledge – either by necessity or by choice – and that a small group makes no use at all of local sources.

Thus there are different strategies: some are mainly or exclusively based on local networks, some are mainly or exclusively based on distant networks; and we also find strategies that rely on different combinations of local and distant networks. But the ability to pursue with these different - and seemingly contradictory - options only becomes understandable at the light of the mobilisation by the entrepreneurs of a mix of relationships that facilitate knowledge access and where non-physical forms of proximity play an important explanatory role.

From a policy standpoint, the importance of local sources, the finding that their use decreases the tendency to use geographically distant ones and the relevance of sources located within the national borders, is particularly interesting. It suggests the presence of good country-level capabilities in some fields, an idea that is strengthened by the fact that a substantial proportion of the local ties are based on the entrepreneurs' academic and professional trajectories. When compared with previous research about an earlier generation of biotechnology firms (Fontes, 2005), these results denote important changes in the country's ability to provide the knowledge setting for the creation and early development of biotechnology firms. It confirms the suggestion put forward by Fontes (2007) about the emergence of a new generation of biotechnology firms that show a greater tendency to be created in areas where knowledge production takes place locally, and/or they can benefit from the international connections of local PROs.

Furthermore, considering that all firms displaying local ties have at least one entrepreneur with some type of international background (whether or not the respective potential networks are being used at this early stage), it is possible to argue that these firms appear to be ideally equipped to benefit from the advantages of actual geographic proximity – that facilitates the development of closer and more diversified relationships and the co-evolution of actors; and to mobilise the social networks developed along their international trajectories for gaining access to knowledge available in geographically distant sources, whose transmission is facilitated by the presence of other forms of proximity.

However, one further conclusion from this research is that we should be careful in assuming that the fact that the vast majority of molecular biology firms were created in the same municipality (and sometimes in the same address) of the main research centres with activity in molecular biology is, only by itself, an indicator that firms locate in the vicinity of organisations that provide them with relevant knowledge. Not only firms may have no relationships with these centres (as it happens with a few in this group), but they may have equally - or even more - important knowledge relationships elsewhere¹⁵. Thus the choice of location may be independent from knowledge access, or be balanced against other motives, when there is a variety of alternatives in what concerns proximity to relevant knowledge sources. In this case, firms were also located in a major metropolitan area, where they can benefit from the “economies of urbanisation”, including better accessibility to distant sources, if needed. Nevertheless, the advantages from the presence of these research centres may go beyond their immediate use. In fact, firms may already be indirectly mobilising members of their potential network belonging to them, to gain access to other more distant organisations¹⁶. Or they can be potentially relevant knowledge sources for the future, when firms move beyond the early stages. Research on the evolution of the mobilised networks, which is underway, will enable us to investigate this question.

References

- Ackers, L. (2005) Moving People and Knowledge: The Mobility of Scientists within the European Union. *International Migration*, 43: 99-129.
- Ahuja, G. (2000) Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. *Administrative Science Quarterly*, 45: 425-455.
- Aldrich H E and Zimmer C (1986) Entrepreneurship through Social Networks. In Smilor R, Sexton D (eds.) *The Art and Science of Entrepreneurship*. Ballinger, Cambridge: 154–167.
- Amin, A. and Cohendet, P. (2006) Geographies of Knowledge Formation in Firms. *Industry and Innovation* 12(4): 465-486.
- Antonelli C (1995) *The Economics of Localized Technological Change and Industrial Dynamics*. Kluwer, Dordrecht.
- Audretsch DB and Feldman M (1996) Spillovers and the geography of innovation and production. *American Economic Review*, 86: 630-640.
- Audretsch DB and Stephan PE (1996) Company-Scientist Locational Links: The Case of Biotechnology. *American Economic Review*, 86 (3): 641-652.
- Autant-Bernard C (2001) The geography of knowledge spillovers and technological proximity. *Economics of Innovation and New Technology*, 10: 237-254.
- Bagchi-Sen, S. (2007) Strategic Considerations for Innovation and Commercialization in the US Biotechnology Sector. *European Planning Studies*, 15 (6): 753-766.
- Balconi M., Breschi S. and Lissoni F. (2004) Networks of inventors and the role of academia: an exploration of Italian Patent data. *Research Policy*, 33: 127-145.
- Bönte W (2008) Inter-firm trust in buyer-supplier relations: Are knowledge spillovers and geographical proximity relevant? *Journal of Economic Behaviour & Organization*, 67: 855-870.
- Boschma R A (2005) Proximity and Innovation: A Critical Assessment. *Regional Studies*, 39: 61-74.
- Breschi S and Lissoni F (2001) Knowledge Spillovers and Local Innovation Systems: A Critical Survey. *Industrial and Corporate Change*, 10: 975- 1005.

¹⁵ The *importance* of ties was not considered in this analysis (tie strength, expressing frequency of interaction, is only a very limited proxy to it), so it was not possible to assess the relative importance of different sources for firms that had a variety of ties at different spatial levels. It may provide additional insights into this question.

¹⁶ There is some evidence that this happened in a few cases. Further research may assess whether there are effectively members of the potential network in the nearby centres, and additional interviews may be conducted to assess the eventual use of indirect ties.

- Breschi S and Lissoni F (2004) Knowledge Networks from Patent Data: Methodological Issues and Research Targets. Cespri Working Paper N° 150. <ftp://ftp.unibocconi.it/pub/RePEc/cri/papers/WP150BreschiLissoni.pdf> [last accessed 23 march 2009]
- Burt R (1992) *Structural Holes: The social structure of competition*. Harvard University Press, London.
- Burton, M. D., Sørensen, J. and Beckman, C. (2002) Coming from Good Stock: Career Histories and New Venture Formation. *Research in the Sociology of Organizations*, 19: 229-262.
- Carsrud A and Johnson R (1989) Entrepreneurship: a social psychological perspective. *Entrepreneurship & Regional Development*, 1: 21-31.
- Casper S. (2007). How do technology clusters emerge and become sustainable? Social network formation and inter-firm mobility within the San Diego biotechnology cluster. *Research Policy*, 36: 438-455.
- Casson M and Della Giusta M (2007) Entrepreneurship and Social Capital - Analysing the Impact of Social Networks on Entrepreneurial Activity from a Rational Action Perspective. *International Small Business Journal*, 25(3): 220-244.
- Castells M (1989) *The Informational City. Information Technology, Economic Restructuring, and the urban-regional Process*. Basil Blackwell, Oxford.
- Castilla E, Hwang H, Granovetter E and Granovetter M (2000) Social networks in Silicon Valley. In Lee C M, Miller W, Hancock M G, Rowen H R (eds.), *The Silicon Valley edge - A habitat for innovation and entrepreneurship*. Stanford University Press, Stanford: 217-247).
- Coe, N.M. and Bunnell, T.G. (2003) Spatialising knowledge communities: towards a conceptualisation of transnational innovation networks. *Global Networks*, 3: 437 – 456
- Cohen W M and Levinthal D A (1990) Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, 35: 128-152.
- Coleman J (1988) Social Capital in the Creation of Human Capital. *American Journal of Sociology*, 94: 95-120.
- Colombo, M.G., L. Grilli and E. Piva (2006) In search of complementary assets: The determinants of alliance formation of high-tech start-ups. *Research Policy*, 35: 1166–1199.
- Cooke P (2006) Global Bioregional Networks: A New Economic Geography of Bioscientific Knowledge. *European Planning Studies*, 14(9): 1265-1285.
- Dahlander, L. and McKelvey, M. (2005) The occurrence and spatial distribution of collaboration: biotech firms in Gothenburg, Sweden. *Technology Analysis and Strategic Management*, 17: 409 – 432.
- Davenport, S. (2005) Exploring the role of proximity in SME knowledge-acquisition. *Research Policy*, 2005, 34, p. 683-701;
- Dietz, J.S., Chompalov I., Bozeman B., Lane E.O. and Park J. (2000). Using the curriculum vita to study the career paths of scientists and engineers: an exploratory assessment. *Scientometrics*, 49: 419–442.
- Egelin, J, Gottschalk, S and Rammer, C (2004) Location decisions of spin-offs from public research institutions, *Industry and Innovation*, 11(3): 207–223.
- Elfring, T., and Hulsink, W. (2003). Networks in Entrepreneurship: The Case of High-technology Firms. *Small Business Economic*, 21: 409-422.
- Feldman M (1999) The new economics of innovation, spillovers and agglomeration: A review of empirical studies. *Economics of Innovation and New Technology*, 8:5- 25.
- Fontes M (2005) Distant Networking: The Knowledge Acquisition Strategies of 'Out-cluster' Biotechnology Firms. *European Planning Studies*, 13(6): 899-920.
- Fontes M (2007) Technological entrepreneurship and capability building in biotechnology. *Technology Analysis and Strategic Management*, 13(3): 351-367.
- Fornahl D (2005) Networks and Entrepreneurial Development. In Fornahl D, Zellner C, Audretsch D A (eds.) *The Role of Labour Mobility and Informal Networks for Knowledge Transfer*. Springer, Bloomington.
- Gittelman M. (2007) Does Geography Matter for Science-Based Firms? Epistemic Communities and the Geography of Research and patenting in Biotechnology. *Organization Science*, 18(4): 724-741.
- Granovetter M (1973) The Strength of Weak Ties. *American Journal of Sociology*, 78: 1360-1380.

- Granovetter M (1985) Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, 91: 481-510.
- Gulati R (1998) Alliances and networks. *Strategic Management Journal*, 19: 293-317.
- Hansen M T (1999) The search-transfer problem: the role of weak ties in sharing knowledge across organization studies. *Administrative Science Quarterly* 44: 82-111.
- Hsu D (2007) Experienced entrepreneurial founders, organizational capital, and venture capital funding. *Research Policy*, 36: 722-741.
- Jaffe A B, Trajtenberg M and Henderson R (1993) Geographic localization and knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, 108: 577-598.
- Johannisson B (1998) Personal Networks in Emerging Knowledge-Based Firms: Spatial and Functional Patterns. *Entrepreneurship & Regional Development*, 10: 297-312.
- Kogut B and Zander U (1992) Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3: 383-397.
- Lagendijk, A. and A. Lorentzen (2007) Proximity, Knowledge and Innovation in Peripheral Regions. On the Intersection between Geographical and Organizational Proximity. *European Planning Studies*, 15(4); 457 - 466
- Lane P and Lubatkin M (1998) Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, 19 (5): 461-477.
- Lemarié, S., Mangematin, V. and Torre, A. (2001) Is the Creation and Development of Biotech SMEs Localised? Conclusions Drawn from the French Case. *Small Business Economics*, 17: 61- 76.
- Liebeskind J. P., Oliver A L, Zucker L and Brewer M (1996) Social Networks, Learning and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms. *Organization Science*, 7:428- 443.
- Lovas B and Sorenson O (2008) The mobilization of scarce resources. In Baum J A, Rowley TJ, *Advances in Strategic Management: Network Strategy*, Vol. 25. JAI Press, Amsterdam.
- Low M B and Abrahamson E (1997) Movements, Bandwagons and Clones: Industry Evolution and the Entrepreneurial Process. *Journal of Business Venturing*, 12: 435- 457.
- Lundvall B A (1993) Explaining interfirm cooperation and innovation. Limits of the transaction-cost approach. In Grabher G (ed.) *The Embedded Firm. On the Socioeconomics of Industrial Networks*. Routledge, London: 52-64.
- Marshall A. (1919) *Industry and Trade*, Macmillan, London.
- Maskell P and Malmberg A (1999) Localised learning and industrial competitiveness. *Cambridge Journal of Economics*, 23: 167-185.
- Maskell P, Eskelinen H, Hannibalson I, Malmberg A and Vatne E (1998) *Competitiveness, localized learning and regional development: Specialisation and prosperity in small open economies*. Routledge, London.
- McEvily B and Zaheer A (1999) Bridging ties: a source of firm heterogeneity in competitive capabilities. *Strategic Management Journal*, 20: 1133-1156.
- McKelvey, M., H. Alm and M. Riccaboni (2003) Does Co-location Matter for Formal Knowledge Collaboration in the Swedish Biotechnology-Pharmaceutical Sector. *Research Policy*, 32: 483-501.
- McMillan, G.S., F. Narin and D.L. Deeds (2000) An analysis of the critical role of public science in innovation: the case of biotechnology, *Research Policy*, 29 : 1-8.
- McPherson M, Smith-Lovin L and Cook J (2001) Birds of a feather: homophily in social networks. *Annual Review of Sociology*, 27: 415-444.
- Murray F (2004) The role of inventors in knowledge transfer: sharing in the laboratory life. *Research Policy*, 33: 643-659.
- Orsenigo, L. (1989). *The Emergence of Biotechnology. Institutions and Markets in Industrial Innovation*, London: Pinter Publishers.
- Owen-Smith J and Powell W W (2004) Knowledge Networks as Channels and Conduits: The Effects of Spillovers in the Boston Biotechnology. *Organization Science*, 15(1): 6-21
- Powell W, Koput K and Smith-Doerr L (1996) Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*, 41: 116-145.

- Powell W, Koput K W, Bowie J I and Smith-Doerr L (2002) The Spatial Clustering of Science and Capital: Accounting for Biotech Firm-Venture Capital Relationships. *Regional Studies*, 36(3): 291-305.
- Sapsed, J, D. Gann, N. Marshall and A. Salter (2005) From here to eternity - The practice of knowledge transfer in dispersed and co-located project organizations. *European Planning Studies*, 13 (6), 831-851.
- Saxenian, A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA.
- Saxenian A and Hsu JY (2001) The Silicon Valley-Hsinchu Connection: Technical Communities and Industrial Upgrading, *Industrial and Corporate Change*, 10: 893- 920.
- Shane S and Venkataraman S (2000) The promise of entrepreneurship as a field of research. *Academy of Management Review*, 25: 217–226.
- Singh, J. (2003). Inventor Mobility and Social Networks as Drivers of Knowledge Diffusion. [<http://www.people.hbs.edu/jsingh/academic/papers.html> - Last Accessed 6/5/2008]
- Sorenson O (2003) Social networks and industrial geography. *Journal of Evolutionary Economics*, 13: 513-527.
- Sorenson, O. (2005). Social Networks, Informational Complexity and Industrial Geography. In D. Fornahl, C. Zellner, and D. A. Audretsch, *The Role of Labour Mobility and Informal Networks for Knowledge Transfer*. Bloomington: ISEN, Springer, pp. 79-96.
- Stahlecker, T. and K. Koschatzky (2004) On the significance of geographical proximity for the structure and development of newly founded knowledge-intensive business service firms, Fraunhofer Institute for Systems and Innovation Research, Working Paper No. R2/2004, http://www.isi.fhg.de/p/arbeitspapiere_u-r/ap_r2_2004.pdf
- Steinmueller, E. (2000) Does Information and Communication Technologies Facilitate ‘Codification’ of Knowledge ? *Industrial and Corporate Change*, 9: 361-376.
- Stuart T, Sorenson O (2003) The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms. *Research Policy*, 32: 229-253.
- Torre, A. and A. Rallet (2005) Proximity and Localization. *Regional Studies*, 39(1): 47-59,
- Uzzi B (1997) Social structure and competition in interfirm networks: the paradox of embeddedness. *Administrative Science Quarterly*, 42: 35-67.
- Van Geenhuizen M (2008). Knowledge networks of young innovators in the urban economy: biotechnology as a case study. *Entrepreneurship and Regional Development*, 20: 161-183.
- Williams, A.M., V. Baláz and C. Wallace (2004) International Labour Mobility and Uneven regional Development. Human Capital, Knowledge and Entrepreneurship, *European Urban and Regional Studies*, 11: 27 - 46.
- Wink, R. (2008) Gatekeepers and Proximity in Science-driven Sectors in Europe and Asia: The Case of Human Embryonic Stem Cell Research. *Regional Studies*, 42:6,777 — 791
- Witt U and Zellner C (2007) Knowledge-Based Entrepreneurship: The organizational side of technology commercialization. In Malerba F, Brusoni S (eds.) *Perspectives on Innovation*. Cambridge University Press.
- Wolfe D A and Gertler M S (2001) Globalization and economic restructuring in Ontario: from industrial heartland to learning region? *European Planning Studies*, 9(5): 575-592.
- Yli-Renko, H., Autio, E. and Sapienza, H.J. (2001) Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms. *Strategic Management Journal*, 22: 587-613.
- Zucker L, Darby M and Brewer M (1998) Intellectual capital and the birth of US biotechnology enterprises. *American Economic Review*, 88: 290-306.