Social Networks and the entrepreneurial process in molecular biotechnology in Portugal: From science to industry

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Social Networks and the entrepreneurial process in molecular biotechnology in Portugal: From science to industry[1]

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Abstract

This paper addresses the network building strategies followed by Portuguese biotechnology start-ups, as well as their implications for the configuration of firms' networks.

Results show that firms combine the use of entrepreneurs' social capital with an effort to build up new relationships, thus allowing the resource search space to be expanded. The network building strategy is influenced by the team's characteristics and the nature of the resources searched (knowledge, complementary assets, credibility), which generate different network structures. Results also highlight context-related specificities, such as the central role of research organizations in accessing non-technological resources and the relevance of international relationships.

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1. INTRODUCTION

This paper addresses the strategies followed by Portuguese molecular biology firms to build the networks that are relevant in accessing resources for creation and early development. It addresses the conditions that lead starting-up companies to search for external sources of key resources and discusses the type of decisions they make regarding the mobilisation of pre-existing and new relationships to access these resources, as well as the implications of these decisions for the configuration of firms' networks.

Previous research on the case of the Portuguese biotechnology industry has shown that entrepreneurs with a scientific background are behind a substantial proportion of new firm formation and that these firms tend to be created to apply advanced technologies or new technological knowledge, acquired by the founders during their activities as scientists (Fontes, 2005a). In addition, it has been shown that, given the global nature of knowledge production in this field and the high scientific mobility that characterises it, the sources of knowledge used by these entrepreneurs as a basis for firm creation and early development, are both organisations located in their local/regional environment and organisations in more distant locations (Fontes, 2005b). As is the case in other peripheral economies, distant sources can be as much (or even more) important than the local ones and their mobilisation is often facilitated by entrepreneurs' international experiences (Saxenian and Hsu, 2001, Gilding, 2008).

However, the transformation of a technological opportunity into a marketable technology, product or service and its commercialisation requires the combination of technological and non-technological competences and resources (Autio, 1997; Mustar et al, 2006). Scientific entrepreneurs often lack managerial competences as well as industrial experience and contacts (Ensley and Hmieleski, 2005), even if teams sometimes integrate members with a managerial background. Thus, this type of firms will typically need to resort extensively to the environment, in order to acquire non-technological assets and they may also be less well prepared to identify and select the more adequate sources and to negotiate their access (Colombo and Piva, 2008; Costa et al, 2004). But the mobilisation of external resources may raise particular problems in the case of firms operating in emerging fields, given the high levels of uncertainty (both technological and market) associated with their business (Yli-Renko et al, 2001). Thus the degree and quality of the assistance that entrepreneurs find in the environment is critical to successful firm formation (Van de Ven, 1993; Stuart and Sorenson, 2003).

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The conditions found in less advanced contexts may make the external search for resources more complex for technology intensive companies in emerging fields. In fact, these contexts are likely to be less effective in providing a set of resources and competences that are critical for this type of firms, such as capital, market-related resources, specialised services and business intelligence (Mustar et al, 2006; Druilhe and Garnsey, 2004; Degroof and Roberts, 2004).

Research on biotechnology firms in Portugal has shown that there was a gap between the capacity of the local environment as supplier of knowledge and broker towards international knowledge networks and as supplier of these other resources, or at least as facilitator in the access to sources located elsewhere (Fontes, 2007; Arantes-Oliveira, 2007). But it has also uncovered an evolution in the conditions faced by biotechnology start-ups, from the early pioneers that were confronted with particularly severe conditions at all levels – including in terms of knowledge sources – to the younger generation of companies. In fact, changes in the institutional environment, that took place in the last decade, have gradually improved the process of firm creation, even if not overcoming all the difficulties. These changes included a greater interest of public research organisations in the commercialisation of research results and in supporting academic entrepreneurship; (re)orientation of government policies and mechanisms towards technological (or even scientific) entrepreneurship, which led to a sudden increase in the incentives to start-ups; greater involvement of private actors in the development of technology-intensive entrepreneurial initiatives, namely (but not exclusively) at the financial level. It should however be pointed out that most institutional initiatives were directed towards the process of firm formation. Thus, several obstacles to an effective take-off of the sector still remain, namely in what concerns the access to non-technological resources that are critical for firms' subsequent development (Fontes, 2007). In particular, young biotechnology firms are confronted with the limited interest/investment of large developed companies, which can be partly explained by the country's specialisation in sectors that are not drivers of biotechnology development and by the limited presence (and mostly commercial activity) of multinational companies operating in these sectors (Fontes and Padua, 2002).

Despite these limitations, the on-going changes led to a sudden increase in the number of firms created, thus leading to the embryo of a "sector", which gained some visibility given the political relevance of the biotechnology industry. As pointed out by the new institutionalist literature, entrepreneurial firms that "run in packs" will have more chances of being successful (Van de Ven, 1993), because there will be convergence of interests and efforts towards the construction of a supportive infrastructure and also because a growing number of actors can bring about the positive effects of agglomeration (Stuart and Sorenson, 2003). This "collective

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process" can be particularly important in the emergence of a new industry, and entrepreneurs play a key role in it, since not only they develop new technologies, but they also engage in social and political actions in order to mobilise resources, competences and social support. This process is evident in Portugal, where biotechnology entrepreneurs, particularly the "pioneer" ones, have been involved in extensive political action and institution building, have promoted the exchange of experiences with and amongst the new generations of firms and effectively contributed to an increased structuring and visibility of the sector.

The characteristics of the industry, the background of its entrepreneurs and the environmental context where firms are created will thus have a profound influence on the nature of the networking activities that are developed by start-ups. They contribute to define the resource requirements, but also influence the ease of access to these resources and, to some extent, delimit the search space for them. In addition, biotechnology firms operating in the typical environment of an intermediate economy, are faced with a context that will tend to exacerbate a set of features that often burden new ventures in this field: easier access to knowledge resources than to other types of resources; importance of credibilisation and intermediation; need to go beyond the national boundaries and develop international connections.

Therefore it can be argued that the strategies for network building followed by the biotechnology firms in this type of contexts will combine behavioural aspects that are typical of biotechnology entrepreneurs, with other that are a response to the conditions found in their particular environment. These strategies will be strongly influenced by sectoral and environmental determinants, whose impact will be felt at the level of the social capital built by entrepreneurs and at the level of the need of and scope for mobilising this capital and/ or creating new relationships. However, the firms' ability to identify, search for and activate or build the set of formal and informal relationships that can facilitate the access and effective use of available resources and competences will obviously be the critical element.

This chapter will investigate the decisions made by the most science-based sub-set of biotechnology companies - molecular biology companies – regarding the origin, composition and mode of mobilisation of their resource access networks, contributing to a better understanding of the network building strategies of this type of firms and their impact on the entrepreneurial process.

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2. THE MOLECULAR BIOLOGY FIRMS

The development of the Portuguese biotechnology sector is a relatively recent phenomenon. The process of firm creation in biotechnology started in the mid-80s, but only took-off in the early 2000s, driven by a combination of favourable factors that was described above. Despite the recent entrepreneurial upsurge, the number of dedicated biotechnology firms is still relatively small: there were 79 firms formally in operation at the beginning of 2009[2]. The main areas of application are health (human and animal) (45%), agriculture and food production (respectively 30% and 16%) and environment (9%). The proportion of firms operating in the health area has increased in recent years. It includes mainly firms oriented to clinical applications, although there are a growing number of firms in biopharmaceuticals.

The vast majority of the Portuguese biotechnology firms were created from 2003 onwards. Thus several firms are still in an early stage of development and only a small group has 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 conditions in which firm formation took place meant that the majority was a direct or indirect spin-off from research and that a substantial proportion involved or were created through the initiative of young scientists.

The analysis conducted in this paper 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.

2.1. Global characterisation of the firms

The sub-set of molecular biology companies, includes 23 firms, most of which belong to the younger generation of Portuguese biotechnology (Figure 1). Their activities are mainly concentrated in the human health sector, with a predominance of therapeutic applications, while a smaller group target the agro-food sector (Figure 2).

[2] Data obtained from a proprietary database on Portuguese biotechnology firms compiled by the authors since 1998.Besides the firms formally in operation, there are also several firm projects, in various stages of development, which are expected to give rise to new firms in the near future.

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Figure 1 – Year of firm creation

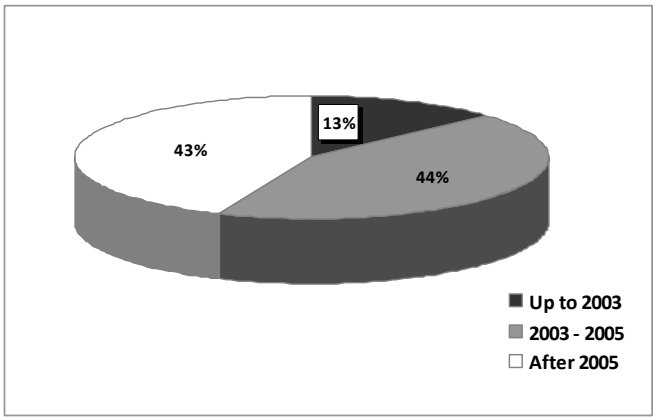
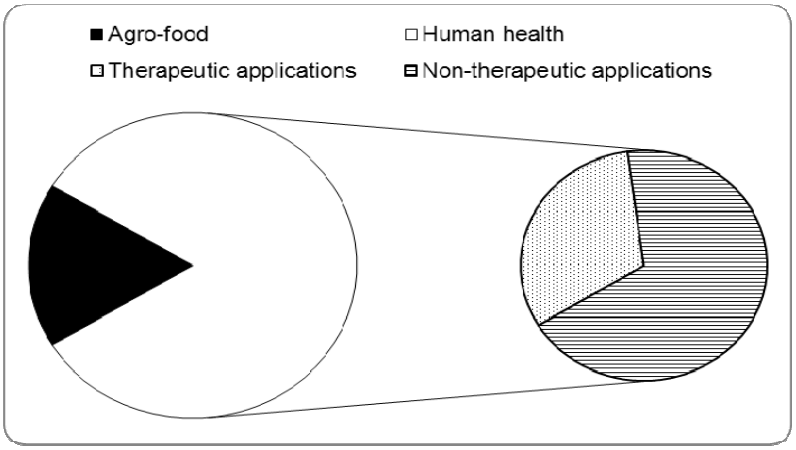


Figure 2 – Area of firm activity



Portuguese biotechnology firms are generally located in the main urban centres where the principal research organizations are also established, where incubation and other support infrastructures and specialised services are increasingly available and where they can benefit from the easy access to international airports. This group follows the same pattern, being clustered around three metropolitan areas: the Greater Lisbon (57%), responsible for the highest R&D investment in the country; the town of Coimbra (26%), which has developed good competences in the health sector, around a major university hospital; and the country's second city, Porto (13%).

Most of the molecular biology companies are very small: the majority has 10 employees or less, the average number being 8 (Figure 3). These employees include a high number of doctorates: 65% have at least one doctorate and in 30% of the cases they represent at least 50% of the total employees.

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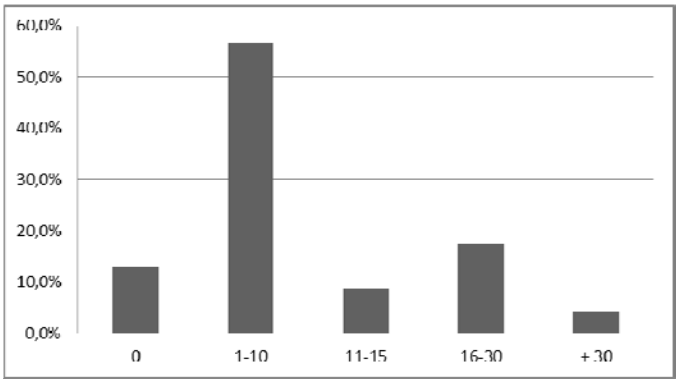
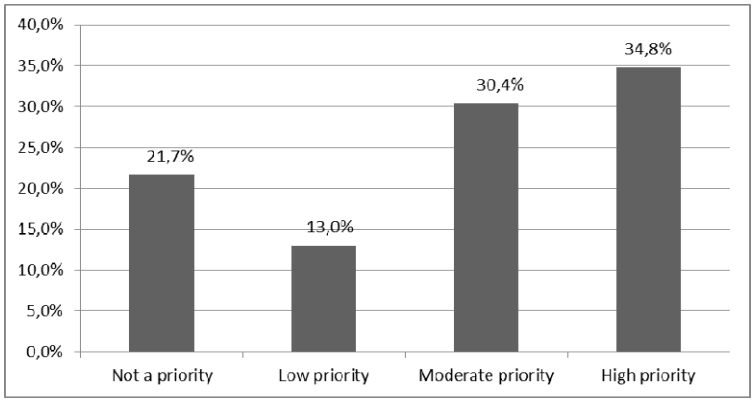
Figure 3 – Number of workers



In what concerns the business model, most firms aim to develop a product or service and commercialise it. Only two companies aim to exclusively sell or license the technology, while other seven (30%) intend to combine this activity with the development of products/services, three of them expecting the sale/licensing of the technology to become their main source of income in the future.

In spite of being relatively young, only a minority of these companies (13%) refer not yet having a product/technology developed and able to be commercialized. Most indicate that they have already introduced a product, service or technology in the market. Nevertheless, 65% of them consider the scale-up of technology as a priority for the next three years (Figure 4), with particular emphasis on newer companies. This result suggests that in many cases, although the firms are on the market, they are not yet commercializing their main product/technology or are only commercializing preliminary versions of it, produced on a limited scale, fact that was confirmed in several interviews. In these cases the market entry is made for reasons of survival or to assess/start to open the market and is often based on services (including contract research).

Figure 4 – Priority level attributed to the scale-up of technology



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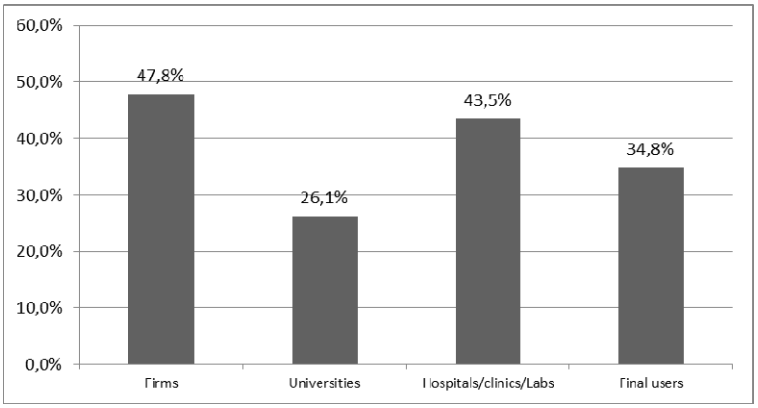
The incipient nature of the commercial activity of these firms (or its limited success) is supported by the fact that, even among companies that reported having already introduced their technology in the market, 37.5% have a turnover below 100,000 euro and only 31% (not necessarily among the older ones) have reached the level of a million euro in sales.

The main customers are other companies and hospitals/clinics/laboratories, followed by end-users and universities/ research centres (Figure 5). Although internationalization is generally considered as a strategic goal, only about half of the companies sell products/services in foreign markets. On average, the weight of exports on turnover is 34%. European countries are the main export destinations, followed by the United States.

Figure 5 – Main clients



More than half of the firms have external capital and a significant number have venture capital (35%). Regarding the sources of funding, the majority of companies rely both on equity and on funding from outside investors (including venture capital, corporate investors and private investors or business angels). Nearly half of the companies received public incentives which, on average, account for 21% of the total funding (Figure 6).

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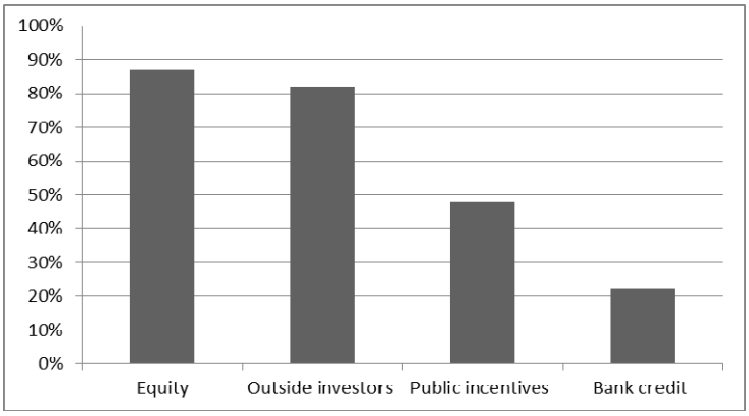
Figure 6 – Funding sources



These companies were usually created by teams composed, partly or exclusively, of scientists from national universities or research centres, or returning to the country after completion of PhDs or post-doctorates in foreign organisations. Accordingly, 20 of the 23 companies can be considered research spin-offs - that is, they apply knowledge or technology developed by its founders in research organisations. However, the relevance attributed by the companies to knowledge transferred from the parent organisations (as compared with knowledge developed, more or less autonomously, already in the new firm) varies from company to company. About half of the companies consider that the technology was transferred from the parent organisation, through formal (2/3) or informal (1/3) transfer mechanisms, the entrepreneurs having been involved in the development of this technology. But a still large share of companies affirms that the technology was primarily developed in-house. Finally, in a small group of firms, the technology was essentially developed by another company, being incorporated in equipment used or in the techniques applied to provide a service.

Most companies (74%) describe their technology as a platform that underpins the various products/services. This is namely the case of companies whose business models focus on the sale or licensing of technology, or that combine this activity with the development of original products.

The vast majority of companies (78%) refer to conduct R&D activities, although only two mention to be involved in basic research. In about half of them, these activities represent at least 50% of the turnover. Similarly, 65% of the companies mention to have human resources devoted to R&D and, for a significant number (35%), these represent more than 50% of total employment. This high R&D intensity can be explained by the fact that many of these companies are still largely focused on the development of their first technology. The

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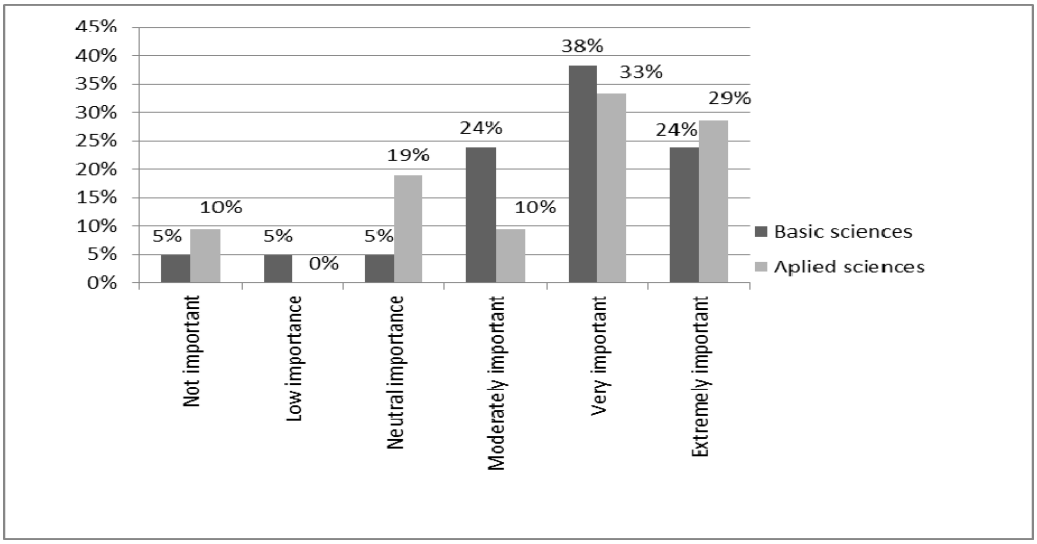
technological intensity of this group of firms is confirmed by the fact that about half have submitted patents.

In addition, a significant proportion of these firms describe advances in academic research – resulting from basic and/or applied sciences - as a very important or extremely important source of technological opportunity (Figure 7). Advances resulting from basic sciences are globally assigned a higher importance, confirming the scientific basis of this group of firms.

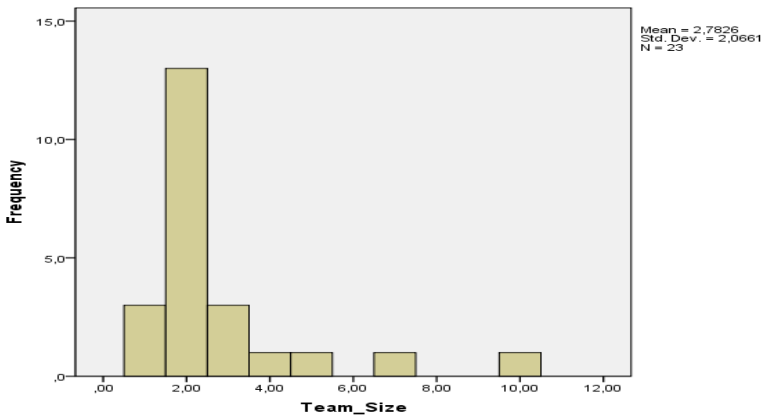
Figure 7 – Advances in academic research as source of technological opportunity



2.2. The entrepreneurial teams

The creation process of the molecular biology companies described in the previous section involved, in most cases, a team of entrepreneurs. The size of the teams varies between two and ten entrepreneurs, the most frequent size being two (Figure 8).

Figure 8 – Size of entrepreneurial teams



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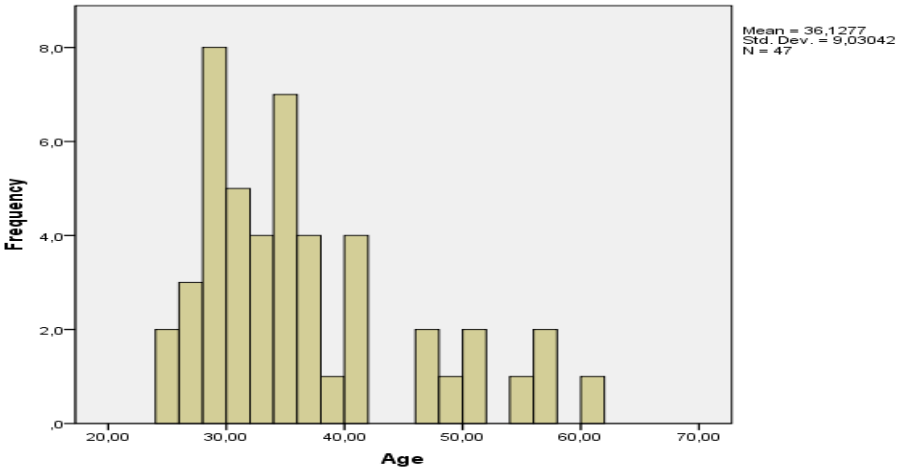
The teams are mostly composed of by young entrepreneurs – the average age at the time of firm creation being 36 years (Figure 9). But some firms also involved or were created through the initiative of more mature entrepreneurs – frequently senior scientists or individuals with business experience.

Figure 9 – Age of entrepreneurs



As pointed out above, a large share of these companies are research spin-offs, created by entrepreneurs originating from research organizations. However, some teams (26%) also include individuals with managerial or industrial experience.

The academic origin is reflected in the entrepreneurs' qualifications: the majority (74%) held a PhD at the time of firm creation. All but one have at least a graduate degree, the most frequently represented fields being biological sciences (39%) followed by engineering (17%). The entrepreneurs' scientific background is confirmed by the fact that about 80% had participated in research projects and had published in scientific journals. Almost 30% had been involved in patenting as applicants or inventors. In addition, several teams include one senior scientist – sometimes a highly reputed one – who retained the post at the university and ensures a close connection with the academic environment, thus contributing to strengthen the science-based nature of the firm.

The number of entrepreneurs with previous technical experience in an industrial context is relatively small (Figure 10). An even smaller number have business or management experience, although some have, at some point, attended short courses on management or entrepreneurship and two have a MBA. It should nevertheless be pointed out that firms created more recently

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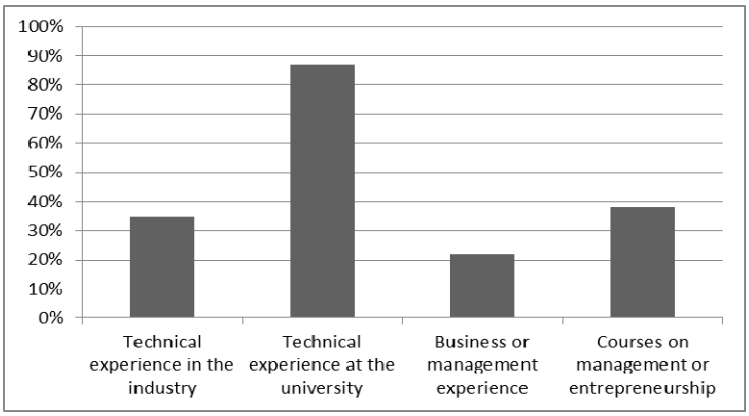
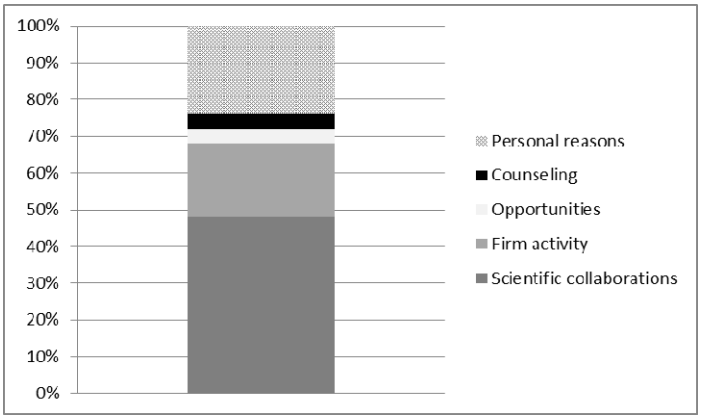
frequently added members with non-technological competences to the team. Indeed, this was often a requirement put forward by the start-up support programmes or the external funding sources to which the younger generation of firms increasingly resorted.

Figure 10 – Entrepreneurs previous experience



A significant number of entrepreneurs studied or worked abroad over a period of time, manly in European countries and in the US (65%). These mobility experiences enabled the development of a set of links, most of which (86%) were maintained through time, being used by the entrepreneurs as a source of new scientific collaborations or as support to firms' activities (Figure 11).

Figure 11 – Reasons to maintain relations with foreign organisations from the trajectory



The characteristics of the entrepreneurial teams – in particular their youth, the predominance of academic backgrounds, the frequent international experience, as well as the occasional presence of "star" scientists on the one hand, and of individuals with non-technological backgrounds (and

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in a few cases, with effective business experience), more frequent among the firms created more recently, on the other hand – are important elements to understand the networking behaviour of this group of firms.

3. THE NETWORK BUILDING STRATEGIES OF ENTREPRENEURIAL START-UPS

3.1. Factors influencing early network configuration

When addressing the strategies followed by start-up firms to build the networks that are relevant in accessing resources for creation and early development, the first question that can be raised concerns the origin of these networks. In fact, entrepreneurs can mobilise their social capital, i.e. draw on the personal networks that were built along their trajectory, but they can also create new links in order to obtain resources that are not accessible through the former.

The relationships that compose the entrepreneurs' social capital are often equated in the literature with the firms' early stage network (Hsu, 2007). Behind this inference is the assumption that entrepreneurs' trajectory led to the establishment of relationships with members of the organisations that were part of that trajectory and that these relationships automatically become part of the network of the new firm (Shane and Stuart, 2002). Our proposal is that the links maintained with individuals from trajectory organisations configure a *potential network*, to which the entrepreneurs may or may not resort during the process of firm creation and early development. Thus, it is to be expected that only a subset of this potential network will be effectively mobilised for firm's purposes becoming part of the firm's network and so, that entrepreneurs will actively shape this network (Gilsing et al, 2007). It is therefore important to understand whether and to what extent entrepreneurs activate their social capital.

Ties that originate from the entrepreneurs' social capital have several advantages: they are usually characterised by higher levels of trust, which facilitate communication and information exchanges (Burt, 1997). Moreover, because these relations are often based on shared experiences, there is a good understanding of the potential contributions they can offer. These experiences may also have led to the development of cognitive proximity, that facilitates the transmission of knowledge, particularly when such knowledge is complex or less structured (Breschi and Lissoni, 2001). However, exactly because these ties are associated with the entrepreneurs' personal trajectory, they may be less useful when it comes to accessing resources and competences that are more distant from the entrepreneur's own experience (Ensley and

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Hmieleski, 2005). In addition, some authors also call attention to the dangers of over-embeddedness and excessive reliance on social capital (Adobor, 2006, Uzzi, 1997).

Thus, in order to expand the search scope, entrepreneurs will need to go beyond their personal network and purposefully establish new relations. Lin (1999) speaks of "instrumental actions related with contact resources" to describe the efforts conducted for this purpose. These new ties, described by Hite and Hesterly (2001) as "calculative networks", are usually created with a specific purpose and thus are likely to be more goal-oriented than trajectory-based ties. The members of the existing network can still be instrumental at this level, assisting in the identification of relevant individuals/organisations and acting as mediators or credibilisers towards them (Moensted, 2007; Shane and Cable, 2002; Wink, 2008).

In addition to the origin of ties, the configuration of the networks mobilised by the firms will be influenced by two types of factors: the nature of the resources being searched and the mode of mobilisation chosen.

Previous research has shown that the structure and composition of networks differ according to the nature of the resources being accessed (Sammarra and Biggiero, 2008; Sousa et al, 2011). Thus, it is to be expected that the search for different types of resources will lead to different network building strategies, not only in terms of tie origin (trajectory or intentional), but also in terms of type and variety of actors mobilised and in terms of their mode of mobilisation.

In the case of science-based entrepreneurship, key resources include scientific and technological knowledge (a critical asset for these firms); reputation and credibility; capital, human resources, information about markets, financing, regulatory processes, intellectual property; counselling and mediation in these same fields (Mustar et al, 2006; Druilhe and Garnsey, 2004; Vohora et al, 2004). Considering the nature of the resources potentially searched and also the fact that we are addressing the firm formation period, it seems relevant to consider the three network types mentioned by Castilla et al. (2000): *networks of access and opportunity*, which are related to opportunity identification and exploitation and to obtaining tangible resources*; networks of production and innovation*, where knowledge is the main resource that circulates (and thus in this can be more adequately labelled as *networks of knowledge*); and *networks of power and influence*, which can be associated with the credibilisation and mediation dimensions described above.

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Regarding the mode of mobilisation, two aspects emerge as particularly relevant. First, the level of specialisation of the tie: relationships can be mobilised to access only one specific type of resource, or rather, afford access to various types of resources. Despite the potential relevance attributed to these "multiplex ties" in the entrepreneurship literature (Scott, 1991, Greve and Salaff, 2003), research on multiplex networks is still limited (Lee and Monge, forthcoming; Lomi and Pattison, 2006). Thus we are interested in assessing whether firms resort to the same actor for a variety of purposes, in which circumstances these multiplex ties occur and which forms they assume.

Second, the formalisation of the tie: both trajectory relationships and new links may be kept informal or may be formalised through some type of contractual relationship (e.g. projects, contracts, alliances) (Powell and Grodal, 2005). The relevance of formal and informal networks for resource access is frequently discussed in the literature (Ozman, 2009; Audretsch and Feldman, 2003). But while there is an extensive body of empirical research on the formal alliances of young technology-intensive companies - which frequently focus on the case of biotechnology firms and their relations with large established firms or with universities (Audretsch and Feldman, 2003; Baum, Calabrese, Silverman, 2000; Stuart et al, 2007; Roijakkers and Hagedoorn, 2006; Levitte and Bagchi-Sen, 2010; Street and Cameron, 2007) - informal networks are much less studied (Schwartz and Hornych, 2010) and often still in the context of formal collaborations.

The strongest body of research has focused on informal knowledge flows, being frequently conducted in the context of a discussion on the presence and effective role played by knowledge spillovers (Audretsch and Feldman, 1996). This research has generally used proxies to knowledge flows between organisations, such co-patenting / patent citations or co-authorships (Breschi and Lissoni, 2004; Singh, 2005; Murray, 2002). Only a few authors have investigated the actual informal interactions between individuals in the search for knowledge or other resources (Kreiner and Schultz, 1993; Giuliani and Bell, 2005; Lissoni, 2001; Dahl and Pedersen, 2004; Østergaard, 2009; Morrison and Rabelotti, 2009). This research describes informal networks as being often associated with the trajectory of the individuals or with previous interactions in formal partnerships, as tending to be geographically localised and as depending strongly on loyalty and reciprocity for their continuity (Dahl and Pedersen, 2004; Huggins and Johnston, 2010; Kachra and White, 2008;). One interesting finding concerns the differences between knowledge networks and what is described as "business networks", the former being more selective and restrict, while the latter tend to be denser and more evenly

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distributed (Giuliani, 2007). But, with few exceptions, this research was largely concerned with the informal networks of firms' employees and rarely considered the entrepreneurs own networking activities. However, the entrepreneurs' networks are particularly relevant in the case of technology-intensive start-ups (Johanisson, 1998) and are likely to have specific characteristics, given their greater alignment with the firms' interests (Grabher and Ibert, 2006).

Despite the frequent assertion that formal and informal relationships are closely interlinked (Powell et al, 1996, Gulati, 1998) the simultaneous consideration and comparison between their nature and roles is particularly scarce (Trippl et al, 2009, Kang and Kang, 2009, Huggins and Johnston, 2010).

Thus, we are interested in looking in greater detail at formal and informal networks, with a view to understand whether the nature of resources being searched has implications in terms of the level of formality of the ties established, as well as to investigate whether entrepreneurs perceive formal and informal ties differently in terms of their importance to access the various resources. In addition, we are also interested in investigating whether there are differences between the formal and informal component of the firms' networks, namely in terms of actor composition and origin of the ties.

3.2. Understanding network building strategies

The building up of firms' networks is, therefore, influenced by three factors: the type of resource searched (what for?), the nature of the relationships mobilised to access them (who?) and the mode of mobilisation of these relationships (how?). In this section, we advance and test a set of hypothesis on the expected influence of the decisions made, regarding these factors, on the configuration of firms' early networks.

Potential networks provide the social capital that entrepreneurs can mobilise to access the resources needed for firm creation and early development. So, we can consider them as the starting point of the process of resource mobilisation, and thus assume that mobilised networks are partially built around organisations that were present in the potential network (Murray, 2002). However, entrepreneurs will not necessarily mobilise all their social capital, while the new firm requirements may lead them to search for and add new relations to their networks. So, mobilised networks are likely to be different from the potential networks.

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Hypothesis 1 – Entrepreneurs only mobilise a subset of their potential network.

The size of the network is a relevant aspect for start-ups: larger networks will, in principle, broaden the search space, enabling entrepreneurs to gain access to a greater variety of suppliers of these resources (Burt, 2000). On the other hand, larger networks can be more difficult to manage, particularly when they involve a high proportion of new ties (Standing et al, 2008).

Assuming that entrepreneurs will always draw more or less extensively on the potential network, their decisions regarding the extent to which new relations are established – and therefore new actors are mobilised and become part of the firm network - will have an impact on its size. So,

Hypothesis 2 – **Firms that mobilise a higher proportion of intentional ties will have larger networks.**

On the other hand, the decisions regarding the mode of mobilisation can equally have an impact on network size. In fact, entrepreneurs can either opt for diversifying their ties, or for following the strategy of mobilising the same tie to access different resources, building multiplex ties. The latter are associated with a higher richness of information (Koka and Prescott, 2002). Thus, the mobilisation of this type of ties enable firms to build networks involving a limited number of organizations, with whom there is a variety of exchanges. In this case, it is possible to access all the resources mobilising smaller networks. So,

Hypothesis 3 – Firms that establish multiplex ties with the same actor will have smaller networks.

The decisions on the formalisation of the tie will also have implications for the network configuration. We expect to find differences between formal and informal networks in terms of their origin and composition.

Trajectory ties are associated with previous social interactions, which may have promoted the emergence of trust-based relations with members of a given organisation, while trust usually still needs to be developed in the case of intentional ties. This can be a slow process, with levels of commitment from the partners increasing through time (Lorenz, 1999). In these conditions,

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we expect that entrepreneurs will tend to formalise relations with organizations when lower levels of trust are present at the outset. Thus, we can advance that:

Hypothesis 4 – Formal networks have a higher proportion of intentional ties than informal networks.

The formalisation of a relation requires a codified agreement between actors. Those formal agreements will usually have a very precise content, thus formal relationships are likely to be more targeted than informal ones. The option for establishing ties with multiple objectives with the same actor increases the level of risk, in case something goes wrong with the relationship – thus, multiplex ties are more likely to arise with actors whom entrepreneurs trust (Uzzi, 1997). Moreover, as was pointed out above, the ability to resort to the same actor for different purposes requires a good knowledge of its possible contributions. This combination of awareness and trust will often be based on previous experiences that led to mutual learning (Koka and Prescott, 2002), which in the case of start-up firms is associated with members of the trajectory network. Thus, it is to be expected that, at least in early stages, multiplex ties arise more frequently in the context of informal relations:

Hypothesis 5 – Formal networks have a lower proportion of multiplex ties than informal networks.

As was pointed out above, the process of resource mobilisation is affected by the nature of the resources being searched. Access to different types of resources may require the mobilisation of different types of actors and the use of different modes of mobilisation. Moreover, depending on the entrepreneurs' backgrounds, the social capital will be more effective to access certain types of resources than others. So, networking strategies will vary across resources, leading to networks with different configurations.

Since almost all entrepreneurs have an academic background and a scientific professional trajectory, their social capital will be particularly useful to access scientific and technological knowledge. Potential networks will be less valuable to access resources needed for the identification and exploitation of the opportunity and thus firms will need to establish new intentional ties for that purpose. However, given the knowledge intensive nature of firms' business and the novelty of their technologies/ products, the entrepreneurs' social capital can play a key role in power and influence networks. In fact, the association with reputed research

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organisations or scientists can have a quality signalling and credibilisation effect, which is critical in early stages, particularly for those firms that are not otherwise connected (Luo et al, 2009).

Therefore, we can propose that entrepreneurs will be more likely to mobilise the potential networks based on their trajectory to gain access to knowledge and for intermediation and credibilisation purposes (P&I network) and will be more likely to create and mobilise new intentional ties to gain access to other resources (O&A network).

Hypothesis 6 – O&A networks have a higher share of intentional ties than knowledge and P&I networks.

The fact that O&A networks have a higher share of intentional ties, have implications in terms of the nature of the relationships established. In fact, if formalisation is more likely in the case of intentional ties, as proposed in Hypothesis 4, this means that it will also be more likely in the access to resources where trajectory ties are less present. Thus, while knowledge-oriented trajectory relations will sometimes evolve to contractualisation (particularly when they involve intellectual property) (Smith-Doerr and Powell, 2005) and while firms may establish new intentional ties to access knowledge, on the whole, this type of relations are expected to remain more frequently informal. Similarly, informal relationships derived from the trajectory are likely to play a more important role in intermediation and credibilisation because trust may have not yet similarly developed in most formal relationships, given the early stage of the firms. In addition, it is to be expected that the access to material resources such as finance and physical facilities or the development of production or commercial alliances will always require contractual agreements. Thus:

Hypothesis 7 – O&A networks have a higher share of formalised ties than knowledge and P&I networks.

O&A networks include a more heterogeneous set of resources, which requires mobilising actors with different types of competences and located in different organisations. On the contrary, knowledge networks rely on a more specialised set of actors, while P&I networks are likely to be populated by a small set of highly trusted actors. Thus we propose that when searching for resources necessary to exploit the business opportunity, entrepreneurs will mobilise a wider and more varied set of actors than when looking for knowledge or when attempting to build credibility. Thus:

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Hypothesis 8 – O&A networks are bigger and have higher variety of actors than knowledge and P&I networks.

These hypotheses are subsequently tested for the case of the social networks built by the molecular biology firms under analysis.

4. THE PROCESS OF NETWORK MOBILISATION: EMPIRICAL ANALYSIS

4.1. Reconstruction of firm's networks: methodology

To test the above hypotheses we have (re)constructed the social networks mobilised by the entrepreneurs during the firm formation period. "Firm formation" 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. The networks were (re)constructed according to the origin, type of resource and mode of mobilisation.

Data on the firms' networks 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 systematic and 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, strategy and performance. This combination of methods represents a novel approach 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

The (re)construction of the networks mobilised by the firms draw on these sources and followed two main steps. First, 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

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personal relationships might have been established. The combined individual trajectory networks composed the firms' "*potential network*".

Subsequently, the interviews permitted to identify the networks that were *effectively mobilised* by the entrepreneurs during the creation and early development of the firm. For this purpose, we used the information provided by the entrepreneurs about the actors they regarded as important to identify the opportunity and to obtain the critical resources and about their specific contributions. This information was combined with data on the formal partnerships, cooperation agreements and other formal relationships established by the firm up to the third year of its existence, which was collected during the firm-oriented section of the interviews.

This process enabled us to identify two components of the *mobilised network*. On the one hand, interview data permitted to identify the members of the potential network that were effectively mobilised during the formation process – the "*trajectory networks*". On the other hand, interview data combined with documentary analysis, 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 includes ties from entrepreneurs' trajectory that were mobilised for this purpose - *trajectory network* - and ties intentionally established – *intentional network.*

The information was collected for different types of activities, thus enabling us to individualise the three networks proposed by Castilla et al. (2000). The *opportunity and access (O&A) network* is composed of all the actors/relationships used to identify the opportunity and to access and acquire the tangible resources (capital, human resources and facilities) necessary to exploit it. The *knowledge network* includes actors/relationships used to obtain scientific and technological knowledge. The *power and influence (P&I) network* is related with the use of well positioned and influential individuals as mediators in the access to key sources of resources/competences and as credibilisers towards key actors who could not be mobilised without proper references.

The data obtained also permitted to distinguish between *formal* and *informal* ties. The former correspond to contractual agreements between actors (which usually involve a system of authority, distribution of competences, rights and duties and a device for conflict resolution), whether they represent the formalisation of pre-existing personal relations, or are formal from

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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 resource acquisition. 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 that are both formal and informal.*

4.2. The configuration of firms' networks

In this section we present the results of the empirical analysis of the networks mobilised by this group of molecular biology firms to access resources during firm creation and early development.

4.2.1. Global characterisation

The analysis confirms that networks combine ties from different origins: the academic and professional trajectory of the entrepreneurs (potential network) and the intentional effort to build a relation that will grant access to the resource.

The potential networks reflect the social capital of entrepreneurs at start-up and thus their size and composition are influenced by the dimension of the entrepreneurial team and by the differences in the academic and professional path of its members. On average, they have 16 organisations and are composed of only three types of actors (Table 1). As would be expected, those networks are largely dominated by universities, reflecting the academic trajectory of a substantial proportion of the entrepreneurs.

Table 1 – Potential networks

	Average	Maximum	Minimum	Coefficient of variation
Size	16	62	2	0.9
Variety of actors	3	5	1	0.5
% of mobilised ties	30	100	0	0.8

The data presented in Table 1 reveals that the entrepreneurs do not mobilise all the relations in their potential network, i.e., they do not activate all their social capital, confirming hypothesis 1. In fact, on average, entrepreneurs mobilise only 30% of their social capital, although there is

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some variety among the firms analysed. Two of them follow extreme strategies: one only mobilises ties that come from entrepreneurs trajectory and the other only mobilises intentionally built relations.

So, the predominant strategy to access resources seems to be building networks that mix people with whom the entrepreneurs are already acquainted with a set of new actors that can act as new sources of relevant resources. Hence, we can conclude that, for the majority of the firms, the resources that the entrepreneurs can access through their potential networks are not sufficient for the formation and early development of the firm, leading them to purposefully establish contacts with organisations that were not part of their trajectory. This combination of existing (trajectory) and new (intentional) ties constitutes the firm's "mobilised network".

Table 2 presents data on the mobilised networks. It is possible to conclude that, on average, entrepreneurs mobilise 11 organisations of 4 different types to access all relevant resources during the firm creation process. However there is large amplitude on network size values, indicating possible differences in the mobilisation strategies. Results show that none of the companies mobilises all types of actors to access the whole set of resources and that each company mobilises at least 2 different types of actors. Compared with potential networks (see Table 1), mobilised networks are smaller and more diversified. The higher variety of actors reflects the additional requirements of transforming technological knowledge into a product or service and commercialising it. Thus the construction of the firms' network will usually require the addition of new types of actors to those present in the potential networks.

Table 2 – Mobilised networks

	Average	Maximum	Minimum	Coefficient of variation
Size	11	36	3	0.8
Variety of actors	4	6	2	0.3
Proportion of intentional ties	65	100	0	0.3

To uncover possible factors that lead to networks of different sizes, we tested for the signal and statistical significance of the relationships between the number of organisations that integrate the mobilised network and the proportion of intentional ties, variety of actors and proportion of multiplex ties. For that purpose we used the Pearson correlation coefficient between the variables, at firm level. The results presented in Table 3 support hypothesis 2 and 3, permitting to conclude that when firms choose to build a higher proportion of intentional ties, they end up with larger networks, which also include a more diverse set of actors, each targeting a specific goal.

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Table 3 – Pearson correlation between network composition and size

	Share intentional ties	Variety of actors	Share multiplex ties
Size	0.407 **	0.574 ***	-0.343 *

N=23; * significant at 0.10 level (1-tailed); ** significant at 0.05 level (1-tailed); *** significant at 0.01 level (1-tailed)

The mobilised networks of these firms are rather heterogeneous in their composition (see Table 4). On average, they are dominated by universities, which represent about 40% of all organisations in the network. Non-biotech firms (22%) are the second most important actor, while relations with other biotechnology firms are less frequent. Hospitals are only present in the networks of 4 firms, but for these firms they are a very relevant actor, representing about 25% of their relations and being usually associated with the experimental stage of clinical research. Financial institutions are similarly an important actor for the sub-set of firms that resort to external capital, their role sometimes going beyond that of capital suppliers.

Table 4 – Composition of the mobilised networks (%)

	Average	Maximum	Minimum	Coefficient of variation
Firms – Bio	10	36	0	1.2
Firms – Other	22	50	0	0.7
Universities	39	75	0	0.4
S&T Parks	12	33	0	0.9
Hospitals	4	50	0	2.6
Financial Institutions	6	33	0	1.6
Other actors	8	25	0	1.1

It is also relevant to note that the vast majority of firms (70%) have foreign actors in their mobilised networks, those accounting, in average, for 33% of their relationships. We can even find a small group of highly internationalised firms, which have over 50% of their network located abroad. If we look in greater detail to these foreign actors we realise that research organisations and hospitals prevail, being twice as much as firms. Among the latter, biotechnology firms are the most frequent (63%), followed by pharmaceutical companies (21%). Interestingly, few organisations are part of the network of more than one of the firms studied, signifying that international relations are exclusive ones. Regarding the geographical location, we observe that this group of firms is strongly connected with European countries. In

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the case of foreign research organisations, European actors represent 78% of foreign relations, with German organisations emerging as core partners (20%), followed by US ones (16%). In the case of foreign firms, the distribution is more balanced: European firms still account for 42% of the international relations, but global companies (frequently pharmaceutical) account for 33% and US firms for 21%.

Regarding the mode of mobilisation, we can observe in Table 5 that, on average, more than half of mobilised ties are formal ties. This means that molecular biology firms feel the need to formalise relations used for accessing resources. But it is also interesting to note that in almost 1/3 of the cases the entrepreneurs establish, with a given organisation, ties that are simultaneously formal and informal. Such cases appear to be related with the formalisation of ties that originate from the trajectory.

Table 5 – Mode of mobilisation (%)

	Average	Maximum	Minimum	Coefficient of variation
Proportion of informal ties	44	1	10	0.6
Proportion of formalised ties	56	90	0	0.4
Proportion of dual ties (formal and informal	31	67	0	0.7
Proportion of multiplex ties	41	100	10	0.6
Proportion of duplex ties	27	67	0	0.8
Proportion of triplex ties	14	57	0	0.9

Table 5 also shows that firms frequently mobilise the same actor for obtaining different resources, establishing multiplex ties. This strategy was present in all firms, although only one firm relied exclusively on it. Since we are analysing three types of resources, we were able to separate between duplex ties (granting access to 2 resources) and triplex ties (granting access to 3 resources). Mobilised networks have, on average, about 40% of multiplex ties, duplex ties being the most frequent. Duplex ties occur mainly in the combination of knowledge and P&I. The relatively high share of multiplex ties means that mobilised networks are smaller than they would be if entrepreneurs used each organisation to access only one type of resource.

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4.2.2. Formal versus Informal networks

In order to understand eventual differences between formal and informal networks, we have separated and compared the (re)constructed formal and informal mobilised networks, in terms of the relative importance of intentional ties and trajectory ties and in terms of the intensity of mobilisation of each tie. Table 6 shows that the proportion of intentional ties in the total number of ties is, on average, higher in the formal networks. Table 7 shows that formal networks have, on average, a smaller proportion of multiplex ties, which are mostly present in informal networks.

Table 6 – Proportion of intentional ties in formal and in informal networks (%)

	Average	Maximum	Minimum	Coefficient of variation
Formal	77	100	0	0.3
Informal	54	100	0	0.5

Table 7 – Proportion of multiplex ties

	Average	Maximum	Minimum	Coefficient of variation
Formal	5	100	0	1.7
Informal	50	100	0	0.4

To assess whether the differences between formal and informal networks are statistically significant, we used the non-parametric Wilcoxon signed-rank test, which tests for differences between two related samples[3]. Table 8 shows that there are significant differences between both networks. Formal networks have a higher proportion of intentional ties than informal networks and have a smaller proportion of multiplex ties, providing evidence that supports hypotheses 4 and 5.

Table 8 – Testing differences between formal and informal networks

	Wilcoxon signed-rank test
Proportion of intentional ties in informal and in formal networks	Informal < Formal z = -3.011***
Proportion of multiplex ties in informal and in formal networks	Informal > Formal z = -4.198***

N=23; *** significant at 0.01 level

[3] This option is related to the fact that the variables do not follow a normal distribution, perhaps due to the size of the sample. Non-parametric techniques provide robust results for smaller samples and are less likely to provide spurious results.

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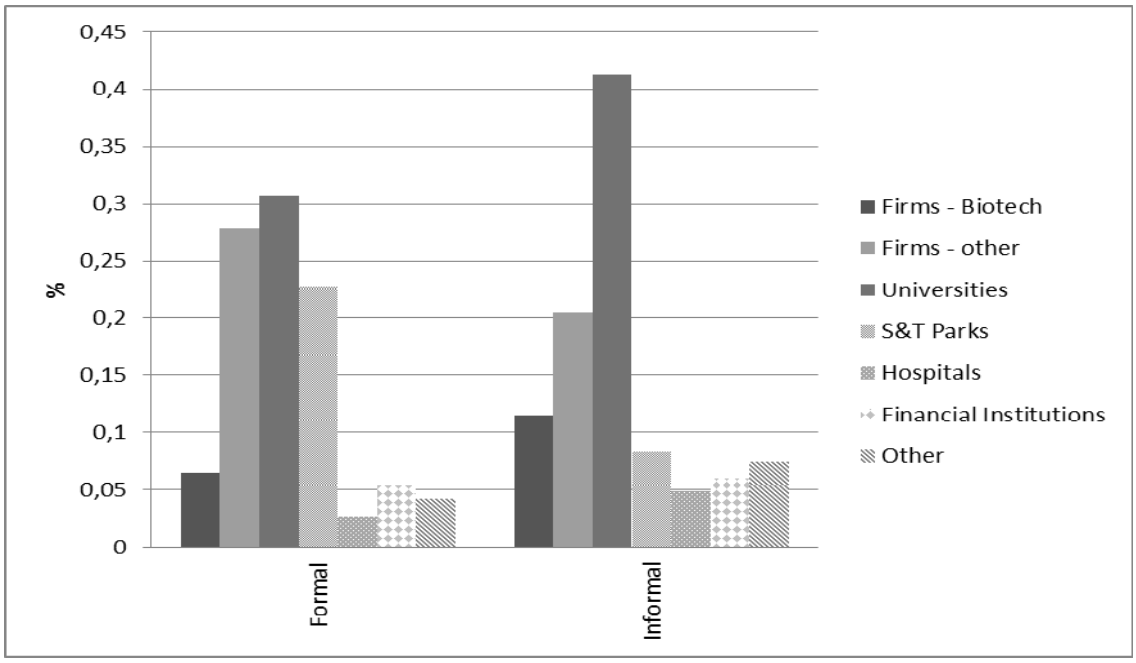
Finally we have also looked into the actor composition of both networks (Figure 12). The role of universities is more pronounced in informal networks. Relations with non-biotech firms and with science and technology parks are preferably formalised, the opposite happening in the case of relations with other biotech firms and with hospitals[4].

Figure 12 – Network composition by mode of mobilisation (average)



4.2.3. Network mobilisation for different types of resources

The process of resource mobilisation is affected by the nature of the resource being searched. So, to understand the network strategies followed by molecular biology firms we have (re)constructed the networks mobilised for different purposes - opportunity and access (O&A), knowledge, power and influence (P&I) networks – and investigated the eventual differences between them, regarding the origin of ties, their mode of mobilisation and composition (size, type and variety of actors).

First of all, we considered eventual differences in the network origin, by looking into the proportion of intentional ties. Table 9 indicates that O&A networks exhibit a larger share of intentional ties: on average, about 2/3 were purposefully established. The proportion is smaller

[4] These conclusions are supported by the results of the Wilcoxon signed ranks test.

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in the case of knowledge and P&I networks, although intentional ties still account, on average, for almost one half of the mobilised ties.

Table 9 – Proportion of intentional ties in each type of network (%)

	Average	Maximum	Minimum	Coefficient of variation
O&A	67	100	0	0.4
Knowledge	43	100	0	0.9
P&I	44	100	0	0.8

To assess whether the differences between the three types of resources are statistically significant, the procedure was as follows: the Friedman test was conducted to detect the presence of significant differences between the three resource networks; then the Wilcoxon signed-rank test was applied to pairs of resources in order to understand where the differences did emerge.

Table 10 shows that there are statistically significant differences in the proportion of intentional ties in the networks mobilised to access different types of resources and that the proportion of intentional ties tends to be higher in O&A networks, compared to both knowledge and P&I networks, confirming hypothesis 7. This result suggests that entrepreneurs put more effort in establishing new relations with the purpose of gaining access to tangible and intangible assets related to the identification and exploitation of the opportunity, relying more strongly on their social capital for knowledge access and intermediation.

Table 10 – Proportion of intentional ties – testing differences between resources

Test	Result
Friedman – Chi-square	8.208**
Wilcoxon signed-rank Knowledge vs. O&A	Knowledge < O&A z = -2.446***
Wilcoxon signed-rank P&I vs. Knowledge	No significant differences z = -0.310
Wilcoxon signed-rank P&I vs. O&A	P&I < O&A z = -3.007***

N=23; ** significant at 0.05 level; *** significant at 0.01 level

Regarding the mode of mobilisation, Table 11 indicates that firms, on average, opt for more formalised relations when it comes to access knowledge and resources related to the opportunity identification and exploitation. Table 12 shows that there are significant differences between resources at this level: P&I networks have a significantly lower proportion of formalised

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relations than O&A and knowledge networks. However, no significant differences were found between O&A and knowledge access modes. So, results only support partially hypothesis 8.

Table 11 – Proportion of formalised ties

	Average	Maximum	Minimum	Coefficient of variation
O&A	46	86	0	0.5
Knowledge	50	100	0	0.8
P&I	16	100	0	1.8

Table 12 – Proportion of formalised ties – testing differences between resources

Test	Result
Friedman – Chi-square	13.825***
Wilcoxon signed-rank **Knowledge vs. O&A**	No significant differences z = -0.543
Wilcoxon signed-rank **P&I vs. Knowledge**	P&I < Knowledge z = -2.967***
Wilcoxon signed-rank **P&I vs. O&A**	P&I < O&A z = -3.494***

N=23; *** significant at 0.01 level

According to these results, firms appear to have a higher than expected tendency to an early formalisation of knowledge oriented relationships, even when these involve trusted partners. This can be explained by the strategic role played by knowledge in biotechnology and the by intermediate role played by dedicated biotechnology firms between research organisations and large established companies (Stuart et al, 2007).

An analysis of the cases where firms establish both formal and informal relationships with the same organization (Table 13) seems to corroborate this conclusion. In fact the presence of dual relationships is more expressive, on average, in knowledge networks, suggesting that in order to gain access to this type of resources molecular biology firms need to formalise relations with some organisations, but continue to maintain informal relations with them.

Table 13 – Proportion of dual ties (formal and informal)

	Average	Maximum	Minimum	Coefficient of variation
O&A	19	60	0	0.9
Knowledge	28	100	0	1.3
P&I	3	43	0	3.1

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Regarding the size of networks mobilised to access the three types of resources, Table 14 shows that, on average, O&A networks are larger than knowledge and P&I networks, but that the latter two display great heterogeneity between firms. Table 15 confirms that O&A networks are significantly bigger than P&I networks. This result supports hypothesis 9 only partially, since differences between the size of O&A and knowledge networks are not statistically significant.

Table 14 – Network size

	Average	Maximum	Minimum	Coefficient of variation
O&A	6	14	2	0.4
Knowledge	5	25	1	1.1
P&I	4	16	1	0.9

Table 15 – Network size – testing differences between resources

Test	Result
Friedman – Chi-square	12.265***
Wilcoxon signed-rank	No significant differences
Knowledge vs. O&A	z = -1.594
Wilcoxon signed-rank	No significant differences
P&I vs. Knowledge	z = -0.678
Wilcoxon signed-rank	P&I < O&A
P&I vs. O&A	z = -2.355**

N=23; ** significant at 0.05 level; *** significant at 0.01 level

The degree of actor variety between the networks mobilised for the three different types of resources was also considered. Table 16 shows that the construction of O&A networks seems to entail, on average, the mobilisation of a higher variety of actors. Table 17 confirms that there are statistically significant differences between the O&A networks and both knowledge and P&I networks, the former exhibiting a more diversified set of actors as proposed in hypothesis 8. No statistically differences were found between knowledge and P&I networks regarding the variety of actors.

Table 16 – Variety of actors in the networks

	Average	Maximum	Minimum	Coefficient of variation
O&A	4	6	2	0.3
Knowledge	2	4	1	0.5
P&I	2	5	1	0.6

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Table 17 – Variety of actors – testing differences between resources

Test	Result
Friedman – Chi-square	30.333***
Wilcoxon signed-rank	Knowledge < O&A
Knowledge vs. O&A	z = -4.091***
Wilcoxon signed-rank	P&I < Knowledge
P&I vs. O&A	z = -3.821***
Wilcoxon signed-rank	No significant differences
P&I vs. Knowledge	z = -1.310

N=23; *** significant at 0.01 level

Network composition varies with the nature of the resource, as we can observe in Figure 13. The presence of universities is particularly high in knowledge networks, which is in line with the nature of biotechnology firms' knowledge base (particularly in early stages). Interestingly, universities also emerge as important actors in P&I and O&A networks. In the first case, academic actors have a prominent role in enhancing firms' credibility and mediate their access to other organisations. Regarding O&A, interview data suggest that universities are equally instrumental in opportunity identification and early decision making process, as well as in the access to human resources and facilities. However in O&A networks, the share of universities is lower, other actors - including non-biotech firms, science and technology parks, hospitals and financial institutions[5] - assuming a relatively more important position.

[5] These conclusions are supported by the results of Friedman and Wilcoxon non-parametric tests.

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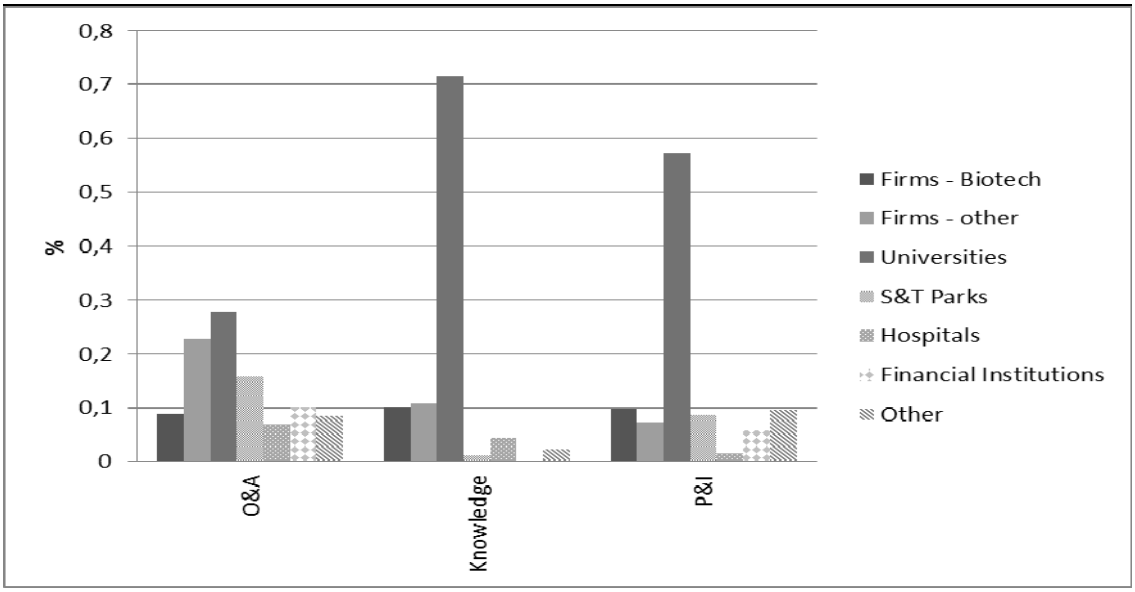
Figure 13 – Network composition by resource (average)



4.3. The role of social capital

In the previous section, it was found that the entrepreneurs only activated about 1/3 of their potential networks to access the resources needed in the process of firm creation and early development. Since the potential networks encompass the organisations that were part of the entrepreneurs' academic and professional trajectory we can assume that they represent the entrepreneur's social capital associated with that trajectory[6].

The literature recognises the importance of social capital to entrepreneurial process and considers it as a resource at the disposal of entrepreneurs. So, social capital is a latent resource that can be mobilised. But the literature also acknowledges that the relationships relevant for firm creation can be intentionally searched for and built. However, to the best of our knowledge, no study focuses on the factors that influence the activation of social capital. This section contributes to fill this gap, finding evidence to answer the question: what drives the activation of social capital (as compared with the building up of new relations)?

To sketch an answer to this question, we propose and test an econometric model where the dependent variable is a measure of the propensity to activate social capital. We measure

[6] This means that we are not considering the social capital associated with friendship and kinship ties.

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activated social capital as the share of the potential network mobilised by each entrepreneurial team.

To explain the propensity to activate social capital we consider six independent variables. The first variable is associated with the characteristics of the potential network, namely its size (Pot_Size). If members of the entrepreneurial teams have a very rich trajectory, characterised by interaction with a large number of organisations this will result on a large potential network, which is more likely to include the resources needed for firm creation, thus increasing the propensity to activate the social capital. However, larger networks may have many similar actors making some of them redundant, being sufficient to mobilize a small portion of its members.

The second variable relates to the background of the entrepreneurial team, namely to the presence of members with non-academic experience. Almost all teams have at least one entrepreneur with academic experience. If the entrepreneurial team also includes individuals with non-academic experience, this will reflect a more varied trajectory, which can influence the activation of social capital. So we included a dummy variable (Team_Variety) that assumes the value of 1 if the team has at least one member with non-academic experience.

The third and fourth variables are related with the mobilisation strategy. First we consider the intensity of mobilisation of each actor, measured by the share of multiplex ties in the total number of ties (Multiplex). If an entrepreneurial team uses each actor in a very intense way, establishing a high proportion of multiplex ties, it is less likely that a large number of organisations is mobilised and thus the propensity to activate social capital will tend be lower. We also consider that the option/need to formalise relations may affect the propensity to mobilise trajectory relations. So, we have included a variable that expresses the share of formal ties in all mobilised ties (Share Formal).

The fifth variable is related with the characteristics of the firm created. It is a dummy variable that indicates weather the firm is dependent from the parent organisation (Dependency_Parent). We consider that this dependency is present when there is a triplex tie with the parent organisation (indicating that it is mobilised to access all resource types) that represents more than ¼ of the mobilised ties. If a firm is highly dependent on its parent we expect a lower propensity to activate its remaining social capital, since it will rely extensively in only one tie.

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The last variable is related with the context of firm creation. It is a dummy variable that indicates if the firm was created after 2003 (After_2003). It is a control variable that provides an indirect measure of the institutional context where the firms are created. As pointed out above, older firms are more likely to have been created in a period when the environment provided fewer resources and these were more difficult to access, given the limited knowledge about the industry and its high perceived uncertainty by the local actors. Thus, older firms are expected to have experienced a greater need to resort to their social capital than more recent ones, which typically experienced a more favourable environment[7].

Table 18 presents the Spearman correlation coefficients between the independent variables. There is no evidence of strong linear relationships between them, with one exception, but the collinearity diagnostics returned values for the variance inflation factor (VIF) that never exceeded 3, far below the often recommended threshold of 10.

Table 18 – VIF and Spearman correlation coefficients (rho) matrix

	VIF	Pot_ Size	Team_ Variety	Multiplex	Share_ Formal	Dependency_ Parent	After_ 2003
Pot_Size	1.136	1.000	0.263	0.058	0.052	0.176	0.050
Team_Variety	1.328		1.000	-0.239	0.139	-0.096	-0.321
Multiplex	2.673			1.000	-0.382*	0.743**	0.259
Share_Formal	1.186				1.000	-0.273	-0.165
Dependency_Parent	2.830					1.000	0.434*
After_2003	1.435						1.000

N=23; * significant at 0.10 level (1-tailed); ** significant at 0.05 level (1-tailed)

The model was estimated using the OLS procedure. Results from the estimation are reported in Table 19. All variables included in the model emerge as statistically significant in the explanation of the proportion of social capital that is mobilised by the entrepreneurs.

It is possible to conclude that the share of the social capital that is activated by the entrepreneur is larger when: i) the potential networks are smaller; ii) the team does not include members with non-academic experience; iii) the firm preferably establishes relations targeted to a single type of resource; iv) the share of formal relations is higher; v) the firm is dependent on the parent organisation; vi) the firm was created before 2003.

[7] The choice of 2003 is based on it being a threshold in terms of firm creation, which took-off after this date (see section2), suggesting the presence of favourable factors in the institutional environment

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Table 19 – Estimation results

Variable	Values
Constant	0.400***
	(2.785)
Pot_Size	-0.008***
	(-3.010)
Team_Variety	-0.151*
	(-1.965)
Multiplex	-0.762*
	(-1.781)
Share_Formal	0.294*
	(2.003)
Dependency_Parent	0.431***
	(3.688)
After_2003	-0.184*
	(-2.043)
N	23
R^2	0.641
F	4.763***

t values in parentheses; * significant at 0.10 level; *** significant at 0.01 level

These results suggest that the propensity to activate the entrepreneurs social capital is influenced by factors related with the trajectory of the entrepreneurs, to the strategy of tie mobilisation, and to the conditions in which firm formation took place.

First of all, teams with larger social capital appear to have a lower propensity to mobilise a large share of it. This can be explained by the redundancy of ties (Granovetter, 1973), since larger potential networks may be composed of many similar actors and thus provide access to the same type of resources. Since bigger networks are more complex to manage, entrepreneurs will select only the ones they consider to be more appropriate for accessing each resource or the whole set of resources. In addition, the results suggest that the inclusion in the team of individuals with non-academic experience reduces the need to activate social capital. This fact may be explained by the presence of relevant competencies in the team, which make it unnecessary to resort to external organisations.

Regarding the strategy of tie mobilisation, when entrepreneurs choose to mobilise a large set of multiplex ties they resort less to their potential network. This calls the attention to one particular network building strategy. Mobilised networks are built around a key organisation that was part of the entrepreneur's previous trajectory. So, entrepreneurs only activate one of the members of

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their potential network and this key organisation provides a wide set of resources. The resources that are not obtained through it will be accessed through new, intentionally built relationships.

The results also show that when firms are dependent on the organisation that was the source of the technology being exploited, they resort more to their social capital. This suggests that for these firms the potential network is central in the process of resource mobilisation.

On the other hand, the results show that social capital is more likely to be activated when the share of formalised relationships is larger. This appears to contradict the usual assumption that social capital is related with trust-based relations. However, as pointed out in the previous section, molecular biology entrepreneurs feel the need to formalise those relations whose origin was their previous academic and professional trajectory. Trust is not enough. So there is a significant share of trajectory organisations, with which entrepreneurs establish both formal and informal relations, this being particularly evident in the case of knowledge networks. This may explain the result obtained, which is consistent with the idea that, in biotechnology, knowledge assets are a key competitive factor and thus their protection from leakage or opportunism is a requirement (Smith-Doerr and Powell, 2005).

Finally, the results suggest that the context in which the entrepreneurship process occurred is relevant for the decision to activate the social capital. Firms created before 2003 relied more on their social capital than those created more recently. As pointed out above, this corresponds to a period when the Portuguese context was less favourable and thus entrepreneurs needed to resort more to ex-colleagues or to senior members of their previous organisations to gather resources or to serve as intermediaries to resource providers (Fontes, 2007).

4.4. The importance attributed by firms to social networks

Our research on the biotechnology firms' networks started from the assumption – grounded on the entrepreneurship literature – that social networks have a key role in the process of creation and early development of the new firm, facilitating entrepreneur's access to critical resources. In this section we have tried to understand whether the biotechnology entrepreneurs own opinion on the importance of the relationships – formal or informal - with individuals from other organisations or with family, friends and other acquaintances, effectively supports these assertions.

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For this purpose the entrepreneurs were asked to rate, in a Likert scale of 1 to 7 the importance attributed to formal relationships with other firms and with universities and other research organisations (denoted as "universities" from now on), to access a set of resources and competences. In addition they were asked to rate, in a similar way, the importance attributed to informal/personal relationships with the individuals from other organisations (independently of the nature of the organisation), to access the same resources. Table 20 presents, by resource, the importance assigned to those relationships by this group of firms[8].

Table 20 – Importance attribute to formal relationships with individuals from universities and firms and to informal relationships by resource.

		Formal with Firms		Formal with University		Informal	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Knowledge	Scientific knowledge	2,50	1,592	5,63	2,094	4,39	2,33
	Technological knowledge	3,50	2,366	4,88	2,527	4,83	2,037
	International knowledge networks	3,19	1,759	4,56	1,825	4,30	2,098
	Access to intellectual property	2,94	2,323	3,81	2,509	3,22	2,373
	Qualified human resources	3,94	1,914	5,75	1,238	4,13	2,029
	Regulatory knowledge	3,75	2,176	2,69	2,089	3,61	1,877
O&A	Information on financing / sources	2,81	2,007	3,19	2,257	3,91	2,021
	Access to financing	3,06	2,016	2,81	2,167	3,70	2,204
	Access to facilities	3,63	2,125	5,56	1,825	4,43	2,107
	Information international markets	4,25	2,017			4,74	1,685
	Information national markets	3,44	2,220	2,31	2,089	3,91	2,065
	Access to distribution channels	4,75	2,017			3,45	2,087
	Other complementary assets	3,69	2,182	3,56	1,965	3,87	1,938
P&I	Credibilisation / signalling	5,12	2,187	4,75	2,266	4,91	1,952
	Information on potential partners	3,81	2,198	3,69	2,056	4,70	1,743
	Valid cases	16		16		23	

[8] It should be noticed that only 16 out of the 23 firms mentioned to have formal relationships with firms and/or universities, while all the firms referred to have informal ones. However, it was considered adequate to compare the two groups: if firms did not mobilise formal relationships at start-up/early stage, this can be interpreted as these relationships being unimportant for resource access at that stage.

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The data shows that networks, both formal and informal are effectively perceived as important to gain access to some types of resources and competences. Of particular relevance is the role played by both formal and informal networks in the credibilising and signalling of the firm, in directing it to potential partnerships, in facilitating access to specialised facilities, in obtaining information on international markets and in gaining access to technological knowledge.

However, these results also suggest that there are differences in terms of the importance and role attributed by firms to formal and to informal networks, as well to (formal) relationships with firms and with universities. These differences are addressed in more detail below.

The individual resources/competences were grouped according to the three main categories, defined in this research: knowledge; opportunity and access (O&A) and power and influence (P&I). A comparison between the importance attributed by each firm to formal and to informal relationships to access the same type of resource was then conducted, again using the non-parametric Wilcoxon signed-rank test. Formal relations with universities and with firms were individualised and compared with the informal relationships taken globally.

Table 21 presents the results for each type of resource, highlighting the cases where differences are statistically significant, that is, where the number of entrepreneurs who rated one type of relationship as more important than the other is significantly higher than the number of those who did not. Tables 22 and 23 go into greater detail and present the case of individual resources for which significant differences were found between the importance attributed to formal and to informal relationships.

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Table 21– Differences in the importance attributed by the entrepreneurs to informal relationships and to formal relationships with other firms and with universities

Type of resource	Wilcoxon signed-rank test
Knowledge: Importance of informal vs. formal relationships with ***firms***	**Informal > formal** ***Z=--2.274****
Knowledge: Importance of informal vs. formal relationships with ***universities***	No significant differences *Z=--0.725*
Opportunity & access: Importance of informal vs. formal relationships with ***firms***	No significant differences *Z=--1.603*
Opportunity & access: Importance of informal vs. formal relationships with ***universities***	**Informal > formal** ***Z=--1.664****
Power & influence: Importance of informal vs. formal relationships with ***firms***	No significant differences *Z=--0.253*
Power & influence: Importance of informal vs. formal relationships with ***universities***	No significant differences *Z=--1.540*
* significant at 0.1 level; ** significant at 0.05 level	N=16

It is possible to conclude that there are significant differences in the importance attributed to formal and informal relationships to access knowledge and to access O&A resources, while there are no such differences in the case of P&I. Interestingly, informal relationships are relatively more important than formal relationships *with firms* to access *knowledge resources*; and they are relatively more important than formal relationships *with universities* to access *O&A resources*[9]. These results point to the presence and perceived importance of "knowledge bartering" with other firms (Kreiner and Schultz, 1993). They also suggest that informal exchanges with people at the parent university, or other universities where the entrepreneurs have contacts, play an important role as intermediaries to sources of non-technological resources and competences.

This is further confirmed, when we look at the individual resources. Informal relationships, as compared with formal relationships with firms, appear to be particularly relevant to access scientific and technological knowledge. On the other hand, informal relationships, as compared with formal relationships with universities, appear to be particularly important to obtain information about markets. Formal relationships are only relatively more important than informal ones in three cases: with firms, to gain access to distribution channels; with universities, to gain access both to facilities and specialised technical resources and to qualified

[9] It is equally interesting to notice that the relative importance of informal and formal relationships appears to be exactly the inverse for the case of university in the access to knowledge resources and for the case of firms in the access to O&A resources, although in these cases the differences are not statistically significant.

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human resources. These results suggest that formal relationships established with other firms are perceived as more important to actually enter the market, while in the case of universities formalisation is a requirement to gain access to specific material or human resources that often can only be found there.

The absence of significant differences in the importance attributed to formal and informal relationships for the case of P&I – which in this case encompasses support in the identification of partners and signalling and credibilisation towards them - is also interesting, suggesting that this role is effectively played at various levels. Nevertheless, in the case of universities, the results (although not statistically significant) appear to point to a relatively greater importance of the informal relationships.

Table 22 – Individual resources: Importance of informal relationships vs. formal relationships with *Firms*

	Resources	Wilcoxon signed-rank test
K.	Scientific knowledge	Informal > formal z=-2.713***
	Technological knowledge	Informal > formal z=-1.968**
O&A	Distribution channels	Formal > informal z=-1.968**

** significant at 0.05 level; *** significant at 0.01 level N=16

Table 23 – Individual resources: Importance of informal relationships vs. formal relationships with *Universities*

	Resources	Wilcoxon signed-rank test
O&A	Information about international markets & clients	Informal > formal Z=-2,920**
	Information about national markets & clients	Informal > formal Z=-2,099**
	Access to facilities	Formal > in formal z=-1,935*
K.	Access to highly skilled human resources:	Formal > informal z=-2,089**

* significant at 0.1 level; ** significant at 0.05 level N=16

Finally, the entrepreneurs were also asked to rank, in a Likert scale of 1 to 7, the importance assumed by the personal network of family, friends and acquaintances in the process of firm

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formation and in the early activities of the firm. The average importance attributed to this network is respectively 5.52 and 5.39 and the results show that over 80% of the firms consider this network important (at least) to the creation and to the early activity of the firm. However, these networks emerge as particularly important for firm creation: 43.5% of the firms rated them as crucial for this purpose, while only 26.1% considered them as crucial to the early activity.

Interestingly, when we look at the relationship between the importance of the personal network for firm creation and the characteristics of the entrepreneurial team, we observe that the network was relatively more important for firms who had entrepreneurs with previous professional experience outside the academic context, as well as to those who had been abroad during their previous trajectory[10]. This suggests that those entrepreneurs will resort more extensively respectively to their industrial and international contacts to support the creation process. The relevance of international ties is consistent with data from the interviews, where internationalised entrepreneurs mentioned to resort extensively to senior ex-colleagues as advisors.

4.5. Decisions and outcomes in the process of network mobilisation: discussion

The empirical research permitted to conclude that social networks are perceived by molecular biology entrepreneurs as having an important role in the process of accessing resources to build the new firm, thus confirming the assertion of the social network literature. On the other hand, the evidence obtained provided some insights on the network building strategies of this group of science-based companies that, in some aspects, do not closely adhere to frequently held ideas on the networking behaviour of entrepreneurial start-ups. This is not unexpected, since entrepreneurial start-ups are far from being an homogeneous group and thus the process of network mobilisation for resource access is likely to be influenced by the nature of the firm – in this case we are addressing science-based firms - and the context where its formation takes place - in this case in an intermediate economy.

One first point concerns the role played by social capital. The networks mobilised by entrepreneurial firms are frequently equated in the literature with the entrepreneurs' social capital. However, our results show that entrepreneurs only mobilise a share of the relationships originating from their previous academic and professional trajectory and that, in addition, they also create new links in order to obtain resources that are not accessible otherwise. The results

[10] Man Whitney test $p<0.1$

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also show that the propensity to activate social capital varies, being related to factors such as the trajectory of the entrepreneurs, the role played by the "parent" organisation, the strategy of tie mobilisation and the context where firm formation took place.

Thus, our results recommend caution towards the assumption that social capital is automatically turned into valuable ties or that it is sufficient for firms' early needs. Indeed, it suggests that networks relevant to the process of firm creation are strategically built and include, already at an early stage, an important component of new relationships, absent from the entrepreneur's social capital. This extensive departure from the entrepreneurs' personal network is often described in the literature as associated with firms' evolution (Hite and Hesterly, 2001).

So, to understand entrepreneurial processes it is necessary to analyse in greater detail the networks that were *effectively mobilised* by the entrepreneurs and the decisions behind that mobilisation.

It was found that the construction of firms' networks reflects decisions regarding the use to be made of trajectory-based relations and regarding the objectives of the new relations. According to our results, trajectory ties are more often mobilised for knowledge access and for power and influence (P&I) purposes. In the first case, they are more often formalised, even if universities (from where trajectory networks more frequently originate) are the largest contingent in informal networks. In the case of P&I we find that informal ties prevail, suggesting that the credibilisation and intermediation functions are performed by a small set of highly trusted actors. Intentionally build relations are more often mobilised to access resources related with opportunity identification and exploitation (O&A) and are typically more formal and also more targeted. Thus, as would be expected, entrepreneurs tend to formalise relations with organizations when lower levels of trust are present (as occurs in the case of new relations) and those formal agreements are usually directed to the access of specific resources. Rather, when firms opt for mobilising the same actor to access a varied set of resources (multiplex ties) they resort more often to their potential networks, fact that is particularly evident in the case of triplex ties. Multiplex ties are also more frequently informal.

The network building strategies are also influenced by the nature of the resources being accessed. In fact, the results reveal that O&A networks are significantly different from both knowledge and P&I networks, the latter two being similar in many respects. The access to O&A resources often involves establishing relationships with types of actors who were not present in

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the potential network, namely financial institutions and S&T infrastructures. Additionally, the access to some material resources such as finance and physical facilities or the development of production or commercial alliances will always require contractual agreements. These two aspects can contribute to explain the more formal nature of O&A networks. Interestingly, knowledge networks, where trajectory ties play an important role, have a higher than expected component of formal ties, even if these often involve organisations with whom informal ties are also established. This reflects a basic concern of small technology-intensive firms operating in a sector where protection of knowledge assets is a requirement and thus trust may not be enough.

Finally, the results also show that when firms adopt a strategy that involves the mobilisation of a greater proportion of intentional ties and rely less on multiplex ties, the networks end-up being larger and composed of a greater variety of actors.

The analysis of entrepreneurs' perception of the relevance of networks confirms or qualifies some of these results. First of all, it shows that, at least in early stages, informal relations are critical: while several firms did not mention formal relationships, all of them mention informal ones. In particular, it stresses the importance attributed to informal relations for knowledge access where, interestingly, informal bartering with firms is regarded as more important than with universities, possibly because it adds different elements to the knowledge base.

Universities play a dual role: they are an informal source of knowledge, but since they probably are the main source of critical knowledge assets, firms tend to formalise a substantial proportion of these relations. Formalisation is also present in the access to human resources and in the access to complementary assets that enable knowledge activities to take place. Interestingly, informal relations with universities are also perceived as particularly important to source information on non-technological aspects, such as national and international markets.

This result calls the attention to the potentially relevant role played by the relationships established both with internationalised Portuguese universities (whose global networks firms integrate) and with foreign universities, in learning about and gaining access to foreign markets. This function is particularly important since many Portuguese biotechnology firms are required to enter these markets at very early stages, as is evident from the strong presence of foreign firms in some firms' networks. Such role can be partly explained by the absence, in the Portuguese context, of large technology advanced firms or international venture capital companies, which, in other contexts, act as international brokers for biotechnology firms.

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Finally, entrepreneurs assign a high importance to formal relationships with other firms to access distribution channels, which is consistent with the need for commercial alliances in this sector.

These results suggest that universities and firms are perceived to have different functions and that the selection of a given type of actor influences the relative importance attributed to formal and informal relations. There is an exception: firms and universities are perceived to have similar importance for intermediation and credibilisation.

5. CONCLUSIONS

This chapter examined the decisions made by Portuguese molecular biology companies regarding the origin, composition and mode of mobilisation of their resource access networks, with a view to contribute to a better understanding of the network building strategies of this type of firms, in the particular context of an intermediate economy. The networking strategies of these entrepreneurs are expected to be influenced by the nature of the science-based sector where the firms operate, thus presenting behavioural features that are typical of biotechnology. But they will also be influenced by the conditions found in their particular environment, which can have an impact on the type of social capital built by entrepreneurs along their trajectories, as well as on their need for and capacity of mobilising pre-existing relationships and/or creating new ones, with implications for the configuration of the firms networks.

The research presented in this chapter provides some insights into the network building strategies of science-based start-ups. It shows that these firms combine the use of entrepreneurs' social capital, typical of entrepreneurial start-ups, with a sometimes extensive effort to build up new relationships, that enable them to expand the scope of their resource search, frequently also using the social capital to facilitate this task. The relative weight of pre-existing and new relationships and the modes through which each of them is mobilised, are influenced by the characteristics of the team as well as by nature of the resources being searched, thus generating potentially different network structures. But the search for some type of resources appear to be more closely associated with the familiar territory and the trust-based relations from the entrepreneurs trajectory, while access to others appears to be more amenable to arms-length relationships, or only be possible through them. Interestingly, while there is a frequent tendency to associate social capital with informal networks, we find that in this group of firms these trust-based ties often end-up formalised, namely when they are associated with key assets such as

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knowledge. Finally, we find an important presence, in some firms, of ties that grant access to different resources through the same organisation (multiplex), these ties being frequently established with actors whom the entrepreneurs know well and trust.

In addition, three aspects emerge that suggest context-based specificities and deserve a closer exploration in the future. One regards differences in networking behaviour between firms created in different time periods, which are likely to be associated with different environmental conditions that influence the human and social capital of the entrepreneurs and the ease in identifying and gaining access to sources of key resources.
Thus, a progress in the infrastructure for entrepreneurship and the densification of the biotechnology system has an impact on firms networking needs and sources.

The other regards the importance of research organisations in the identification and access to non-technological resources. This may be related with the inevitably stronger connections and/or familiarity of entrepreneurs with scientific organisations and contexts, but is also likely to be related with the strength of these organisations in the Portuguese context and with the absence of similarly relevant industrial or financial actors.

The third aspect regards the strong weight of foreign actors in the early stage networks of a significant proportion of these firms. Those include not only foreign firms – which could be explained by the limited presence of this actor in the local context – but also research organisations. This suggests that despite their often close connection with one or more local organisations, the need to obtain specialised advanced knowledge and/or to keep up with knowledge production in fields less developed at country level, may lead firms to adopt a broader knowledge search strategy. The international scope of these knowledge networks is closely linked with the entrepreneurs' extensive international backgrounds – which are a striking feature of the Portuguese firms - and is apparently also used to support the access to other non-technological resources.

These results are politically relevant, since they confirm some of the limitations of this type of context but also uncover some of the ways biotechnology start-ups try to compensate for them through their networking strategies. An understanding of these limitations and strategies may support the definition of policies that respond more closely to firms' needs.

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