Available online at www.sciencedirect.com

ScienceDirect

Research Policy 35 (2006) 1166–1199

research policy

www.elsevier.com/locate/respol

In search of complementary assets: The determinants of alliance formation of high-tech start-ups

Massimo G. Colombo *, Luca Grilli, Evila Piva

Politecnico di Milano, Department of Management, Economics and Industrial Engineering, P.za Leonardo da Vinci, 32, 20133 Milan, Italy

Available online 17 October 2006

Abstract

Why do new technology-based firms (NTBFs) cooperate? Starting from Teece's [Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy. Research Policy 15, 285–305] conceptual framework and taking advantage of subsequent literature on alliance formation in the resource and competence-based tradition and in the social structure perspective, we derive an empirical model that aims at highlighting the inducements and obstacles that these firms face in alliance formation according to firm-specific characteristics and the nature of the alliance. In particular, a distinction is made between exploitative commercial alliances and explorative technological alliances. The econometric estimates, based on a large sample of Italian young high-tech firms that are observed from 1994 to 2003, provide strong evidence supporting two key intuitions of Teece's work. First, the "combination of specialized complementary assets" appears to be a key driver of the formation of exploitative commercial alliances by NTBFs. More specifically, patent holding affects positively the likelihood to establish commercial alliances, but this propensity is found to rapidly decrease with firm size, suggesting that as long as NTBFs become larger and possess specialized commercial assets their urge for commercial alliances diminishes. Second, following the parallelism set forth by Teece between search for alliance partners and access to external financing, the analysis indicates that potentially beneficial alliances may not take place because of the high transaction costs faced by smaller NTBFs. In this respect, our results clearly support the view that sponsor institutions as public research organizations, venture and corporate venture capitalists may sensibly reduce these costs and that their role crucially depends on both the identity of the sponsor and the type of alliance.

Keywords: Innovation; Alliances; New technology-based firms; Complementary assets; Teece

1. Introduction

How can firms profit from innovation? "The successful commercialization of innovations requires that the know-how in question be utilized in conjunction with other capabilities or assets. Services such as marketing, competing manufacturing, and after sales support are almost always needed. These services are often obtained from complementary assets which are specialized... In some cases, as when the innovation is systemic, the complementary assets may be other parts of a system" (Teece, 1986, p. 288).

Since the seminal work by Teece (1986), alliances have been regarded by scholars inspired by the resource- and competence-based views as an effective mechanism allowing to combine the technological capabilities of innovative firms with the *specialized complementary assets* possessed by other firms so as to obtain synergistic gains (see among others Kogut, 1988; Das and Teng, 2000; Grant and Baden Fuller, 2004).

* Corresponding author.
E-mail address: massimo.colombo@polimi.it (M.G. Colombo).

0048-7333/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.respol.2006.09.002

Following previous literature, in this work we use the term "alliance" quite comprehensively to refer to any formal collaborative relation between independent firms that constraints *ex ante* their future conducts and may pertain to any sphere of firm's activity (see among others Contractor and Lorange, 1988; Williamson, 1991; Hagedoorn, 1993; Hagedoorn and Schakenraad, 1994; Gulati, 1995; Oxley, 1997; Colombo, 2003). Accordingly, alliances include *technological agreements* (e.g. joint development agreements, research joint ventures, technology transfer and technology sharing agreements) and *commercial agreements* (e.g. licenses, joint distribution agreements, customer–supplier relations, and many others). Moreover, independently of the content of the collaboration (either technological or commercial), alliance partners may resort to an equity governance structure (i.e. equity joint ventures and acquisitions of a minority stake) or to a contractual one, either of bilateral (as in cross-licensing) or unilateral (as in a simple license) type.[1] Conversely, mergers and acquisitions are excluded from this definition.

The "combination of complementary assets" motive for alliance formation is particularly pertinent for new technology-based firms (NTBFs), especially if they have been founded to exploit commercially a major technological innovation (Eisenhardt and Schoonhoven, 1996; Cooper, 2002; Gans and Stern, 2003). In fact, these firms possess distinctive technological competencies relating to a new product, process or service idea, that need to be used in conjunction with other specialized assets in order to generate economic returns.

Nonetheless, Teece (1986) also emphasized the difficulties inherent in the use of alliances to combine the specialized complementary assets possessed by different firms. "Strategic contractual partnering… is exposed to certain hazards, particularly for the innovator… First it may be difficult to induce suppliers to make costly irreversible commitments which depend for their success on the success of the innovation… The innovator has incentives to overstate the value of the innovation, while the supplier has incentives to 'run with the technology' should the innovation be a success" (Teece, 1986, p. 294). Again, this reasoning perfectly applies to NTBFs. So, NTBFs have great inducements to but also face serious obstacles in establishing alliances with third parties.

In this paper, we will start from Teece's (1986) conceptual framework and taking advantage of subsequent work on alliance formation in the resource- and competence-based tradition and in the social structure perspective, we claim that the extent of these inducements and obstacles depends on the firm-specific characteristics of NTBFs. More importantly, we contend that the influence that these firm-specific characteristics exert on the likelihood of alliance formation by NTBFs differs according to the *type of alliance* under consideration. This will lead to the formulation of a series of hypotheses relating to the firm-specific factors that drive NTBFs to establish *exploitative commercial alliances* and *explorative technological alliances*.[2] In the empirical section of the paper we will provide evidence in support of these theoretical hypotheses through an econometric analysis of the cooperative behavior of a large sample of Italian NTBFs that are observed from 1994 to 2003.

Several previous empirical studies have analyzed the firm-specific determinants of alliance formation. They have highlighted that firm size, the intensity of R&D expenses and the prior outcome of the innovative activity of firms are positively associated with the likelihood of a firm being engaged in alliances (see among others Link and Bauer, 1987; Kleinknecht and Reijnen, 1992; Colombo, 1995; Röller et al., 1997; Sakakibara, 1997, 2002; Hagedoorn et al., 2000; Fritsch and Lukas, 2001; Tether, 2002; Belderbos et al., 2004). Moreover, the social capital of firms connected with their network of prior collaborative relations with other firms

[1] For a detailed discussion of the different alliance governance modes see Oxley (1997, pp. 389–392). According to the terms used by Teece (1986), the definition of alliance adopted in this paper includes: (i) contractual modes (e.g. licenses, supply or distribution agreements, R&D contracts), including "strategic partnering" (Teece, 1986, p. 293) and (ii) mixed modes "involving judicious blends of integrating and contracting" (Teece, 1986, p. 298). An example of the former category is provided by the alliance that IBM established with Microsoft to use MS DOS as the operating system of the IBM PC. An example of the latter category is offered by IBM's acquisition in 1982 of a minority stake in Intel to support the development of the IBM PC around Intel's microprocessor technology. Note also that properly speaking, while the *combination* of the specialized complementary assets and capabilities possessed by different firms is a crucial driver of alliance formation, only some types of alliances imply *access* by the innovator to the specialized complementary assets possessed by partner firms. Other alliance types (basically, all unilateral contractual alliances) can be considered as a substitute to accessing these assets. For instance, a license implies that the innovator (the licensor) sells to the other party (the licensee) the right to use under some specified conditions the technology it developed in combination with the assets this latter possesses. In this way the licensor directly profits from the innovation without getting access to specialized complementary assets. Nonetheless, it is noteworthy to stress that the specialized complementary assets of the partner firm play a key role also in this situation, as they determine the amount the licensee is ready to pay to obtain access to the innovator's technology.

[2] The differences between these two types of alliances will be discussed in detail in Section 2.1.

has also been found to favor the formation of subsequent alliances, at least up to a threshold after which the effect becomes negative (Gulati, 1995; Ahuja, 2000; Chung et al., 2000).

Empirical studies that have analyzed the determinants of the alliances of NTBFs are less numerous. Even though results sometime diverge, they suggest that the alliance formation decisions of NTBFs differ from those of other firms. Shan (1990) considers a sample composed of 278 biotechnology company-products; he shows that smaller firms that are in an adverse competitive position are more prone to establish collaborative relations than their larger, more powerful counterparts. Shan et al. (1994) examine mutual causality relations between innovation output and inter-firm commercial collaborations of biotech start-ups through the estimates of a cross-sectional simultaneous equation model; they fail to find any effect of firm size and innovation output on the number of commercial ties. Conversely, they find that access to public funding and network position are positively associated with alliance formation. Eisenhardt and Schoonhoven (1996) analyze alliances established by 98 US new semiconductor firms through event history techniques. Firms with more technically innovative strategies, in emergent-stage markets and in markets with many competitors exhibit greater likelihood of alliance formation. In addition, the likelihood increases with the size and social capital of firms' founding teams. Walker et al. (1997) find further evidence from the biotech industry that the social capital of start-ups makes it easier for them to establish subsequent alliances. Gans et al. (2002) consider a sample composed of 63 high-tech firms financed by the Small Business Innovation Research (SBIR) program and 55 venture capital (VC)-backed companies. They show that firms that hold at least one patent and have obtained VC financing are relatively more likely to license technology to (and be acquired by) other firms. Hsu (2006) considers the post-funding cooperative behavior of a similar but larger sample of US start-ups in five high-tech industries; his econometric results again document that VC-backing boosts cooperation.

To sum up, previous studies generally suggest that innovative high-tech start-ups of smaller size are more likely to establish alliances with third parties. They also indicate that the social capital of NTBFs and their endorsement by reputable organizations such as VC investors facilitate alliance formation. The present paper replicates and extends these results, offering an original contribution to the extant empirical literature. First, while most previous studies analyzed a specific sector (especially biotechnology), we consider here a large and heterogeneous sample composed of more than 500 NTBFs, that spans over all high-tech sectors, both in manufacturing and services. Moreover, as far as we know, this is the first large scale econometric study that exclusively focuses attention on the determinants of alliance formation by NTBFs located outside the USA. Second, we use in the econometric estimates a rather long longitudinal dataset relating to a 10 years period (1994–2003). The rich information available on sample firms, their founders and the industries in which they operate allow to specify a rather comprehensive model and reduce omitted variable problems. Third, we contextually consider and compare the effects on NTBFs' likelihood of alliance formation of VC- and corporate venture capital (CVC)-backing and non equity-based endorsement by academic institutions. Lastly, we distinguish empirically the effects of the firm-specific variables of interest on the likelihood of NTBFs being involved in alliances according to the type of alliance. In particular, we highlight that the determinants of exploitative commercial alliances and explorative technological alliances do systematically differ.

In the paper we illustrate the estimates of several econometric models. First, we resort to survival data analysis models to evaluate factors that influence the time that elapses since firm's foundation up to the year in which the firm establishes its first alliance(s). As in alliance activity success breeds success, with the likelihood of alliance formation initially increasing with the number of prior alliances, the formation of the first alliance is a crucial milestone for a NTBF. Then we consider the type of the first agreement established by sample NTBFs distinguishing technological and commercial ones and we estimate competing risks models so as to highlight the determinants of the establishment of different types of agreements. Lastly, we focus on research joint ventures, a category of agreements that has received considerable attention in the extant empirical literature (Röller et al., 1997; Sakakibara, 1997, 2002; Hernan et al., 2003), and can be regarded as a good approximation of explorative technological alliances. The available data refer to all research joint ventures funded by the European Union (EURJVs) in which sample firms were involved; so we estimate panel data probit models.

The results of the econometric estimates are consistent with the view that the need for specialized commercial assets represents a fundamental driver of the *exploitative commercial alliances* established by NTBFs. In particular, the relation between firm size and the hazard rate of formation of the first commercial alliance is found to be inverted U-shaped. Moreover, the positive effect of the number of patents on the hazard rate is decreasing with the size of NTBFs. We interpret these results as suggesting that larger NTBFs allegedly are more often endowed than their smaller counterparts with the specialized commercial assets necessary for successful introduction of an innovation into the market; therefore, they have less inducement to establish this type of alliance, as they are able to pursue a go-it-alone commercialization strategy. The same pattern does not seem to emerge for *explorative technological alliances*. We deduce that the "combination of specialized complementary assets" argument has less explanatory power of the formation of this latter type of alliance. Second, for very small NTBFs the hazard rate of the first commercial alliance is found to increase with firm size; in addition, we highlight a positive relation between firm size and the likelihood of establishing an EURJV. These findings may be considered as an indication that the largely fixed nature of the transaction and management costs of alliances represents a serious obstacle for small NTBFs. Support from "sponsor institutions" may mitigate these costs, but sponsors' role crucially depends on their identity and differs according to the nature of the alliance. In particular, VC-backed firms are found to be more prone to establish exploitative commercial alliances, while CVC-backing and non-equity endorsement by academic institutions exert a positive impact on the hazard rate of the first technological alliance. Lastly, our estimates highlight the peculiarity of EURJVs. The establishment and management of this type of alliance involve sizable transaction and administrative costs, which can be reduced through learning by doing. Accordingly, these alliances are rarely established by small NTBFs. In addition, the likelihood of a firm forming an EURJV increases with the number of prior EURJVs, at last up to a threshold.

The results that have been illustrated above are in line with Teece's (1986) intuition that the commercial value of an innovation crucially depends on whether the distinctive technological capabilities of the innovator are used in conjunction with the specialized complementary assets, especially of commercial nature, that are necessary for its commercial exploitation. Those assets are often controlled by large incumbent firms; so exploitative commercial alliances are instrumental to achieve this combination. As is suggested by the EMI's CAT scanner and Searle's Nutrasweet cases illustrated by Teece (1986), the efficient use of this type of alliance often discriminates between success and failure of innovative NTBFs. Our findings also help get a better understanding of the limits in the use of alliances as a specialized assets combination device. On the one hand the "combination of specialized complementary assets" argument seems to have limited explanatory power of the formation by NTBFs of explorative technological alliances. On the other hand, Teece (1986) emphasized the appropriability hazards and the other transaction costs that are involved in the formation of alliances, be they exploitative or explorative. Large incumbent firms are better positioned to deal with these problems, which instead are a serious deterrent for small innovative firms and especially for NTBFs. So for these latter firms support from a high profile sponsor often is a necessary condition to be able to implement an effective alliance strategy.

The paper proceeds as follows. In Section 2, we review the extant literature and illustrate the conceptual framework. This leads to the development of the theoretical hypotheses in Section 3. Then we describe the sample and provide descriptive statistics on alliance formation by sample firms. In Section 5, we specify the econometric models and describe the dependent and independent variables that are used in the econometric analysis. Section 6 is devoted to the illustration of the results of the econometric estimates, while some summarizing remarks in Section 7 conclude the paper.

2. Conceptual background

2.1. Exploitation versus exploration in alliance activity

Previous work has emphasized the distinction between *exploitative* and *explorative* alliances. The intent of exploitative alliances is to use more intensely partners' existing assets and capabilities through a division of tasks, with each partner specializing in the task in which it has a relative advantage; conversely, explorative alliances are motivated by the wish of partner firms to discover new opportunities and build new capabilities (Koza and Lewin, 1998).[3]

Commercial alliances of NTBFs are clearly driven by *exploitative* motives. The aim of NTBFs that enter into this type of alliance is to profit from the specialized assets possessed by would-be partners, that are difficult to build autonomously or acquire because of shortage of time and/or financial resources, and are necessary for successful commercialization of the innovative knowledge (allegedly) possessed by the focal NTBF.

[3] For a discussion of the properties of "explorative" and "exploitative" activities of firms see March (1991) and Levinthal and March (1993). For a multi-dimensional view of the notion of "exploitative" and "explorative" alliances that also considers the identity and the attributes of partners, see Lavie and Rosenkopf (2006).

These assets include a well-known brand, a trained sale force, specialized distribution channels, knowledge of international markets, low-cost manufacturing capacity, a network of reliable suppliers, and other assets that are often controlled by large incumbent firms. The majority of the alliances concluded by biotech start-ups with large pharmaceutical companies belong to this category (see among others Pisano, 1989, 1991; Arora and Gambardella, 1990; Shan, 1990; Shan et al., 1994; Powell et al., 1996; Walker et al., 1997; Rothaermel, 2001; Rothaermel and Deeds, 2004).

On the contrary, the motives of *technological* alliances are less clear cut. On the one hand, they may also be exploitative in that they allow a NTBF to access the complementary technological knowledge that is possessed by partners and is difficult for the focal NTBF to reproduce. In these alliances both the NTBF and its partners maintain their distinctive bases of specialized knowledge (Hamel, 1991; Grant and Baden Fuller, 2004). Research contracts and in-licensing agreements that provide a NTBF with the right to utilize a proprietary technology developed by a partner firm are examples of this type of agreements that lead to more extensive individual exploitation of firms' technological capabilities (Mowery et al., 1996; Nakamura et al., 1996). On the other hand, authors in the competence-based perspective have argued that technological alliances often are instrumental to extending a firm's collection of distinctive capabilities through inter-organizational learning (see among others Kogut, 1988; Hamel, 1991; Parkhe, 1991; Powell et al., 1996; Khanna et al., 1998, 2000; Nagarajan and Mitchell, 1998. For a detailed discussion of this literature see Colombo, 2003; Grant and Baden Fuller, 2004). According to this view, this type of technological alliance has an *explorative* nature in that it allows the focal NTBF to develop new technological capabilities through the pooling of its own knowledge with that of the partner or more simply through the internalization of partner's knowledge. Research joint ventures in untested technological fields belong to this latter category.

In this paper we contend that the "combination of specialized complementary assets" model is suitable to explain the establishment of *exploitative commercial alliances* by NTBFs. Conversely, its explanatory power of the formation of *explorative technological alliances* is fairly limited. Moreover, the transaction and administrative costs that firms encounter in establishing and managing these two types of alliances substantially differ. As a corollary, we expect the firm-specific characteristics of NTBFs that influence the likelihood to form an alliance to differ widely according to the type of collaboration under scrutiny.

2.2. Benefits and costs of alliances for NTBFs

In this paper we adhere to the view that alliance formation is driven by joint value maximization (Zajac and Olsen, 1993). Accordingly, we will assume that an alliance is established when the net present value of the pay off that partners[4] expect to reap from the collaboration (i.e. the difference between the benefits and the production and transaction costs of the collaboration) exceeds that of proceeding alone or acquiring the partner. We claim that the benefits and costs of an alliance vary with both the characteristics of NTBFs and the type of alliance that firms intend to form. In the remaining of this section, we consider the determinants of the benefits and costs of exploitative commercial alliances and explorative technological alliances for NTBFs and their partners.

Let us first consider the benefits of alliances. As was mentioned in the introduction, the innovative technological knowledge possessed by NTBFs generates a synergistic gain when it is used in conjunction with specialized commercial assets. Exploitative commercial alliances are an effective vehicle to obtain this combination when (i) the required commercial assets cannot be effectively accessed by NTBFs through arm's length arrangements due to high transaction costs and (ii) the internalization of these assets is ineffective as transaction costs are not so high as to mandate hierarchical integration (Williamson, 1991). Even in situations when internalization is the first-best solution, time and financial constraints[5] often prevent NTBFs from building internally or acquiring the specialized commercial assets that they would otherwise like to control and that are generally controlled by large incumbent firms (Teece, 1986, p. 295. See also Gans and Stern, 2003). Accordingly, NTBFs will have great incentives to establish commercial alliances with other firms unless they already possess the specialized assets necessary for commercial exploitation of their technological knowledge (Gomes-Casseres, 1997; Ahuja, 2000). The greater the firm's deficiency of commercial assets, the greater the propensity to form exploitative commercial alliances with other firms, with all else equal.

[4] In principle, the conceptual framework that will be illustrated below applies to all alliances formed by NTBFs, independently of the number of partners. For expositional purposes, we will assume in the text that alliances are established by two partners.

[5] For a detailed discussion of the financial constraints from which NTBFs suffer and their implications for firms' investment strategy, see Carpenter and Petersen (2002a,b).

Nonetheless, NTBFs' inducement is a necessary but not sufficient condition for alliance formation. In order for an alliance to be established, the benefits to the candidate partner must also exceed the costs that it incurs. In this perspective, the *opportunity* of NTBFs to form commercial alliances depends on their possession of valuable assets that are difficult to reproduce and therefore make them attractive to candidate alliance partners (Ahuja, 2000). The most attractive of these assets is a stock of state-of-the-art ready-to-use technological knowledge that can be synergistically combined with the specialized commercial assets possessed by would-be partners. In accordance with this view, Rothaermel (2002) shows that large incumbent pharmaceutical firms that control valuable commercial assets, are especially attracted by biotech start-ups that have a good record of new product development and an intense patent activity. Therefore, the greater the prior innovation output of NTBFs that can immediately be exploited commercially, the greater their probability to form exploitative commercial alliances, with all else equal.[6]

Moreover, it is important to emphasize that absent inducement, opportunity has no influence on the likelihood of NTBFs establishing commercial alliances (see again Ahuja, 2000). Consider a NTBF that has developed an innovative product or service or possesses ready-to-use proprietary technological knowledge. If this firm also possesses the specialized complementary assets required for commercialization it will have no incentives to look for alliance partners. In other words, the positive effect of prior innovation output on alliance formation is lower the larger the set of specialized commercial assets possessed by NTBFs.

The above arguments do not apply to the explorative technological alliances of NTBFs. Namely, these alliances are motivated by the wish of NTBFs and their partners to internalize each other's technological competencies or to combine their technological competencies so as to build new shared competencies that could not be developed in isolation. Therefore, the lack of specialized commercial assets by a NTBF constitutes no inducement, nor the possession of technological knowledge ready for commercialization in and of itself makes it attractive as an alliance partner. As previous studies have documented, what matters here is the scientific and technological competencies of firms (Colombo and Garrone, 1996, 1998; Veugelers, 1997; Khanna et al., 1998, 2000; Piga and Vivarelli, 2004), their "absorptive capacity" (Cohen and Levinthal, 1990), and the cognitive distance between them (Nooteboom, 1992, 1999), which creates both opportunity for and obstacles to the generation of synergistic gains (Mowery et al., 1998; Cantwell and Colombo, 2000; Wuyts et al., 2005). As will be emphasized below, the prior innovation output of a NTBF may have an indirect positive effect on the formation of explorative technological alliances as it may be regarded as a signal of the scientific and technological competencies of the NTBF, thus reducing the transaction costs incurred in the search for partners.

Let us now turn attention to the costs of alliances and their firm-specific determinants. The costs of alliances are the sum of the transaction costs incurred by each individual party and the management costs of alliance operations. The former category includes (i) the costs of the search for suitable partners; (ii) the costs of partners' assessment and selection; (iii) negotiation and other contractual costs; and (iv) the appropriability hazards engendered by the alliance. Management costs mainly coincide with the opportunity costs of the time and effort that firms' managers devote to the organization, management and control of the alliance, to the detriment of other activities.

First of all, we claim that transaction and management costs have a relatively greater hindering effect on the formation of alliances (both exploitative and explorative) for smaller NTBFs. In fact, smaller NTBFs typically have no slack. The time and attention of their owner-managers are especially valuable resources, and it may be very detrimental to firm's destiny to divert them from research and technological development, the activity in which they generally are most productive. Hence, the opportunity costs of the search for, assessment and screening of, and negotiation with candidate partners, and those subsequently incurred for the organization, management and control of the alliance, are greater for smaller NTBFs than for their larger counterparts. In addition, most of these costs either are fixed or increase less than proportionately with the scale of operation of alliances; this again favors larger NTBFs as they tend to be involved in larger scale alliances.

Second, the technological prestige of NTBFs plays a key role in reducing the transaction costs associated with alliance formation. As Teece (1986) originally highlighted, in the search for partners innovative firms encounter similar adverse selection problems to those encountered in the search for financial investors. These problems are especially severe for NTBFs (Carpenter

[6] The establishment of exploitative commercial alliances with innovative start-ups also plays a key role in allowing incumbent firms that have tight control over specialized commercial assets to adapt to radical technical change. See Mitchell and Singh (1992), Tripsas (1997) and Rothaermel (2001) for examples in the medical instrument, typesetting and biotechnology industries.

and Petersen, 2002a). As it is often difficult for would-be alliance partners to assess the quality of the untested technological capabilities of NTBFs, they will likely abstain from joining forces with these firms. In fact, the value of the relation-specific investments they commit to an alliance will vanish if this is interrupted due to failure or underperformance of the partner NTBF. Under these circumstances, the ability of NTBFs to credibly signal their quality to uninformed external parties through previous technological achievements plays a key role (Spence, 1984). Accordingly, NTBFs that exhibit a brilliant patent activity (Stuart, 1998; Stuart et al., 1999) or have a portfolio of successful new products (Rothaermel, 2002) enjoy an advantage, as this confers them both visibility and legitimacy.

Lastly, the extent of the transaction costs that NTBFs incur in alliance formation can be reduced through support from a "sponsor institution". Sponsors include financial intermediaries and other firms which take equity positions in NTBFs, that is institutions involved in VC and CVC investments. They also include other organizations that provide NTBFs with access to specialized services and may or may not hold an ownership stake of the sponsored firm. The support that is offered by parent research organizations (PROs) to the start-ups founded by their academic personnel as to issues such as the legal protection of scientific and technological knowledge, use of laboratory facilities and rental of equipped offices at subsidized rates qualifies them as "sponsors". Sponsorship by a reputable organization decreases the search, negotiation and other contractual costs of alliances incurred by NTBFs. It also reduces the appropriability hazards to which NTBFs may be exposed through the alliances they establish.

First of all, social capital theorists argue that the social capital that accrues to a firm by virtue of possessing a network of collaborative ties with other firms facilitates up to a threshold level the formation of subsequent alliances as it provides the focal firm with both informational and reputation benefits (Gulati, 1995, 1999; Chung et al., 2000). The beneficial effects of social capital are fundamental for NTBFs (Walker et al., 1997). On the one hand, owner-managers of NTBFs can leverage the social contacts of alliance partners, thus saving their own time in the search for other partners. On the other hand, the certification effect of endorsement by a prestigious organization credibly signals to uninformed external parties the good quality of a high-tech start-up, thus alleviating the above mentioned adverse selection problems (Teece, 1986, p. 293, see also Stuart et al., 1999). As a consequence, NTBFs that are endorsed by reputable alliance partners gain an advantage in their subsequent attempts to establish collaborative links with third parties. In accordance with this argument, Stuart et al. (1999) find that the time to IPO of biotech start-ups decreases if they are affiliated with prominent alliance partners, while the market value at IPO increases; this effect is stronger for young companies and companies that have previously raised a lower amount of capital from investors, that is for companies whose quality is more uncertain. Similarly, Stuart (2000) highlights that alliances with large and innovative partners have a more beneficial impact on sales growth and innovation for young and small semiconductor firms than for large and established firms that have a verifiable reputation.

Nonetheless, it is important to recognize that in the early years of their life, NTBFs lack an extensive social network. Therefore, even though in alliance formation success breeds success, it may be difficult for them to start the process. For this purpose, they have initially to rely on the personal contacts and reputation of owner-managers.[7] Sponsored NTBFs enjoy an advantage with respect to their non-sponsored counterparts as they can also rely on the social network of and endorsement by the sponsor (Gans et al., 2002; Gans and Stern, 2003; Hsu, 2006). To the extent that the sponsor both has deep knowledge of the needs and capabilities of the focal start-up and is aware of collaboration opportunities that exist in the business environment, it can perform a valuable information intermediation function to the advantage of the sponsored NTBF. In addition to this broker role, selection by a reputable sponsor certifies the quality of the focal NTBF to uninformed third parties and conveys social status to it.[8]

Moreover, sponsorship mitigates the risk of opportunistic behavior that NTBFs incur while establishing an alliance. As is highlighted by transaction cost economics, alliances involve appropriability hazards (Teece, 1986; Williamson, 1991; Oxley, 1997, 1999). These hazards are especially severe for NTBFs. As proprietary technological knowledge generally is the main, if not the unique asset of these firms, expropriation of this knowledge due to unintended leakage to alliance partners

[7] In accordance with this view, Eisenhardt and Schoonhoven (1996) find that among US semiconductor companies that were founded between 1978 and 1985, firms with larger founding teams, whose members had previously worked for many semiconductor companies in high managerial positions, have significantly higher rates of formation of product development alliances.

[8] A similar certification effect may arise from the support from a public administration that provides subsidies to the R&D activity of the NTBF. For instance, Lerner (1999) provides evidence relating to the certification effect of the SBIR program in the USA.

may considerably damage firm's competitive position, and it may even threaten survival. Therefore fear of expropriation may induce NTBFs to abandon otherwise beneficial alliances and turn to a go-it-alone strategy. Sponsorship mitigates the risk of opportunistic behavior that NTBFs incur, as it makes cooperation defection more expensive for alliance partners (Gans et al., 2002; Gans and Stern, 2003; Hsu, 2006). In fact, sponsors like VC and CVC investors, universities and other research institutions have a portfolio of supported firms. Hence, they may credibly threaten retaliation in that they will exclude a partner that behaves opportunistically from future alliances with their portfolio firms; they may even force portfolio firms to dissolute extant collaborations with this partner. Moreover, due to their high visibility and widespread network of social contacts, sponsors are in the position to substantially damage the reputation as a trustworthy partner of an alliance partner that indulged in opportunistic behavior to the detriment of a portfolio firm. Of course, this option is precluded to individual non-sponsored NTBFs.[9]

Nonetheless, there also are opposing arguments suggesting that under certain circumstances, support from a sponsor may increase the transaction and management costs of the alliances of NTBFs (see Dushnitsky and Lavie, 2005). First, if the sponsor has veto rights on key strategic decisions and the managers of sponsored firms share with it responsibility for alliance strategy, selection of alliance partners and management of alliances may become a rather cumbersome process that will experience all the organizational inefficiencies of joint decision-making. Even if firms' managers retain autonomous decision authority over alliance activity, maintaining ties with sponsors may absorb their time and effort at the expense of other potentially profitable activities. This again implies that managers of sponsored firms may be less prone to establish alliances with third parties than those of non-sponsored ones. Second, as to explorative technological alliances, while the presence of a sponsor reduces the appropriability hazards in which NTBFs incur when they team up with other firms, it may increase the appropriability hazards perceived by would-be alliance partners. In fact, through the alliance the proprietary technological knowledge of alliance partners may flow to and be exploited by the sponsor and other firms it is connected with. Lastly, there may be a substitution effect between sponsors and alliance partners that reduce NTBFs' inducement to form alliances. In fact, sponsors and would-be alliance partners may compete for getting exclusive access to the technological knowledge possessed by a NTBF or they may offer to it access to similar specialized complementary assets. Moreover, if support from a sponsor relaxes the financial constraints from which the sponsored NTBF suffers, it may make a go-it-alone commercialization strategy more attractive to it.

To sum up, it is fair to recognize that since there are opposed forces at work, whether sponsorship results in an increase or a decrease of the likelihood of alliance formation by NTBFs is a matter of empirical testing. The balance of the different effects that were described above will crucially depend on both (i) the identity of the sponsor, and (ii) the type of alliance under examination. In fact, the identity of the sponsor shapes the characteristics of its network of social contacts, it determines the nature of the certification effect and the effectiveness of the shield against opportunistic behavior from alliance partners that its endorsement provides to sponsored NTBFs, and it influences the appropriability hazards experienced by third parties if they join forces with sponsored start-ups. It also influences the type of specialized assets it possesses. In turn, these factors are likely to have different effects on the formation of exploitative commercial alliances and explorative technological alliances.

3. Theoretical hypotheses

The conceptual background that has been illustrated in the previous section leads to a series of testable theoretical hypotheses relating to firm-specific determinants of the likelihood of formation of exploitative commercial alliances and explorative technological alliances by NTBFs. Among these determinants, we consider here firm size, prior innovation output, and the identity of sponsor institutions.

3.1. Firm size

Size has been used in previous works on alliances as a proxy of the commercial capital possessed by firms

[9] The key role played by extant ties and reputation effects in deterring opportunistic behavior has long been highlighted in the alliance literature. For instance, Gulati (1995) and Gulati and Singh (1998) provide evidence that the likelihood of choosing an equity joint venture (and a minority investment) as opposed to a contractual form decreases with the number of prior alliances established by partners with each other. Robinson and Stuart (2000) contend that actors that are centrally located in a network of alliances suffer the greatest reputation penalties if they behave opportunistically. More importantly for our purpose, they also argue that these actors are ideally placed to damage the reputation of alliance partners. In accordance with this view, they show that the likelihood of resorting to a non-equity governance structure for an alliance and the cash infusion associated with the alliance increase with the centrality of the partner in the network of extant alliances.

(Ahuja, 2000). The relation between size and possession of commercial assets is likely to be very close for NTBFs.[10] In fact, due to deficiency in financial and managerial resources, small NTBFs are likely to focus almost exclusively on core research and other technical activities (i.e. design, engineering and testing), while larger NTBFs are progressively able to integrate other functions of the value chain like production, distribution, customer care, after-sale services. If NTBFs possess the specialized commercial assets complementary to their technological knowledge and required for its successful commercial exploitation, they will be less prone to establish exploitative commercial alliances. According to this argument, we expect the likelihood of formation of this type of alliance to decline with firm size. Conversely, both small and large NTBFs are equally forced to continuously update their technological capabilities so as to sustain over time their technology-based competitive advantage. Therefore, as to explorative technological alliances, the inducement associated with the desire of NTBFs to improve and extend their set of technological capabilities through inter-organizational learning will probably be independent of firm size.

Nonetheless, we have emphasized in the previous section the largely fixed nature of the costs of the search for, assessment and selection of and negotiation with partners, and of the costs incurred by NTBFs to organize, manage and control an alliance, be it exploitative or explorative. While these costs are likely to represent a serious obstacle to alliance formation for small NTBFs, we expect their negative effect to progressively vanish with an increase of firm size.

While combining the above arguments, we predict a curvilinear, inverse U-shaped relation between the size of NTBFs and the likelihood of formation of exploitative commercial alliances. Very small firms that focus on core technical activities, in spite of great inducement, will be unlikely to establish this type of alliance, as the transaction and production costs of the collaboration often are higher than the additional revenues they can reap from it. In spite of the fact that these costs do not prevent large NTBFs from joining forces with other firms, they will have low inducement to collaborate as they will often be able to opt for a go-it-alone commercialization strategy. Conversely, we expect the likelihood of formation of explorative technological alliances to increase with firm size due to the effect of alliances' transaction and management costs.

[10] Evidence relating to Italian NTBFs that clearly documents this positive relation will be provided in Section 5.

Hypothesis 1A. With all else equal, the relation of the likelihood of formation of exploitative commercial alliances to the size of NTBFs will be inverse U-shaped, with this likelihood first increasing and then decreasing with an increase of firm size.

Hypothesis 1B. With all else equal, the likelihood of formation of explorative technological alliances will increase with the size of NTBFs.

3.2. Prior innovation output

In the previous section, we have argued that a NTBF is more attractive as partner of exploitative commercial alliances if it possesses a stock of state-of-the-art ready-to-use technological knowledge that represents the output of firm's prior innovation activity.

Nonetheless, even though other firms will be more prone to collaborate with a NTBF the greater its prior technological achievements, whether exploitative commercial alliances are formed or not ultimately depends on the strategic choices of NTBFs. As was mentioned earlier, these firms will not be inclined to look for partners for the commercialization of their innovations if the required specialized commercial assets are available in house. In other words, there is a negative interactive effect between opportunity of and inducement to commercial collaborations with third parties: the positive effect on alliance formation of the prior innovation output of NTBFs is lower the larger the size of the firm.

As to explorative technological alliances, the synergistic gains that can be obtained from them depend on the technological competencies of NTBFs. The prior technological accomplishments of these firms signal the stature of their technological competencies to uninformed third parties (Narin et al., 1987; Trajtenberg, 1990). Hence they help address the adverse selection problems that hinder alliance formation, thus reducing the costs incurred by NTBFs for partner search. Again, this effect will be relatively more important for smaller firms that suffer most from high partner search costs.

Hence we derive the following hypotheses.

Hypothesis 2A. With all else equal, the likelihood of formation of both exploitative commercial alliances and explorative technological alliances will increase with the prior innovation output of NTBFs.

Hypothesis 2B. With all else equal, the positive effect of the prior innovation output of NTBFs on the likelihood of alliance formation will decrease with the size of NTBFs.

3.3. Sponsorship

We focus attention here on three types of sponsor: VC investors, CVC investors, and PROs.

VC investors are financial intermediaries that specialize in taking (generally minority) stakes in the equity capital of high-tech start-ups.[11] Their investment activity is driven by financial objectives: they aim at obtaining the greatest possible capital gain in the shortest possible time. For this purpose, they struggle to peak hidden winners, add value to them, propel their growth, and exit.

Support from VC investors has important implications for the formation of exploitative commercial alliances by NTBFs. First of all, the added value that these investors bring to their portfolio start-ups lowers the costs of the search for candidate partners. VC firms reportedly have a widespread network of social contacts in the business community and perform a key information intermediation function to the advantage of sponsored NTBFs. In accordance with this view, Lindsey (2002) documents a greater likelihood of alliance formation among firms within a VC investor's portfolio. In addition, VC firms generally have the reputation of being able to judge the hidden value of high-tech entrepreneurial projects and pick winners (Chan, 1983; Amit et al., 1998). Moreover, they have the incentives to do so in order to rapidly obtain a sizable capital gain. Therefore, they certify to candidate alliance partners the hidden commercial value of the technology developed by the NTBFs in which they invest. The findings of previous empirical studies support this view. For instance, Megginson and Weiss (1991) find that VC-backed IPOs exhibit smaller underpricing than non VC-backed ones that are matched by sector and IPO size (see also Wang et al., 2003; for opposed results see Lee and Wahal, 2004). Moreover, Hsu (2004) finds that financing offers from VC investors with high reputation are more than three times more likely to be accepted from recipient firms than other offers. In addition, these investors obtain a substantial discount on the purchase price of the participation.

Second, VC firms perform a key coaching function. In fact, they provide portfolio companies with advising services in fields where these firms typically lack internal capabilities. For instance, Hellmann and Puri (2002) document that VC investors favor the recruitment of external managers, the adoption of stock option plans, and the revision of human resource policies by portfolio firms, thus contributing to their managerial "professionalization". Moreover, these companies take advantage of the links of their sponsors with providers of specialized services like legal, accounting, head hunting, and public relation services (Bottazzi et al., 2004). This support is very helpful for NTBFs in the assessment and screening of and negotiation with candidate alliance partners, and in contract writing and enforcement.

Lastly, sponsorship by a VC firm mitigates the appropriability hazards NTBFs incur while forming exploitative commercial alliances with third parties. The shield against the risk of opportunistic behavior will be quite effective as these investors generally have a rather large number of portfolio firms, are reputable organizations, and have a widespread network of institutionalized business contacts. So the threat of retaliation against a firm that behaved opportunistically in a collaborative relation with one of their portfolio NTBFs is concrete.

On the contrary, there are no reasons to believe that VC-backing may negatively affect the probability of formation of exploitative commercial alliances by NTBFs. First, even though in principle VC financing may make a go-it-alone commercialization strategy viable, the resources provided by VC investors to sponsored NTBFs are unlikely to substitute for the specialized commercial assets provided by alliance partners. Second, appropriability hazards are negligible for candidate partners of this type of alliance, as their contribution to the alliance is confined to commercial assets. Third, VC investors are experienced in dealing with managers of sponsored NTBFs; therefore, even though conflicts may arise, it is quite unlikely that VC-backing interferes negatively with the management of the alliance activity of sponsored NTBFs.

Hypothesis 3A follows from the above arguments.

Hypothesis 3A. With all else equal, the likelihood of formation of exploitative commercial alliances will be greater for VC-backed NTBFs than for their non VC-backed counterparts.

On the contrary, the effect of VC-backing on the likelihood of formation of explorative technological alliances is more controversial. First, the network of social contacts of VC investors is less extensive in the technological community than in the business community. So VC sponsorship is likely to have a smaller positive effect on the costs of the search for partners of explorative technological alliances. Moreover, the links of these investors to their portfolio firms may substantially increase the appropriability hazards in which

[11] There is a vast literature on the characteristics and objectives of VC investors. See for instance Sahlman (1990), Gompers and Lerner (2001), Kaplan and Strömberg (2001, 2004) and Denis (2004).

partners of this type of alliance may incur; so they may constitute a serious obstacle to alliance formation. As there likely are opposed forces at work, we have no predictions as to the impact of VC-backing on the likelihood of formation of exploratory technological alliances by NTBFs.

Let us now turn attention to CVC. CVC investors generally are subsidiaries of large incumbent firms that acquire minority shareholdings in start-ups involved in research and development activities in technological fields that are somehow related to the business of the investing firm. Accordingly, while CVC investors may also pursue financial objectives, strategic objectives prevail (Chesbrough, 2002). In particular, CVC is often used by incumbent firms to scan for external sources of technology.[12] Hence, CVC investors generally have a more proactive and invasive attitude than VC firms in managing relations with sponsored NTBFs (Birkinshaw et al., 2002). In addition, previous studies have highlighted that while early stage financing of high-tech firms is the core business of VC firms, it is an ancillary activity for CVC parent companies. Therefore, CVC subsidiaries may have more limited screening and investment management capabilities than VC firms.[13] These characteristics have important implications for the transaction and management costs of alliances incurred by sponsored NTBFs.

First of all, while CVC-backing unequivocally certifies the quality of the technological competencies of sponsored NTBFs, the signal it provides to third parties as to the commercial value of their innovative technologies is more ambiguous. Second, the strategic interests of CVC-backed firms may not be aligned with those of their sponsor. Formation of explorative technological alliances by sponsored NTBFs may be encouraged to the extent that they amplify the technology window effect of CVC investments. Conversely, exploitative commercial alliances with third parties will be favored only to the extent that they are not detrimental to the investing firm. For the same reason, conflicts may arise between the CVC investor and the managers of sponsored NTBFs, making the establishment and management of alliances more demanding of managers' time and effort. Lastly, incumbent firms involved in CVC activity generally possess specialized commercial assets that are valuable to sponsored NTBFs. While CVC-backed NTBFs may obtain privileged access to these assets, CVC investors may demand for an exclusive relation; in other words, there may be a substitution effect that crowds out collaborations with other firms (Dushnitsky and Lavie, 2005).

The above arguments imply that sponsorship from CVC will be positively related to the establishment of explorative technological alliances by NTBFs. Conversely, its effect on the likelihood of formation of exploitative commercial alliances is uncertain. Hypothesis 3B follows.

Hypothesis 3B. With all else equal, the likelihood of formation of explorative technological alliances will be greater for CVC-backed NTBFs than for their non CVC-backed counterparts.

Lastly, let us consider sponsorship of academic start-ups (ASUs) by PROs. PROs are increasingly involved in supporting the firms created by their academic personnel, as part of the new mission of the "entrepreneurial university" (Lockett et al., 2003; Clarysse et al., 2005). Nonetheless, there are several reasons why the positive effect of this support on the likelihood of alliance formation by ASUs will be confined to explorative technological alliances. First, the network of social contacts of universities and other research organizations mainly includes links with other research organizations and R&D laboratories of private firms. Hence, the information broker function performed by PROs to the benefit of sponsored NTBFs, and the associated reduction of partner search costs, will be valuable as to explorative technological alliances, but it is likely to have negligible effects on the formation of exploitative commercial alliances. Second, the association with a PRO will be perceived by third parties as an endorsement only with respect to areas in which the sponsor has specific competencies and enjoys a reputation of excellence. Therefore, PROs' support is unlikely to affect outsiders' perception of the commercial value of the innovative technologies developed by ASUs. Conversely, it will certify the scientific and technological competencies of these firms. Third, to the extent that PROs do not possess ownership

[12] Siegel et al. (1988) show that "exposure to new technologies and markets" is the most important motive for firms to engage in CVC. Similarly, Ernst et al. (2005) document that CVC is used by large German firms for technology window purposes; in fact, it allows parent companies to closely monitor the development of promising technological innovations related to their core business on the part of young firms, and then possibly to acquire them. The evidence provided by Dushnitsky and Lenox (2005a,b) relating to the determinants and the effects on innovation output of the CVC activity of large US firms supports the view that through CVC investments, incumbent firms supplement their internal innovative efforts by tapping into the innovation knowledge generated by new ventures.

[13] For instance, it has been argued that it may be rather difficult for CVC investors to design an incentive structure for managerial personnel apt to attract highly qualified individuals (Block and Ornati, 1987; Chesbrough, 2000).

stakes in ASUs, their ties to these firms are weaker than those linking VC and CVC investors to their portfolio firms. Accordingly, the ability of PROs to provide sponsored NTBFs with an effective shield against partners' opportunistic behavior will be more limited than that of VC and CVC investors, as the threat of retaliation is less credible. Retaliation will also be more difficult and probably confined to explorative technological alliances because of the nature of the social networks of PROs. Conversely, neither PROs nor most of the organizations with which they collaborate possess the capabilities necessary for commercial exploitation of technological knowledge; hence, appropriability concerns are unlikely to prevent would-be partners from teaming up with ASUs for exploration of untested technologies. The above arguments lead to the following hypothesis.

Hypothesis 3C. With all else equal, the likelihood of formation of explorative technological alliances will be greater for PRO-sponsored NTBFs than for their non PRO-sponsored counterparts.

4. The dataset

4.1. The sample

In this paper we consider a sample composed of 522 Italian NTBFs. Sample firms were established in 1980 or later, were independent at founding time and have remained so up to 1 January 2004 (i.e. they are not controlled by another business organization even though other organizations may hold minority shareholdings in the new firms). They operate in the following high-tech sectors in manufacturing and services: computers, electronic components, telecommunication equipment, optical, medical and electronic instruments, biotechnology, pharmaceuticals, advanced materials, avionics, robotics and process automation equipment, multimedia content, software, Internet services (e-commerce, ISP, web-related services), and telecommunication services. The sample of NTBFs was extracted from the RITA (Research on Entrepreneurship in Advanced Technologies) database, developed at Politecnico di Milano.

RITA provides information on 1974 Italian NTBFs that comply with the above mentioned criteria relating to age and sector of operations. For the construction of the RITA population of firms a number of sources were used. These included lists provided by national industry associations, on-line and off-line commercial firm directories, and lists of participants in industry trades and expositions. We also considered information provided by the national financial press, specialized magazines, other sectoral studies, and regional Chambers of Commerce. Unfortunately, data provided by official national statistics do not allow to obtain a reliable description of the universe of Italian NTBFs. The RITA database is the most complete source of information presently available on Italian NTBFs.[14]

Data contained in the RITA database were collected from two types of sources. Data on NTBFs' patent activity and participation in EURJVs within the Framework Programs and other research projects (e.g. Eureka) were obtained from public sources (i.e. the databases of the patent offices and the Cordis database, respectively) and are available for all RITA firms during their entire life. Financial and economic data, including the number of firms' employees, come from firms' annual reports. Even though these data are public for most RITA firms from 1994 onward, they are available in the database for a subset of firms (i.e. the firms that participated in the below described surveys).

The second source of information from which RITA data were collected consists in a series of national surveys that were administered in the first semester of the years 2000, 2002 and 2004. The sample considered in this paper includes all RITA firms that participated in the 2004 survey and for which we were able to build a complete dataset relating to the variables of interest (see Section 5.2). The surveys were based on a questionnaire that was sent to the contact person of the target firms (i.e. one of the owner-managers) either by fax or by e-mail. The first section of the questionnaire provides detailed information on the human capital characteristics of firms' founders. The second section comprises further questions concerning the characteristics of the firms, including financing, alliances and innovation activity (excluding patent activity and participation in EURJVs for which data were provided by public sources). Then, answers to the questionnaire were checked for internal coherence by educated personnel and were compared with information published in firms' annual reports and in the press. In several cases, phone or face-to-face follow-up interviews were made with firms' owner-managers. This final step was crucial in order to obtain missing data and ensure that data were reliable.

As to alliances, owner-managers were asked to indicate the dates of the first technological and commercial alliances in which their firms were involved. The lack of

[14] The main problem is that in Italy most individuals who are defined as "self-employed" by official statistics actually are salaried workers with atypical employment contracts. Unfortunately, on the basis of official data such individuals cannot be distinguished from entrepreneurs who created a new firm.

information on the number of alliances established by firms, with the exception of the longitudinal data relating to EURJVs, is the major limitation of the dataset. Unfortunately, it was impossible to systematically collect reliable survey-based information on all alliances formed by sample firms. Conversely, the first alliance generally is a crucial milestone in the life of a high-tech start-up. Accordingly, it was quite easy for firms' owner-managers to indicate when it occurred.[15] Therefore, even though there may be a retrospective bias in the data used in this paper, its extent is likely to be fairly limited.

As was said earlier, the sample used in the present work consists of all RITA firms for which we were able to create a complete data set. Two χ^2 tests show that there are no statistically significant differences between the distributions of sample firms across industries and regions and the corresponding distribution of the population of 1974 RITA firms from which the sample was obtained ($\chi^2(4) = 2.29$ and $\chi^2(3) = 3.90$, respectively).

The sample is quite large and it exhibits considerable heterogeneity as to the relevant explanatory variables. In particular, it includes several small privately-owned start-ups that may have been underrepresented in previous studies on the alliance activity of US NTBFs. Note however that there is no presumption here to have a random sample. First, in this domain representativeness is a slippery notion as new ventures may be defined in different ways (see for instance Birley, 1984; Aldrich et al., 1989; Gimeno et al., 1997). Second, as was mentioned above, absent reliable official statistics, it is very difficult to identify unambiguously the universe of Italian NTBFs. Therefore, one cannot check ex-post whether the sample used in this work is representative of the universe or not. Third, only firms having survived up to the survey date could be included in the sample: attrition may generate a survivorship bias that may distort the estimates. In fact, larger more successful firms are more likely to survive, with all else equal (see Sutton, 1997; Caves, 1998, and the studies mentioned therein). If they also are more likely to establish alliances, data on alliance formation in our sample will be distorted. As in most survey-based studies, it is impossible to properly control for this survivorship bias. The best we can do is to check its extent.

For this purpose, we focused attention on the RITA 2000 sample. This sample is composed of 401 NTBFs (see Colombo et al., 2004) for 385 of which we have data on alliance activity. Out of these latter firms 291 had been involved in one or more alliances from their foundation up to the end of 1999. We examined the exit rate of these 385 firms in the 2000–2003 period, due to either bankruptcy or mergers and acquisitions. Fifty-two NTBFs that had established alliances exited during this period, that is a 17.9% share. The corresponding share relating to firms that had not formed any alliance was substantially higher (36.2%, 34 firms). A χ^2 test shows that there are statistically significant differences at conventional confidence levels between the two samples ($\chi^2(1) = 13.72$). Actually, the difference between the two percentages was almost entirely attributable to firms that went bankrupt. The failure rate was as high as 24.5% in the "non-allied firm" category (23 firms), while it was only 8.6% (25 firms) in the "allied firm" category. Again, the difference is highly significant ($\chi^2(1) = 17.63$). In other words, firms that did not form any alliance were far more likely to go bankrupt than other firms. Conversely, the difference relating to firms that merged with or were acquired by another firm was not statistically significant ($\chi^2(1) = 1.60$). We then run a probit model of the likelihood of firms having survived in the 2000–2003 period, conditional on survival up to 2000. In addition to firm- and industry-specific controls, the explanatory variables included all variables that according to the theoretical hypotheses developed in Section 3, are likely to affect alliance formation and hence will be considered in the econometric analysis. Only firm size was found to significantly and positively influence the likelihood of survival, while the remaining variables (i.e. whether the firm was granted one or more patents and was sponsored by a VC investor, a CVC investor or a PRO) were not significant. We deduce that while it is fair to acknowledge that our sample suffers from a survivorship bias, we are quite confident that this does not greatly influence the results of the estimates that will be illustrated in the following sections, with the possible exception of the effect of firm size. As to this variable, smaller firms that have not entered into any alliance are those less likely to survive. Therefore, our econometric results may overestimate the likelihood of alliance formation of smaller NTBFs.

4.2. Alliance activity of Italian NTBFs

This section has purely illustrative purposes. We use information on the 522 RITA sample firms to provide a preliminary description of the alliance activity of Italian NTBFs. Three hundred and sixty-five out of these firms established one or more alliances during their life

[15] Note that for only three firms the set of owner-managers at survey date did not include at least one of the founders of the firm. The fact that founders still held a managerial position was very helpful in collecting retrospective data.

Table 1
Distribution of sample firms and firms that established alliances, by industry and geographic area

	Sample firms		Firms that established alliances		Alliance formation rate (b)/(a)
	No. of (a)	%	No. of (b)	%	
Industry					
ICT manufacturing	114	21.8	74	21.6	64.9
Robotics and automation	47	9.8	17	4.6	36.2
Biotechnologies, pharmaceutics and advanced materials	22	4.2	15	4.1	68.2
Software	156	29.9	114	31.2	73.1
Internet and TLC services	157	30.1	123	33.7	78.3
Multimedia content	26	5.0	22	6.0	84.6
Total	522	100.0	365	100.0	69.9
Geographic area					
North-west	245	46.9	161	44.1	65.7
North-east	118	22.6	77	21.1	65.2
Centre	83	15.9	66	18.1	79.5
South	76	14.5	50	13.7	65.8
Total	522	100.0	365	100.0	69.9

(69.9% of the sample). The distribution of these firms across industries and geographic areas and the rate of alliance formation measured by the ratio of the number of firms that established one or more alliances to the total number of firms in a given industry or geographic area, are illustrated in Table 1.

Differences across geographic areas in the rate of alliance formation are fairly limited. Conversely, there are considerable differences across industries. In particular, in line with the evidence provided by previous studies (see for instance Tether, 2002; Belderbos et al., 2004), alliance formation rates turn out to be greater in services than in manufacturing industries. Multimedia content presents the greatest share of firms engaged in alliances (84.6%), while firms in the Robotics and automation sector are those that are less likely to establish collaborative agreements (36.2%).

Table 2 shows the distribution of firms that established alliances by type of the first alliance. For this purpose we distinguish collaborations that involve commercialization or production and so clearly have an exploitative intent from those that exclusively have a technological content. This latter category includes both exploitative "access alliances" (e.g. technology transfer agreements, research contracts) with no inter-organizational learning involved, and explorative alliances through which NTBFs may wish to develop new technological competencies (e.g. research joint ventures). For the majority of sample NTBFs that have established alliances, the first alliance belongs to the "commercial alliance" category (208 out of 294, that is 70.7%). This evidence is in line with that provided by previous studies (see for instance Rothaermel and Deeds, 2004) as to the crucial role that exploitative commercial collaborations play for NTBFs. This type of alliance is prevalent in almost all industries. There are two exceptions, namely the Robotics and automation and Biotechnologies, pharmaceutics, and advanced materials industries, where the share of firms that firstly established a commercial collaboration is 38.5% and 37.5%, respectively. Again there are no sensible differences across geographic areas as to the relative propensity of NTBFs towards commercial or technological alliances.

In Fig. 1, we plot the estimated (smoothed) hazard rate, that is the conditional probability of establishing an alliance given that this has not happened up to time t, computed by the Nelson–Aalen estimator (see Nelson, 1972; Aalen, 1978). We also distinguish the hazard rates of commercial and technological alliances. Fig. 1 reveals that after an initial peak, corresponding to a firm age equal to 3.5 years, the hazard rate of the first alliance decreases over time. Note however that this estimator does not control for other covariates that may influence the hazard rate. In particular, as firm size generally grows over time in the observation period, the decrease over time of the hazard rate might indicate that larger firms are less likely to join forces with other organizations. So it is fair to acknowledge that to disentangle these different effects, a more structured analysis highlighting the effects of covariates is in order. A similar pattern applies over time to both commercial and technological

Table 2
Distribution across first alliance types of firms that established alliances, by industry and geographic area[a]

	Commercial alliances		Technological alliances[b]		Total	
	No. of firms	%	No. of firms	%	No. of firms	%
Industry						
ICT manufacturing	41	69.5	18	30.5	59	100.0
Robotics and automation	5	38.5	8	61.5	13	100.0
Biotechnologies, pharmaceutics and advanced materials	3	37.5	5	62.5	8	100.0
Software	65	72.2	25	27.8	90	100.0
Internet and TLC services	80	76.9	24	23.1	104	100.0
Multimedia Content	14	70.0	6	30.0	20	100.0
Total	208	70.7	86	29.3	294	100.0
Geographic area						
North-west	103	76.9	31	23.1	134	100.0
North-east	40	64.5	22	35.5	62	100.0
Centre	28	60.9	18	39.1	46	100.0
South	37	71.2	15	28.8	52	100.0
Total	208	70.7	86	29.3	294	100.0

[a] The table does not include 71 firms as the type of their first alliance is unknown.
[b] This category includes alliances focused exclusively on technology (research joint ventures, research contracts, technology transfer and technology sharing agreements).

alliances. However, the hazard rate is higher and the peak occurs earlier for the former type of alliance.

Let us now focus on EURJVs. As was mentioned earlier, data on the number of alliances in which sample firms were involved and on the year in which all these alliances were established unfortunately are not available. Nonetheless, we do have these longitudinal data for EURJVs. These are cross-border alliances that are aimed at basic research or pre-competitive technological development and so can be considered as a good proxy of

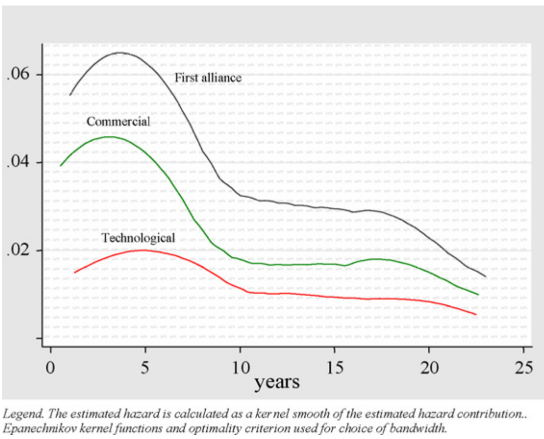

Fig. 1. Estimates of the hazard functions of the first alliance, by type of alliance.

explorative technological alliances. Financing by the EU is provided on a competitive basis. Participation in these projects is a rare event for Italian NTBFs: only 34 out of the 522 sample firms (6.5%) have been involved in one or more EURJVs during their life. This low percentage may be a consequence of the high partner search costs, or of the high administrative costs involved in this type of collaboration (or of both) which, as we were told during interviews with firms' owner-managers, discourage most NTBFs from participation. The very competitive selection procedure adopted by the EU may constitute an additional obstacle. Nonetheless, most of the firms that were involved in this type of alliance established more than one. This may suggest that even though NTBFs face substantial barriers to entry into the EU funded international collaborative research network, once they manage to do so participation in subsequent EURJVs is considerably facilitated. Table 3 illustrates the distribution of NTBFs that have participated in one or more EURJVs by industry and geographic area. Quite unsurprisingly, with a 22.7% share, firms in the Biotechnologies, pharmaceutics and advanced materials industry are relatively more likely to be involved in these alliances than firms in other sectors. On the contrary, the formation rate of EURJVs is very low in Internet and TLC services (2.5%). As to the geographical distribution, firms located in the Centre and in the North-east are more likely to participate in EURJVs (10.8% and 8.5%, respectively), while firms located

Table 3
Distribution of sample firms and firms that established EU funded research joint ventures (EURJVs), by industry and geographic area

	Sample firms		Firms involved in EURJVs		EURJVs formation rate (b)/(a)
	No. of (a)	%	No. of (b)	%	
Industry					
ICT manufacturing	114	21.8	9	26.5	7.9
Robotics and automation	47	9.8	2	5.9	4.3
Biotechnologies, pharmaceutics and advanced materials	22	4.2	5	14.7	22.7
Software	156	29.9	11	32.4	7.1
Internet and TLC services	157	30.1	4	11.8	2.5
Multimedia content	26	5.0	3	8.8	11.5
Total	522	100.0	34	100.0	6.5
Geographic area					
North-west	245	46.9	12	35.3	4.9
North-east	118	22.6	10	29.4	8.5
Centre	83	15.9	9	26.5	10.8
South	76	14.5	3	8.8	3.9
Total	522	100.0	34	100.0	6.5

in southern regions are rarely involved in these projects (3.9%).

5. The methodology of the econometric analysis

5.1. The specification of the econometric models

We investigate the determinants of alliance formation by NTBFs through the estimates of different econometric models.

First, we estimate models relating the observed spell (measured in years since foundation) needed for firms to start their alliance activity to variables that reflect firm-specific characteristics, the human capital of their founders and other control variables (see Section 5.2). The model is specified in terms of the duration of a NTBF not stipulating any alliance, which represents the dependent variable of the model. The basic tool for modeling duration data, given the right-censored nature of the sample (i.e. the presence within the sample of firms that did not establish any alliances) is a duration or hazard model.[16] The probability distribution of duration can be specified by the distribution function $F(t) = Pr(T < t)$, which specifies the probability that the duration variable T is less than some value t. The hazard function is defined as $h(t) = f(t)/S(t)$, where $f(t)$ is the probability density function and $S(t)$, which is equal to $1 - F(t)$, is the survivor function. The hazard function can be viewed as the instantaneous probability of forming an alliance, provided that this has not occurred by t. As is frequent in this type of literature we choose to model the hazard function by a semi-parametric approach (Cox, 1972):

$$h_i(t) = h_0(t)\exp(\beta' x_{it}), \tag{1}$$

and

$$S_i(t) = [S_0(t)]^{\exp(\beta' x_{it})} \tag{2}$$

where $h_0(t)$ is the baseline hazard rate at time t, i.e. the hazard rate when all explanatory variables equal zero, x_{it} is the vector of (possibly time-varying) explanatory variables, β is a vector of parameters and $S_0(t) = \exp\left(-\int_0^t h_0(s)\,\mathrm{d}s\right)$. This semi-parametric estimation method has the advantage of being insensitive to the specification of the baseline hazard, alleviating any possible miss-specification problem related to the hazard rate and it is particularly indicated when the main interest is on the influence of the explanatory variables (see among others Cameron and Trivedi, 2005, p. 592; Kennedy, 2003, p. 298). By construction, it imposes that each subject's hazard function is proportional to the baseline hazard. A proportional hazards test based on Grambsch and Therneau (1994) may be employed in order to investigate whether the set of independent variables violates this assumption.[17]

[16] For a comprehensive treatment of survival analysis, see Kalbfleisch and Prentice (1980), Keifer (1988), and Cameron and Trivedi (2005).

[17] We also implemented a fully parametric approach modeling the hazard function by a Weibull distribution (see among others Colombo and Delmastro, 2002; Chen, 2002). In this case $h_i(t) = \lambda_{it} p(\lambda_{it} t)^{p-1}$ and $S_i(t) = \exp[-(\lambda_{it} t)^p]$, where $\lambda_{it} = \exp(-\beta' x_{it})$ and p is the param-

In order to investigate the determinants of alliance formation by NTBFs while distinguishing between different types of alliances, the second step of our empirical analysis is to resort to a competing risks framework (Kalbfleisch and Prentice, 1980; Lancaster, 1990; Cameron and Trivedi, 2005). In particular, we may observe firms starting their alliance activity by stipulating a technological alliance (ta) or a commercial one (ca). We observe duration T, where $T = \min(t_t, t_c)$, that is only the shortest duration is observed and the rest is censored. In order to ease the computational complexity of the model, we follow previous studies in assuming independent risks (see Carling et al., 1996; Jansson, 2002; Green and Leeves, 2004; Cameron and Trivedi, 2005, p. 658). This means that the probability of forming an alliance of type k (k = ta, ca) in t, conditional on not having stipulated any alliance yet, is the same whether k is one of the risks or the only risk. Accordingly, the hazard functions can now be defined as

$$h_i^k(t) = h_0^k(t)\exp(\beta_k' x_{it}) \quad \text{with}\, k = \text{ta, ca}, \tag{3}$$

and the interpretation of the models remains unchanged.[18]

Lastly, the analysis of the determinants of firms' participation in EURJVs is carried out through econometric estimates of a random effects panel data probit model. The structure of the model is as follows:[19]

$$y_{it}^* = \beta' x_{it} + \varepsilon_{it} \quad \text{with}\, \varepsilon_{it} = v_{it} + u_i,$$

$$y_{it} = 1 \quad \text{if}\, y_{it}^* > 0 \quad \text{and} \quad y_{it} = 0\, \text{otherwise}. \tag{4}$$

y_{it}^* is the latent variable that captures firms' propensity to participate in EURJVs at time t and y_{it} is the observed outcome which equals 1 for participation and 0 for non-participation. The vector of explanatory variables x_{it} includes again firm-specific characteristics and measures of the human capital possessed by entrepreneurs plus other control variables. The effects of the covariates on the probability to participate in EURJVs are accounted for by the parameter vector β. The error component u_i represents time invariant firm-specific effects not reflected by the independent variables, while v_{it} is the remainder time-varying disturbance. Both components are assumed to be normally distributed with zero means and independently of one another, so that:

$$\text{Var}[\varepsilon_{it}] = 1 + \sigma_u^2; \qquad \text{Corr}[\varepsilon_{it}, \varepsilon_{is}] = \rho = \frac{\sigma_u^2}{1 + \sigma_u^2}; \tag{5}$$

where a likelihood ratio test of H_0: $\rho = 0$ may be used to evaluate the appropriateness of the panel specification against the pooled estimator.

5.2. The explanatory variables of the econometric models

A summary of the explanatory variables used in the estimation of the econometric models is reported in Table 4. They include firm-specific variables, founder-specific variables, and industry controls. All time-varying variables, indicated by suffix t, are one period lagged so as to mitigate endogeneity problems.

Let us first consider firm-specific variables. The size of NTBFs is measured by the logarithm of the number of employees ($LSize_t$). On the one hand this variable is considered here as a proxy of possession of specialized commercial assets.[20] On the other hand it inversely reflects the extent of the opportunity costs of alliance formation and management. Previous evidence on the effect of NTBF size on the formation of alliances is mixed. Shan (1990) highlights a negative effect for biotech start-ups. Nonetheless, this result is not confirmed by subsequent studies (Shan et al., 1994; Eisenhardt and Schoonhoven, 1996; Gans et al., 2002; Rothaermel, 2002; Rothaermel and Deeds, 2004; Hsu, 2006). Actually, as to exploitative commercial alliances, Hypothesis 1A predicts an inverted U-shaped relation between firm size and the probability of alliance formation. So we resorted to a quadratic specification, introducing into the model $SqLSize_t$, the squared value of $LSize_t$. We predict a positive coefficient for $LSize_t$ and a negative one for $SqLSize_t$. Conversely, in accordance with Hypothesis

---

eter that rules duration dependence: when p equals one, there is no duration dependence, when p is greater (lower) than one there is positive (negative) duration dependence. The results of the estimates are presented in Appendix A (see Table A1). We also tried different functional forms (e.g. Gompertz, exponential) but results remain almost unchanged. They are available from the authors upon request.

[18] For the Weibull case it is: $h_i^k(t) = \lambda_{it}^k p^k (\lambda_{it}^k t)^{p^k - 1}$. Estimation results are presented in the Appendix A (see Table A2).

[19] See Bulter and Moffitt (1982) and Greene (2000) for full details on the estimation of this type of models.

[20] A better proxy would be the number of firm's employees involved in commercial and production activities. Unfortunately the composition of the workforce of sample NTBFs by type of activity is not available for all firm-year observations of the dataset. Nonetheless, for almost all sample firms we do have data on the number of employees involved in technical (i.e. R&D, design and engineering) and non technical activities in at least 1 year. Therefore, we regressed the percentage of employees in non technical activities against the size of firms, after controlling for the industry in which firms operate. The sign of the coefficient of firm size was positive and significant at 99% (results of the estimates of the double censored Tobit model are available from the authors upon request).

Table 4
Definition of the explanatory variables

Variable	Description
$NEURJV_t$	Number of EU funded research joint ventures in which the firm has been involved up to year $t-1$
$SqNEURJV_t$	Squared number of EU funded research joint ventures in which the firm has been involved up to year $t-1$
Age_t	Number of years since firm's foundation at t
$LSize_t$	Logarithm of the size of the firm at $t-1$ measured by the number of employees
$SqLSize_t$	Squared logarithm of the size of the firm at $t-1$ measured by the number of employees
$NPatents_t$	Number of patents that were granted to the firm at $t-1$
DASU	One for academic start-ups (i.e. firms with at least one founder with a previous work experience in a university or in another public research organization)
$DSVC_t$	One for firms that up to year $t-1$ have obtained venture capital financing from a specialized financial intermediary
$DCVC_t$	One for firms that up to year $t-1$ have obtained corporate venture capital financing
$DPublicSubsidy_t$	One for firms that up to year $t-1$ have obtained public subsidies
NFounders	Number of founders
Education	Mean number of years of education of founders
SpecWorkExp	Mean number of years of work experience gained by founders in the same sector of the start-up before firm's foundation
OthWorkExp	Mean number of years of work experience gained by founders in other sector than the one of the start-up before firm's foundation
DManager	One for firms with one or more founders with a prior management position
Appropriability	Industry average of the scores assigned by RITA NTBFs' owner-managers to the importance of patents, secrecy, product complexity, lead time, brand and production costs to appropriate the benefits from innovations on a Likert scale from 1 (weak appropriability) to 6 (strong appropriability)
Competition	Normalized industry average of the scores assigned by RITA NTBFs' owner-managers to the importance of price competition as an obstacle to innovation measured from −1 (low competition) to 1 (strong competition)
TechOpportunities	Ratio of the number of RITA NTBFs that introduced radically innovative products or services compared to the offer of the industry to the total number of RITA NTBFs in the industry
Uncertainty	Industry average of the normalized standard error of the market price of newly listed firms in the 50 days following the IPO
DInternet	One for firms in the Internet and telecommunication services industry
DSoftware	One for firms in the Software industry
DMultiContent	One for firms in the Multimedia content industry
DICTmanufacturing	One for firms in the ICT manufacturing industry
DBiotech	One for firms in the Biotechnology, pharmaceutical and advanced materials industry

1B which predicts a positive relation between NTBF size and the formation of explorative technological alliances, we expect $LSize_t$ to exhibit a positive coefficient in the EURJV model and possibly in the technological alliance equation of the competing risks model.

$NPatent_t$ is the count of the number of patents granted to firms. We follow previous literature on NTBFs' alliances in using it as an indicator of innovation output (see among others Shan et al., 1994; Baum et al., 2000; Gans et al., 2002; Baum and Silverman, 2004; Rothaermel and Deeds, 2004). Of course, not all innovative knowledge can be codified and patented. Furthermore, firms sometimes abstain from patenting for strategic reasons. In fact, patents diffuse information to third parties, generating technological spillovers. Moreover, as was effectively documented by Teece (1986), they often are quite ineffective in protecting an innovator's technological knowledge from imitation by other firms. Therefore, instead of patenting an innovation, firms may resort to other strategic protection mechanisms, such as the development of a brand or reliance on lead time and learning curves in production (see Levin et al., 1987). Nonetheless, these mechanisms require substantial investments that are out of reach for most NTBFs. So while we cannot exclude that a NTBF that possesses valuable technological knowledge ready for commercial exploitation chooses not to rely on patent protection, we may reasonably assume that this situation is quite uncommon. It follows that in accordance with both Hypothesis 2A and the evidence provided by most previous studies (Gans et al., 2002; Rothaermel, 2002; Rothaermel and Deeds, 2004; Hsu, 2006. For an exception see Shan et al., 1994), we expect $NPatent_t$ to positively influence the likelihood of formation of alliances, be they exploitative or explorative. We also predict that the effect of this variable will be relatively greater for smaller firms (Hypothesis 2B). Therefore, we introduce into the specification of the econometric models an interactive term $NPatent_t \times LSize_t$, for which a negative coefficient is expected.

Let us now turn attention to the role played by sponsor institutions. We consider different types of sponsors. $DSVC_t$ is equal to one for firms that have obtained VC financing. In accordance with both Hypothesis 3A and the evidence offered by previous studies (Gans et al., 2002; Baum and Silverman, 2004; Hsu, 2006), we expect this variable to have a positive effect on the likelihood of alliance formation by NTBFs, but we also expect this effect to be confined to exploitative commercial alliances. Conversely, we have no predictions as to the effect of this variable on the formation of technological alliances in general and EURJVs in particular.

$DCVC_t$ indicates NTBFs that received equity capital infusion by other firms generally of large size. In accordance with Hypothesis 3B, we expect $DCVC_t$ to have a positive effect on the formation of EURJVs and possibly on the hazard rate of the first technological alliance. Conversely, the effect of $DCVC_t$ on the establishment of the first commercial alliance is controversial. So we leave to the empirics the determination of its sign.

DASU equals one for NTBFs that, being founded by academic entrepreneurs, benefit from the support possibly offered by their PROs. In accordance with Hypothesis 3C, we predict a positive coefficient for *DASU* in the technological alliance equation of the competing risks model and above all in the EURJV panel data probit model. Conversely, we expect *DASU* to have a negligible effect on the hazard rate of the first commercial alliance.

We introduced into the specification of the econometric models several firm-, founder- and industry-specific control variables. $DPublicSubsidy_t$ denotes firms that obtained financial help from the Italian Central Government or local authorities. Lerner (1999) provides evidence of a certification effect engendered by financing obtained from the US SBIR program. Nonetheless, access to public subsidies may provide NTBFs with the financial resources that make a go-it-alone commercialization strategy viable. Accordingly, Gans et al. (2002) and Hsu (2006) show that SBIR funded NTBFs have a lower likelihood of establishing alliances than VC-backed ones. So we leave to the empirics the determination of the impact of this variable on alliance formation.

Founder-specific variables include the size of firms' founding team (*NFounders*) and measures of the human capital possessed by founders, both *generic* and *specific*.[21] As to the former category, we consider the level of education measured by the mean number of years of education of founders (*Education*), and the mean number of years of professional experience in other sectors than the one of the new firm (*OthWorkExp*). As to specific human capital, *SpecWorkExp* measures the years of professional experience of founders in the same sector of activity of the new firm, while *DManager* equals 1 if prior to the establishment of the new firm, one or more founders had a managerial position in another company. NTBFs with larger founding teams composed of more educated and more experienced individuals can benefit from the network of business relations of their founders (Eisenhardt and Schoonhoven, 1996). Moreover, in the early years of firm's life, the distinctive capabilities of NTBFs coincide with those of their founders;[22] therefore, NTBFs established by individuals with greater human capital may be more attractive as alliance partners, with all else equal. Nonetheless, these firms may also be more capable of and have the financial resources for adopting a go-it-alone strategy.[23] So we have no predictions as to the sign of the coefficients of founder-specific variables.

As to industry-specific controls, we introduce four variables into the econometric models. *Appropriability* is a qualitative measure that, in the spirit of Levin et al. (1987), inversely captures the extent of technological spillovers in the industry in which a NTBF operates. Owner-managers of RITA NTBFs were asked to rate, on a Likert scale from one to six, the importance in their industry of six strategies aimed at appropriating the benefits from new or improved products, services and processes. These included the importance of patent and copyright protection, trade secrecy, product complexity, lead time generating a first-mover advantage, learning curves, and strategic barriers to entry (e.g. brand, customer care, control of distribution channels). *Appropriability* measures the industry average of the mean ratings attributed by each firm to the six mechanisms: the higher the value of this variable, the stronger the appropriability regime, and thus the less the extent of technological spillovers in the industry. Both the industrial organization theoretical literature (see De Bondt and

[21] See Becker (1975) for such distinction and Colombo et al. (2004) and Colombo and Grilli (2005) for its empirical application.

[22] "For a new, high-technology firm, the primary assets are the knowledge and skills of the founders. Any competitive advantage the new firm achieves is likely to be based upon what the founders can do better than others" (Cooper and Bruno, 1977, p. 21. See also Feeser and Willard, 1990, p. 88).

[23] Previous empirical studies support the view that there is a positive relation between the human capital of individuals and their wealth. For instance, Åstebro and Bernhardt (1999) while examining 986 US start-ups, show that with all else equal, the household income of entrepreneurs is positively related to their educational attainments and years of work experience (see also Xu, 1998).

Veugelers, 1991) and the results of previous empirical studies (Hernan et al., 2003; Belderbos et al., 2004) suggest a negative coefficient for this variable, as the returns from a cooperative strategy increase with the extent of technological spillovers.

Then we created a proxy for industry competition. RITA NTBFs' owner-managers were asked to assess the extent, on a Likert scale from one to six, of price competition in their industry. *Competition* measures the normalized industry average of these ratings; a higher value of this variable indicates a more competitive industry. There are different views in the extant literature about the effect of competition on the likelihood of alliance formation. On the one hand, firms facing fierce competition are in a vulnerable strategic position; hence they may be forced to join forces with other firms so as to share risks and costs and increase their market power. On the other hand, internalization of technological spillovers through alliances is more effective if there are less firms and less competitive pressures in the industry. Empirical results also are not unanimous. For instance, Eisenhardt and Schoonhoven (1996) highlight that the likelihood of alliance formation of semiconductor start-ups increases with the number of competitors, while an opposite effect on the establishment of EURJVs is found by Hernan et al. (2003). So we leave to the empirics the determination of the sign of this variable.

In industries with strong technological opportunities and rapid technological developments, firms are induced to form alliances so as to monitor different technological trajectories and speed up the commercialization of innovative technologies. As a proxy of the extent of technological opportunities in an industry, following Belderbos et al. (2004) we resorted to the ratio of the number of RITA firms that reported that they had introduced radically innovative products and services in comparison with the offer of the industry to the total number of RITA firms that operate in the industry (*TechOpportunities*). We predict a positive coefficient for this variable.

Lastly, we considered a proxy for industry uncertainty. For this purpose, we resorted to the database on European initial public offerings (IPO) that was jointly developed by Politecnico di Milano and Tilburg University. This database includes data on 482 IPOs that occurred between 1996 and 2001 in five European new stock markets (Neuer Markt, Nuovo Mercato, Nouveau Marchè, Euro NM, Nmax).[24] *Uncertainty* measures the industry average of the normalized standard error of the market price of newly listed firms in the 50 days following the IPO. The aim of this variable is to capture incentives to form alliances for risk sharing purposes.

Of course, there may be other industry-specific characteristics that influence alliance formation by NTBFs. To check for the robustness of the empirical results the above mentioned industry-specific variables were replaced by five sectoral dummies: *DInternet*, *DSoftware*, *DMultiContent*, *DICTManufacturing*, *DBiotech*, equal to one for firms in the Internet and TLC services, Software, Multimedia content, ICT manufacturing and Biotechnologies, pharmaceutics and advanced materials industries, respectively. So the baseline of these estimates is the Robotics and automation industry.

A final remark is in order. Previous studies suggest that the inclination of firms to form an alliance may depend on past alliance experience. This may reflect the existence of a fixed cost associated with alliance formation which makes establishment of subsequent alliances less costly once the first alliance has been formed. It may also reflect alliance-specific learning effects or the enlargement of a firm's network of business relations that follows the establishment of alliances (Gulati, 1995; Ahuja, 2000; Chung et al., 2000). In accordance with these arguments, Hernan et al. (2003) show that the likelihood of a firm joining a EURJV significantly increases with the cumulated number of prior participations in these collaborative ventures. Therefore, in the EURJV model we introduced in the set of explanatory variables the number of prior EURJVs in which a NTBF was involved ($NEURJV_t$). In order to check whether there is an inverted U-shaped relation between this variable and the likelihood of formation of subsequent EURJVs as is claimed by the social capital literature, we also introduced into the model its squared value ($SqNEURJV_t$).

Table 5 illustrates descriptive statistics relating to the explanatory variables included in the models.

6. Results of the econometric analysis

The results of the econometric analysis are illustrated in Tables 6–8. In Table 6 we present the estimates of the survival data analysis model of the hazard rate of the first alliance. Table 7 reports the estimates of the competing risks model aimed at disentangling the effects of the covariates according to the type of alliance initially formed by NTBFs. We distinguish commercial

[24] Data on IPOs have been collected primarily through IPO brochures and companies' web sites, while data on market prices have been obtained from the Datastream database and the web sites of the above mentioned new markets. For further details, see Giudici and Roosenboom (2002).

Table 5
Descriptive statistics of the explanatory variables of the econometric models

Variable	Number of observations	Mean	S.D.	Minimum	Maximum
$NEURJV_t$	4140	0.165	1.129	0.000	18.000
$SqNEURJV_t$	4140	1.301	14.432	0.000	324.000
Age_t	4140	8.303	5.582	1.000	24.000
$LSize_t$	3468	1.927	1.179	0.000	6.452
$SqLSize_t$	3468	5.103	5.422	0.000	41.629
$NPatents_t$	4140	0.022	0.235	0.000	9.000
DASU	4140	0.090	0.286	0.000	1.000
$DSVC_t$	4140	0.027	0.162	0.000	1.000
$DCVC_t$	4140	0.045	0.207	0.000	1.000
$DPublicSubsidy_t$	4140	0.210	0.408	0.000	1.000
NFounders	4140	2.717	1.744	1.000	21.000
Education	4140	15.022	2.675	0.000	22.500
SpecWorkExp	4140	4.109	6.146	0.000	35.500
OthWorkExp	4140	7.401	7.994	0.000	49.000
DManager	4140	0.249	0.433	0.000	1.000
Appropriability	4140	3.587	0.271	3.298	4.683
Competition	4140	0.001	0.206	-0.683	0.445
TechOpportunities	4140	0.558	0.087	0.200	0.700
Uncertainty	4140	0.034	0.003	0.000	0.039

alliances from alliances relating exclusively to technological activities. Lastly, in Table 8 we present the findings relating to the panel data probit model of the establishment of EURJVs.

Let us first focus attention on the first alliance established by high-tech start-ups (see Table 6). Firm size is found to significantly influence the hazard rate; the null hypothesis that the coefficients of $LSize_t$ and $SqLSize_t$ be jointly equal to null in models 1 and 3 is rejected at conventional confidence levels by a Wald χ^2 test ($\chi^2(2) = 6.54$ and 7.19, respectively). The relation between firm size and the hazard rate of alliance formation indeed is inverse U-shaped, with $LSize_t$ and $SqLSize_t$ exhibiting a positive coefficient and a negative one, respectively. The coefficient of $NPatents_t$ is positive and significant at conventional confidence levels in all the models of Table 6. In models 2 and 4 we introduced the interactive term $NPatents_t \times LSize_t$; its coefficient is negative and (weakly) significant. The joint effects of firm size and patent activity on the hazard rate of the first alliance of sample NTBFs are illustrated in Fig. 2. The figure shows that for firms that were granted no patent, the relation between firm size and the multiplier of the hazard rate is inverted U-shaped. That is, the hazard rate first increases with firm size up to a size corresponding to about nine employees and then it decreases when firm size grows larger. Note also that when firm size is greater than 85 employees the multiplier of the hazard rate becomes smaller than unity, indicating a negative effect on the likelihood of alliance formation. The figure also shows the relation between firm size and the multiplier of the hazard rate when $NPatents_t$ equals 1. In this case, when firm size is relatively small the multiplier of the hazard rate is much greater than unity and it also is greater than the value obtained when $NPatents_t = 0$. Again the hazard rate initially increases with firm size. However, the peak occurs much earlier (i.e. when firm size is less than two employees) and then the hazard rate declines quite abruptly, becoming less than unity for a size greater than 83 employees. When $NPatents_t$ equals 2 or has a greater value, the multiplier of the hazard rate decreases monotonically with firm size (for the sake of synthesis, these curves are not shown in Fig. 2).

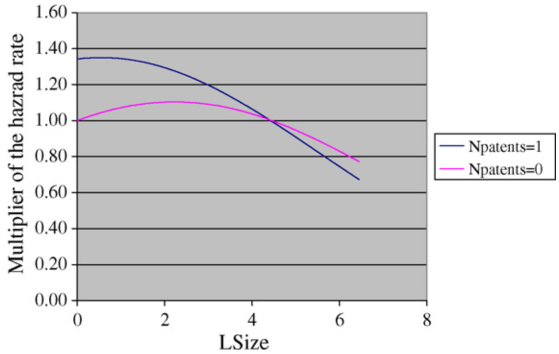

Fig. 2. Effect of firm size and patent activity on the hazard rate of the first alliance.

Table 6
The determinants of firms' first alliance: Cox proportional hazards model

	Model 1	Model 2	Model 3	Model 4
a_1 *LSize$_t$*	0.096 (0.044)**	0.089 (0.043)**	0.100 (0.045)**	0.093 (0.044)**
a_2 *SqLSize$_t$*	−0.021 (0.009)**	−0.020 (0.008)**	−0.023 (0.009)***	−0.021 (0.009)**
a_3 *NPatents$_t$*	0.042 (0.020)**	0.294 (0.140)**	0.055 (0.019)***	0.300 (0.132)**
a_4 *NPatents$_t$ × LSize$_t$*	–	−0.067 (0.036)*	–	−0.065 (0.034)*
a_5 *DASU*	0.432 (0.184)**	0.421 (0.184)**	0.446 (0.190)**	0.436 (0.190)**
a_6 *DSVC$_t$*	0.120 (0.066)*	0.125 (0.066)*	0.113 (0.065)*	0.118 (0.066)*
a_7 *DCVC$_t$*	0.074 (0.037)**	0.075 (0.036)**	0.065 (0.036)*	0.065 (0.036)*
a_8 *DPublicSubsidy$_t$*	−0.003 (0.030)	−0.010 (0.031)	0.011 (0.029)	0.004 (0.030)
a_9 *NFounders*	0.003 (0.029)	0.003 (0.029)	0.009 (0.034)	0.010 (0.034)
a_{10} *Education*	0.024 (0.026)	0.024 (0.026)	0.035 (0.025)	0.034 (0.025)
a_{11} *SpecWorkExp*	−0.008 (0.014)	−0.009 (0.013)	−0.005 (0.014)	−0.006 (0.014)
a_{12} *OthWorkExp*	0.001 (0.009)	0.001 (0.009)	0.005 (0.009)	0.005 (0.009)
a_{13} *DManager*	0.219 (0.150)	0.216 (0.150)	0.188 (0.153)	0.186 (0.153)
a_{14} *Appropriability*	−0.565 (0.252)**	−0.577 (0.252)**	–	–
a_{15} *Competition*	−1.075 (0.379)***	−1.081 (0.377)***	–	–
a_{16} *TechOpportunities*	1.612 (0.879)*	1.649 (0.873)*	–	–
a_{17} *Uncertainty*	13.979 (19.806)	14.094 (19.758)	–	–
a_{18} *DInternet*	–	–	0.928 (0.316)***	0.933 (0.319)***
a_{19} *DSoftware*	–	–	0.705 (0.317)**	0.713 (0.319)**
a_{20} *DMultiContent*	–	–	1.211 (0.363)***	1.222 (0.365)***
a_{21} *DICTmanufacturing*	–	–	0.403 (0.334)	0.398 (0.336)
a_{22} *DBiotech*	–	–	0.406 (0.418)	0.390 (0.423)
log-Likelihood	−1072.290	−1071.428	−1071.692	−1070.882
Pseudo R^2	0.09	0.10	0.10	0.10
Wald χ^2 test	56.64 (16)***	60.91 (17)***	57.39 (17)***	63.03 (18)***
Wald χ^2 tests on groups of explanatory variables				
Size: $a_1 = a_2 = 0$	6.54 (2)**	5.59 (2)*	7.19 (2)**	6.15 (2)**
Patents: $a_3 = a_4 = 0$	–	6.35 (2)**	–	9.23 (2)***
Human capital: $a_9 = a_{10} = a_{11} = a_{12} = a_{13} = 0$	3.87 (5)	3.91 (5)	5.09 (5)	5.14 (5)
Industry variables: $a_{14} = a_{15} = a_{16} = a_{17} = 0$	16.88 (4)***	17.62 (4)***	–	–
Industry dummies: $a_{18} = a_{19} = a_{20} = a_{21} = a_{22} = 0$	–	–	18.49 (5)***	18.84 (5)***
Proportional hazards χ^2 test	9.63 (16)	10.04 (17)	10.85 (17)	11.36 (18)
No. of observations	1856	1856	1856	1856
No. of firms	420	420	420	420

*Significance level greater than 90%; **significance level greater than 95%; ***significance level greater than 99%. Robust standard errors and number of restrictions in parentheses. Proportional hazards test based on Grambsch and Therneau (1994), where the null hypothesis is the appropriateness of the proportional hazard assumption. Nagelkerke Pseudo R^2.

Let us now analyze the role of sponsor institutions. We considered support by VC investors, CVC investors and PROs. The econometric findings provide clear evidence that sponsorship plays a key role in making it easier for NTBFs to form alliances. *DSVC$_t$*, *DCVC$_t$* and *DASU* have positive, statistically significant coefficients in all models, even though the magnitude of their effects does differ. For instance, relying on the estimates of model 2, ASUs exhibit a 52% higher hazard rate than non-sponsored firms.[25] The percentage increase of the hazard rate is much smaller for VC-backed and CVC-backed firms (13.3% and 7.8%, respectively).

Further insights into the determinants of alliance formation can be obtained from the estimates of the competing risks model that are illustrated in Table 7. Here we distinguish commercial alliances from alliances that exclusively have a technological component. The most interesting result is that the effects of the explanatory variables are found to clearly differ according to the type of alliance under consideration. First of all, the joint effect of firm size and patent activity that was described above perfectly applies to commercial alliances. In the technological alliance equation, the coefficients of the size and patent terms have the same

[25] The percentage is obtained from: $100[\exp(a) - 1]$, where a is the estimated parameter.

Table 7
The determinants of firms' first alliance distinguishing between types of alliance: Cox proportional hazards competing risks model

	Model 1		Model 2	
	Commercial alliance	Technological alliance	Commercial alliance	Technological alliance
a_1 $LSize_t$	0.132 (0.057)**	0.037 (0.086)	0.124 (0.056)**	0.028 (0.085)
a_2 $SqLSize_t$	−0.031 (0.013)**	−0.007 (0.016)	−0.029 (0.013)**	−0.005 (0.015)
a_3 $NPatents_t$	0.052 (0.024)**	0.035 (0.032)	0.290 (0.172)*	0.516 (0.487)
a_4 $NPatents_t \times LSize_t$	–	–	−0.062 (0.045)	−0.138 (0.152)
a_5 $DASU$	0.094 (0.250)	1.110 (0.284)***	0.080 (0.250)	1.104 (0.285)***
a_6 $DSVC_t$	0.138 (0.077)*	0.129 (0.120)	0.142 (0.076)*	0.136 (0.125)
a_7 $DCVC_t$	−0.009 (0.089)	0.137 (0.044)***	−0.007 (0.088)	0.136 (0.044)***
a_8 $DPublicSubsidy_t$	0.005 (0.034)	−0.012 (0.054)	−0.001 (0.035)	−0.021 (0.056)
a_9 $NFounders$	0.017 (0.037)	−0.019 (0.056)	0.017 (0.037)	−0.018 (0.055)
a_{10} $Education$	0.042 (0.032)	−0.021 (0.048)	0.042 (0.032)	−0.022 (0.047)
a_{11} $SpecWorkExp$	0.009 (0.016)	−0.055 (0.034)	0.008 (0.016)	−0.057 (0.034)*
a_{12} $OthWorkExp$	0.003 (0.011)	−0.008 (0.018)	0.003 (0.011)	−0.008 (0.017)
a_{13} $DManager$	−0.063 (0.188)	0.875 (0.290)***	−0.067 (0.187)	0.880 (0.292)***
a_{14} $Appropriability$	−1.109 (0.364)***	0.405 (0.433)	−1.125 (0.365)***	0.391 (0.435)
a_{15} $Competition$	−0.933 (0.533)*	−0.962 (0.697)	−0.935 (0.532)*	−0.976 (0.703)
a_{16} $TechOpportunities$	1.657 (1.141)	2.292 (1.471)	1.680 (1.133)	2.373 (1.4729)
a_{17} $Uncertainty$	36.144 (25.142)	−51.447 (44.890)	36.397 (25.130)	−52.165 (44.846)
log-Likelihood	−760.578	−298.778	−760.019	−298.308
Pseudo R^2	0.08	0.09	0.08	0.09
Wald χ^2 test	39.53 (16)***	61.90 (16)***	43.39 (17)***	62.38 (17)***
Wald χ^2 tests on groups of explanatory variables				
Size: $a_1 = a_2 = 0$	5.67 (2)*	0.25 (2)	5.22 (2)*	0.12 (2)
Patents: $a_3 = a_4 = 0$	–	–	8.08 (2)**	2.61 (2)
Human capital: $a_9 = a_{10} = a_{11} = a_{12} = a_{13} = 0$	2.24 (5)	10.06 (5)*	2.18 (5)	10.30 (5)*
Industry variables: $a_{15} = a_{16} = a_{17} = a_{18} = 0$	20.30 (4)	10.88 (4)**	20.89 (4)***	11.05 (4)**
Proportional hazards χ^2 test	17.38 (16)	7.54 (16)	17.70 (17)	7.93 (17)
No. of observations	1856	1856	1856	1856
No. of firms	420	420	420	420

*Significance level greater than 90%; **significance level greater than 95%; ***significance level greater than 99%. Robust standard errors and number of restrictions in parentheses. Proportional hazards test based on Grambsch and Therneau (1994), where the null hypothesis is the appropriateness of the proportional hazard assumption. Nagelkerke Pseudo R^2.

sign as in the commercial alliance equation, but they are insignificant at conventional confidence level.

These differences suggest an interpretation of the results of the estimates in line with the theoretical hypotheses relating to exploitative commercial alliances that have been formulated in Section 3. In fact, small NTBFs in spite of great inducements to team up with other firms due to lack of specialized commercial assets, face serious obstacles engendered by the great transaction costs, including those associated with appropriability hazards, and management costs of alliances. These barriers can be partially overcome if NTBFs are able to signal their quality to uninformed third parties through previous technological accomplishments. Patents indeed perform this signaling role. They also make a NTBF more attractive to would-be alliance partners that possess specialized commercial assets because of the synergistic gains that can be obtained when these assets are utilized in conjunction with the innovation output of the focal NTBF, allowing its successful commercial exploitation. When the size of NTBFs increases, the inducement effect generated by lack of specialized commercial assets progressively disappears; therefore, the enabling effect of patents becomes less important. Accordingly, the hazard rate of the first commercial alliance decreases with the size of NTBFs, independently of their technological achievements.

To sum up, our estimates are consistent with Teece's (1986) original intuition that exploitative commercial alliances are motivated by the economic value that is created if NTBFs and their partners exchange access to their respective irreproducible specialized complementary assets. Nonetheless, as was also claimed by Teece (1986), they suggest that transactions costs may

Table 8
The determinants of firms' participation in EU funded research joint ventures: a panel data probit model

	Model 1	Model 2
a_0 *Constant*	−3.467 (2.233)	−3.468 (2.230)
a_1 $NEURJV_t$	0.313 (0.109)***	0.313 (0.109)***
a_2 $SqNEURJV_t$	−0.020 (0.007)***	−0.020 (0.007)***
a_3 Age_t	−0.005 (0.019)	−0.005 (0.019)
a_4 $LSize_t$	0.310 (0.099)***	0.313 (0.099)***
a_5 $NPatents_t$	0.029 (0.148)	0.238 (0.506)
a_6 $NPatents_t \times LSize_t$	–	−0.069 (0.093)
a_7 *DASU*	0.743 (0.272)***	0.741 (0.271)***
a_8 $DSVC_t$	0.190 (0.364)	0.208 (0.361)
a_9 $DCVC_t$	0.096 (0.320)	0.084 (0.320)
a_{10} $DPublicSubsidy_t$	0.233 (0.176)	0.237 (0.176)
a_{11} *NFounders*	−0.029 (0.058)	−0.030 (0.058)
a_{12} *Education*	0.060 (0.042)	0.060 (0.042)
a_{13} *SpecWorkExp*	0.005 (0.020)	0.005 (0.020)
a_{14} *OthWorkExp*	−0.011 (0.015)	−0.011 (0.015)
a_{15} *DManager*	−0.251 (0.249)	−0.255 (0.249)
a_{16} *Appropriability*	0.090 (0.369)	0.086 (0.368)
a_{17} *Competition*	−0.981 (0.562)*	−0.955 (0.561)*
a_{18} *TechOpportunities*	−0.493 (1.085)	−0.494 (1.079)
a_{19} *Uncertainty*	−30.467 (32.989)	−29.492 (33.025)
ρ	0.293 (0.116)	0.291 (0.115)
log-Likelihood	−206.60	−206.34
Pseudo R^2	0.12	0.12
Wald χ^2 test	76.48 (18)***	77.12 (19)***
Wald χ^2 tests on groups of explanatory variables		
Number of EURJVs: $a_1 = a_2 = 0$	8.16 (2)**	8.32 (2)**
Patents: $a_5 = a_6 = 0$	–	1.10 (2)
Human capital: $a_{11} = a_{12} = a_{13} = a_{14} = a_{15} = 0$	4.18 (5)	4.15 (5)
Industry variables: $a_{16} = a_{17} = a_{18} = a_{19} = 0$	6.71 (4)	6.32 (4)
No. of observations	3468	3468
No. of firms	522	522

*Significance level greater than 90%; **significance level greater than 95%; ***significance level greater than 99%. Robust standard errors and number of restrictions in parentheses.

prevent NTBFs, especially those of smaller size and more uncertain quality, from establishing otherwise beneficial commercial alliances. The above arguments are less pertinent to explorative technological alliances. So the limited explanatory power of the hazard rate of the first technological alliance exhibited by the size and patent variables does not come unexpected.

Let us now consider the effects of sponsorship. Again our expectations that these effects are contingent on both the identity of the sponsor and the type of alliance are confirmed by the estimates. In accordance with Hypothesis 3A, $DSVC_t$ has a positive statistically significant coefficient in the commercial alliance equation of both models 1 and 2. Based on these latter estimates, the hazard rate of VC-backed firms is 15.2% higher that the one of their non VC-backed counterparts. Conversely, the coefficient of this variable though positive, is not significant in the technological alliance equation, due to a much greater standard error. This possibly reflects the different value across alliance types of the broker information function performed by VC investors to the advantage of sponsored NTBFs. It may also be a consequence of the greater appropriability hazards that VC sponsorship generates for candidate alliance partners of technological alliances.

As to $DCVC_t$ and *DASU*, we obtain opposed results. These variables exhibit positive statistically significant coefficients in the technological equation of both models 1 and 2 as was predicted by Hypotheses 3B and 3C, while their effect on the hazard rate of the first commercial alliance is negligible. According to the estimates of model 2, CVC-backing increases the hazard rate of the first technological alliance by 14.7%. The positive effect of *DASU* is much greater: ASUs have a three times greater hazard rate than non sponsored NTBFs.[26] This latter finding suggests that the social contacts of research organizations in the scientific and technological community and the certification effect of the technological competencies of sponsored NTBFs that their endorsement provides substantially reduce the transaction costs in which ASUs incur in forming technological alliances; thus they facilitate their establishment. These effects are absent in commercial alliances. Results relating to CVC also are extremely interesting. As to commercial alliances, the negligible effect of CVC-backing may be traced to the fact that the signal to third parties of the commercial value of the innovative technologies developed by sponsored NTBFs and the access to an external network of social contacts are not as effective as those provided by VC-backing. Alternatively, the allegedly positive effects of CVC-backing are balanced by opposed effects that may arise from the exclusive nature of the relation with the sponsor, the substitution between the specialized commercial assets it possesses and those that could be provided by alliance partners, and the conflict between the strategic objectives of the CVC investor and its portfolio firms. Conversely, CVC-backing has a positive impact on the hazard rate of the first technological alliance of NTBFs. Technological alliances are more coherent than commercial ones with the strategic "technology window" objectives pursued by CVC investors; so these latter may actively encourage sponsored NTBFs to form this type of alliance, both with them and third parties. Our estimates suggest that this effect dominates any negative influence that is possibly associated with the greater appropriability hazards perceived by would-be alliance partners of NTBFs due to the strong ties of these latter firms with their CVC investors.[27]

Let us now consider the results relating to control variables. $DPublicSubsidy_t$ has a weak negative effect on alliance formation. Therefore, our findings do not support the view that public subsidies have a certification effect of the quality of NTBFs. Nonetheless, this variable does not distinguish subsidies according to the nature and the objective of the supporting program. In fact, it includes both subsidies to R&D and other supporting measures. Moreover, it includes automatic measures and programs that rely on competitive evaluation of firms' projects. So it is fair to recognize that in order to have a better understanding of whether and when public subsidies favor alliance formation, a more thorough analysis is in order.

Most of founder-specific control variables are not statistically significant at conventional confidence levels in the estimates of both Tables 6 and 7, with the exception of *DManager* that has a positive statistically significant coefficient in the technological alliance equation of the competing risks models. So the human capital of founders seems to have a minor effect on the likelihood of NTBFs establishing alliances with other organizations. The reason may be that human capital variables reflect different factors (i.e. the distinctive capabilities of NTBFs, the network of business relations on which they rely, the extent of internal financial resources) that are likely to have divergent effects on alliance formation.

In models 1 and 3 of Table 6 we consider several industry-specific variables. As is shown at the bottom of Table 6, the null hypothesis that the coefficients of these variables be jointly equal to null is rejected by a Wald χ^2 test at 99%. Results generally are in line with those of previous studies mentioned in Section 5. In particular, the likelihood of alliance formation by NTBFs is greater in industries with greater technological spillovers, a higher rate of technological development, and greater uncertainty. Conversely, cut-throat competition negatively influences the establishment of alliances. Results of the estimates of the competing risks model in Table 7 are similar, with the exception of the positive, though insignificant coefficient of *Appropriability* in the technological alliance equation. In models 3 and 4 of Table 6 the above mentioned industry-specific variables are replaced by industry dummies. Again these dummies are shown by a Wald χ^2 test to be jointly significant at 99%. The remaining results are almost unchanged. It is also interesting to note that all service industries (i.e. Software, Internet and TLC services, and Multimedia content) exhibit a higher probability of alliance formation than manufacturing industries. This result confirms those of previous studies as to the key role of alliances for high-tech service firms.

The Cox proportional hazards model does not allow to analyze the dependency on duration of the hazard rate of alliance formation. For this purpose, we resorted to a Weibull specification and rerun all the regressions of Tables 6 and 7. The estimates, that are reported in Appendix A, indicate that the *p* parameter of the Weibull

[26] This might also be the result of an intrinsic greater propensity of ASU founders towards exploration oriented research alliances.

[27] CVC financing may be contextual with the establishment of an alliance between the sponsored NTBF and the corporate investor. As $DCVC_t$ is lagged one period in models 1 and 2, this may downward bias the estimates. Therefore, we replaced $DCVC_t$ with a dummy that equals unity for firms that have obtained CVC financing up to year *t*. Results were unchanged (they are available from the authors upon request). Unfortunately, we do not know the identity of the alliance partners of NTBFs. So we cannot distinguish alliances with the CVC investor from those that involve other firms.

specification is not significantly different from unity: in other words, the hazard rate seems not to be influenced by the age of firms. As a corollary, the age dependence highlighted by Fig. 1 is to be attributed to the influence exerted on the hazard rate by time varying covariates. The effects of the other variables are largely in line with those presented in Tables 6 and 7.

Let us now analyze the estimates of the panel data probit model relating to EURJVs (see Table 8). As was mentioned earlier, this type of alliance can be regarded as a rather accurate proxy of explorative technological alliances. The results of the estimates confirm the peculiarity of EURJVs. First, the number of patents NTBFs have been granted has a positive, but insignificant influence on the likelihood of formation of these alliances. The coefficient of the interactive term $NPatents_t \times LSize_t$ also is insignificant, though negative as was expected. Therefore, as regards explorative technological alliances the evidence in support of Hypotheses 2A and 2B is rather weak. Second, the size of NTBFs has a positive coefficient, significant at 99%: the larger firm size, the greater the likelihood of establishing EURJVs, with all else equal.[28] This evidence is in accordance with Hypothesis 1B and points to the great transaction and management costs that are involved in this type of alliance. It also is in line with the contention that possession of specialized commercial assets does not play any role in the establishment of explorative technological alliances. Third, in accordance with the empirical results provided by previous studies in the social capital stream (see for instance Ahuja, 2000), we found that there is an inverted U-shaped relation between the likelihood of formation of EURJVs and firms' past EURJV experience. In fact, $NEURJV_t$ exhibits a positive coefficient, while its squared term ($SqNEURJV_t$) has a negative coefficient; both coefficients are significant at 99%. In other words, the likelihood of a NTBF forming an EURJV in a given year first increases with firm's past alliance experience up to a threshold level. This result can be regarded as further evidence of the relevance of transaction costs in hindering the formation of this type of alliance by NTBFs. It may also reflect the existence of alliance-specific learning by doing effects. Then, after a threshold corresponding to around eight alliances is reached, the likelihood of establishing an additional EURJV declines with a further increase of the number of previous EURJVs, possibly as a consequence of managerial diseconomies.

Let us now consider the effect of sponsorship. While all the three dummy variables that capture sponsorship have a positive coefficient, only *DASU* is significant (at 99%). This result confirms Hypothesis 3C. It can be interpreted as an indication that the support provided by PROs to the start-ups founded by their academic personnel consistently reduces the transaction costs of the formation of explorative technological alliances. Conversely, neither VC-backing nor CVC-backing have a similarly positive influence. This latter finding contradicts Hypothesis 3B. It suggests that as opposed forces are associated with CVC-backing, their balance possibly depends on the specific nature of the alliance under consideration.

As to control variables, they are found to have negligible effects on the formation of EURJVs. This also applies to industry-specific characteristics, with the exception of *Competition* which has a negative, weakly significant coefficient. These results may be a consequence of the nature of these alliances. They relate to basic research and pre-competitive technological development; these activities are far from the commercialization stage and they inherently involve large technological spillovers, independently of the specific industry in which alliance partners operate. Accordingly, the nature of the appropriability regime and other characteristics of the business environment in which NTBFs operate play a minor role.

7. Concluding remarks

The aim of this paper was to analyze empirically the determinants of alliance formation of high-tech start-ups through the estimates of several econometric models. Particular attention was devoted to highlight the effects of firm size, prior innovation output measured by patent activity, and support from sponsor institutions on the likelihood of formation of exploitative commercial alliances and explorative technological alliances. For this purpose, we have taken advantage of a 10-year long longitudinal dataset relating to a large and heterogeneous sample composed of Italian NTBFs that operate in high-tech sectors both in manufacturing and services.

The results of the econometric estimates provide evidence supporting Teece's (1986) intuition that underlies the "combination of specialized complementary assets" model of alliance formation. In fact, they are consistent with the view that the economic value that is created when the innovative technological knowledge developed by NTBFs is used in conjunction with the

[28] We also tried a quadratic specification for firm size. Both $LSize_t$ and $SqLSize_t$ have positive, though insignificant coefficients, due to collinearity problems. Accordingly, the null hypothesis that their coefficients be jointly equal to null is rejected by a Wald χ^2 test at 99%.

specialized commercial assets possessed by candidate alliance partners is a key driver of the formation of *exploitative commercial alliances*. Indeed this argument helps explain the lower propensity of larger NTBFs that are more likely to possess those commercial assets, to form this type of alliance. Moreover, this argument also suggests that patent holding NTBFs that have developed ready-to-use proprietary technological knowledge are considered more attractive as alliance partner than firms that were granted no patents. In accordance with the results of most previous studies (Gans et al., 2002; Rothaermel, 2002; Rothaermel and Deeds, 2004; Hsu, 2006), we indeed found that the former NTBFs are more likely to be involved in exploitative commercial alliances than the latter ones. Nonetheless, the propensity towards this type of alliance of patent holding NTBFs turned out to rapidly decrease with firm size. Again if NTBFs' size is sufficient to make a go-it-alone commercialization strategy viable, inducements to exploitative commercial alliances vanish (see Ahuja, 2000 for similar results). The case study evidence illustrated by Teece (1986) helps highlight the implications of our results for the performance of NTBFs. The EMI's CAT scanner case clearly documents that absent control of specialized commercial assets, a go-it-alone commercialization strategy is very dangerous for an innovative firm, even if it has developed a major innovation. Conversely, the Searle's Nutrasweet case indicates that if the protection regime of technological knowledge is tight (see below), a small innovative firm can effectively resort to commercial exploitative alliances to get access to the specialized production, sales and distribution assets that are necessary for commercial exploitation of its technology. Hence, effective use of this type of alliance may have a major positive influence on the performance of small innovative NTBFs.

On the contrary, our findings seem to indicate that the lack of specialized commercial assets from which smaller NTBFs often suffer generates no inducement towards the establishment of *explorative technological alliances*. So they cast doubts on whether the "combination of specialized complementary assets" model has any explanatory power of the formation of this type of alliance.

In addition, the larger positive effect that the number of patents has on the probability to form commercial alliances of relatively smaller NTBFs and the fact that for very small firms that were not granted any patent, this probability increases with firm size are consistent with another important intuition originally set forth by Teece (1986, p. 294). Potentially beneficial alliances are not formed by NTBFs because of the high transaction costs inherent in alliance formation. In fact, in the search for alliance partners NTBFs encounter similar adverse selection problems to those that hinder external financing. Their deficiency of social capital is likely to make these problems even more acute. Therefore, it is very difficult for these firms to find an alliance partner unless they are able to signal to uninformed third parties the quality of their technological achievements. Moreover, alliances involve appropriability hazards that may be very detrimental to NTBFs, as technological knowledge generally is the main, if not the unique asset of these firms and so it is the key source of their competitive advantage (Gans and Stern, 2003).

Actually, the above mentioned transaction costs are common to both exploitative and explorative alliances. So they also help explain why the likelihood of formation of EURJVs that can be regarded as a fairly good approximation of explorative technological alliances, monotonically increases with the size of NTBFs. In fact, partner search, negotiation and other contractual and administrative costs are especially high for this type of alliance; so they are likely to discourage most small NTBFs.

Teece (1986) argues that large incumbent high-tech firms are better positioned than their smaller and younger peers to deal with the transaction costs inherent in alliances. As the successful introduction in the early 1980s of the IBM PC clearly shows (see Teece, 1986, p. 299), these firms can use their brand, reputation, and other specialized complementary assets to convince third parties to join forces with them, thus further enlarging the set of specialized complementary assets on which they can rely. In addition, threat of retaliation mitigates the appropriability hazards that large partners experience while teaming up with other firms.

Nonetheless, NTBFs can reduce the transaction costs of alliance formation including those generated by appropriability hazards, if they manage to get support from a "sponsor" (Stuart et al., 1999; Gans et al., 2002; Gans and Stern, 2003; Hsu, 2006). Sponsors include VC and CVC investors. They also include other institutions that may have weaker ties to sponsored NTBFs: an interesting example is provided by the support increasingly offered by PROs to the start-ups founded by their academic personnel. Sponsors may perform a valuable broker information and endorsement function to the benefit of sponsored NTBFs; they may also provide a shield against opportunistic behavior on the part of NTBFs' alliance partners. However, it is fair to recognize that under certain circumstances, sponsorship may be counterproductive to alliance formation by NTBFs (Dushnitsky and Lavie, 2005). In fact, sponsors may demand for an exclusive relation with the sponsored firm or their support may be substitutive of the specialized commercial assets of alliance partners. Sponsorship may also increase the appropriability hazards perceived by candidate alliance partners of NTBFs, especially in explorative technological alliances. Therefore, we claim that the value of sponsorship crucially depends on both the identity of the sponsor and the type of alliance. Our econometric results clearly support this view. While VC-backing is found to have a positive effect on the likelihood of formation of the first commercial alliance, support by CVC investors and PROs does not affect this type of alliance. Conversely, these two latter types of sponsorship have a positive influence on the formation of technological alliances. In particular, PRO's direct and indirect support turns out to play a crucial role in reducing the barriers that NTBFs encounter in establishing EURJVs.

We think that this study considerably extends our understanding of the determinants of the alliances of NTBFs. However, we also are aware that it suffers from several limitations. The most serious one probably is the lack of data relating to the number and the type of alliances concluded by NTBFs over time, with the exception of EURJVs. First, this makes it impossible to distinguish NTBFs according to the *extent* of use of alliances. Second, we were forced to focus attention on the first alliance in which NTBFs were involved (with the exception of EURJVs). Actually, the determinants of the first alliance may well differ from those of subsequent alliances. For instance, as far as NTBFs develop an autonomous network of business relations and benefit from endorsement from reputable alliance partners the role of sponsors may become less important. Third, again with the exception of EURJVs, we had no precise indication as to the motives of the alliances formed by sample firms. We could only distinguish commercial alliances from alliances that exclusively have a technological component. While commercial alliances mainly have exploitative motives, the motives of technological alliances are likely to be quite heterogeneous. Moreover, we had no information on other interesting characteristics of the alliances established by sample NTBFs, such as the identity of the partners and the governance structure. Absence of this information may help justify the relatively low amount of total variance explained by some models. More importantly, in addition to EURJVs there are other alliance types that merit special attention. An increasingly popular category is given by (out)licenses, which allow NTBFs to profit from innovations without having to bother about access to the specialized commercial assets possessed by partner firms (even though these assets clearly influence the establishment and the contractual terms of the license, as was mentioned in footnote 1). More generally, in the very spirit of Teece's (1986) work, it would be interesting to compare how effectively the technological knowledge possessed by NTBFs can be combined with the specialized complementary assets possessed by other firms through the use of different institutional mechanisms, including different types of alliances and mergers and acquisitions. In this perspective, one may extend the conceptual framework proposed by Gans and Stern (2003) to the analysis of the environmental (e.g. appropriability regime) and firm-specific factors that influence the relative efficiency of the above mentioned non-market arrangements.

A second important limitation regards the sponsorship variables. We considered here three categories of sponsors, VC investors, CVC investors, and PROs. Actually, within each category, sponsors are likely to differ as to crucial factors such as their experience, reputation and the extent of their network of social contacts.

A third limitation arises from the fact that we were not able to measure the specialized assets possessed by firms. Accordingly, we used firm size as a proxy of control of specialized commercial assets, as is common in the alliance literature (e.g. see Ahuja, 2000). Moreover, we deduced the complementary or substitutive nature of the specialized assets possessed by sponsors and candidate alliance partners of NTBFs on the basis of the identity of the sponsor and the type of alliance under consideration. Of course, a more direct assessment of the explanatory power of the "combination of specialized complementary assets" model of alliance formation would require the development of more accurate indicators of the assets possessed by firms.

Fourth, we took advantage here of quite unique longitudinal data relating to a large cross-industry sample of Italian NTBFs. In spite of the merits of this dataset, the issue of the generalizability of the results illustrated in this paper clearly arises. For instance, our results might be influenced by the specific institutional setting in which Italian NTBFs may be embedded. Similarly, the 10-year period under consideration might exhibit specific characteristics relating to such aspects as the policy of research organizations towards ASUs or the munificence of VC and CVC investors. Therefore, these results wait for further corroboration from replications of this study in different countries and time periods.

Another interesting issue that has not been covered in the present study relates to the dynamic relations between different types of alliances. In fact, the establishment of explorative technological alliances may be instrumental to the creation of new technological competencies by NTBFs. In order to be exploited commercially, this technological knowledge needs to be combined with specialized commercial assets that may be controlled by other firms. In turn, this increases the likelihood of NTBFs forming exploitative commercial alliances (for a similar reasoning see Rothaermel and Deeds, 2004).

The limitations that have been mentioned above open up interesting avenues for future research. Nonetheless, in spite of these limitations, the results of this study provide an interesting contribution to the scientific debate on NTBFs and alliances originated by Teece's (1986) work. We also think that they have important implications for both NTBF managers and policy makers.

Managers of NTBFs generally are aware of the tangible direct benefits of support from a sponsor. These benefits include financing and access to specialized services. We have shown here that under certain circumstances, sponsorship also provides an indirect intangible benefit in so far as it facilitates alliance formation. Nonetheless, this latter benefit is contingent on the identity of the sponsor and the type of alliance in which the focal NTBF is mostly interested. It follows that in the early years of the life of a NTBF, the choice of the right sponsor may be an even more challenging decision for NTBF's managers than the choice of alliance partners. In any case, these two choices need not to be considered in isolation (see also Dushnitsky and Lavie, 2005).

As to policy makers, our estimates suggest that public subsidies to Italian NTBFs failed to have any certification effect. Evidence on this issue is controversial (Lerner, 1999; Gans et al., 2002; Hsu, 2006). More generally, there is no robust evidence that direct subsidies to NTBFs are beneficial (see for instance

Table A1
The determinants of firms' first alliance: a survival data analysis model (Weibull specification)

	Model 1	Model 2	Model 3	Model 4
a_0 *Constant*	−3.581 (1.729)**	−3.583 (1.730)**	−4.134 (0.585)***	−4.132 (0.585)***
a_1 $LSize_t$	0.358 (0.199)*	0.353 (0.200)*	0.324 (0.194)*	0.321 (0.195)*
a_2 $SqLSize_t$	−0.151 (0.061)**	−0.149 (0.061)**	−0.147 (0.059)**	−0.145 (0.059)**
a_3 $NPatents_t$	0.549 (0.272)**	0.813 (0.816)	0.722 (0.268)***	0.888 (0.872)
a_4 $NPatents_t \times LSize_t$	–	−0.076 (0.221)	–	−0.048 (0.236)
a_5 *DASU*	0.569 (0.209)***	0.567 (0.209)***	0.590 (0.219)***	0.589 (0.219)***
a_6 $DSVC_t$	0.949 (0.312)***	0.948 (0.312)***	0.947 (0.345)***	0.946 (0.345)***
a_7 $DCVC_t$	0.168 (0.362)	0.171 (0.362)	0.077 (0.347)	0.078 (0.347)
a_8 $DPublicSubsidy_t$	−0.395 (0.238)*	−0.397 (0.237)	−0.241 (0.233)	−0.243 (0.233)
a_9 *NFounders*	0.032 (0.032)	0.032 (0.032)	0.036 (0.039)	0.036 (0.039)
a_{10} *Education*	0.039 (0.028)	0.039 (0.028)	0.047 (0.027)*	0.047 (0.027)*
a_{11} *SpecWorkExp*	0.001 (0.015)	−0.001 (0.015)	0.002 (0.016)	0.002 (0.016)
a_{12} *OthWorkExp*	0.005 (0.009)	0.005 (0.009)	0.008 (0.010)	0.008 (0.010)
a_{13} *DManager*	0.187 (0.172)	0.188 (0.172)	0.159 (0.175)	0.160 (0.175)
a_{14} *Appropriability*	−0.651 (0.285)**	−0.651 (0.285)**	–	–
a_{15} *Competition*	−1.319 (0.431)***	−1.320 (0.430)***	–	–
a_{16} *TechOpportunities*	1.730 (0.910)*	1.735 (0.908)*	–	–
a_{17} *Uncertainty*	54.145 (23.874)**	54.274 (23.896)**	–	–
a_{18} *DInternet*	–	–	1.342 (0.336)***	1.343 (0.337)***
a_{19} *DSoftware*	–	–	0.856 (0.338)**	0.856 (0.338)**
a_{20} *DMultiContent*	–	–	1.699 (0.394)***	1.701 (0.394)***
a_{21} *DICTmanufacturing*	–	–	0.468 (0.354)	0.468 (0.354)
a_{22} *DBiotech*	–	–	0.453 (0.473)	0.453 (0.473)
p	0.980 (0.047)	0.984 (0.048)	1.016 (0.049)	1.016 (0.049)
log-Likelihood	−416.606	−416.582	−412.375	−412.366
Pseudo R^2	0.16	0.16	0.17	0.17
Wald χ^2 test	77.67 (16)***	78.54 (17)***	82.05 (17)***	82.04 (18)***
Wald χ^2 tests on groups of explanatory variables				
Size: $a_1 = a_2 = 0$	6.89 (2)**	6.60 (2)**	7.72 (2)**	7.44 (2)
Patents: $a_3 = a_4 = 0$	–	4.13 (2)	–	7.13 (2)**
Human capital: $a_9 = a_{10} = a_{11} = a_{12} = a_{13} = 0$	5.28 (5)	5.30 (5)	6.22 (5)	6.22 (5)
Industry variables: $a_{14} = a_{15} = a_{16} = a_{17} = 0$	27.15 (4)***	27.42 (4)***	–	–
Industry dummies: $a_{18} = a_{19} = a_{20} = a_{21} = a_{22} = 0$	–	–	35.96 (5)***	35.95 (5)***
No. of observations	1856	1856	1856	1856
No. of firms	420	420	420	420

*Significance level greater than 90%; **significance level greater than 95%; ***significance level greater than 99%. Robust standard errors and number of restrictions in parentheses. For p the test is H_0: $p = 1$. Weibull hazard functions. Nagelkerke Pseudo R^2.

Table A2
The determinants of firms' first alliance according to the type of alliance: a competing risks model (Weibull specification)

	Model 1		Model 2	
	Commercial alliance	Technological alliance	Commercial alliance	Technological alliance
a_0 *Constant*	−3.159 (2.244)	−5.332 (3.086)*	−3.159 (2.244)	−5.354 (3.089)*
a_1 $LSize_t$	0.533 (0.248)**	−0.030 (0.370)	0.533 (0.250)**	−0.051 (0.367)
a_2 $SqLSize_t$	−0.178 (0.078)**	−0.092 (0.098)	−0.177 (0.079)**	−0.084 (0.097)
a_3 $NPatents_t$	0.489 (0.348)	0.713 (0.365)*	0.495 (1.300)	1.513 (1.183)
a_4 $NPatents_t \times LSize_t$	–	–	−0.002 (0.337)	−0.226 (0.292)
a_5 *DASU*	0.251 (0.270)	1.140 (0.327)***	0.251 (0.271)	1.129 (0.328)***
a_6 $DSVC_t$	0.971 (0.358)***	0.977 (0.779)	0.971 (0.358)***	0.972 (0.780)
a_7 $DCVC_t$	−0.119 (0.552)	0.527 (0.464)	−0.119 (0.553)	0.538 (0.465)
a_8 $DPublicSubsidy_t$	−0.309 (0.267)	−0.526 (0.477)	−0.309 (0.267)	−0.532 (0.475)
a_9 *NFounders*	0.042 (0.040)	0.019 (0.045)	0.042 (0.040)	0.020 (0.045)
a_{10} *Education*	0.055 (0.034)*	0.009 (0.049)	0.055 (0.034)*	0.008 (0.049)
a_{11} *SpecWorkExp*	0.016 (0.017)	−0.045 (0.035)	0.016 (0.017)	−0.046 (0.034)
a_{12} *OthWorkExp*	0.007 (0.011)	−0.002 (0.018)	0.007 (0.011)	−0.002 (0.018)
a_{13} *DManager*	−0.111 (0.207)	0.856 (0.305)***	−0.111 (0.207)	0.858 (0.305)***
a_{14} *Appropriability*	−1.193 (0.401)***	0.211 (0.453)	−1.193 (0.400)***	0.214 (0.453)
a_{15} *Competition*	−1.163 (0.588)**	−1.175 (0.739)	−1.163 (0.588)**	−1.179 (0.738)
a_{16} *TechOpportunities*	1.852 (1.125)*	2.144 (1.501)	1.852 (1.124)*	2.168 (1.498)
a_{17} *Uncertainty*	76.337 (28.786)***	−11.416 (49.393)	76.339 (28.816)***	−10.890 (49.426)
p	0.938 (0.054)	1.086 (0.090)	0.938 (0.054)	1.086 (0.090)
log-Likelihood	−348.349	−183.597	−348.349	−183.511
Pseudo R^2	0.13	0.10	0.13	0.10
Wald χ^2 test	62.96 (16)***	62.21 (16)***	63.30 (17)***	62.61 (17)***
Wald χ^2 tests on groups of explanatory variables				
Size: $a_1 = a_2 = 0$	5.21 (2)*	5.14 (2)*	5.09 (2)*	4.93 (2)*
Patents: $a_3 = a_4 = 0$	–	–	2.12 (2)	3.61 (2)
Human capital: $a_9 = a_{10} = a_{11} = a_{12} = a_{13} = 0$	4.91 (5)	10.41 (5)*	4.91 (5)	10.61 (5)*
Industry variables: $a_{15} = a_{16} = a_{17} = a_{18} = 0$	32.45 (4)***	8.63 (4)*	32.60 (4)***	8.80 (4)*
No. of observations	1856	1856	1856	1856
No. of firms	420	420	420	420

*Significance level greater than 90%; **significance level greater than 95%; ***significance level greater than 99%. Robust standard errors and number of restrictions in parentheses. For p the test is H_0: $p = 1$. Weibull hazard functions. Nagelkerke Pseudo R^2.

Siegel et al., 2003. For the Italian case see Colombo and Grilli, 2006). This paper indicates that policy measures that help NTBFs in obtaining support from reputable and well connected sponsors may have an indirect very beneficial effect on the ability of these firms to obtain access to the specialized assets and competencies of other firms. Accordingly, in this domain this type of indirect policy scheme may constitute a better use of public money than direct subsidies to NTBFs.

Acknowledgements

Financial support from the FIRB 2003 fund and the Venture Fun project promoted by the Network of Excellence PRIME of the EU is gratefully acknowledged. The authors are grateful for useful comments and suggestions to participants in the conference on "Innovation and growth" hosted by University of Bozen in May 2006, three anonymous referees and two of the editors of this special issue. The usual disclaim applies.

Appendix A

The survival data analysis and the competing risks models with Weibull specification are shown in Tables A1 and A2.

References

Aalen, O.O., 1978. Nonparametric inference for a family of counting processes. Annals of Statistics 6, 701–726.

Ahuja, G., 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. Strategic Management Journal 21, 317–343.

Aldrich, H.E., Kallenberg, A., Marsden, P., Cassell, J., 1989. In pursuit of evidence: sampling procedures for locating new businesses. Journal of Business Venturing 4, 367–386.

Amit, R., Brander, J., Zott, C., 1998. Why do venture capital firms exist? Theory and Canadian evidence. Journal of Business Venturing 13, 441–466.

Arora, A., Gambardella, A., 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. Journal of Industrial Economics 38, 361–379.

Åstebro, T., Bernhardt, I., 1999. The winner's curse of human capital. Working Paper CES 99-5, Center for Economic Studies, U.S. Department of Commerce.

Baum, J.A.C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone: alliance networks and startups' performance in Canadian biotechnology. Strategic Management Journal, Winter special issue 21, 267–294.

Baum, J.A.C., Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. Journal of Business Venturing 19, 411–436.

Becker, G.S., 1975. Human Capital. National Bureau of Economic Research, New York.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., Veugelers, R., 2004. Heterogeneity in R&D cooperation strategies. International Journal of Industrial Organization 22, 1237–1263.

Birkinshaw, J., van Basten Batenburg, R., Murray, G.C., 2002. Corporate venturing: the state of the art and the prospects for the future. London Business School, Mimeo.

Birley, S., 1984. Finding the new firm. In: Proceedings of the Academy of Management Meetings, vol. 47, pp. 64–68.

Block, Z., Ornati, O.A., 1987. Compensating corporate venture managers. Journal of Business Venturing 2, 41–51.

Bottazzi, L., Da Rin, M., Hellmann, T., 2004. The changing face of the European venture capital industry: facts and analysis. The Journal of Private Equity 7, 26–53.

Bulter, J.S., Moffitt, R., 1982. A computationally efficient quadrature procedure for the one-factor multinomial probit model. Econometrica 50, 761–764.

Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press, New York.

Cantwell, J., Colombo, M.G., 2000. Technological and output complementarities, and inter-firm cooperation in Information Technology ventures. Journal of Management and Governance 4, 117–147.

Carling, K., Edin, P.-A., Harkman, A., Holmlund, B., 1996. Unemployment duration, unemployment benefits, and labor market programs in Sweden. Journal of Public Economics 59, 313–334.

Carpenter, R.E., Petersen, B.C., 2002a. Capital market imperfections, high-tech investment, and new equity financing. Economic Journal 112, F54–F72.

Carpenter, R.E., Petersen, B.C., 2002b. Is the growth of small firms constrained by internal finance? The Review of Economics and Statistics 84, 298–309.

Caves, R.E., 1998. Industrial organization and new findings on the turnover and mobility of firms. Journal of Economic Literature 36, 1947–1982.

Chan, Y.S., 1983. On the positive role of financial intermediation in allocation of venture capital in a market with imperfect information. Journal of Finance 35, 1543–1568.

Chen, M.-Y., 2002. Survival duration of plants: evidence from the US petroleum refining industry. International Journal of Industrial Organization 20, 517–555.

Chesbrough, H.W., 2000. Designing corporate ventures in the shadow of private venture capital. California Management Review 42, 31–49.

Chesbrough, H.W., 2002. Making Sense of Corporate Venture Capital. Harvard Business Review.

Chung, S., Singh, H., Lee, K., 2000. Complementarity, status similarity and social capital as drivers of alliance formation. Strategic Management Journal 21, 1–22.

Clarysse, B., Wright, M., Lockett, A., ven de Velde, E., Vohora, A., 2005. Spinning out new ventures: a typology of incubation strategies from European research institutions. Journal of Business Venturing 20, 183–216.

Cohen, M.D., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152.

Colombo, M.G., 1995. Firm size and cooperation: the determinants of cooperative agreements in information technology industries. International Journal of the Economics of Business 2, 3–29.

Colombo, M.G., 2003. Alliance form: a test of the contractual and competence perspectives. Strategic Management Journal 24, 1209–1229.

Colombo, M.G., Delmastro, M., 2002. The determinants of organizational change and structural inertia: technological and organizational factors. Journal of Economics Management Strategy 11, 595–635.

Colombo, M.G., Delmastro, M., Grilli, L., 2004. Entrepreneurs' human capital and the start-up size of new technology-based firms. International Journal of Industrial Organization 22, 1183–1211.

Colombo, M.G., Garrone, P., 1996. Technological cooperative agreements and firm's R&D intensity. A note on causality relations. Research Policy 25, 923–932.

Colombo, M.G., Garrone, P., 1998. A simultaneous equations model of technological agreements and inframural R&D. In: Colombo, M.G. (Ed.), The Changing Boundaries of the Firm. Routledge, London, UK, pp. 140–157.

Colombo, M.G., Grilli, L., 2005. Founders' human capital and the growth of new technology-based firms: a competence based view. Research Policy 34, 795–816.

Colombo, M.G., Grilli, L., 2006. Supporting high-tech start-ups: lessons from Italian technology policy. International Entrepreneurship and Management Journal 2, 189–209.

Contractor, F.J., Lorange, P., 1988. Why should firms cooperate? The strategic and economics basis for cooperative ventures. In: Contractor, F.J., Lorange, P. (Eds.), Cooperative Strategies in International Business. Lexington Books, Lexington, MA, pp. 3–30.

Cooper, A.C., 2002. Networks, alliances, and entrepreneurship. In: Hitt, M.A., Ireland, R.D., Camp, S.M., Sexton, D.L. (Eds.), Strategic Entrepreneurship. Blackwell Publishers, Oxford, UK, pp. 203–222.

Cooper, A.C., Bruno, A.V., 1977. Success among high-technology firms. Business Horizons 20, 16–22.

Cox, R.D., 1972. Regression models and life tables. Journal of the Royal Statistical Society 34, 187–220.

Das, T., Teng, B., 2000. A resource-based theory of strategic alliances. Journal of Management 26, 31–61.

De Bondt, R., Veugelers, R., 1991. Strategic investment with spillovers. European Journal of Political Economy 7, 345–366.

Denis, D.J., 2004. Entrepreneurial finance: an overview of the issues and evidence. Journal of Corporate Finance 10, 301–326.

Dushnitsky, G., Lavie, D., 2005. Strategic alliances versus corporate venture capital: substitutes or complements? In: Strategic Management Society 25th Annual International Conference, Orlando, FL, October 24.

Dushnitsky, G., Lenox, M.J., 2005a. When do incumbents learn from entrepreneurial ventures? Corporate venture capital and investing firm innovation rates. Research Policy 34, 615–639.

Dushnitsky, G., Lenox, M.J., 2005b. When do firms undertake R&D by investing in new ventures? Strategic Management Journal 26, 947–965.

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms. Organization Science 7, 136–150.

Ernst, H., Witt, P., Brachtendorf, G., 2005. Corporate venture capital as a strategy for external innovation: an exploratory empirical study. R&D Management 35, 233–242.

Feeser, H., Willard, G., 1990. Founding strategy and performance: a comparison of high and low growth tech firms. Strategic Management Journal 11, 87–98.

Fritsch, M., Lukas, R., 2001. Who cooperates on R&D? Research Policy 30, 297–312.

Gans, J.S., Hsu, D.H., Stern, S., 2002. When does start-up innovation spur the gale of creative destruction? RAND Journal of Economics 33, 571–586.

Gans, J.S., Stern, S., 2003. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. Research Policy 32, 333–350.

Gimeno, J., Folta, T., Cooper, A., Woo, C., 1997. Survival of the fittest? Entrepreneurial human capital and the persistence of underperforming firms. Administrative Science Quarterly 42, 750–783.

Giudici, G., Roosenboom, P., 2002. Pricing initial public offerings on European "new" stock markets. In: Proceedings of the XIII Tor Vergata Financial Conference, Rome, Italy.

Gomes-Casseres, B., 1997. Alliance strategies of small firms. Small Business Economics 9, 33–44.

Gompers, P., Lerner, J., 2001. The venture capital revolution. Journal of Economic Perspectives 15, 145–168.

Grambsch, P.M., Therneau, T.M., 1994. Proportional hazards tests and diagnostics based on weighted residuals. Biometrika 81, 515–526.

Grant, R.M., Baden Fuller, C., 2004. A knowledge accessing theory of strategic alliances. Journal of Management Studies 41, 61–85.

Green, C., Leeves, G., 2004. Casual jobs and internal labour markets. Manchester School 72, 658–676.

Greene, W.H., 2000. Econometric Analysis, 4th ed. Prentice-Hall International.

Gulati, R., 1995. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. Academy of Management Journal 38, 85–112.

Gulati, R., 1999. Network location and learning: the influence of network resources and firm capabilities on alliance formation. Strategic Management Journal 20, 397–420.

Gulati, R., Singh, H., 1998. The architecture of cooperation: managing coordination costs and appropriation concerns in strategic alliances. Administrative Science Quarterly 43, 781–814.

Hagedoorn, J., 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. Strategic Management Journal 14, 371–385.

Hagedoorn, J., Schakenraad, J., 1994. The effect of strategic technology alliances on company performance. Strategic Management Journal 15, 291–309.

Hagedoorn, J., Link, A.N., Vonortas, N.S., 2000. Research partnerships. Research Policy 29, 567–586.

Hamel, G., 1991. Competition for competence and inter-partner learning within international strategic alliances. Strategic Management Journal 12, 83–103.

Hellmann, T., Puri, M., 2002. Venture capital and the professionalization of start-up firms: empirical evidence. Journal of Finance 57, 169–197.

Hernan, R., Marin, P.L., Siotis, G., 2003. An empirical evaluation of the determinants of research joint venture formation. The Journal of Industrial Economics 51, 75–89.

Hsu, D.H., 2004. What do entrepreneurs pay for venture capital affiliation? Journal of Finance 59, 1805–1844.

Hsu, D.H., 2006. Venture capitalists and cooperative start-up commercialization strategy. Management Science 52, 204–219.

Jansson, F., 2002. Rehires and unemployment duration in the Swedish labour market. New evidence of temporary layoffs. Labour 16, 311–345.

Kalbfleisch, J.D., Prentice, R.L., 1980. The Statistical Analysis of Failure Time Data. Wiley, New York.

Kaplan, S.N., Strömberg, P., 2001. Venture capitalists as principals: contracting, screening and monitoring. American Economic Review 91, 426–430.

Kaplan, S.N., Strömberg, P., 2004. Characteristics, contracts and actions: evidence from venture capitalists analyses. Journal of Finance 59, 2177–2210.

Keifer, N., 1988. Economic duration data and hazard functions. Journal of Economic Literature 26, 646–679.

Kennedy, P., 2003. A Guide to Econometrics. Blackwell Publishers, Oxford, UK.

Khanna, T., Gulati, R., Nohria, N., 1998. The dynamics of learning alliances: competition, cooperation, and relative scope. Strategic Management Journal 19, 193–210.

Khanna, T., Gulati, R., Noria, N., 2000. The economic modeling of strategy process: 'clean models' and 'dirty hands'. Strategic Management Journal 21, 781–790.

Kleinknecht, A., Reijnen, J.O.N., 1992. Why do firms cooperate on R&D? An empirical study. Research Policy 21, 347–360.

Kogut, B., 1988. Joint ventures: theoretical and empirical perspectives. Strategic Management Journal 9, 319–332.

Koza, M.P., Lewin, A.Y., 1998. The co-evolution of strategic alliances. Organization Science 9, 255–264.

Lancaster, T., 1990. The Econometric Analysis of Transition Data. Cambridge University Press, Cambridge, UK.

Lavie, D., Rosenkopf, L., 2006. Balancing exploration and exploitation in alliance formation. Academy of Management Journal 49, 797–818.

Lee, P.M., Wahal, S., 2004. Grandstanding, certification and underpricing of venture capital backed IPOs. Journal of Financial Economics 73, 375–407.

Lerner, J., 1999. The government as venture capitalist: the long-run effects of the SBIR program. Journal of Business 72, 285–318.

Levin, R., Klevorick, A., Nelson, R.R., Winter, S.G., 1987. Appropriating the returns from industrial R&D. Brookings Papers on Economic Activity, 783–820.

Levinthal, D.A., March, J.G., 1993. The myopia of learning. Strategic Management Journal 14, 95–112.

Lindsey, L., 2002. The venture capital Keiretsu effect: an empirical analysis of strategic alliances among portfolio firms. Working Paper, Stanford University.

Link, A.N., Bauer, L.L., 1987. An economic analysis of cooperative research. Technovation 6, 247–260.
Lockett, A., Wright, M., Franklin, S., 2003. Technology transfer and universities' spin-out strategies. Small Business Economics 20, 185–200.
March, J.G., 1991. Exploration and exploitation in organizational learning. Organization Science 2, 71–87.
Megginson, W., Weiss, K., 1991. Venture capital certification in initial public offerings. Journal of Finance 46, 879–903.
Mitchell, W., Singh, K., 1992. Incumbents' use of pre-entry alliances before expansion into new technical subfields of an industry. Journal of Economic Behavior & Organization 18, 347–372.
Mowery, D.C., Oxley, J.E., Silverman, B.S., 1996. Strategic alliances and interfirm knowledge transfer. Strategic Management Journal 17, 77–91.
Mowery, D.C., Oxley, J.E., Silverman, B.S., 1998. Technological overlap and inter-firm cooperation: implication for the resource-based view of the firm. Research Policy 27, 507–523.
Nagarajan, A., Mitchell, W., 1998. Evolutionary diffusion: internal and external methods used to acquire encompassing, complementary, and incremental technological changes in the lithotripsy industry. Strategic Management Journal 19, 1063–1078.
Nakamura, M., Shaver, J.M., Yeung, B., 1996. An empirical investigation of joint venture dynamics: evidence from US–Japan joint ventures. International Journal of Industrial Organization 14, 521–541.
Narin, F., Nom, E., Perry, R., 1987. Patents as indicators of corporate technological strength. Research Policy 16, 143–155.
Nelson, W., 1972. Theory and applications of hazard plotting for censored failure data. Technometrics 14, 945–965.
Nooteboom, B., 1992. Towards a dynamic theory of transactions. Journal of Evolutionary Economics 2, 281–299.
Nooteboom, B., 1999. Interfirm Alliances: Analysis and Design. Routledge, London, UK.
Oxley, J.E., 1997. Appropriability hazards and governance in strategic alliances: a transactions cost approach. Journal of Law Economics and Organization 13, 387–409.
Oxley, J.E., 1999. Institutional environment and the mechanisms of governance: the impact of intellectual property protection on the structure of inter-firm alliances. Journal of Economic Behavior & Organization 38, 283–309.
Parkhe, A., 1991. Interfirm diversity, organizational learning, and longevity in global strategic alliances. Journal of International Business Studies 22, 579–601.
Piga, C., Vivarelli, M., 2004. Internal and external R&D: a sample selection approach. Oxford Bulletin of Economics and Statistics 66, 457–482.
Pisano, G.P., 1989. Using equity participation to support exchange: evidence form the biotechnology industry. Journal of Law, Economics, and Organization 5, 109–126.
Pisano, G., 1991. The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. Research Policy 20, 237–249.
Powell, W.W., Koput, K.W., Smith-Doerr, L., 1996. Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. Administrative Science Quarterly 41, 116–145.
Robinson, D., Stuart, T., 2000. Network Effects in the Governance of Strategic Alliances in Biotechnology. University of Chicago GSB, Mimeo.
Röller, L.H., Tombak, M.M., Siebert, R., 1997. Why firms form research joint ventures: theory and evidence. CEPR Discussion Paper Series, No. 1654.
Rothaermel, F.T., 2001. Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry. Research Policy 30, 1235–1251.
Rothaermel, F.T., 2002. Technological discontinuities and interfirm cooperation: what determines a start-up's attractiveness as alliance partner? IEEE Transactions on Engineering Management 49, 388–397.
Rothaermel, F.T., Deeds, D.L., 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal 25, 201–221.
Sahlman, W.A., 1990. The structure and governance of venture-capital organizations. Journal of Financial Economics 27, 473–521.
Sakakibara, M., 1997. Heterogeneity of firm capabilities and cooperative research and development: an empirical examination of motives. Strategic Management Journal, Summer Special Issue 18, 143–164.
Sakakibara, M., 2002. Formation of R&D consortia: industry and company effects. Strategic Management Journal 23, 1033–1050.
Shan, W., 1990. An empirical analysis of organizational strategies by entrepreneurial high-technology firms. Strategic Management Journal 11, 129–139.
Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strategic Management Journal 15, 387–394.
Siegel, R., Siegel, E., MacMillan, I., 1988. Corporate venture capitalists: autonomy, obstacles and performance. Journal of Business Venturing 3, 233–247.
Siegel, D., Wessner, C., Binks, M., Lockett, A., 2003. Policies promoting innovation in small firms: evidence from the U.S. and U.K. Small Business Economics 20, 121–127.
Spence, M., 1984. Cost reduction, competition and industry performance. Econometrica 52, 101–121.
Stuart, T.E., 1998. Network positions and propensities to collaborate: an investigation of strategic alliance formation in a high-technology industry. Administrative Science Quarterly 43, 668–698.
Stuart, T.E., Hoang, H., Hybels, R.C., 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. Administrative Science Quarterly 44, 315–349.
Stuart, T., 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strategic Management Journal 21, 791–811.
Sutton, J., 1997. Gibrat's legacy. Journal of Economic Literature 35, 40–59.
Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy. Research Policy 15, 285–305.
Tether, B.S., 2002. Who co-operates for innovation, and why. An empirical analysis. Research Policy 31, 948–967.
Trajtenberg, M., 1990. A penny for your quotes. Rand Journal of Economics 21, 172–187.
Tripsas, M., 1997. Unraveling the process of creative destruction: complementary assets and incumbent survival in the typesetter industry. Strategic Management Journal, Summer Special Issue 18, 119–142.
Veugelers, R., 1997. Internal R&D expenditures and external technology sourcing. Research Policy 26, 303–315.

Walker, G., Kogut, B., Shan, W., 1997. Social capital, structural holes and the formation of an industry network. Organization Science 8, 109–125.

Wang, C.K., Wang, K., Lu, Q., 2003. Effects of venture capitalists' participation in listed companies. Journal of Banking and Finance 27, 2015–2034.

Williamson, O.E., 1991. Comparative economic organization: the analysis of discrete structural alternatives. Administrative Science Quarterly 36, 269–296.

Wuyts, S., Colombo, M.G., Dutta, S., Nooteboom, B., 2005. Empirical tests of optimal cognitive distance. Journal of Economic Behavior & Organization 58, 277–302.

Xu, B., 1998. A reestimation of the Evans-Jovanovic entrepreneurial choice model. Economics Letters 58, 91–95.

Zajac, E.J., Olsen, C.P., 1993. From transaction cost to transaction value analysis: implications for the study of interorganizational strategies. Journal of Management Studies 30, 131–145.