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Types of proximity in knowledge access by science-based start-ups

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Abstract

This paper addresses the strategies adopted by science-based start-ups to gain access to knowledge resources at different spatial levels. The goal of the paper is to investigate the presence and relative importance of ties endowed with different types of proximity in firms' knowledge networks, as well as the role played by non-geographical proximity in gaining access to knowledge sources, both located nearby and at a distance. For this purpose we develop an analytical framework that permits to distinguish between two dimensions of proximity: geographical, associated with the spatial location of the actor; relational, associated with the origin of the tie – leading to different modes of proximity that are further linked with modes of knowledge access (formal or informal). We also develop a methodology to reconstruct the knowledge networks, permitting to identify origin, location and nature of the ties and to position them along modes of proximity. The results show that the incidence and mix of these modes of proximity vary in firms' individual networks, being possible to identify different patterns of knowledge access. But they also uncover the overall relevance of “relational proximity”, whether or not coexisting with geographical proximity and often compensating for its absence. The paper contributes to our understanding of knowledge access strategies of science-based start-ups and uncovers the spatial spanning role played by the entrepreneurs' personal networks.

Keywords: knowledge networks, relational proximity, science-based firms, formal and informal ties

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1. Introduction

Knowledge access by biotechnology firms presents some specificity, related with the nature of this industry. Biotechnology is a science-based industry, so high-level scientific capabilities are at the root of firms' competitiveness (Orsenigo, 1998). Indeed, very frequently firms are created to exploit knowledge originating from academic research, the process being conducted by the scientists involved in its development (Murray, 2004). Moreover, biotechnology firms often act as intermediaries between scientific research and commercial applications and therefore their success depends on the capacity to keep good connections with frontier research (Stuart et al, 2007). Thus relationships with research organisations are critical for biotechnology start-ups, being instrumental for the development of the first technologies or products (McMillan et al, 2000).

Science-based start-ups are sometimes described as being strongly dependent on the source research organisation and as tending to be located in its vicinity (Lemarié et al, 2001). However, the literature has also shown that given the variety of fields that contribute to biotechnology development and the distributed nature of knowledge production, firms may need to resort, from very early stages, to a variety of organisations in a diversity of locations, in order to obtain the required knowledge mix (Owen-Smith & Powell, 2004; Moodysson, 2008). This is even more so in the case of firms created in less munificent environments, to which connections with major centres of biotechnology knowledge production may be determinant (Gilding; 2008; Fontes, 2005).

This means that firms' knowledge networks will often combine relationships characterised by geographical proximity with relationships where such proximity does not exist; although the respective incidence and relevance in the "relationship mix" is likely to vary between firms (Mangematin et al, 2002; Lowe and Gertler, 2009). Thus, biotechnology start-ups provide an interesting setting to discuss the relevance of different types of proximity to sources in knowledge.

Geographical proximity is generally assumed to facilitate knowledge exchange, particularly when knowledge is complex and has a strong tacit component (Lorenzen, 2007; Zucker et al, 2002). However, it has also been argued that the relevance of geographical proximity lies mainly in the fact that co-location favours the development of other types of proximity – social, cognitive, organisational – which are the effective facilitators of knowledge transmission (Breschi and Lissoni, 2001; Boschma, 2005); and which can persist even after co-location ceases (Torre and Rallet, 2005). The presence and persistence of these types of proximity may also contribute to support processes that involve knowledge exchange at a distance (Breschi and Lissoni, 2001), which is recognised to entail greater difficulties (Bathelt et al, 2004).

Recent research has shown that those types of proximity between organisations are associated with the presence of knowledge relationships (Broekel and Boschma, 2012). However, there is still a limited understanding of the relative relevance of non-geographical proximity in knowledge access by individual firms. In particular, there is a limited understanding of how firms combine geographical and non-geographical proximity considerations in their knowledge access strategies. Similarly, there is limited knowledge on whether and how firms profit from these other forms of proximity to gain access to knowledge sources, both located nearby and (particularly) located at a distance.

Finally, we also do not know whether proximity between knowledge sources has implications for the nature of relationships established.

The objective of this paper is to address this gap, investigating the presence and relative importance of relationships endowed with different types of proximity in the knowledge networks of biotechnology start-up firms, as well as the process behind their establishment. In addition it will also attempt to achieve a better understanding of the nature of these relationships, by investigating whether different types of proximity are associated with specific modes of interaction, formal or informal. Because research organisations are the key (and sometimes the only) external source of scientific and technological knowledge in biotechnology firms early years, we will focus on the relationships established with these sources.

The occurrence of non-geographical proximity with knowledge sources tends to be difficult to identify (Boschma, 2005). In order to address this problem we propose that since entrepreneurs are the main agents in the process of knowledge access in science-based start-ups (Mustar et al, 2006), their trajectories can be instrumental to uncover the eventual development of these forms of proximity. Drawing on contributions from the entrepreneurship literature (Burton et al, 2002), we argue that the networks built by the entrepreneurs along their academic and professional trajectory encompass the types of experiences that permit the emergence of alternative forms of proximity, which, according to the literature on proximity, can facilitate knowledge access and transmission at different spatial levels.

Following this approach we build an analytical framework that permits to distinguish between, but also combine, two dimensions of proximity: *geographical*, related with the spatial location of the source; *relational*, associated with the origin of the relationship. This enables us to propose a taxonomy of proximity and put forward some propositions concerning the dominant modes of interaction (formal or informal) associated with them. In addition, we also develop a methodology to reconstruct the knowledge network built by each start-up firm, permitting to identify the origin, location and nature of the ties that compose them; and enabling us to position them along levels of proximity.

This framework is applied to the empirical analysis of the networks established, in early stages, by Portuguese molecular biology firms, in order to access knowledge from research organisations. The results contribute to our understanding of the relative importance of different types of proximity with knowledge sources in the knowledge access strategies of science-based start-ups, uncovering the relevance of forms of “relational proximity”, whether or not coexisting with geographical proximity and highlighting the spatial spanning role played by the entrepreneurs’ personal networks.

2. Knowledge access by science-based firms

Biotechnology is characterised by the proximity between scientific research and the market, which creates opportunities for transforming research results into technologies, products and services (Orsenigo, 1989) and gives scientific entrepreneurs some advantages in the identification and exploitation of new business opportunities (Zucker et al, 2002). Thus new biotechnology firms are often created to exploit knowledge originating directly from academic research, or technologies whose complete development still relies extensively on advanced knowledge produced in academic

settings (Murray, 2004). Relationships with research organisations - and in particular with the source organisation(s) - are therefore instrumental at the firms' early stages (McMillan et al, 2000; Lemarié et al. 2001). Moreover, since new biotechnology firms frequently occupy an intermediate position in a value chain that connects scientific research with commercial applications, they need to maintain close relationships with leading research organisations in relevant fields (Stuart et al, 2007).

Irrespective of the origin of the technological opportunities being exploited, biotechnology firms are technology intensive companies that derive their competitiveness from the capacity to quickly build, expand and renew their knowledge base, in order to generate a steady stream of innovations (Liebeskind et al, 1996; Owen-Smith and Powell, 2004). Because they operate in a field characterised by fast technological change and because they are small firms with inevitable resource limitations, biotechnology firms often end up being strongly reliant on scientific and technological knowledge originating from external sources (Baum et al, 2000; Levitte and Bagchi-Sen, 2010). The literature has shown that, given the complex and distributed nature of the knowledge required, biotechnology firms will often need to resort to a variety of external knowledge sources, in different locations (Moodysson, 2008; Gertler and Levitte, 2005; Gilsing, 2008).

The relevance assumed by external knowledge resources leads entrepreneurs to mobilise a set of relationships that can facilitate access to key sources (Liebeskind et al, 1996). The literature on entrepreneurship has stressed the importance of the entrepreneurs' social networks in accessing resources and competences (Elfring and Hulsink, 2003; Johannisson, 1998). In what concerns the access and exploitation of knowledge, social networks can be crucial (Kogut and Zander, 1992; Murray, 2004) permitting to increase the scope, depth and efficiency of knowledge exchanges (Lane and Lubaktin, 1998). Research has shown that the process of identification and access to key knowledge sources, as well as the process of admittance to the circles where such knowledge circulates and where alliances are built, rely strongly on networks (Fontes, 2005; Liebeskind et al, 1996; Murray, 2004; Owen-Smith and Powell, 2004).

In the case of research-based firms originating from academic research, the presence in the entrepreneurial team of scientists who were involved in the development of the technology considerably eases the access to and exchanges with the "parent organisation" (Mustar et al, 2006). It may also enable the indirect access to other organisation to which these scientists or their previous research teams were connected (Grimaldi and Grandi, 2003). On the other hand, the presence of reputed scientists in the entrepreneurial team or, more generally, the association of the firm to a prestigious research organisation, signals competence and can facilitate access to other organisations. This type of intermediation is especially relevant for a new firm that has not yet built a reputation and may require some type of credibilisation (Powell et al, 1996). It can be particularly critical in emerging fields, since entry in the "epistemic communities" where new knowledge is produced and transmitted is often restricted (Breschi and Lissoni, 2001).

3. Firms knowledge networks

Thus, young science-based firms will mobilise or develop a set of knowledge-related relationships that can facilitate access to key knowledge sources. These relationships will configure the firm's knowledge network. They encompasses the set of personal relationships established by the entrepreneurs along their academic and professional

trajectory, which they mobilise for knowledge access purposes (Burton et al, 2002; Saxenian and Hsu, 2001); and the new linkages established at firm level with strategic purposes (which are often mediated by the former) (Hite and Hesterly, 2001)

Both ties that derive from the trajectory and new ties may be kept informal or be formalised through contractual relationships (e.g. projects, contracts, alliances). Thus firms' knowledge networks are usually composed of formal and informal relationships, which can be closely interlinked (Powell et al, 1996). However, the current understanding of formal and informal networks differs significantly.

The vast majority of the literature addresses the formal alliances of biotechnology companies. In what concerns research organisations, biotechnology companies have been found to establish contractual relationships with both the "parent" organisation and other organisations that support their early development activities and/or enable keep abreast of advanced knowledge production in their field(s) (Levitte and Bagchi-Sen, 2010, McMillan et al, 2000). According to this literature, knowledge relationships are often formalised because property and/or control on knowledge assets is a key competitive factor in biotechnology, although the level of formality may decrease as partners engage in successful collaborations and trust develops (Smith-Doerr and Powell, 2003).

The importance of informal knowledge flows in innovation has long been acknowledged, as reflected on the extensive literature on spillovers (Audretsch and Feldman, 1996). But research on informal knowledge networks is still limited, being particularly scarce in what concerns networks with university researchers. The few authors who have investigated the knowledge sharing processes that take place at that level have found evidence of extensive knowledge bartering (Kreiner and Schultz, 1993), although a comparative analysis between networks with university researchers and with other firms' employees describes the former as less frequent and less effective (Østergaard, 2009). Overall, research on informal networks shows that its formation is often linked with the trajectory of individuals or with their previous interaction in formal partnerships (Smith-Doerr and Powell, 2003), and loyalty and reciprocity is stressed as fundamental for their continuity (Dahl and Pedersen, 2004). They are usually described as geographically localised (Audretsh and Stephan, 1996; Huggins and Johnston, 2010) although recent research observed their operation at different spatial levels (Trippi et al, 2009).

One major shortcoming of this research is that it is rarely based on science-based sectors such as biotechnology and frequently concerns the networking of firms' employees. However, as was pointed out above, entrepreneurs' networks are particularly relevant in the case of knowledge-intensive start-ups (Johanisson, 1998). They are also likely to differ from the employees networks given their greater alignment with the firms' interests (Grabher and Ibert, 2006). Thus, it is important to direct greater attention to their role in knowledge access.

4. The spatial distribution of knowledge networks

Firms vary in terms of external knowledge requirements, which are associated with the nature of their knowledge base and the type of business opportunity being exploited. However, their search for the required knowledge is influenced by the availability and location of relevant knowledge sources - which will be related with the type of knowledge environment where the firm operates; and by the entrepreneurs' ability to

gain access to them – which, in early stages, will be strongly influenced by the quality and range of entrepreneurs’ personal networks. Thus, the spatial distribution of firms’ knowledge networks will reflect the combined consideration of the location of potential sources of key knowledge and the conditions in which these can be accessed.

Science-based start-ups often rely extensively on the organisation that was the source of the knowledge being exploited. These firms are described as tending to be located in the vicinity of their main knowledge source(s) and to develop extensive relationships with them (Lemarié et al, 2001). However, the literature also points out that the relevance of local links varies according to the characteristics of firms and the knowledge assets searched (Mangematin et al, 2002; Audretsch and Stephan, 1996). On the other hand the literature has also shown that, given the complexity and frontier nature of the knowledge being exploited, these firms frequently need to search for knowledge wherever it is available and to combine the benefits from networks spanning various spatial levels (Gertler and Levitte, 2005; Waxell and Malmberg, 2007). In the case of firms located in less munificent environments, distant sources may often be more as much or more relevant than nearby ones (Fontes, 2005).

This means that firms’ knowledge networks will often combine relationships characterised by geographical proximity and relationships where such proximity does not exist. It is therefore important to understand the implications of this spatial distribution.

The importance of geographic proximity for knowledge exchange has been extensively discussed in the literature. The social networks literature stresses the importance of geographic proximity since the development and continuity of ties require an intense and frequent pattern of interactions between nodes (Stuart and Sorenson, 2003). The economic geography literature puts some emphasis on geographical proximity, arguing that learning processes are strengthened by the close interaction between organisations that exchange information and knowledge (Lorenzen, 2007; Healy and Morgan, 2009). It has namely been pointed out that geographic proximity can be particularly relevant when the knowledge has a strong tacit component - which in biotechnology will occur in the case of new scientific discoveries, often characterised by “natural excludability” (Zucker et al, 2002); in cases where specific “know-how” is critical; when knowledge is of a sensitive nature; or when knowledge is highly complex, in which case codification may not guarantee complete comprehension and reproduction (Dasgupta and David, 1994).

Recent research has criticised the excessive emphasis put on geographic proximity *per se* and uncovered some of the mechanisms that are behind the seemingly greater easiness of knowledge exchanges among co-located actors (Breschi and Lissoni, 2001; Boschma, 2005). This literature shows that underneath the importance attributed to geographical proximity lies the role played by co-location in the creation of other forms of proximity - social, cognitive and organisational – that *effectively* facilitate that transmission. Social proximity is important because it eases communication and generates trust. Some degree of cognitive proximity is necessary to assess the value of the knowledge produced and to fully understand it, as well as to absorb and apply it effectively (Cohen and Levinthal, 1990). This is particularly the case in the case of emerging fields, due to the localised nature of the knowledge being produced and shared (Antonelli, 1995). Moreover a combination of social and cognitive proximity may be required to be part of “epistemic communities”, that is, groups of scientists sharing the same knowledge base, as well as common codes of behaviour and communication that permit exchange of knowledge that

is not intelligible for external actors not acquainted with the codes (Breschi and Lissoni, 2001). Finally, organisational proximity (previous or actual) facilitates interaction, since it enables an understanding of the rules, hierarchies and codes of behaviour that prevail in a given organisation.

These types of proximity often result from the frequent face to face interaction and experience sharing enabled by co-location (Torre and Rallet, 2005) and the ability to fully profit from them is potentially enhanced when the actors are co-located (Healy and Morgan, 2009). This partly explains why firms may prefer to establish knowledge relationships with organisations that are geographically close (Aharonson et al, 2007).

However, as pointed out by Torre (2008) these effects may also be at least partly achieved through temporary co-location of individuals and thus knowledge sources characterised by some type of non-geographical proximity are not necessarily co-located. In fact, while co-location may be a condition for the *creation* of these types of proximity, the capacity to *maintain* and *benefit from them* does not always require continued physical proximity (Fontes, 2005). Relationships endowed with them can persist after the individuals draw apart and support subsequent knowledge exchanges at a distance, as shown by research on mobility between firms (Oettl and Agrawal, 2008; Rosenkopf and Almeida, 2003; Saxenian and Hsu, 2001).

Such persistence of relational effects over time and space provides an explanation for the operation, at a distance, of some of the mechanisms that facilitate knowledge exchange with organisations located in the vicinity. They may be especially relevant in the case of relationships with research organisations located outside country borders that are often critical for biotechnology firms and that may involve greater barriers given differences in institutional contexts. Considering that biotechnology entrepreneurs are often scientists, it can be argued that the growing international scientific mobility offers extensive opportunities for the development of persistent relationships¹ encompassing social and cognitive elements (Williams et al, 2004). Advances in communication technologies, that make access to information at a distance easier and affordable and new opportunities for temporary co-location facilitate social interaction and create the conditions for maintaining co-production of knowledge and thus cognitive proximity (Torre and Rallet, 2005), avoiding decay. Thus, the presence of these forms of proximity eases, although not completely offsetting, the greater difficulties entailed in knowledge access and exchange at geographical distance (Bathelt et al, 2004; McKelvey et al, 2003).

4. Proximities, networks and knowledge access

So, when addressing the spatial distribution of the knowledge networks of biotechnology start-ups, it is necessary to take into account both geographical proximity and other forms of proximity. Moreover, the above discussion suggests that the presence of other forms of proximity with knowledge sources, irrespective of their location, is likely to be an important element in the knowledge search decisions of biotechnology entrepreneurs. It is therefore important to understand whether this is effectively the case, and the extent to which entrepreneurs rely on non-geographical proximity in the building-up of their knowledge networks at different spatial levels.

¹ Research on international mobility of scientists has shown that they tend to include the organisations where they spent at least one year among their most important knowledge sources (Fontes et al, 2012)

Recent research has shown that those different types of proximity, individually or in combination, increase the likelihood of the presence of knowledge relationships between organisations (Broekel and Boschma, 2012; Ponds et al, 2007). However, it does not address firms' decisions regarding their activation in knowledge access, neither the eventual differences between firms in such activation.

This paper addresses this gap and investigates the presence and relative importance of relationships endowed with different types of proximity in the knowledge networks established by biotechnology start-ups with research organisations. Start-ups offer an interesting setting for this analysis since it is possible to track down the formation of their networks and to identify the origin of the ties that compose them. This is relevant, since it enables us to address a key problem in the analysis of non-geographical proximity: the operationalisation of the different types of proximity, which can be complex (Boschma, 2005) and in many cases has been object of relatively rough approximations.

In the case of the knowledge relationships established by science-based start-ups, we propose, drawing on social network and entrepreneurship literature, that the trajectories of entrepreneurs can be instrumental to uncover the presence of non-geographical proximity. In fact, according to the social network literature, entrepreneurs' experiences that take place along their academic and professional trajectory lead to the development of the personal networks that support firm creation (Hsu, 2007; Burton et al, 2002). In other words, entrepreneurs' permanence in one or more organisations along their trajectory created the conditions for co-location between individuals permitting the development of close relationships. These may have led to the development of social and, in some circumstances, also cognitive proximity between them. In addition, permanence in a give organisation may have enabled entrepreneurs to gain a better understanding of the prevailing culture and routines. Thus, it is possible to argue that the personal networks connecting entrepreneurs with organisations from their trajectory that are potential sources of knowledge are likely to encompass at least some of the forms of proximity that facilitate knowledge transmission at different spatial levels. The ability to fully disentangle between the various forms of proximity depends on the level of detail that can be obtain on these personal networks, but as pointed out by Boschma (2005) there is a strong overlap between them.

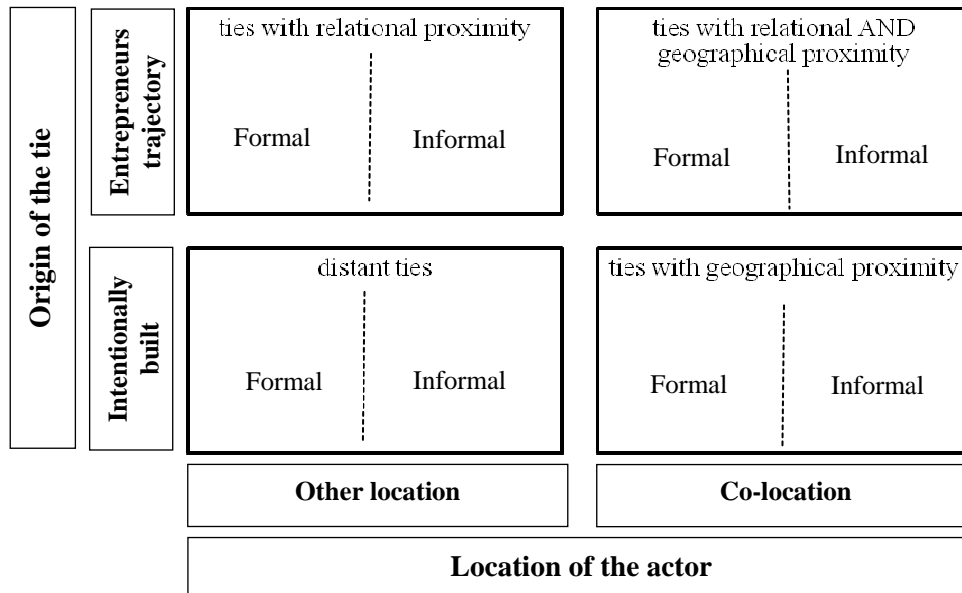
This approach permits us to distinguish between two main dimensions of proximity: geographical proximity, related with the spatial location of the knowledge source; and non-geographical proximity (in this case taken overall), related with the origin of the relationship. Given the more relational nature of its components (Carrincazeaux et al, 2008) the latter will subsequently be denoted as "relational proximity".

Drawing on this distinction we develop a framework to analyse the knowledge networks that link biotechnology start-ups and research organisations. According to this framework, the ties that compose these networks can have diverse origins and encompass diverse spatial levels. The combination of these dimensions can lead to different "forms of proximity" (Figure 1):

- Ties can result from the mobilisation of entrepreneurs' pre-existing personal network. These ties can be established with actors who are in the vicinity of the firm being created, and thus involve both *geographical and relational proximity*. If those ties are established with actors who are geographically distant, they will only involve *relational proximity*.

- Ties can be based on a purposeful effort to develop new relationships with actors that possess knowledge regarded as critical, but with whom there was no previous involvement, thus no relational proximity was developed. These actors can be in the vicinity of the firm and thus ties will involve only *geographical proximity*. If not, we are in the presence of *distant ties*, both in geographic and relational terms.

Figure 1 - Research framework



The nature of the ties mobilised for knowledge access may also differ: relations can be formalised or be kept informal. The social network literature leads us to expect that intentionally built ties are more frequently formalised, because trust does not exist from the outset and has to be built (Lorenz, 2007), while it is more likely to be already present in the case of trajectory ties (Burt, 1997). In addition, the cluster literature suggests that local interactions may be easier to sustain in an informal mode, given the opportunity for frequent interactions that act as trust enhancer and facilitate the control for opportunism (Dahl and Pedersen, 2009), while geographically distant relationships may require the additional glue of contractual agreements. Thus, while in principle ties belonging to the different categories of proximity may be informal or become formalised, the nature of the ties that prevail in each category (or their specific combination) may differ. Therefore formal and informal ties will be also considered along with the different forms of proximity, as shown in Figure 1.

This framework will base our approach to the main objectives of this paper:

1. Investigate the presence and relative importance of relationships endowed with different forms of proximity in the knowledge networks of science-based firms
2. Investigate whether firms profit from relational proximity to gain access to knowledge sources, located nearby and/or located at distance
3. Investigate whether different types of proximity are associated with specific modes of interaction, formal or informal.

Finally, since firms are likely to differ concerning the spatial availability of the required knowledge and the conditions to gain access to it, they are also likely to display different proximity mixes in their networks. So, an additional objective is:

4. Assess whether it is possible to identify patterns of proximities (i.e. combinations of different forms of proximity) at the level of individual firms' networks

4. Empirical research: proximity in the networks of Portuguese biotechnology firms

The research uses the case of Portuguese biotechnology industry as empirical setting, addressing the networks established by biotechnology start-ups to access knowledge from research organisations. Portugal is a country where a reasonable knowledge base was developed in biotechnology and that has gone through a process of scientific internationalisation, but that has obvious limitations in terms of amount and variety of autonomous knowledge production. A biotechnology industry has emerged, but is still in a relatively incipient stage of development. For these reasons the case of Portugal was regarded as a particularly interesting to address the different proximity dimensions of firms' knowledge access strategies, in a multi-spatial context.

The research focuses on starting-up firms and addresses the period of "firm formation", which is assumed to be a process that includes the pre-start-up period, the year of formal creation and the two subsequent years of activity.

4.1. Empirical context

The analysis focuses on the most science-based sub-set of the biotechnology industry: firms whose activities are based on the development/application of molecular biology. It encompasses 23 out of the 25 firms identified in Portugal in this field, thus covering almost all the known population at the time of this research. This group of firms belongs to the younger generation of biotechnology companies: only 3 were over 5 years old at the time of data collection and about half were still in the "formation period" as defined above. The oldest firms (created between 1996 and 2001) belong to a small group of pioneer biotechnology firms, that were established before a take-off on firm creation, observed from 2003 onwards, induced by changes in the institutional and political environment (Fontes, 2007). Firms' activities are mainly concentrated in the health sector (78%), although predominantly outside the biopharmaceutical industry (which only accounts for 4 firms), while a smaller group targets the agro-food sector (22%). Their creation involved a total of 61 entrepreneurs, the vast majority originating from national universities/research centres or returning to the country after completion of PhDs or post-doctorates in foreign research organisations. Thus 20 out of the 23 firms were created by teams composed, partly or exclusively of scientists, although some brought-in individuals with managerial or industrial experience. The firms were usually created by young entrepreneurs (the average age was 36), but 40% also involved at least one senior scientist, who retained the university position.

Portuguese biotechnology firms are generally located in the main urban centres where the principal research organisations are also established and where support infrastructures are increasingly available. This group follows the same pattern, being clustered around three metropolitan areas: the Greater Lisbon (56%), responsible for the highest R&D

investment in the country; the town of Coimbra (27%), which has developed good competences in the health sector, around a major university hospital; the country's second city, Porto including the nearby town of Braga, which together concentrate two important universities and a few highly reputed research centres (17%). Given the limited presence of large advanced companies whose activities involve the development or use of biotechnology, this type of anchor is not a relevant factor in firms' location.

Thus, these firms are clustered around the main Portuguese centres of knowledge production in their field. This choice may indicate a decision to create the firm in the vicinity of key knowledge sources. If that is the case, firms' knowledge networks are expected to include a large proportion of geographically close ties. On the other hand, practically all firms had at least one entrepreneur with an international trajectory (graduate training or work in centres of excellence), suggesting that personal networks involving these centres could assume a central role in their search for knowledge.

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

To address the research questions, a two-step methodology was developed. The first step entails the (re)construction of social networks mobilised by the entrepreneurs for knowledge access during the firm formation period, to obtain their composition, origin and nature of the ties. The second step involves an analysis of proximity relatively to the research organisations that were accessed through these networks.

Information on the networks mobilised by the entrepreneurs for knowledge access was collected using a combination of complementary methods that are usually applied independently (Sousa et al, 2011), and involved both search for documentary information and in-depth face-to-face interviews with the founders. The former included: the Curriculum Vitae of the entrepreneurs, published data about formal collaborative projects, partnerships and patents, and a variety of documentary information about the entrepreneurs' personal trajectories and firm formation histories. The interviews, conducted during 2008, were based on a semi-structured questionnaire and had two parts. The first focused on the entrepreneurs' personal network and its importance to the creation process, allowing the collection of fine grained information about the people who were important during that process, including the origin of the relationships and the type, nature and relevance of their contributions. The second addressed the firm's activities and strategy, with particular emphasis on innovation and technological development and on formal cooperation arrangements. The young age of the vast majority of the firms permitted to collect detailed information on their start-up process, avoiding (in most cases) the recollection bias that is likely to be present in older firms.

The (re)construction of the networks mobilised by the firms to access knowledge draw on these sources and followed three main steps. First, documentary analysis of CVs, confirmed and complemented where necessary by the interviews, permitted to reconstruct the paths of the 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. The combined individual trajectory networks composed the firms' *potential network*.

Subsequently, the interviews permitted to identify the research organisations present in the potential network that were *effectively mobilised* for knowledge access during the

formation process – the *trajectory networks*. The interviews, combined with documentary analysis, also permitted to identify the networks *purposefully built* for knowledge access during firms' formation that connect them to organisations not previously part of the entrepreneurs' networks (even though in some cases existing network members acted as mediators to them) – the *intentional networks*. So, the *mobilised network* of each firm was built combining ties from entrepreneurs' trajectory that were mobilised - *trajectory networks* - and ties intentionally established – *intentional networks*.

In both cases the data obtained permitted to distinguish between *formal* and *informal* ties. The former correspond to the contractual knowledge-oriented relationships established (joint projects, co-patents, technology contracts), whether they represent a formalisation of pre-existing personal relations, or are formal from the outset. The latter include both the members of the trajectory networks with whom the relation remained informal, and new, non-formalised relations that the entrepreneurs identified, during the interview, as relevant in the process of knowledge access. For operational purposes, informal relations were assigned to the organisations to which the individuals belonged. When conducting this task, it was found that, in some cases, firms established both formal and informal relations with the same organisation. This led us to consider three, instead of only two types of ties: *formal ties*, *informal ties* and *ties both formal and informal*.

The last step was to assess the level of proximity of each tie, along the two dimensions proposed. The literature presents several measures of *geographical proximity*. In this research the option was to define three spatial levels of proximity between firms and research organisations with which the relation was established: *local* (co-located in the same address or the same municipality); *national* (in a different municipality but within country borders); *international* (in a foreign country). Regarding *relational proximity* and following the approach defined in the conceptual framework, the distinction was made between ties deriving from the entrepreneurs' personal networks, which are assumed to involve some social, cognitive or organisational proximity; and new intentional ties, which are assumed to lack it. The rationale behind this assumption is that these other types of proximity need time to develop (Rutten et al, 2010) and therefore they are not likely to have been achieved with elements of the new organisations (even if they may develop, in the future).

4.3. Empirical results

4.3.1 Knowledge networks: a description of the ties in terms of proximity

The first goal of the empirical research is to assess the geographical location of the research organisations that were mobilised by firms for knowledge access. That is, to investigate whether and to what extent firms sourced knowledge from nearby organisations and/or resorted to geographically distant sources.

Table 1 shows that, even if molecular biology firms are located in the vicinity of the main Portuguese centres of knowledge production in their field, ties with local research organisations (universities and research centres), only represent a subset of their knowledge sourcing activities. In fact during the start-up period, they resort more frequently to geographically distant knowledge sources. Almost 2/3 of the ties mobilised by the firms are related to non-local organisations and international organisations are the most frequently sought.

Table 1 – Location of knowledge sources: relative importance of geographical proximity

	Frequency	Relative frequency
Local ties	37	36%
National ties	25	24%
International ties	41	40%
Total	103	100%

The next step was to trace the origin of these relationships in order to understand if the ties mobilised were related with the entrepreneurs' previous academic or professional trajectory or if they were intentionally built.

Table 2 shows a slight predominance of intentional ties. These ties were purposefully established, to access particular “pieces” of knowledge, with organisations that were not present in the previous trajectory of the entrepreneurs, and consequently where relational proximity was absent. However, trajectory ties, i.e. ties that are close in relational terms, still represent a substantial part of the firms' networks.

Table 2 - Origin of the ties: relative importance of relational proximity

	Frequency	Relative frequency
Trajectory ties	43	42%
Intentional ties	60	58%
Total	103	100%

In order to identify the eventual presence and relevance of the different forms of proximity proposed in our framework, we need to combine the geographical and relational dimensions of proximity. For that purpose we have considered simultaneously the origin and the location of the tie. Regarding the latter we have distinguished between local and extra-local (national and international) ties.

Table 3 shows the importance of the various forms of proximity. Surprisingly, distant ties (ties without geographical or relational proximity) emerge as the most frequent. This somewhat paradoxical result is partly explained by the involvement of several firms in large European research projects with many foreign partners, external to the entrepreneurs' personal network; even if often accessed through it (as the interviews permitted to uncover)². These ties answer to the need of gaining access to new knowledge that was not available locally, nor could be accessed through entrepreneurs pre-existing networks with distant organisations, being more frequent among the “pioneer” firms. Despite its high incidence, this is a very circumscribed behaviour - four firms (of which three pioneers) concentrate 38 out of the 47 entirely distant ties – which reduces the relevance of these ties, as compared to the ones with some type of proximity.

About ¼ of the ties combine physical proximity with relational proximity, being more frequent than ties with only one kind of proximity. Ties that only involve relational proximity represent 18%. Those ties are associated with geographically distant knowledge sources with which entrepreneurs had developed other forms of proximity during their previous trajectory. Remarkably those ties are more frequent than ties with organisation that are geographically close but relationally distant

² Although we did not explore further the case of indirect ties, previous qualitative research on Portuguese “pioneer” biotechnology firms documented the presence of such mediation and credibilisation relatively to these more “distant” organisations (Fontes, 2005).

Table 3 - Importance of different types of proximity

		Location of actors	
		Extra-local ties	Local ties
Origin of ties	Trajectory ties	Ties with relational proximity only 18.4%	Ties with relational AND geographical proximity 23.3%
	Intentional ties	Distant ties (in geographical AND relational terms) 45.6%	Ties with geographical proximity 12.6%

So these results show that the ties that compose the networks mobilised by Portuguese molecular biology firms to access knowledge include effectively different forms of proximity, but suggest that an important role is played by relational proximity.

4.3.2. Types of proximity and formal and informal relations

The next step was to understand whether these different forms of proximity are also associated with different channels for knowledge access, i.e. whether they differ regarding the relative importance of formal and informal relations.

Thus mobilised ties were distinguished in terms of their nature. Table 4 shows that there is a certain balance between formal and informal ties, as well as that their simultaneous presence in the relation with the same organisation is less frequent.

Table 4 - The nature of the tie

	Frequency	Relative frequency
Formal ties	45	44%
Informal ties	40	39%
Ties both formal & informal	18	17%
Total	103	100%

Subsequently we have investigated the relationship between the forms of proximity and the nature of the ties. Table 5 shows the relative weight of the different types of ties (formal, informal or both) in each category of proximity. Table 6 presents the results of the Spearman (non-parametric) correlation between them.

Table 5 - Proximit(ies) and the nature of the tie

	Formal	Informal	Formal & Informal	Total
Ties with relational & geographical proximity	4%	67%	29%	100%
Ties with relational proximity only	11%	68%	21%	100%
Ties with geographical proximity only	54%	8%	38%	100%
Distant ties (geographical & relational)	75%	21%	4%	100%

Table 6 – Correlation between forms of proximity and nature of the tie

	Formal	Informal	Formal & Informal
Ties with relational & geographical proximity	-0.439**	0.315**	0.170
Ties with relational proximity only	-0.318**	0.289**	0.045
Ties with geographical proximity only	0.078	-0.243**	0.210*
Distant ties (geographical & relational)	0.568**	-0.330**	-0.319**

* significant at the 5% level (2-tailed); ** significant at the 1% level (2-tailed)

The results show that ties with relational proximity, whether or not combined with geographical proximity, are more frequently informal. Thus, previous shared experiences create the conditions for informal knowledge exchanges, even with organisations that are geographically distant, in which case the presence of trust may compensate for the less frequent face to face interaction. A still substantial proportion of these ties involve formal and informal interactions, suggesting that, in what concerns a critical asset such as knowledge, trust may not always be enough and that some informal relations will need to be formalised at some point.

On the contrary, ties that lack relational proximity are more frequently formalised. This is particularly evident in the case of distant ties, but is also the case for ties with geographical proximity. This contradicts the frequent association between co-location and extensive informal exchanges. Rather, it confirms the idea that, at least in what concerns knowledge exchanges, informal bartering does not necessarily take place just because the organisations are co-located, often requiring relational proximity to be pursued. In addition, the fact that ties with only geographical proximity are associated with a combination of formal and informal interactions suggests that co-location may favour the creation of informal ties with members of organisations with whom formal relations exist. As expected, in the case of distant ties - that correspond to new relations with unfamiliar organisations with whom frequent interaction is not possible - formalisation appears to be a requirement.

In summary, the empirical data show that differently forms of proximity between science-based start-ups and research organisations are effectively associated with different modes of knowledge access. Thus, when networks have a high predominance of ties with relational proximity, knowledge access will more frequently take place through informal relations with research organisations. When networks have a higher predominance of distant ties, or of ties with only geographical proximity, knowledge access will more frequently involve formal relations.

4.3.3. Variety in the role of proximities at firm level

In the previous sections we have considered the tie as the level of analysis and have addressed each form of proximity separately, finding that all of them are present in this group of firms. However, it is expected that each firm mobilises a particular mix of ties of different origins and involving organisations located in different geographical spaces, thus building networks that combine those forms of proximity. In this section we turn to the firm network, as the level of analysis, and try to identify patterns in what concerns these potential combinations of forms of proximity.

To identify those patterns we grouped the firms according to the proportion of ties of their network that encompass each form of proximity. For that purpose we conducted a cluster analysis, using the hierarchical cluster procedure with Ward's cluster method and squared Euclidean distance measure. It was possible to identify three clusters, which effectively correspond to different patterns of behaviour.

Figure 4 shows the positioning of the three clusters in terms of the proportion of each type of ties. The graph reveals that the networks of firms belonging to different clusters exhibit different patterns in terms of relative importance of different forms of proximity. Firms in Cluster 1 have a higher proportion of distant ties in their networks; firms in Cluster 3 have only ties with both forms of proximity; firms in Cluster 2 establish more frequently ties characterised by only one type of proximity, either geographical or relational, although they also have a significant component of ties with both types of proximity. Firms in Cluster 2 are closer to the average distribution for the whole sample.

Figure 4 – Clusters and forms of proximity

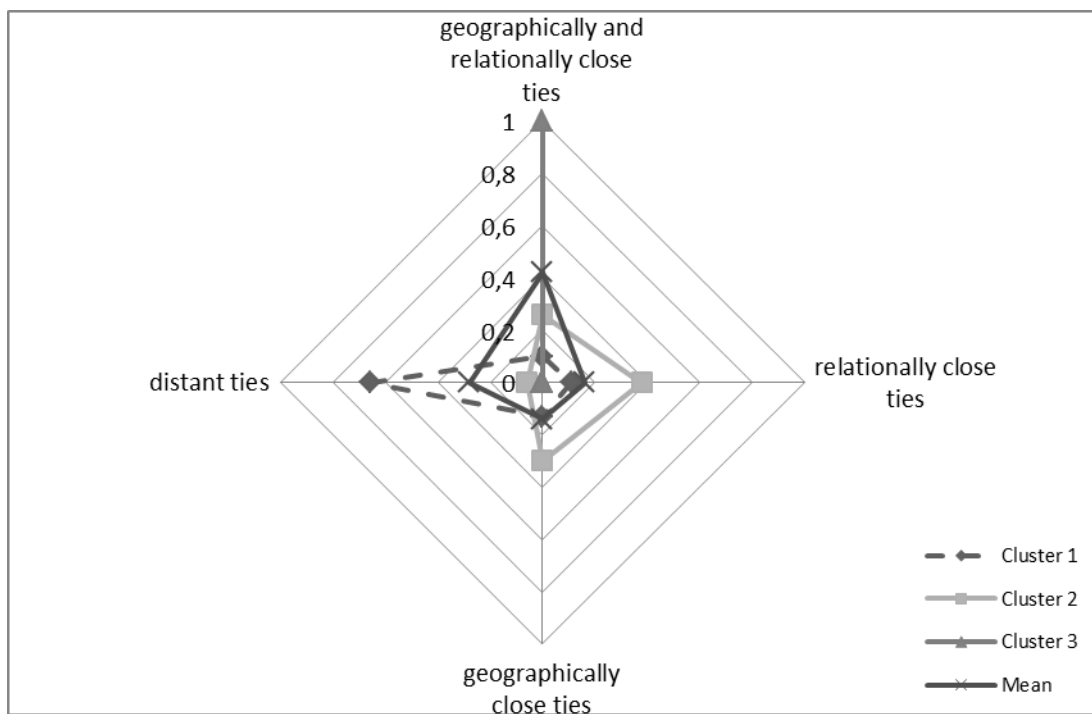


Table 7 presents data that enable further characterisation of each cluster. Cluster 1 concentrate the firms created before 2003, that is, in a period when the Portuguese context was less favourable for biotechnology start-ups (Fontes, 2007). This may partly explain the need to resort extensively to new ties with knowledge sources in distant locations, frequently abroad. In fact, as we saw above, a substantial proportion of those distant ties involved the participation in European projects that were critical for firms' knowledge development, permitting them to gain access to frontier knowledge. It is also relevant to notice that in Cluster 1 we find all firms active in pharmaceuticals, whose global nature is likely to have required firms to expand their early knowledge search activities. It is not surprising that a high share of these firms is located in the Lisbon area, where research and supportive infrastructures were available earlier and where international connections were facilitated.

Table 7 - Cluster description

	Cluster 1	Cluster 2	Cluster 3
Focus	Distant ties	Ties with only one form of proximity	Ties with both forms of proximity
No Firms	9	7	7
Firms funded after 2003 (%)	33	100	100
Location (%)			
Lisbon	78	43	43
Coimbra (Centre)	22	43	14
Porto/Braga (North)	0	14	43
Application area (%)			
Pharmaceuticals	45	0	0
Other health	33	71	71
Agro-food	22	29	29
Technology transferred from parent (%)	33	29	86

Firms in Cluster 2 e 3 belong to the younger generation and while also being mostly active in the health sector, they are not in pharmaceuticals. The main difference between firms in the two clusters regards the origin of their technology and its implications for nature of the relationship established with the source organisation. All firms from Cluster 3 are research spin-offs created on the basis of technology transferred from the parent organisation, to which they are usually co-located and extensively resorted, establishing ties with dual proximity. Conversely, firms in Cluster 2 have more frequently developed the technology already in-house, which may have required a more diversified set of relationships. They also appear to resort extensively to organisations geographically co-located, even when these are not part of the entrepreneurs' trajectory and they combine this with distant search, which is supported by other forms of proximity.

5. Conclusions

This paper aimed at contributing to a better understanding of the strategies adopted by science-based start-ups to gain access to knowledge resources at different spatial levels and, in particular, the role played by non-geographical proximity in those strategies.

Previous research has shown that the knowledge networks of biotechnology firms tend to combine geographically close and distant relationships. Recent debates on proximity have expanded the concept of proximity, showing that the processes involving knowledge transmission will often require more than simple co-location, and introducing other types of proximity. But there is still a limited understanding of the relative importance of different forms of proximity in knowledge access by individual firms. In particular, there is limited knowledge on whether and how firms profit from these other types of proximity to gain access to knowledge sources, both located nearby and (particularly) located at a distance.

In order to address these gaps this paper proposed different forms of proximity that combine two basic dimensions: geographical proximity and "relational" proximity, which, in the case of science-based start-ups, we proposed to be associated with ties from the entrepreneurs' personal networks, resulting from their previous trajectory and mobilised for knowledge access. The presence and relative importance of these forms of

proximity was tested in the networks built by Portuguese biotechnology firms to access knowledge from research organisations. In addition, the paper also took into account the fact that different forms of proximity may be associated with specific channels for knowledge access and investigated the relationship between the proximity categories identified and the nature of the ties – formal or informal – established. The empirical research required the development of a methodology for the reconstruction of the knowledge networks mobilised for knowledge access during firm formation and early development. The methodology enables the identification of the origin, location and nature of the ties, permitting to position them along different categories of proximity and assess the type of channel - formal and informal – used in each case.

The different forms of proximity proposed were found to be present in the networks of the firms studied. But it was also found that their global incidence varies and that firms' networks involve particular combinations of these forms of proximity, being possible to identify some patterns.

Overall, the results show the relevance of relational proximity, whether exclusively or coexisting with geographical proximity. Ties involving relational proximity are more frequently informal, although the relevance assumed by knowledge assets in biotechnology leads firms to formalise some of these relations (while maintaining also the informal ties). But the movement towards formalisation is not more pronounced when organisations are geographically distant, suggesting that the need for knowledge protection is independent from the location of the source. Globally these results confirm that relational proximity can effectively compensate for geographical distance, highlighting the spanning role of entrepreneurs' personal networks.

But biotechnology start-ups also need to establish new relationships where, in principle, relational proximity did not have time to develop. These are more frequently established with organisations that are also geographically distant - suggesting that, in the vicinity, entrepreneurs tend to resort more to their personal networks – and, as expected, are more frequently formal (McKelvey et al, 2003). But while formalisation is a requirement when relational distance co-exists with geographical distance, it is also present when it co-exists with geographical proximity. This confirms that co-location may not be enough to enable informal knowledge bartering, which requires the additional glue of trust (Dahl and Pedersen, 2004) and/or shared knowledge bases (Breschi and Lissoni, 2001). An extensive presence of ties that are distant at both levels is confined to a small group of firms – usually the “pioneers”– and involve mainly organisations located abroad, which are used to source knowledge that cannot be obtained locally or through the entrepreneurs personal networks.

This latter finding calls for a greater attention to context-related conditions. In fact, the results confirm that the conditions found in the local environment are likely to influence the decision to establish ties with geographically distant research organisations (Gertler and Levitt, 2005, Gilding, 2008). Among the biotechnology firms studied, we observe a clear change of orientation between “pioneer” firms, which account for the highest proportion of distant ties, and younger firms, which resort more frequently to local ones, reflecting the changes in the capacity of the Portuguese context to supply relevant knowledge (Laursen et al, 2011). They also show that even within the relatively homogeneous group of molecular biology firms there are differences between sub-fields, with biopharmaceutical firms and other more science-oriented firms using more

frequently ties that are both geographically and relationally distant. But the results also show that even firms starting-up in a relatively more favourable environment may be required to expand the search space (Owen-Smith and Powell, 2004), an effort that is sustained by relational proximity.

While the results of this research are obviously influenced by the nature of the context where the firms are located, it can be argued that the characteristics of this context offered an interesting setting to observe the different dimensions of proximity at work and to gain a first understanding of the mechanisms through which relational proximity can contribute to span spatial boundaries in knowledge access. This preliminary approach needs to be complemented with further research that explores those mechanisms in more detail (namely associating them with different types of knowledge) and, in particular, that refines the operationalisation of relational proximity, namely attempting to disentangle the presence and influence of different types of proximity (Broekel and Boschma, 2012). In addition to these more general contributions, our empirical results are particularly relevant for science-based start-ups located outside the main concentrations of knowledge in their field, since they reflect the networking strategies adopted by this type of firms and provide some insights on the local conditions that may facilitate their knowledge access efforts.

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