



Building innovation networks in science-based young firms: the selection of knowledge sources

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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 (versus the intentional inclusion of new knowledge sources) and the persistence of ties from start-up to the early growth phase. The data collected for a subset of the Portuguese biotechnology sector are analysed with a view to answer to four 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?; iv) Is there tie persistence in knowledge networks between the start-up and the early growth phases?

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 network building strategies and appear to indicate a tendency for continuity of attitudes over the companies' life. 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. In this process, 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).

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). Scholars also stress the relevance of persistence in network formation (Kim et al, 2006).

However, how entrepreneurs choose which previous relationships to maintain and which new ones to build is 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. Drawing on the extant literature, we consider two different dimensions of this strategic choice: the activation of the entrepreneurs' social capital (versus the intentional inclusion of new knowledge sources) and the persistence of ties, from start-up to the early growth phase.

Using Portuguese biotechnology firms as empirical setting and drawing on social networks analysis tools we reconstruct the entrepreneurs' trajectory previous to the firm foundation and the firms' knowledge networks, both at start-up and at the early growth phase.

The paper is structured as follows. The next section addresses the extant literature on network building strategies. The third section presents the research methodology, stressing in particular the empirical context, the (re)construction of networks and the collection of data. 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 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 firms (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 firms will also need to establish relationships with non-academic organisations, since the transformation of a technological opportunity into a marketable technology, product or service and its commercialisation, requires the combination of a variety of technological and non-technological resources and competences (Autio, 1997; Teece, 1986). Therefore it is expected that their knowledge networks integrate several types of actors (Baum et al, 2000).

However, developing and maintaining 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/innovation 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.

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, and thus of path dependent processes (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. Two different explanations are advanced for it: i) trust and learning effects associated with previous relationships (Hallen, 2008); and ii) behavioural persistence at organizational level, related with the prevalence of routines and inertia (Kim et al, 2006) or with imprinting effects (Milanov and Fernhaber, 2009).

The importance of tie persistence is supported by research on alliances 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 social network scholars, who highlight 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, can 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, the risks of over-embeddedness are also acknowledged (Uzzi, 1996).

In fact, 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). Therefore, establishing relations with a diverse set of actors lessens the risks of redundancy and over-embeddedness (Adobor, 2006, Uzzi, 1997) and facilitates the access to different types of knowledge (Baum et al., 2000).

New relationships, on the other hand, bring novel information and knowledge (Baum et al, 2000). The selection of the new members to include in firms' 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 Gargiulo, 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).

Summing up, previous research acknowledges the importance of entrepreneurs' social capital and tie persistence in the network building process. However, what is not fully understood is the extent to which firms choose to maintain previous relationships or to build new ones, both at start-up – selecting from the entrepreneurs' trajectory or establishing new relations – and at later stages – selecting from the existing network or establishing new relations. 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 S&T 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?
4. Is there tie persistence in knowledge networks between the start-up and the early growth phases?

3. Design of the empirical study

3.1 Empirical setting

In order to answer 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 – tends to follow the described pattern. But, given the nature of the technologies being exploited, their activities tend to be more concentrate in the health sector, with a greater predominance of clinical applications (as opposed to pharmaceuticals). All firms were created by 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, although in some cases there is also a senior researcher in the team, who tends to retain the post in the university.

3.2 Data collection and network (re)construction

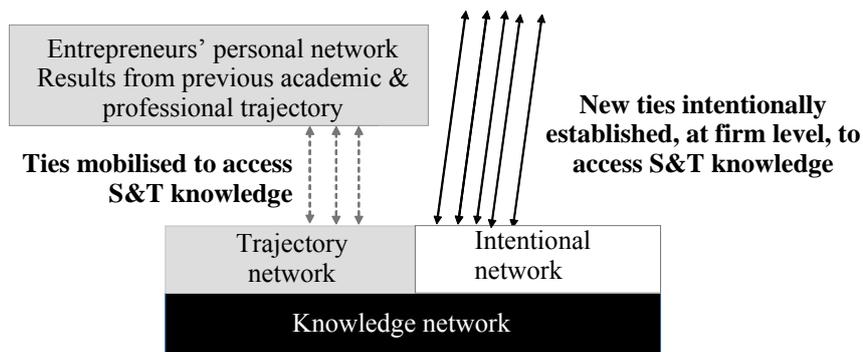
A central aspect of the methodology was the (re)construction of firms' networks (for a detailed description see Sousa, 2012). We have considered the distinction between non-intentional and intentional networks: the former is a by-product of the entrepreneur activity/trajectory, its presence not being necessarily related with a particular goal – it is a “potential network” that may be activated or remain latent; the last is purposefully created to achieve a goal. This distinction draws on Lin's (1999) and Hite and Hesterly's (2001) work: the first distinguishes between “instrumental actions related with contact resources” and “expressive actions related with accessible resources”; the latter between “calculative networks” and “identity-based networks”.

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. Next we have (re)constructed the knowledge networks, which represent the ties that were effectively used to access knowledge.

Knowledge networks were reconstructed for two different time periods: during the formation process (pre-start-up period, the year of formal creation and the two subsequent years of activity) and at the time of the interview, thus obtaining the *start-up networks and the early growth period networks*. For some of the interviewed there is an overlap between formation period and present moment. This situation occurs for 10 firms who were created in 2006 or after, which will only be included in the analysis of the start-up period.

Knowledge networks can have their origin in the potential networks or can have been intentionally built. In the first case we call them trajectory networks and in the latter we call them intentional networks. Figure 1 depicts the whole network reconstruction process.

Figure 1 – 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).

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

4. 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.

Table 1 - Potential networks

	Average	Maximum	Minimum	Coeff. 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

Table 2 - Knowledge networks - start up

	Average	Maximum	Minimum	Coeff. 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)

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 types¹, although there is some variation between the 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.

Knowledge networks are larger and less diversified in their composition, when compared with potential one. 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 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 networks literature. However, we also find that these ties tend to be formalised, contrary to the results of previous research where the establishment of informal networks is often linked with the trajectory of the individuals or with their previous interaction in formal partnerships, and loyalty and reciprocity is stressed as fundamental for their continuity (Dahl and Pedersen, 2004; Kachra and White, 2008).

This result indicates that trust may not be enough: firms appear to have a higher than expected tendency to an early formalisation of knowledge oriented relationships, even when these involve trusted partners. It can 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).

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 the 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

¹ Organizations were classified in six different types: biotechnology firms, firms from other sectors, universities and research centres, hospitals, science and technology parks and other organisations (including financial institutions, professional and trade associations and governmental agencies).

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 of them the knowledge they can access through these relations seems to be insufficient for the new firms 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 and trajectory ties
Number of firms	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 mix 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.

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)

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 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.

However, the expression 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 a technological opportunity into a marketable technology, product or service and its commercialisation, requires a combination of the academic knowledge, accumulated throughout the entrepreneurs' career path, with other (particularly non-technological) competences and resources (Colombo et al, 2006), more difficult to access on the basis of entrepreneur's previous (largely scientific) trajectory. Moreover, intentional networks are dominated, on average terms, 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.

4.3. Tie persistence in knowledge networks

Our last question regards the persistence of knowledge sources. In the context of this research, the persistence of ties denotes that once the firm as choose an organisation as a knowledge source at start-up, it will continue to use it at the early growth phase. Therefore, in the analysis of tie persistence we will only consider the 13 firms that are already at the early growth phase, i.e., those that were created before 2006.

More than half (55%) of the ties established at start-up to access S&T knowledge persist in the early growth phase. This reveals that, for these firms, a higher share of relations

tend to be long-lasting. This is particularly the case of relations with the parent organisations (Mustar et al, 2006).

Once again it is possible to identify three different strategies: three firms have renewed their knowledge sources completely; four firms maintain all knowledge sources used at start-up; the remaining six exhibit a mix of persistence and decay.

If we consider the two dimensions of knowledge network building strategy simultaneously, i.e. the activation of social capital and the persistence of ties, three different paths emerge (Table 5)¹:

- Firms that only use trajectory ties at start-up tend to maintain these ties in the early growth phase. These ties tend to be strong and centred on the parent organisation. These firms adopt an inertia attitude on their network building, being highly dependent on the relations built during the entrepreneurs' trajectory. This group of firms confirms the relevance of social capital and of close networks for the access to knowledge sources.
- Firms that only resort to intentional ties at start-up, tend to abandon them in the early growth phase. This result seems to indicate that these firms adopt an agency attitude on their network building, following a strategy driven by "instrumental actions" and evaluation mechanisms. These firms are acting in areas where the entrepreneurs' social capital is of little use and opt for short-term relations that enable the access to specific "pieces" of relevant knowledge.
- Firms that resort to a mix of trajectory and intentional ties at start-up also tend to follow a mix strategy in terms of tie persistence. This group of firms seems to balance agency and inertia in the selection of their knowledge sources. This enables them to avoid the constraining effect of excessive path dependence on the (largely academic) entrepreneurs' personal networks, and also permits to accommodate the changing needs of the evolving firm. They also combine strong and weak ties.

Table 5 – Network building strategies

		Tie persistence between start-up and early growth			
		All ties persist	All ties decay	Mix of persistent and decayed ties	Total
Social capital activation	Only trajectory ties	3	1	1	5
	Only intentional ties	0	2	0	2
	Mix of trajectory and intentional ties	1	0	5	6
	Total	4	3	6	13

5. Conclusion

This paper investigates the strategic choices made by young science-based firms' regarding the selection of knowledge sources. Drawing on the extant literature we consider two different dimensions of this strategy: the activation of the entrepreneurs'

¹ Likelihood-ratio $\chi^2(4) = 12.5961, p < 0.05$

social capital (versus the intentional inclusion of new knowledge source) and the persistence of ties, from start-up to the early growth phase.

Results demonstrate that to access S&T 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 existing networks (activate 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 S&T knowledge. The exclusive reliance on entrepreneurs' social capital is related with academic spin-offs that build their networks around the parent organisation, with which they establish strong relations, which tend to be formalised.

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 relations intentionally built tend to be formalised and weak.

Regarding tie persistence, we observe that, overall, decay of existing ties, between start-up and early growth phases, is less frequent than their persistence, confirming the existence of some network inertia, which is particularly strong when firms choose to rely exclusively on their entrepreneurs' social capital.

Our results depart from some frequently held assumptions: i) that entrepreneurs' social capital is the main (and sometimes sole) source of entrepreneurial firms' network ties, since we have found other network building strategies, which are supported, exclusive or not, by intentionally built ties; ii) that close networks based on strong ties are governed by trust-based mechanisms, since this group of science-based firms opts for formalising knowledge access relations from early stages.

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 and appears to indicate a tendency for continuity of attitudes over the company's life. It also suggests that differences in the network building strategies may be 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 to achieve a more in-depth understanding of the process of selection of new partners.

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