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Knowledge networks in science-based start-ups: actors and strategies

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Abstract

The paper investigates the strategic choices made by young science-based firms' regarding the selection of knowledge sources. Drawing on two streams of research – on alliances and on social networks – two different dimensions of this strategy are considered: the activation of the entrepreneurs' social capital and the intentional inclusion of new knowledge sources. The data collected for a subset of the Portuguese biotechnology sector are analysed with a view to answer to three research questions: i) To what extent firms' rely on entrepreneurs' personal networks, activating their social capital to access scientific and technological knowledge at start-up; ii) To what extent are new actors added to knowledge networks at start-up; iii) Are there differences between existing and new ties in terms of strength and formalisation. The results obtained confirm the consideration of the strategies underlying network building is vital for an understanding of the configuration of young science-based firms' knowledge networks. They reveal the existence of different knowledge network building strategies that often combine tie persistence with search for novelty. They also suggest that differences in the network building strategies may be the behind the somewhat contradictory results presented in the literature about the network configuration that is more favourable for innovation.

Keywords: Knowledge network, entrepreneurship, network building strategy, science-based firm

1. Introduction

The creation of a new firm in a science-based field is a complex process which requires entrepreneurs to mobilise a variety of resources that complement those available to the founding team. Scientific and technological knowledge is a critical asset for biotechnology start-ups and these firms frequently combine good internal competences with an extensive reliance on external knowledge sources. Thus, the knowledge networks that entrepreneurs are able to build are particularly important for the new firm. In fact, not only they sustain firms' early innovative activities (Street and Cameron, 2007; Brinckmann and Hoegl, 2011), but they can also have an imprinting effect on firms' subsequent evolution (Milanov and Fernhaber, 2009).

But developing and maintaining networks is a complex and costly process, requiring entrepreneurs to make some strategic choices. While the literature analyses the *existing* knowledge networks and relate their characteristics with innovation performance, the process of *network formation* is much less understood.

At this level, research on social networks stresses the importance of entrepreneurs' social capital and has shown that entrepreneurs rely on their existing ties to access the knowledge required for innovation (Hsu, 2007). In addition, research on alliances has shown that young firms also establish new relationships with key actors (Baum et al, 2000), using several evaluation mechanisms for this purpose, since there is no direct knowledge of partners' capabilities (Li and Rowley, 2002).

However, how entrepreneurs choose which previous relationships to maintain and which new ones to build is still not fully understood. In this paper we address this gap, focusing on the strategic choices made by young science-based firms regarding the selection of knowledge sources. Departing from the frequently held assumption that entrepreneurs' social capital is the main (and sometimes sole) source of firms' network ties (Hsu, 2007) we investigate the process of knowledge network formation during the start-up stage and discuss the choices made by entrepreneurs regarding the activation of their social capital versus the intentional inclusion of new knowledge sources.

Using Portuguese biotechnology firms as empirical setting and drawing on social networks analysis tools we map the entrepreneurs' trajectory previous to the firm creation and reconstruct and analyse the firms' early knowledge networks.

The paper is structured as follows. The next section addresses the extant literature on network building strategies. The third section presents the research methodology, describing the empirical context, the data collection and the process of network (re)construction. Section 4 presents the results and section 5 concludes by summarising the main findings.

2. Building innovation networks: background literature

The relevance of networks for innovation processes is particularly evident in science-based sectors, where most of the firms, and particularly small and medium sized ones, complement their internal capabilities with external knowledge (Ozman, 2009; Laursen and Salter, 2004). In these sectors, new business opportunities are often associated with the transformation of results from academic research into technologies, products and services (Zucker et al, 2002). Firms need to gain access to knowledge that is characterised by high complexity, multidisciplinary and fast change and is increasingly distributed among various organisations (Moodysson et al, 2008; Metcalfe and Coombs, 2000).

Therefore, relationships with research organisations, namely those conducting frontier research, can be crucial for the development of the new firm (Murray, 2004; Bagchi-Sen, 2007), not only for completing the first technologies/products, but also for sustaining their competitiveness through time (McMillan et al, 2000; Witt and Zellner, 2007). Spin-off companies, which are particularly frequent in these sectors, tend to maintain close relationships with their parent research organisations, especially in the early stages (Mustar et al, 2006), since research conducted in these organisations is usually the source of the technological opportunity.

But the transformation of an opportunity originating from science into a marketable technology, product or service requires a greater variety of resources and competences (Autio, 1997; Teece, 1986), which are possessed by other types of actors (Baum et al, 2000). In the particular case of biotechnology, technological (or techno-commercial) alliances with firms from user sectors and/or possessing complementary competences have also been found to be critical, both for firms operating under the "classical" business model of technology

development and licensing, and for product oriented firms, or firms engaging in the hybrid business models currently emerging in health biotechnology (McKelvey, 2008, Sabatier et al, 2010, Lukkonen, 2005).

Given the global nature of knowledge in biotechnology, firms' networks often involve organisations located around the world (Owen-Smith and Powell, 2004). Extra-local networks are particularly critical for firms located outside the main biotechnology clusters (Gilding, 2008, Fontes, 2005).

However, developing and maintaining knowledge networks is a complex and costly process. Thus entrepreneurs have to make some strategic choices regarding the sources of knowledge relevant for innovation. Scholars argue that the selection of partners is designed (Nooteboom, 2008) and affected by search costs and uncertainty, raising adverse selection and moral hazard problems (Kirkels and Duysters, 2010).

In order to understand the strategic choices made by entrepreneurs from young science-based firms in what concerns the selection of knowledge sources, two streams of research are considered in this paper: research on alliances and research on social networks. Both streams tend to focus on the analysis of the structural characteristics of knowledge/innovation networks, in an attempt to identify the network configurations that are more favourable to the process of innovation (Tödtling et al, 2009; Schilling and Phelps, 2007; Anderson and Miller, 2003; Elfring and Hulsink, 2003).

The relevance of this theme led to an intense debate centred on the relation between innovation performance and network structure. For some authors, densely embedded networks with many strong ties - "closed networks" - are more beneficial, as they generate trust and cooperation between the actors (Ahuja, 2000). This network configuration enables the exchange of high quality information (Gulati, 1998; Van Geenhuizen, 2008) and increases the likelihood of detecting business opportunities (Arenius and De Clercq, 2005). However, other authors claim that more "open" networks with many weak ties and structural holes (Burt, 1992) have more advantages. Those networks enable individuals to build relationships with several unconnected actors and explore brokerage opportunities (Burt, 1992), thus facilitating the access to non-redundant knowledge (McEvily and Zaheer, 1999; Low and Abrahamson, 1997). Some scholars defend a mix of strong and weak ties (Uzzi, 1997), the former enabling the exchange of fine-grained information and tacit knowledge and trust-based

governance, the latter providing access to novel (non-redundant) information. This discussion gives us some insights about the type of relations that compose knowledge networks, suggesting that weak ties and open networks tend to favour exploration, while long term relations based on reciprocity and trust tend to favour exploitation (Gilsing and Nooteboom, 2006),

The network building processes are not so extensively addressed by these streams of literature. However, they offer some insights on the process of partner selection that are relevant for our argument. Scholars highlight that, when selecting a partner, firms can rely on their past relationships or look for a new organization (Hite and Hesterly, 2001; Lin, 1999). In the first case, we are in the presence of persistence (Walker et al, 1997). In the second case, new actors join the firm's network, bringing novelty and variety that are vital for innovation (McEvily and Zaheer, 1999).

Tie persistence is discussed by both literatures, being frequently explained by trust and learning effects associated with previous relationships (Hallen, 2008). In the alliances literature the importance of tie persistence is supported by research that uncovered firms' propensity to establish relationships with organizations they know from prior partnerships (Gulati, 1995a), resulting in path-dependent routines on partner selection (Li and Rowley, 2002). This strategy contributes for the reduction of search costs and uncertainty, since it allows firms to discern capable and reliable partners, based on previous alliance experiences (Gulati and Gargiulo, 1999).

The relevance of previous relations is equally stressed by the social network literature, which highlights the importance of entrepreneurs' previous personal relations (Adobor, 2006), often related with their social capital (Anderson et al, 2007). The professional and academic trajectory of the entrepreneurs can be considered a basic element in the formation of the personal networks that, according to this literature, support the creation process (Hsu, 2007). It is frequently assumed that relationships established along this trajectory become automatically part of the early network of the new firm (Shane and Stuart, 2002). In the limit the firm's network at start-up is equated with its entrepreneurs' social capital (Hsu, 2007).

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 (Koka and Prescott, 2002). These experiences may also have led to the development of cognitive proximity, facilitating 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 Hmieleski, 2005). Scholars point to the advantages of diversity in network composition: if actors are very similar they can become redundant (Burt, 1992), having reduced benefits in terms of information and knowledge (Nooteboom, 1999). The excessive reliance on entrepreneurs' social capital also raises the risk of over-embeddedness (Uzzi, 1996), whereby firms get trapped in existing networks, showing less propensity to searching outside them and thus gaining access to novel information and knowledge. This causes negative effects since it has been shown that repeat partnerships in embedded groups will generate decreasing marginal returns over time (Hagedoorn and Frankort 2008). Therefore, establishing relations with a diverse set of actors lessens the risks of redundancy and over-embeddedness (Adobor, 2006, Uzzi, 1997).

New relationships bring novel information and knowledge (Baum et al, 2000). Selection of the new members to integrate the firm's network is driven by evaluation mechanisms, since there is no direct knowledge of partners' capabilities (Li and Rowley, 2002). Some scholars support that this evaluation, which results in the selection of unknown organisations, has to be understood in the context of existing networks. Thus, some studies have shown that firms tend to form partnerships with organizations they know indirectly, i.e., with whom they share a partner (Gulati, 1995b), or with organizations that occupy a central position in the network, thus signalling their quality and reliability (Gulati and Garguilo, 1999). Others argue that these new ties are preferably formed with organizations with which firms share traits that favour trust-building (McPherson et al, 2001); or that facilitate knowledge exchange, namely the same position in geographic space and/or a certain degree of cognitive/institutional proximity (Boschma and Frenken, 2010; Nooteboom et al, 2007; Ponds et al, 2007).

But new relationships can be difficult to establish because, in the absence of a previous record, potential partners will have difficulty assessing the quality of the new firm and its technologies (Choi and Shepherd 2005). In these circumstances, members of the entrepreneurs' personal network can still be instrumental, assisting in the identification of

relevant individuals/organizations and acting as mediators or credibilizers (Moensted 2007; Wink 2008).

Summing up, previous research acknowledges the importance of entrepreneurs' social capital, putting some emphasis on tie persistence in the network building process. However, what is not fully understood is the extent to which firms effectively choose to maintain previous relationships – thus selecting from the entrepreneurs' trajectory – or decide to build new ones – thus purposefully adding new actors to their networks. Furthermore, it is not fully understood either, whether persistent ties differ from new ones, namely in terms of formality and strength.

These gaps in the literature have motivated our main research question: what are the strategies adopted by young firms in a science-based sector, to build the networks that enable access to scientific and technological knowledge relevant for innovation? More specifically we want to understand:

1. To what extent do firms' rely on entrepreneurs' personal networks, activating their social capital to access S&T knowledge at start-up;
2. To what extent are new actors added to knowledge networks at start-up;
3. Are there differences between existing and new ties in terms of strength and formalisation?

3. Design of the empirical study

3.1 Empirical setting

In order to answer to these questions we have conducted empirical research on the networks of a specific sub-set of the Portuguese dedicated biotechnology firms: the molecular biology companies. The choice of this sub-group was based on the fact that molecular biology firms configure the most science-based biotechnology subset, enabling us to focus on the specific network building strategies of science-based firms.

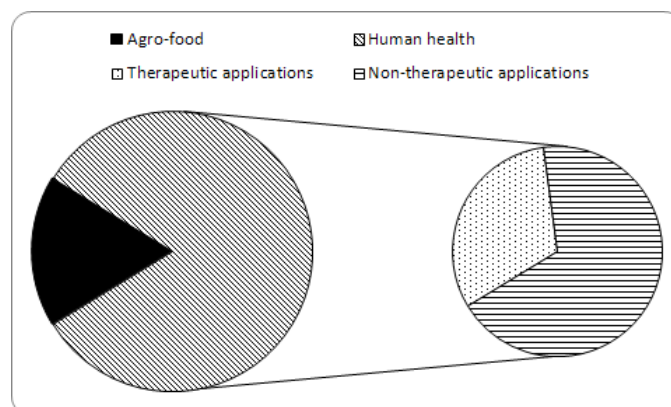
The process of firm creation in biotechnology in Portugal is relatively recent. It started in the mid-80s, but only took-off around 2003. There are currently 79 firms formally in operation¹, of which, 80% were created from 2003 onwards. Thus several firms are still in an embryonic

stage of development and only a small group of pioneers have developed their technologies/products and introduced them into the market. The majority was a direct or indirect spin-off from research and involved the initiative of young scientists.

Their location also reflects their origin, since it follows the main metropolitan areas where the main research organisations are located and where incubation and other support infrastructures and key services are increasingly available. The main areas of application include: health (human and animal) (45%), agriculture and food production (respectively 30% and 16%) and environment (9%).

The group of firms that are the focus of our research – the molecular biology firms – tend to follow the pattern described above. But given the nature of the technologies being exploited, their activities are more concentrated in the health sector, although with a predominance of non-therapeutic applications. Only a small group targets the agro-food sector (Figure 1).

Figure 1 – Areas of activity of Portuguese molecular biology firms



This group also belongs to the younger generation of biotechnology companies: only 3 were over 5 years old at the time of data collection and about half were still in the start-up period (as defined in this research). Their creation involved a total of 61 entrepreneurs, the vast majority originating from national universities/research centres or returning to the country after completion of PhDs or post-doctorates in foreign research organisations. Thus, almost all teams involve at least one entrepreneur coming from universities or research organisations; even though in several cases non-academic individuals joined the team (e.g. graduates with managerial competences, entrepreneurs, and practitioners in the applications field). The teams are mostly composed of young entrepreneurs (average age is 36), although in about half of the

cases there is also a senior researcher in the team, who tends to retain the post in the university.

3.2 Data collection

Data was collected about 61 entrepreneurs and their 23 firms, based on a combination of complementary methods, involving both search for documentary information and in-depth face-to-face interviews with the founders (Sousa et al 2011).

The former included: the Curriculum Vitae (CV) 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 were based on a semi-structured questionnaire and had two parts. The first focused on the entrepreneurs' personal network and on the importance of that network to firm creation process and early growth, allowing the collection of more systematic and fine grained information about the people who were/are important during the two periods, including the origin of the relationships and the type, nature and relevance of their respective contributions. The second addressed the firm activities, strategy and performance, with particular emphasis on innovation and technological development and on formal cooperation arrangements with other firms and with research organisations.

This combination of data collection methods – career trajectory, project analysis, patent analysis and primary data collected through interviews - that are usually applied independently, not only provides a richer set of data, but also offers the possibility of confronting distinct sources and perspectives, thus improving the robustness of the data. It namely permits to identify the relations that were actually mobilized by the firms, to trace the origin of these relationships, to characterize their type/nature and to assess the relevance of their respective contributions.

3.3 Network (re)construction

In section 2 we have discussed the process of network building and argued that firms may choose to select their network members from the entrepreneurs' previous trajectory or to bring-in new members. In order to further conceptualise the type of decisions that take place along this process, we draw on the work of Hite and Hesterly (2001) and Lin (1999) who discuss different mechanisms behind the formation of entrepreneurial networks. Thus Hite

and Hesterly (2001) distinguish between close networks of family and friends or “identity-based networks” (which she associates with early stages) and more open and business focused networks, or “calculative networks” (which are associated with later stages). Lin (1999) distinguishes between “expressive actions related with accessible resources” and “instrumental actions related with contact resources”, the latter encompassing a more purposive search. Following these approaches we identify two main modes of network building: the former is a by-product of the entrepreneur activity/trajectory, its presence not being necessarily related with a particular goal – in which case we have *non-intentional networks*, associated with persistence of existing knowledge ties; the latter is purposefully created to achieve a goal – in which case we have *intentional networks*, associated with search for new knowledge sources that enable to expand the existing network scope.

This framework guided our (re)construction of firms’ networks (for a detailed description see Sousa, 2012). We have started by (re)constructing “potential networks”, which reflect the latent set of ties resulting from entrepreneurs’ academic and professional trajectory i.e., their social capital. This exercise was based on documentary analysis, complemented where necessary by the interviews, which permitted to reconstruct the paths of all members of each firm’s founding team and to map the organisations where they had developed training or professional activities and, thus, where personal relationships might have been established. The combined individual trajectory networks of all team members composed the firms’ “potential network”.

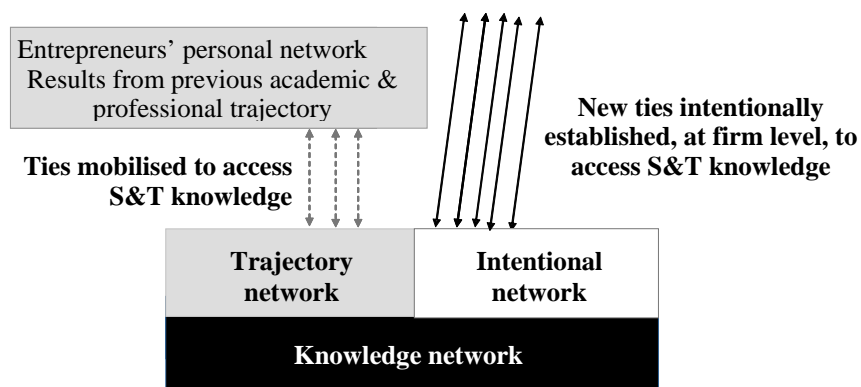
Next we have (re)constructed the actual knowledge networks, which represent the ties that were effectively used to access knowledge during the start-up process (including the pre-start-up period, the year of formal creation and the two subsequent years of activity). For this purpose, we used the information provided by the entrepreneurs about the actors they regarded as important for knowledge access 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 knowledge network. On the one hand, interview data permitted to identify the members of the potential network who 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”.

Since the organisation was chosen as the unit of analysis, when the relationship involved individuals a correspondence was made between the individual and the organisation where he/she was located. Figure 2 depicts the whole network reconstruction process.

Figure 2 – Network reconstruction: trajectory versus intentional networks



In this (re)construction process we have considered that ties can have different characteristics, namely in terms of formalisation and strength. Formal ties entail a formal/codified agreement between actors (that usually involves a system of authority, distribution of competences, rights and duties and a conflict resolution device) while informal ties are more spontaneously created, and are frequently associated with personal ties which are directly mobilised or act as mediators when accessing knowledge. In practice, the distinction between formal and informal ties is not always so clear. The firm sometimes establishes formal and informal ties with the same organization at different moments or for different purposes and, as stressed by several authors, formal ties are frequently based on previous informal relations (Uzzi 1999).

We measure the strength of the ties using two criteria: the frequency of the contacts and the existence of more than one type of relation (formal or informal) between our firms and other actors. According to these criteria a strong tie is one where an informal (personal) relationship is sustained at least through one monthly contact (though these can obviously be more frequent on a weekly or daily basis) or where there is more than one type of relationship (i.e. a formal and an informal relation, more than one formal relation, or more than one informal

relation). Conversely, a tie will be considered weak when it is supported by a sporadic informal relation and when there is only one type of relation (e.g. when the two institutions only participate jointly in one project).

Thus, when analysing the firms' knowledge networks it is possible to distinguish between and compare ties from entrepreneurs' trajectory that were mobilised for knowledge purposes - trajectory network - and new ties intentionally established – intentional network.

4. Empirical results

4.1. The activation of social capital

Our first research question relates with the activation of the entrepreneur's social capital in the access S&T knowledge at start-up. To answer this question we start by analysing the potential networks (Table 1) and the knowledge networks (Table 2) of the interviewed firms. For this purpose the organisations that composed the firms' networks were organised in the following groups: biotechnology firms, firms from other sectors, universities and research centres, hospitals, S&T parks and other organisations (includes professional and trade associations, public support organisations, capital providers etc.).

Table 1 - Potential networks

	Average	Maximum	Minimum	Coefficient of variation
Size	16	62	2	0.9
Variety of organisations	3	5	1	0.5
% of universities	69	100	25	0.4
% of foreign organisations	33	80	0	0.8

Since potential networks reflect the entrepreneurs' previous trajectory, their size and composition are influenced by the dimension of the team and by the differences in the academic and professional path of its members. For this group of firms, the potential networks have, on average 15 organisations of 3 different types, although there is some variation between firms. As would be expected, those networks are largely dominated by universities, reflecting the academic background of a substantial proportion of the entrepreneurs, as young or senior scientists. The presence of foreign organisations reflects the international path of

entrepreneurs, since a significant number of them studied or worked abroad over a period of time, mainly in European countries and in the US.

Table 2 - Knowledge networks at start up

	Average	Maximum	Minimum	Coefficient of variation
Size	25	5	1	1.1
Variety of organisations	2	4	1	0.5
% biotech firms	10	100	0	2.3
% non-biotech firms	11	50	0	1.5
% of universities	71	100	0	0.4
% S&T parks	1	25	0	4.7
% hospitals	4	75	0	3.7
% other organisations	2	33	0	3.2
% of foreign organisations	25	100	0	1.2
% strong ties	68	100	16	0.5
% formalised ties	50	100	0	0.8
% of trajectory ties	57	100	0	0.7

(N=23)

Knowledge networks are larger and less diversified in their composition, when compared with potential networks. On average, they are dominated by national universities that were present in the entrepreneurs' trajectory, and with which firms establish strong ties. The importance of academia in knowledge access is in line with the nature of knowledge that is critical to biotechnology firms' innovation processes:

We can observe that strong ties predominate in these knowledge networks, supporting the notion that strong relations have advantages for innovations processes, especially when they are associated with the exploitation of new opportunities, as is the case of most of these firms. The importance of strong ties, namely those established with organisations that were part of the entrepreneurs' trajectory, is in line with the arguments of the social network literature.

However, we also find that these ties tend to be formalised, contrary to the results of previous research which tends to associated informal networks with trust based relationships and which stresses loyalty and reciprocity as fundamental for their continuity (Dahl and Pedersen, 2004; Kachra and White, 2008). Our results indicate that trust may not be enough. In fact, firms

appear to have a higher than expected tendency to an early formalisation of knowledge relationships, even when these involve trusted partners. This may be explained by the strategic role played by knowledge in biotechnology and thus by the need to protect it from leakage or opportunism (Smith-Doerr and Powell, 2003), as well as by the intermediate role played by dedicated biotechnology firms between research organisations and large established companies (Stuart et al, 2007), which compels them to be particularly careful in protecting their main assets from potential appropriation by powerful organisations.

On average, 57% of ties mobilised to access S&T knowledge at start-up were built during the entrepreneurs' academic and professional trajectory, corresponding to the activation of their social capital. If we look closely to firm-level data it is possible to identify three different strategies in the activation of social capital: 8 firms only mobilise ties that come from entrepreneurs trajectory; 3 firms only mobilise intentionally built relations; the remaining 12 build networks that mix people the entrepreneurs know with a set of new actors that act as new knowledge sources. Hence, almost all firms activate a part of their entrepreneurs' social capital. However, for the majority the knowledge that can be accessed through these relations seems to be insufficient for their requirements, leading them to purposefully establish contacts with organisations that were not part of their trajectory, from the early stages.

Firms that rely exclusively on entrepreneurs' social capital to access knowledge at start-up share a set of characteristics (Table 3): they are academic spin-offs created after 2003 with a strong relation with their parent organisations, which tend to be the origin of the technology being exploited and the only source of S&T knowledge. It is also relevant to mention that these entrepreneurs tend to retain their post at the university. The other extreme strategy, i.e. knowledge networks exclusively composed of intentional ties, have a contrasted profile: spin-offs are less frequent and in the case of the only spin-off that adopted it, the technology was not transferred from the parent organisation and the entrepreneurs had left the university. Firms that follow the mixed strategy have the particularity of exhibiting larger knowledge networks, fact that is partly associated with their participation in large European research projects, thus contrasting with the other two groups of firms.

Table 3 – Firm’s characteristics by social capital activation strategy

	Only trajectory ties	Only intentional ties	Mix of intentional & trajectory ties
Number of firms ⁷	8	3	12
Created after 2003 (%)	100	67	67
Academic spin-offs (100%)	100	33	92
Technology transferred from parent (%)	75	0	33
Parent is the only knowledge source	75	0	0
Entrepreneurs retain academic post (%)	88	0	67
Application area: therapeutic applications (%)	13	33	33
Size of knowledge network (average)	1.4	4	8.5

(N=23)

4.2. The inclusion of new members in knowledge networks

In the previous section we saw that the majority of the firms – those that follow the extreme strategy (3) and those that follow the mixed strategy (12) - purposefully established contacts with organisations that were not part of their trajectory to access knowledge. This leads us to the next research question: to what extent are intentional ties established to access knowledge at start-up?

For these 15 firms, intentional ties account, on average, for 2/3 of their knowledge networks at start-up. To uncover the network building strategies of these firms, we observe the composition of intentional networks, which is presented in Table 4.

Universities still play a critical role in intentional ties, suggesting that those new actors may grant access to kinds of knowledge that were absent in the organisation(s) that were part of the entrepreneurs’ trajectory. This is particularly true for the three firms that rely solely on intentionally built relations. The information collected in the interviews reveals that these firms are acting in an area unrelated to the entrepreneurs’ previous academic and professional trajectory, which makes their contacts of little use.

Table 4 – Intentional knowledge networks - start up

	Average	Maximum	Minimum	Coefficient of variation
Size	5	22	1	1.1
Variety of organisations	2	4	1	0.6
% biotech firms	15	100	0	0.3
% non-biotech firms	16	100	0	0.3
% of universities	49	100	0	0.4
% S&T parks	8	100	0	0.3
% hospitals	8	100	0	0.3
% other organisations	4	100	0	0.1
% of international organisations	55	100	0	0.4
% strong ties	35	100	0	1.2
% formalised ties	70	100	0	0.5

(N=15)

However, the weight of universities in intentional networks is lower than in potential and (total) knowledge networks (Tables 1 and 2). The addition of all types of non-academic actors confirms that the transformation of an opportunity originating from scientific research into a marketable technology, product or service requires a combination of the academic knowledge, accumulated throughout the entrepreneurs' career path, with other competences and resources (Colombo et al, 2006), more difficult to access on the basis of their previous (largely scientific) trajectory. Moreover, intentional networks are dominated, on average, by foreign actors, exposing the strategy of establishing ties with “the best” knowledge source, no matter where it is located.

The comparison of data presented on Tables 2 and 4, permits to answer our third question: Are there differences between existing and new ties regarding strength and formalisation? Intentional ties tend to be weaker and more formalised. This result confirms the importance of previous interactions to build strong and trust-based relations.

5. Conclusion

This paper investigates the strategic choices made by science-based start-ups regarding the selection of knowledge sources. Drawing on the extant literature we consider two different

dimensions of this strategy: the activation of the entrepreneurs' social capital versus the intentional inclusion of new knowledge sources.

Results demonstrate that to access scientific and technological knowledge entrepreneurs select only some members of their existing (personal) network, but, at the same time, they frequently add new members to that network. Three network building strategies emerge during the start-up phase: i) entrepreneurs only rely on the networks derived from their previous trajectory, i.e. activate exclusively their social capital; ii) entrepreneurs do not activate their social capital but purposefully build new ties; iii) entrepreneurs use a mixture of trajectory and new intentional ties to access knowledge. The exclusive reliance on entrepreneurs' social capital emerges as a feature of a set of academic spin-offs that are exploiting knowledge directly transferred from the parent organisation and build their networks around that organisation, which they establish strong relations that tend to be formalised. This is consistent with what the literature often describes as the behaviour of academic spin-offs (McKelvey et al, 2003). But our results also confirms that extent to which firms rely on the parent organisation depends on the conditions in which the firm is created and/or the type of knowledge assets it searches (Mangematin et al, 2002), since other firms equally exploiting knowledge originating from research organisations have substantially different strategies.

The addition of new members seems to follow two different approaches: i) the inclusion of non-academic organisations that grant access to knowledge whose nature makes it more difficult to access on the basis of their previous trajectory; ii) the inclusion of new academic partners that enable to expand the knowledge scope. On the other hand, the new members are frequently foreign organisations that compensate for the absence of critical competences in the national environment, or represent an attempt to link to more advanced contexts, where the new firm may subsequently wish to establish other type of alliances. The importance of international networks is not atypical of the biotechnology field, where firms tend to be highly internationalised (Owen-Smith and Powell, 2004). But the very early reliance on this type of networks is less frequent, being a trait of more peripheral locations (Fontes, 2003), that differentiates them from those located in more knowledge intensive environments (McKelvey et al, 2003). The relations intentionally built tend to be formalised and weak.

Our results depart from some frequently held assumptions. The first assumption is that entrepreneurs' social capital is the main (and sometimes sole) source of entrepreneurial firms'

early network ties (Hsu, 2007). Social capital, as reflected in the persistence of ties originating from the entrepreneurs' previous trajectory, is indeed important for several firms. But we have also identified network building strategies which are partly or even exclusively supported by new intentionally built ties. Thus our results suggest that the knowledge networks of science-based entrepreneurial firms are strategically built from an early stage and that they often involve a purposive search for new relationships that go beyond the entrepreneur's personal network. This latter type of behaviour is often mentioned in the literature as associated with the entrepreneurial firms' evolution (Hite and Hesterly 2001), but not necessarily with the early stages.

The second assumption is that close networks, based on strong ties are governed by trust-based mechanisms and thus will tend to be informal. In fact, this group of firms opts for formalising knowledge access relations from early stages, even when these involve trust-based ties originating from entrepreneurs' social capital. The relevance assumed by knowledge assets to science-based firms, particularly when they involve intellectual property (Smith-Doerr and Powell 2005), may partly explain this mode of behaviour.

The results obtained contribute to a more in-depth understanding of the ways science-based entrepreneurs choose their knowledge sources, thus adding to our understanding of the strategic choices underlying the formation of knowledge networks. They confirm that the consideration of the strategies underlying network building is vital for the understanding of the configuration of the knowledge networks of young science-based firms. Our research revealed the presence of different network building strategies. It also suggests that differences in the network building strategies may be the behind the somewhat contradictory results presented in the literature about the network configuration that is more favourable for innovation. Subsequent research will exploit better these results, namely in order achieve a more in-depth understanding of the process of selection of new partners.

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