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Effects of international R&D alliances on performance of high-tech start-ups: a longitudinal analysis

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Abstract

In this article, we use the theoretical lens of resource and competence-based perspectives and global strategic network theories to analyze the effects of international R&D alliances on the performance of high-tech start-ups. In the empirical section of the article, we consider the European Union-funded international R&D alliances established by a large sample of Italian high-tech start-ups over the period from 1994 to 2003. We measure firm performance through total factor productivity, and we resort to generalized method of moments system estimates to detect the treatment effect of alliance formation according to type and home country of the partners. The econometric results suggest that international R&D alliances are most beneficial to high-tech start-ups if (1) they involve industrial partners located in a variety of countries and (2) these countries are closer to world knowledge sources.

Key words: New technology-based firms; international R&D alliances; total factor productivity; global strategic networks; proximity

JEL classification: M13; F23; D21; D24

1 - Introduction

It is agreed among entrepreneurship scholars that strategic alliances are critical to the success of high-tech start-ups, i.e., new technology-based firms (NTBFs). Previous studies have highlighted that these arrangements allow NTBFs to fill the resource and competence gaps they suffer in the early stages of their existence (Pisano, 1991; Eisenhardt and Schoonhoven, 1996; Gans and Stern, 2003). For this purpose, selecting suitable partners is crucial. In fact, appropriate alliance networks may allow NTBFs to rely on a stock of resources and competencies comparable to that of their more established competitors, and to overcome their liability of newness and smallness (Baum, Calabrese, and Silverman, 2000; Lavie, 2006, 2007).

Several empirical studies have analyzed the relation between alliance formation and NTBF performance. They find a positive relation, even though the effects are not uniform across alliance types (Shan, Walker, and Kogut, 1994; Deeds and Hill, 1996; Lee, Lee, and Pennings, 2001; Baum and Silverman, 2004; Rothaermel and Deeds, 2004). A limited number of studies have considered the moderating role of the characteristics of the NTBFs' alliance partners. Stuart, Hoang, and Hybels (1999) showed that affiliation with prominent alliance partners was especially beneficial for biotech start-ups. Similarly, Stuart (2000) highlighted that alliances with large and innovative partners had a positive impact on innovation and sales growth of young and small semiconductor firms. Baum *et al.* (2000) considered the network of alliances established at foundation by Canadian biotech firms. The effects of these alliances on firms' innovation and growth performance, although generally positive, were found, again, to differ according to the type of partners. Alliance networks that, given their size, were composed of more heterogeneous partners and so provided access to more diverse information and capabilities, generally had more beneficial effects.

Recent research (e.g., Lavie and Miller, 2008) has highlighted the importance of the level of internationalization of the firms' alliance portfolios. In accordance with the strategic network perspective (Gulati, 1998, 2007), alliances with foreign partners are an effective mechanism to access resources and competencies over and beyond those possessed by these partners—leveraging the global network of their business links. However, the effects on NTBF performance of the location of NTBF's foreign partners, reflected by the position that their home countries occupy in global networks, have so far remained unexplored.

In this article, we focus attention on the international R&D alliances of NTBFs. We combine insights offered by resource-based, competence-based and global strategic network theories to investigate the performance effects of these alliances contingent on the type and home country of alliance partners. First, we distinguish firms from research organizations, arguing that in the short term, only the former partners contribute to improving NTBF performance. Second, we argue that NTBF performance initially improves, and then declines, with an increase in the international heterogeneity of the portfolio of industrial partners. Conversely, the international heterogeneity of the portfolio of academic partners is expected to negatively affect NTBF performance. Third, drawing on arguments recently advanced in international business literature (Andersson and Forsgren, 2000; Forsgren, Holm, and Johanson, 2005; Nachum, Zaheer, and Gross, 2008), we claim that the selection of suitably located industrial partners allows NTBFs to gain access to worldwide dispersed knowledge which, without these collaborations, would be out of reach to them. Due to this *bridging* role of industrial partners, R&D collaborations with firms located in countries close to world knowledge sources are most beneficial to NTBFs.

To assess the performance effects of international R&D alliances of NTBFs, we focus on a particular type of alliance, i.e., those that are funded by the European Union (EU) within Framework Programs and other support schemes (EU Research Joint Ventures, EURJVs). We analyze the effects on total factor productivity (TFP) of participation in EURJVs for a large sample of Italian NTBFs observed over the 10-year period from 1994 to 2003. Our findings indicate that engagement in international R&D alliances boosts NTBF performance, but the extent of this positive effect crucially depends on the type and home country of the alliance partners. Namely, the

TFP of NTBFs increases with the international heterogeneity of the portfolio of industrial partners. Conversely, the international heterogeneity of academic partners has a negative effect on TFP. More interestingly, alliances with partner firms located in countries that are close to world knowledge sources have a greater positive effect on NTBF performance.

This work is original in various respects. First, to the best of our knowledge, it is the first large-scale empirical study on the moderating effect of the international diversity of alliance partners' portfolios on the relationship between international alliance formation and economic performance of high-tech entrepreneurial firms. In particular, the findings highlighting the bridging function performed by industrial partners of international alliances which connect small firms to worldwide dispersed knowledge sources is an original addition to the extant entrepreneurship literature. Second, the focus on EURJVs provides several advantages that prior studies do not enjoy. As all EURJVs are oriented toward basic and applied research as well as precompetitive technological development, there is no need to control for heterogeneity in alliances' objectives and activities. Moreover, being multilateral and international in scope, these alliances are heterogeneous as to the aspects of interest in this study, notably the type and home countries of the partners. Hence, EURJVs offer an ideal test bed to assess the effects of these factors on firm performance. Finally, the EU's Community Research and Development Information Service (CORDIS) database provides very detailed, public data on the entire population of EURJVs. Therefore—unlike previous studies on the alliances of NTBFs—we do not rely on secondary information obtained from commercial databases or survey data, which are likely to generate sample-selection bias. In fact, secondary and survey data generally include only those alliances in which information was disclosed by partner firms. As information disclosure clearly is not random, these samples of alliances are not representative of the target population.[1] Third, we use TFP to measure the

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[1] For instance, alliances with large incumbent firms are more likely to be made public by NTBFs, as they certify the quality of the NTBFs to uninformed third parties. If their effect on firm performance differed from that of the other alliances, this would engender a bias in the estimate of the treatment effect of alliances. More importantly, NTBFs are

economic performance of NTBFs. TFP is a classical indicator of firms' overall relative efficiency that is attracting increasing interest from entrepreneurship scholars (e.g., Acs, Morck, and Yeung, 1999; Chemmanur and Nandy, 2006; Link and Siegel, 2007; Chemmanur, Krishnan, and Nandy, 2008). However, this study is the first one to apply it in the area of international R&D alliances established by entrepreneurial ventures. The use of TFP is particularly suitable in this context for reasons that will be exposed throughout the text (see Dependent Variable Section later). TFP measures the residual growth in a firm's output not accounted for by the growth in inputs (i.e., labor, capital, materials), given the production technology in place in the firm's sector of operation. An increase in TFP may be the result of demand side effect, i.e., greater ability of the firm to command a premium price for its products or to extend market coverage. Alternatively, an increase in TFP may be due to supply-side effects, i.e., stemming from the use of better quality production inputs or from their efficient use (lower quantity and/or lower price). Whatever the source, a TFP increase documents an increase in a firm's overall economic performance. To properly compute TFP, we employ an increasingly popular semiparametric approach proposed by Olley and Pakes (1996), which offers a more robust solution to omitted variables and simultaneity problems than other approaches (see also Levinsohn and Petrin, 2003; Van Biesebroeck, 2007). Lastly, we estimate the treatment effect of EURJVs on TFP through the generalized method of moments (GMM) system estimator for panel data (Blundell and Bond, 1998. For analogous approaches in similar contexts, see Girma, Görg, and Strobl, 2007; Girma *et al.*, 2008). As our dataset is very informative on sample NTBFs, to the usual set of instruments we are able to add additional instruments aimed at capturing exogenous shifts of the variables of interest (for a similar approach see, for example, Leiponen, 2005; Benfratello and Sembenelli, 2006). In so doing, we effectively

generally eager to disclose information on successful alliances, while reluctant to advertize failures. This generates an upward bias in the estimated treatment effect. An opposite bias is also possible if alliances involving strategic projects that are most beneficial to a firm's destiny are kept secret so as to prevent technological leakages. In fact, it is impossible to assess the net effect of this bias on *a priori* grounds (on this issue, see also Schilling, 2009).

deal with problems possibly arising from time-varying and -unvarying unobserved heterogeneity that might lead to biased estimates of the parameters of interest.

The article is organized as follows. In the next section, we illustrate our theoretical hypotheses on the effects of international R&D alliances on the performance of NTBFs. Then we present the sample of NTBFs and illustrate the characteristics of the EURJVs in which they were involved throughout the period considered. The next section is devoted to the specification of the econometric model and the description of the dependent and independent variables. We then present the results of the econometric estimates. The last section summarizes the main contribution and implications of the article and indicates directions for future research.

2 - Theoretical hypotheses

According to the resource- and competence-based perspectives, a firm's endowment of resources and competencies determines its performance (Penrose, 1959; Grant, 1996). At foundation, NTBFs are unlikely to possess all the resources and competencies necessary to compete successfully with incumbent firms (Colombo and Piva, 2008). Alliances may help fill these gaps. NTBFs can gain access to alliance partners' applied technological competencies, knowledge of the relevant markets, and complementary assets that are useful for the further development and successful commercialization of their technological artifacts. These alliances may also act as bridging ties (McEvily and Zaheer, 1999), allowing NTBFs to take advantage of partners' business contacts to establish business relations with third parties not otherwise accessible to the start-up.

In this perspective, international R&D alliances, i.e., R&D alliances with partners located in foreign countries, play an especially important role. Foreign partners are embedded in innovation and economic systems different from that of the focal NTBF; therefore, they are more likely than domestic partners to possess capabilities that differ from those of the NTBF and generate synergistic gains when combined with them. This greater diversity opens up greater opportunities for interorganizational learning and access to diverse competencies compared to domestic alliances. Thus, foreign partners can offer NTBFs unique opportunities that domestic partners are unable to furnish (Lavie and Miller, 2008).

However, international R&D alliances also engender coordination costs that might negatively affect NTBF performance. As NTBFs possess limited managerial resources, owner-managers have to devote a lot of their time and effort to the organization, coordination, and control of the firm's alliance activities to the detriment of other activities in which they are most productive (such as R&D). If an NTBF enters a large number of alliances, coordination costs rise possibly beyond a point where the costs of additional alliances outweigh the benefits. In other words, there may be negative returns to high levels of alliance activity (for similar arguments, see Rothaermel and Deeds, 2006). The rise of coordination costs is likely to be particularly rapid when the collaborations involve foreign partners. Indeed, as less information generally is known about foreign partners than domestic ones, the behavior of the former partners tends to be less predictable than that of the latter. Developing interorganizational routines is also more complex.

Following these arguments, we predict a curvilinear, inverse U-shaped relation between NTBF involvement in international R&D alliances and firm performance, with performance first improving and then declining with an increase in the number of international R&D alliances in which NTBFs participate. Thus, we formulate the following hypothesis:

Hypothesis 1 (H1): There is an inverse U-shaped relation between the number of international R&D alliances in which NTBFs participate and NTBF performance.

The effects of participation in international R&D collaborations on NTBF performance also depend on the type of alliance partner. We distinguish other firms (notably, large incumbent firms)[2] from research organizations (i.e., universities and other public research centers). As the literature

[2] NTBFs may also establish R&D collaborations with other start-ups. However, they are unlikely to join forces with start-ups located in foreign countries because of the high costs of partner selection. Therefore, we expect the industrial partners of the international R&D alliances of NTBFs to be mainly large incumbent firms.

suggests, (incumbent) firms and research organizations have different competencies (see, among others, Bower, 1993; Betz, 1996; Santoro and Gopalakrishnan, 2000). The former possess applied technological expertise and knowledge of markets that compensate for the scant competencies of most NTBFs in these fields. Therefore, allying with industrial partners is likely to improve NTBF performance. Instead, research organizations are important repositories of scientific knowledge. Allying with academic partners may generate positive returns to NTBFs too, as this significantly enhances NTBFs' absorptive capacity (Hall, Link, and Scott, 2003). Nonetheless, these collaborations typically involve basic research and have quite a long time frame (Hall, Link, and Scott, 2001). Thus, they are likely to result in performance improvements, if any, only in the long term (Medda, Piga, and Siegel, 2005; Nieto and Santamaria, 2009). Hence, we expect the involvement of research organizations as partners in international R&D alliances to have no short-term positive effects on NTBF performance.

Let us now focus attention on the industrial partners of international R&D alliances. We claim that the international heterogeneity of the portfolio of partner firms positively influences the benefits that NTBFs can obtain from these alliances. Indeed, as we argued above, with all else being equal, a firm learns more from a foreign partner than from a domestic one; this is because of the diversity of its national background and culture (Lavie and Miller, 2008). Hence, the greater the international heterogeneity of the portfolio of industrial partners, the greater the learning opportunities for NTBFs.

However, an increase in the international heterogeneity of the portfolio of industrial partners is also likely to increase the coordination and transaction costs associated with the alliances. In fact, great international heterogeneity implies that the NTBF is collaborating with many partners located in different countries. This entails high coordination costs. The transaction costs engendered by appropriation concerns also are high. Indeed, opportunistic behavior may be more likely to arise when alliances involve foreign firms, as there is greater uncertainty in international relations

(Hennart, 2000), and trust tends to emerge less readily between firms that are not socially and culturally similar (Zucker, 1986; Hennart and Zeng, 2002). In addition, when the alliances involve foreign firms, there is greater difficulty in specifying intellectual property rights, legally enforcing intellectual property, and monitoring partner activities (Pisano, 1990; Oxley, 1997)—further increasing transaction costs.

Beyond a certain threshold, the increase in the coordination and transaction costs will overshadow the marginal benefits of access to the foreign partners' competencies. Hence, we expect the relationship between the international heterogeneity of the portfolio of industrial partners and the performance of NTBFs to be curvilinear, first increasing and then decreasing. Hypothesis 2 follows:

Hypothesis 2 (H2): There is an inverse U-shaped relation between the international heterogeneity of the portfolio of industrial partners of the international R&D alliances in which NTBFs participate and NTBF performance.

The above arguments concerning the alleged negative effect on performance of the increase in coordination and transaction costs engendered by an increase in the international heterogeneity of partners also hold true for academic partners. As we expect the positive effects of collaborations with academic partners to be negligible in the short term, we formulate the following hypothesis:

Hypothesis 3 (H3): In the short term, there is a negative relation between the international heterogeneity of the portfolio of academic partners of the international R&D alliances in which NTBFs participate and NTBF performance.

Studies in strategic management have emphasized that a firm's alliance network is a key strategic resource, and its structure greatly influences firm performance (Walker, Kogut, and Shaw, 1997; Baum, *et al.*, 2000; Gulati, Nohria, and Zaheer, 2000; Stuart, 2000; Zaheer and Bell, 2005; Lavie, 2006, 2007). It has also been claimed that 'existing empirical findings point to the centrality of networks in every aspect of the entrepreneurial process' (Stuart and Sorenson, 2007: 211). Moreover, international business literature has documented that firms' networks increasingly involve a variety of actors that are geographically dispersed (see e.g., Andersson and Forsgren, 2000; Andersson, Forsgren, and Holm, 2002; Forsgren *et al.*, 2005). The ability to build and sustain these geographically dispersed networks is a managerial challenge for firms and has itself become an important distinctive capability (Cantwell and Piscitello, 2008). In this perspective, the location of firms in countries that occupy a central position in these networks provides an advantage over and beyond that relating to the competence endowment of these countries. In fact, foreign countries crucially differ as to their proximity to other countries. Accordingly, foreign locations matter not only and simply because of their intrinsic characteristics and competence endowments, but also—and especially—for their structural position, which makes worldwide dispersed factors accessible to firms located in favorably positioned countries (Nachum *et al.*, 2008).

In this article, we are interested in international R&D alliances, hence, we focus on technological knowledge. It is well known that sources of technological knowledge are increasingly dispersed worldwide. Moreover, as it has been widely documented in literature on localized knowledge spillovers, accessing and transferring technological knowledge from a distance is difficult (Jaffe, Trajtenberg, and Henderson, 1993; Almeida and Kogut, 1999). Thus, the proximity of a country to worldwide technological knowledge makes this knowledge more easily accessible for firms located in that country. We claim that in international R&D alliances, an NTBF benefits from the position that the home countries of its partners occupy in global networks. Through the alliance, partners indirectly make available the stock of knowledge accessible from their home countries to the NTBF. In other words, international R&D alliances act as bridging organizational arrangements linking NTBFs with worldwide knowledge. The solidity of the link created by an alliance clearly depends on partners' locations and their proximity to world knowledge. However, it also depends on the type of partners involved in the alliance. In this respect, industrial partners again enjoy an advantage over academic ones. Worldwide technological knowledge produced by industrial firms is most useful to NTBFs. This technological knowledge is likely to be more accessible for other firms rather than for research organizations. In fact, a firm's network of contacts in the private sector is likely to be wider than that of research organizations, which, in turn, will exhibit more numerous ties in the public research sector.

It is important to emphasize that without international R&D alliances, worldwide technological knowledge would not be accessible to NTBFs independent of their location because of the excessive costs that NTBFs would incur in building a global network. Therefore, the closer to world technological knowledge the home countries of the industrial partners in international R&D alliances are, the more positive the effect of these alliances on NTBF performance. Our fourth hypothesis follows:

> *Hypothesis 4 (H4): The effect of the international R&D alliances in which NTBFs participate on NTBF performance is more positive the closer to world technological knowledge the home countries of the industrial partners are.*

3 - Dataset

3.1 Sample

In this article, we empirically examine the effects of NTBF involvement in EURJVs—a special type of international R&D alliance—on NTBF performance. EURJVs are cross-border alliances aimed at basic and applied research and/or precompetitive technological development. They are partly financed by the EU through Framework Programs and other support schemes (e.g., Eureka). Financial support is provided by the EU on a competitive basis, and competition is usually fierce. Hence, the expected output of these alliances is innovative technological knowledge, and the quality of the partners is generally high.

We consider a sample composed of 265 Italian NTBFs. The sample firms were established in 1980 or later. The firms were owner managed at founding and have remained so up to January 1, 2004. 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, software, and Internet and telecommunication services.

The sample firms were extracted from the Research on Entrepreneurship in Advanced Technologies (RITA) database, developed at Politecnico di Milano. The RITA database constitutes the most complete source of information presently available on Italian NTBFs.[3] The database provides information on a population composed of 1,974 Italian NTBFs that comply with the above-mentioned criteria as to age, ownership status, and sector of operation. The RITA population was constructed from a large number of sources. These include lists provided by national industry associations, online and offline commercial firm directories, and lists of participants in industry trade shows and expositions. Information provided by the national financial press, specialized magazines, other sectoral studies, and regional chambers of commerce was also included.

Data contained in the RITA database were collected from two types of information sources. First, secondary sources of information were used. Data on the participation of Italian NTBFs in EURJVs obtained from the CORDIS database are available for all the EURJVs in which RITA firms participated during their lifetime. Financial and accounting data were obtained from the Accessible Information on Development Activities (AiDA) and Cerved commercial databases. Data in these databases are available from 1994 onward only for a subset of RITA firms (i.e., limited liability firms). Information on patent applications was collected through the Esp@ce.net research engine. Second, additional information on sample NTBFs was obtained through a series of national surveys administered in the first half of the years 2000, 2002, and 2004 (for details on the surveys, see Colombo *et al.*, 2006). The surveys provided data for use as control variables and additional instruments in our models (see Econometric Methodology section).

[3] In Italy, data provided by official national statistics do not include a reliable description of the universe of Italian NTBFs. Most individuals who are defined as *self-employed* by official statistics are actually salaried workers with atypical employment contracts. Thus, on the basis of official data, such individuals cannot be distinguished from entrepreneurs who created a new firm. Moreover, there are no official data on firms' ownership status.

The sample considered in this article includes all the NTBFs that participated in the 2004 survey and for which we were able to build a complete dataset relating to the variables of interest. The distribution of sample firms across industries and geographical areas is shown in Table 1. Two χ^2 tests show that there are no statistically significant differences between the distributions of the sample firms across industries and geographical areas and the corresponding distribution of the population of 1,974 RITA firms from which the sample was drawn ($\chi^2(4) = 7.55$ and $\chi^2(3) = 5.74$, respectively).

We do not presume that ours is a random sample. First, in this domain, representativeness is not clearcut, as new ventures may be defined in different ways (see, for instance, Birley, 1984; Aldrich *et al.*, 1989; Gimeno *et al.*, 1997). Second, due to the lack of reliable official statistics, it is difficult to unambiguously identify 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, the analysis presented in this article is based on survey data and, therefore, might suffer from sample-selection bias. In fact, firms performing well are probably more willing to provide information; hence, they are likely to be overrepresented in the sample. More importantly, only firms having survived and remaining independent up to the survey date were considered. This generates a survivorship bias that might have significant consequences for our study. In particular, if NTBFs' participation in EURJVs leads to better economic performance and there is a positive relation between TFP and likelihood of survival (see e.g., Bernard, Jensen, and Schott, 2006, Bellone *et al.*, 2008), our estimates of the treatment effect of EURJVs on NTBFs' TFP will be downwardly biased. An opposite bias is also possible if more efficient NTBFs involved in several EURJVs are more likely to be acquired. As in most survey-based studies, it is impossible to properly control for the survivorship bias. However, here we tried to correct at least partially for this bias through the econometric exercise described later.

3.2 Participation in EURJVs by Italian NTBFs

Participation in EURJVs is a rare event for Italian NTBFs: only 24 out of the 265 sample firms (9.0%) participated in one or more EURJVs in the 1994-2003 period (see Table 1). This low number may be a consequence of the high search costs for international partners, the high administrative costs involved in this type of collaboration, and the highly competitive nature of the selection procedure adopted by the EU. As we were told during interviews with firms' owner-managers, these factors would discourage most NTBFs from participation. Table 1 also illustrates the distribution of the NTBFs that have participated in one or more EURJVs by industry and geographical area. Quite unsurprisingly, with a 21.4 percent share, firms in the biotechnology, pharmaceutical, and advanced materials industries are relatively more likely to be involved in these alliances than firms in other industries. On the contrary, the rate of participation of Internet and telecommunication services firms in EURJVs is quite low (5.2%). As to the geographical distribution, firms located in the central regions are more likely to participate in EURJVs (23.2%) than those located in other geographical areas.

[Table 1 about here]

Table 2 reports some statistics on the 79 EURJVs in which the 24 RITA firms participated in the 1994-2003 period. Of note, the average number of EURJVs in which these firms were involved is 3.3. 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, this facilitates their participation in subsequent EURJVs. As to the characteristics of the alliance partners of NTBFs, the mean number of partners involved in the 79 EURJVs is 9.3, and the mean number of different countries in which they are located is 3.7. Distinguishing partners according to their type, we find that the number of industrial partners is slightly greater than the number of universities and public research centers (*academic partners*): on average there are 3.9 industrial partners and 3.6 academic partners per EURJV. The remaining 1.8 partners are other organizations (e.g., public administrations, associations, foundations). As to the international heterogeneity of these alliances measured by the number of different home countries of these three types of partners, both industrial and academic partners come from 1.9 foreign countries on average, while the diversity is lower (1.1 foreign countries per EURJV) among other partners. The standard deviations of all these variables are quite high, suggesting that the EURJVs in which sample firms participated differ considerably as to both number and characteristics of the partners.

[Table 2 about here]

4 - Econometric methodology

In the econometric analysis, we use NTBFs' TFP as a measure of firm economic performance. To investigate whether participation in EURJVs has an impact on TFP, the following econometric model is specified:

$$\ln TFP_{it} = \alpha + \beta' EURJV_{it} + \gamma' \Pr oximity_{it} + \lambda Age_{it} + \delta' Z_{it} + \eta_i + \varepsilon_{it}, \qquad (1)$$

where $\ln TFP_{it}$ is a measure of TFP (described in detail in the Dependent Variable section); $EURJV_{it}$ is a vector of covariates that captures the number and characteristics of the EURJVs in which sample NTBFs were involved at time *t*; $\Pr oximity_{it}$ is a vector of variables measuring the proximity of NTBFs' alliance partners to the worldwide dispersed knowledge, markets, and resources (see Explanatory Variables section); Age_{it} denotes the age of NTBFs; Z_{it} are a series of control variables that include founder- and firm-specific attributes; η_i are the unobserved firm-specific fixed effects; and ε_{it} are the usual independent and identically distributed (i.i.d.) disturbance terms.

4.1 Estimation technique

In this article, we aim to assess the treatment effect of the formation of EURJVs on the TFP of NTBFs according to partner characteristics, i.e., partner type and location. In so doing, we face two obstacles. First, a positive association between TFP and the formation of specific types of EURJVs may simply be a consequence of reverse causality, with higher TFP firms being more likely to establish these alliances. Second, there may be unobserved factors—such as smart management—that explain both firms' economic performance and their involvement in particular EURJV types. To account for possible time-varying and -unvarying unobserved heterogeneity that, if correlated with regressors, may lead to biased estimates of the parameters of interest, GMM is used for estimation.

More specifically, to take into account problems generated by the potential endogeneity of the explanatory variables, we resort to the GMM-system (GMM-SYS) estimator developed by Blundell and Bond (1998). Accordingly, we simultaneously estimate first-difference and level versions of Eq. (1). As the instruments, we use appropriately lagged values of the endogenous variables for first-difference estimates and appropriately lagged differences for level estimates. This method alleviates the typical problem of weak instruments characterizing the first GMM-difference (GMM-DIF) estimator.[4] Moreover, it preserves information from the level equations, enabling consistent identification of time-invariant covariates. As is customary in this type of analysis (e.g., Girma *et al.*, 2008), we formulate the weakest possible assumption. We consider the EURJV vector as potentially correlated with error terms and accordingly treat it as endogenous. Moreover, to improve consistency of the estimates, we follow previous studies (e.g., Leiponen, 2005; Benfratello and Sembenelli, 2006) in using extraneous information provided by a set of three additional exogenous instruments: (1) the sectoral propensity of RITA NTBFs to participate in EURJV projects (i.e., the share of RITA NTBFs that participated in EURJVs in each industry); and (2) their sectoral propensities to invest in R&D and (3) engineering activities (i.e., proxied by the ratios

[4] In our case, pseudo first-stage regressions support our choice of the GMM-SYS estimator, highlighting that lagged instruments in first differences are strongly correlated with EURJV variables; on the contrary, lagged instruments in levels are poorly correlated with the change in EURJV covariates, pointing to the strength other than the validity of the additional instruments implied by the GMM-SYS estimator with respect to GMM-DIF.

between RITA NTBFs' employees in R&D and engineering functions and total number of employees of RITA NTBFs in each industry, respectively).

To evaluate the relevance of the econometric model, various tests are applied. First, we implement the Arellano and Bond test for first- and second-order serial autocorrelation of residuals (AR(1), AR(2)). If ε_{it} is not serially correlated, the difference of residuals should be characterized by a negative first-order serial correlation and the absence of a second-order serial correlation. Then, the Hansen test for the validity of overidentifying restrictions is implemented. This tests the null hypothesis that the specified orthogonality conditions are equal to zero (Hansen, 1982). Failure to reject the null hypothesis indicates that the instruments are valid. Finally, we also perform Difference-in-Hansen tests that accept the null hypothesis of exogeneity for the $Proximity_{it}$ vector ($\chi^2(3) = 1.91$ for Model 2 in Table 5).

4.2 Dependent variable

We use (relative) TFP to measure the NTBF performance. This indicator reflects how effectively the NTBF uses production inputs to produce output in comparison with other NTBFs that operate in the same industry. In other words, NTBFs perform better if they produce the same output with less inputs or if they use the same inputs but produce more output than other NTBFs in the same industry. This indicator of firm performance is particularly appropriate in the context of our study. First, as TFP reflects both output performance and efficiency in the use of inputs, it is suitable to measure the performance impact of participation in EURJVs that may clearly have beneficial effects on both sides. Moreover, costs arising from the search for candidate partners, procedures for application and bureaucracy in general, and coordination of participants may be high, especially for a small young firm lacking resources. Therefore, considering only output indicators (e.g., innovation output or growth in sales or employees) without any consideration for the cost side (that is, without considering efficiency) would, at best, give only a partial and incomplete indication of firm performance.

Second, the use of typical innovation measures as those based on patent awards is highly problematic in our study. On the one hand, most sample firms operate in service sectors where patents are rarely used to protect innovations (especially in the European context). This would create a serious sectoral bias. On the other hand, patent awards signal the quality of entrepreneurial ventures (Hsu and Ziedonis, 2007), while TFP does not have any signaling effect (since it is not immediately and easily traceable from the outside). This quality signal may positively influence an NTBF's ability to participate in EURJVs (Colombo, Grilli, and Piva, 2006). Therefore, the use of patents as a dependent variable (rather than as a control factor, as we do in our models) may raise reverse causality concerns in the study of performance effects.

Third, TFP takes directly into account the effects of potential technological shifts and organizational changes on the production function, which, again, is extremely pertinent in the context of analyzing the impact of R&D alliances on firm performance (see on this point also Link and Siegel, 2007). In fact, measures of partial productivity (e.g., labor productivity) may fail in doing so, since they do not consider trade-offs among input factors.

In accordance with the above arguments, the use of TFP as an indicator of the performance of small young enterprises operating in knowledge-intensive industries is well established. Examples of applications in samples partially or totally constituted by high-tech firms (e.g., Hall and Mairesse, 1995; Javorcik, 2004; Driffield, Du, and Girma, 2008; Aghion *et al.*, 2009) and young or small firms (Aitken and Harrison, 1999; Acs *et al.*, 1999; Cingano and Schivardi, 2004; Chemmanur and Nandy, 2006; Chemmanur *et al.*, 2008) are well documented in various literature streams.

The TFP of NTBFs is estimated through a semiparametric estimation procedure originally proposed by Olley and Pakes (1996), which allows for firm-specific productivity differences exhibiting idiosyncratic changes over time.[5] This semiparametric approach, increasingly used in empirical industrial organization and international business literature (e.g., Pavcnik, 2003; Cingano and Schivardi, 2004; Blalock and Gertler, 2007), presents several advantages compared with other methods in dealing effectively with the typical simultaneity problem in the choice of inputs (see *infra*).[6] Specifically, the Olley and Pakes methodology assumes that at the beginning of every period a firm chooses variable production factors (e.g., labor) and the level of investments. The latter, together with the current value of the capital stock, determines the capital stock at the beginning of the next period.[7] Starting from a standard Cobb-Douglas production function:

$$y_{it} = \alpha + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it} , \qquad (2)$$

where y_{it}, l_{it}, and k_{it} denote the logarithm of production output, labor, and capital, respectively; subscripts i and t stand for the cross-section dimension and time; ω_{it} represents a productivity difference known to the firm but unobservable to the econometrician; and ε_{it} denotes other sources of i.i.d error. Consistent estimates of the coefficients of the input factors are prevented by an endogeneity problem. In fact, firms choose the input knowing their own level of productivity, leading to correlation between regressors and error terms if (a proxy of) ω_{it} is not specified. To deal with this problem, it is assumed that labor is a variable input while capital is a fixed factor affected only by the distribution of ω conditional on information in $t-1$ and past values of ω (i.e., a first-

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[5] For a survey of the various estimation techniques of TFP and a more detailed description of Olley and Pakes's (1996) methodology, see Levinsohn and Petrin (2003) and Van Biesebroeck (2007). In what follows we adhere closely to Van Biesebroeck (2007).

[6] Quoting Griliches and Mairesse (1998), also reported by Levinsohn and Petrin (2003: 321): 'The major innovation of Olley and Pakes is to bring in a new equation, the investment equation, as a proxy for ω (i.e., the productivity shock), the unobserved component of the error term. Trying to proxy for the unobserved ω (if it can be done correctly) has several advantages over the usual within estimators (or the more general Chamberlain and GMM type estimators): it does not assume that ω reduces to a *fixed* (over time) firm effect; it leaves more identifying variance in l (labor) and k (capital), and, hence, is a less costly solution to the omitted variable and/or simultaneity problem, and it should also be substantively more informative.' Additionally, differently from other alternative methods (e.g., the GMM instrumental variables approach by Blundell and Bond, 2000), it also easily allows separate production functions across sectors to be specified, notably to distinguish manufacturing from services industries, which is particularly indicated for a sectoral heterogeneous sample like the one considered in the present study.

[7] As customary in this context, investments are calculated as the book value of tangible and intangible assets at time t minus the book value of tangible and intangible assets at time $t-1$ plus depreciation at time t.

order Markov process). The level of investments depends on the capital stock and the firm's unobserved productivity: $i_{it} = i_{it}(\omega_{it}, k_{it})$. In turn, if monotonic properties are satisfied, the unobserved productivity ω_{it} can be expressed as a function of observable investments and k_{it}: $\omega_{it} = f(i_{it}, k_{it})$. Then, the function $\vartheta_{it} = \alpha + \omega_{it} + \beta_k k_{it}$ is defined and approximated nonparametrically by a fourth-order polynomial. In the first step, this latter expression is substituted in Eq. (2), to overcome the endogeneity problem and consistently estimate β_l. The coefficient β_k is similarly obtained in a second step by exploiting the assumption that the stock of capital does not immediately respond to productivity shocks, defining and estimating the following equation:

$$y_{it} - \hat{\beta}_l \, l_{it} = \beta_k k_{it} + \psi(\hat{\vartheta}_{it-1} - \beta_k \, k_{it-1}) + \varepsilon_{it} \,, \qquad (3)$$

where again function ψ is approximated nonparametrically by a fourth-order polynomial.

This procedure is run separately for each industry.[8] Then, in the final step, the residuals of the production function ($\ln A_{it}$) segmented for each industry serve to calculate the productivity levels of each firm with respect to the sector average ($\overline{\ln A_t}$) according to the following expression:

$$\ln TFP_{it} = \ln A_{it} - \overline{\ln A_t} = \ln y_{it} - \overline{\ln y_t} - \beta_l (\ln l_{it} - \overline{\ln l_t}) - \beta_k (\ln k_{it} - \overline{\ln k_t}) \,. \qquad (4)$$

4.3 Explanatory variables

Definitions of all the explanatory variables used in the estimation of the econometric model are reported in Table 3. As mentioned above, these variables are classified in three groups.

[Table 3 about here]

The first group of variables captures participation in EURJVs. To test Hypothesis 1, we include in the set of regressors the number of EURJVs in which NTBF *i* participates at *t*

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[8] Note that in order to have a sufficient number of observations in each industry, we aggregate the previously exposed sectors into three macro industries: manufacturing, software, and Internet and telecommunication services.

($NumberEURJV_{it}$) and its squared value ($SqNumberEURJV_{it}$). We expect the coefficient of $NumberEURJV_{it}$ to be positive and that of $SqNumberEURJV_{it}$ to be negative. To test H2 and H3, we use as proxies for the international heterogeneity of the portfolio of the industrial ($CountriesIndustrialPartners_{it}$) and academic partners ($CountriesAcademicPartners_{it}$) at *t*, the number of countries where, respectively, the industrial and the academic partners of NTBF *i* are located, divided by the number of EURJVs in which the NTBF participates at *t*. We set the values of both variables to zero for all the NTBFs that do not participate in any EURJVs at *t*. We predict a positive coefficient for the former variable and a negative coefficient for the latter. As we expect a curvilinear relation between the NTBF performance and the international heterogeneity of their industrial partners, we also include the squared value of $CountriesIndustrialPartners_{it}$ ($SqCountriesIndustrialPartners_{it}$). We predict a negative coefficient for this variable. As a control, we insert an additional variable in the model specification, $CountriesOtherPartners_{it}$, to reflect the average number of countries per alliance where other partners (e.g., foundations, public administrations) of NTBF *i* are located.

The second group of variables includes three measures of the proximity of the home countries of the NTBFs' industrial partners to world knowledge, markets, and resources. We build the three variables relying on the indicators of proximity proposed by Nachum *et al.* (2008). They first calculated a measure of geographical proximity of country *j* to the rest of the world by aggregating the bilateral distance between countries *j* and *k* (DIS_{jk}) across all countries, using capital cities as the actual points of measurement (Alfaro, Kalemli-Ozcan, and Volosovych, 2008). Then, they standardized the basic proximity measures and calculated a country's proximity to world knowledge, markets, and resources, respectively, by weighting the standardized geographical proximity measures by country values of the relevant factors. The three resulting measures are as follows:

- Proximity to knowledge: $PK_j = \sum_k [DIS_{jk} \times RD_k]$, where knowledge ($RD_k$) is measured by the value of R&D investment in country *k*.
- Proximity to markets: $PM_j = \sum_k [DIS_{jk} \times PCGDP_k]$, where markets ($PCGDP_k$) are operationalized by purchasing power parity (PPP) per capita GDP in country *k*.
- Proximity to resources: $PR_j = \sum_k [DIS_{jk} \times LABOR_k]$, where in measuring resources, the focus is on one resource only, labor ($LABOR_k$), that is operationalized by the potential size of the labor force in country *k*, i.e.,, number of people of working age.

In all these proximity measures, higher values imply lower proximity. Nachum *et al.* (2008) calculated the three proximity measures for 119 countries. As the industrial partners that participate in the EURJVs considered in the present study are located in 27 of these countries, we took into consideration only these 27 countries and calculated PK'_j, PM'_j, and PR'_j as follows. PK'_z, PM'_z, and PR'_z were set to zero for the country *z* exhibiting the highest value of PK, PM, and PR, respectively; PK'_j, PM'_j, and PR'_j were set to $1 - PK_j/PK_z$, $1 - PM_j/PM_z$, and $1 - PR_j/PR_z$, respectively, for any other country *j*. Therefore, the values of PK'_j, PM'_j and PR'_j range from zero (lowest proximity) to one (greatest proximity).

The variables $KnowledgeProx_{it}$, $MktProx_{it}$, and $ResourceProx_{it}$ are calculated as the average values of the PK'_j, PM'_j, and PR'_j, respectively, of the countries where the industrial partners of NTBF *i* are located. Contrary to Nachum *et al.* (2008), our proximity variables associate higher values to greater proximity. Therefore, collaborating with firms located in countries that are *close to large knowledge sources* corresponds to high values of $KnowledgeProx_{it}$. Conversely, if all partners are far from large knowledge centers, $KnowledgeProx_{it}$ assumes a low value. As we do for the variables describing the number and characteristics of the partners engaged in EURJVs, we set the values of the three proximity variables to zero for all the NTBFs that do not participate in any EURJVs at *t*. According to Hypothesis 4, the proximity to world knowledge of the home countries of NTBFs' industrial partners should have a positive effect on NTBF performance. Hence, we expect the coefficient of $KnowledgeProx_{it}$ to be positive. However, we have no predictions as to the coefficients of $MktProx_{it}$ and $ResourceProx_{it}$, which, again, are inserted in the model specification as controls.

The third group of variables includes additional controls for firm- and founder-specific characteristics.[9] As a firm's innovativeness is likely to influence productivity (Crepon, Duguet, and Mairesse, 1998; Parisi, Schiantarelli, and Sembenelli, 2006), we introduce firm patent stock ($Patent_{it-1}$) in the model specification to capture a firm's previous patenting activity. We also consider indicators of the firm's financial structure. Following Chemmanur *et al.* (2008), we control for the alleged positive effect of venture capital (VC) backing by including $DIVC_{it-1}$ and $DCVC_{it-1}$, indicating NTBFs that received VC financing from independent VC firms and corporate investors, respectively. We also control for the effect of firm creditworthiness (Becchetti and Trovato, 2002) by including the debt to total assets ratio ($DebtOnAssets_{it-1}$) and for the effect of free cash flow (Brush, Bromiley, and Hendrickx, 2000) by including the cash flow to sales ratio ($CFOnSales_{it-1}$). As NTBF performance is influenced by the characteristics of the founders, we control for the size of the firms' founding team ($NFounders_i$) and include measures of both *generic* and *specific* human capital of the firm's founders.[10] As to the former category, we consider the level of education measured by the mean number of years of university-level education of the founders in both economics and management ($EcoEducation_i$) and technical and scientific fields ($TecEducation_i$), as well as the mean number of years of professional experience in sectors other than that of the new firm ($OthWorkExp_i$). As to specific human capital, $SpecWorkExp_i$ measures the years of professional experience of the founders in the same sector of activity as that of the new firm. Finally, we include two time-invariant firm-specific controls: (1) a dummy ($DASU_i$) equal to one for academic start-ups, that is, NTBFs that were created by one or more individuals with prior

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[9] Following Smarzynska, 2004) and Castellani and Zanfei (2006), our list of controls does not include any measure of NTBF size, as the effect of this variable is already taken into account in the procedure used to calculate firms' TFP.

academic experience; and (2) a measure of the level of infrastructure development in the province (NUTS3 level) of NTBF's location ($LocDevelop_i$).

Descriptive statistics for the explanatory variables are reported in Table 4.

[Table 4 about here]

5 - Theoretical hypotheses

5.1 Results of econometric estimates

Table 5 presents the results of the estimates. The autocorrelation tests and the Hansen test of overidentifying restrictions support our choice of the GMM-SYS estimator. In particular, the Hansen statistics in Models 1-5 accept the null hypothesis on the validity of the set of instruments used for the endogenous variables. Moreover, the autocorrelation tests always exclude the presence of a second-order autocorrelation in the error terms.

[Table 5 about here]

Model 1 includes only control variables. The estimates show that NTBF age has a positive significant impact on TFP. Relatively more mature firms have had more time than very young ones to properly organize their production and sales activity. Quite reasonably, being located in a developed area exerts a positive influence on firm productivity. VC investments are beneficial to TFP (for analogous findings see Chemmanur *et al.*, 2008), but only if they are obtained from an independent VC investor. $DebtOnAssets_{it-1}$ and $CFOnSales_{it-1}$ show positive and statistically significant coefficients. Conversely, none of the founder-specific attributes is found to significantly affect NTBF productivity.

In Model 2, we add to the controls all the explanatory variables of interest for the test of the hypotheses formulated earlier . The addition of these variables substantially increases the

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[10] See Becker (1975) for such distinction and Colombo, Delmastro, and Grilli (2004) and Colombo and Grilli (2005) for its empirical application.

explanatory power of the model, as it is apparent from the value of the Wald test ($\chi^2(6) = 23.91$) significant at 1 percent (reported at the bottom of the table). Contrary to our expectations, the estimates show the absence of any inverse U-shaped relation between TFP and (1) the number of EURJVs (i.e., H1 is not supported) and (2) the international heterogeneity of the portfolio of the industrial partners of NTBFs (i.e., H2 is not supported). In fact, the coefficients of the squared terms of $NumberEURJVs_{it}$ and $CountriesIndustrialPartners_{it}$ are far from being significant. However, two separate Wald tests reject the null hypothesis at conventional confidence levels, i.e., the linear and quadratic terms of these covariates are jointly equal to zero ($\chi^2(2) = 5.76$ and $\chi^2(2) = 6.61$), pointing to the presence of linear effects in both cases. Conforming with our theoretical expectations, the international heterogeneity of NTBF's portfolio of the academic partners is found to exert a negative effect on NTBF productivity (i.e., H3 is supported): the coefficient of the variable $CountriesAcademicPartners_{it}$ is negative and weakly statistically significant. Finally, Hypothesis 4, which theorized an increase in NTBF productivity due to proximity to world technological knowledge of the industrial partners' home countries is supported, as highlighted by the positive (although weakly significant) sign of the variable $KnowledgeProx_{it}$.[11] Of note, proximity of industrial partners to world markets and supply of labor does not seem to exert any positive effect, the coefficients of both $MktProx_{it}$ and $ResourceProx_{it}$ not being significant. Finally the magnitude and statistical significance of the control variables remain almost unchanged (with the exception of $DIVC_{it-1}$, still positive but only close to significance) with respect to the only-controls specification of Model 1, bringing robustness to our findings.

In Model 3, we drop the squared terms of $NumberEURJVs_{it}$ and $CountriesIndustrialPartners_{it}$, allowing a more direct interpretation of the effects of these variables on TFP. The estimates reveal

[11] We also measured the proximity to world knowledge, market, and resources of the home countries of academic partners and substituted these new variables in $KnowledgeProx_{it}$, $MktProx_{it}$, and $ResourceProx_{it}$, respectively. The coefficient of the measure of the proximity of academic partners to world knowledge sources is not significant. As we expected, selecting academic partners located close to world knowledge sources does not contribute to NTBF performance, as research organizations are less effective than firms in providing NTBFs with access to worldwide knowledge. The results are available from the authors upon request.

that both variables have positive and statistically significant coefficients (at the 5% and 1% levels, respectively). Results concerning other variables are very similar to those illustrated above (i.e., only H3 and H4 are supported), the statistical significance of several coefficients being strengthened. In particular, the positive coefficient of $KnowledgeProx_{it}$ is now significant at the 5 percent level.

In Model 4, the variables $IndustrialPartnerPerCountry_{it}$, $AcademicPartnerPerCountry_{it}$, and $OtherPartnerPerCountry_{it}$ are added to the regressors of Model 3. These new variables are calculated as the partners to countries ratios distinguishing the three types of partners in NTBFs' portfolios. The first of these variables is aimed at checking whether the positive effect on TFP that we attributed to the international heterogeneity of the portfolio of industrial partners of NTBFs is simply a consequence of the greater number of partner firms. Should this be the case, the coefficient of $IndustrialPartnerPerCountry_{it}$ would be positive. The other two variables are controls. Actually, the coefficient of $IndustrialPartnerPerCountry_{it}$ turns out to be negative and weakly significant. The addition of a new partner contributes positively to NTBF's productivity only to the extent that it increases the international heterogeneity of the portfolio. If it does not, the effect is negative. As to the remaining explanatory variables, only the coefficients of $NumberEURJVs_{it}$ and $KnowledgeProx_{it}$ are positive and significant as they were in Model 3 (i.e., only H4 is supported).

Finally, Model 5 investigates whether the impact on NTBFs' TFP of the location of their industrial partners depends on the knowledge and resources embedded in the partners' home countries rather than on the proximity of these countries to world technological knowledge. For this purpose, we substitute the three previously employed measures of proximity with three corresponding covariates capturing (1) average R&D expenses ($KnowledgeHomeCountry_{it}$); (2) market size ($MktHomeCountry_{it}$); and (3) labor resources ($ResourceHomeCountry_{it}$), respectively, in the home countries of the alliance partners. These new variables show insignificant coefficients, except for that of $ResourceHomeCountry_{it}$, which is negative and weakly significant. These estimates confirm that the bridging role performed to the advantage of NTBFs by their industrial partners in EURJVs goes far beyond the creation of a link that allows the NTBF to have access to the knowledge embedded in partners' home countries. In fact, the key advantage provided by this link lies in making world knowledge more accessible, something that NTBFs would not be able to do on their own. Results concerning other variables are similar to those in Model 3: only H3 is supported, with the statistical significance of $CountriesIndustrialPartners_{it}$ and $CountriesAcademicPartners_{it}$ being strengthened and that of $NumberEURJVs_{it}$ being weakened.

In summary, the results of our estimates confirm that international R&D alliances potentially have a positive impact on the performance of NTBFs. However, they also indicate that the extent of this allegedly positive impact crucially depends on the selection of suitable partners. Alliances with a plurality of industrial partners, which because of their central location are able to create a bridge between the NTBF and globally dispersed sources of technological knowledge, are the most beneficial ones.

To assess the economic magnitude of the effects on TFP of the EURJVs established by sample NTBFs, we compared the estimated TFP level of a *benchmark* firm (i.e., a firm not participating in any EURJV) with that of the same benchmark firm participating in EURJVs. Initially, based on the estimates of Model 3, we computed the TFP level of a benchmark firm with all other independent variables set at their median value. Then, we considered the same NTBF but with a high propensity to be involved in international R&D alliances (i.e., the 90th percentile of the variable $NumberEURJV_{it}$, with all other variables in the *EURJV* and *Proximity* vectors set at their median values, conditional upon participation in EURJVs). TFP is estimated to increase by 71 percent. Then, we analyzed the marginal effect on TFP generated by changes in the characteristics of alliance partners. With respect to the benchmark NTBF, TFP is found to further increase by 129 percent if (1) there is high heterogeneity in the location of industrial partners and (2) the countries where industrial partners are located are close to world technological knowledge (i.e., *CountriesIndustrialPartners*$_{it}$ and *KnowledgeProximity*$_{it}$ are set at values corresponding to the 75th percentile). According to our estimates, TFP is sensitive to the international heterogeneity of the portfolio of alliance partners, while the magnitude of the effects of proximity to world knowledge is smaller. In fact, if the international heterogeneity of industrial partners is high but their locations are far from world knowledge sources (*CountriesIndustrialPartners*$_{it}$ and *KnowledgeProx*$_{it}$ are set at their 75th and 25th percentiles, respectively), the TFP increase is 96 percent. However, the TFP increase is 19 percent if—albeit close to these knowledge sources—the number of countries where industrial partners are located is low (*CountriesIndustrialPartners*$_{it}$ and *KnowledgeProx*$_{it}$ set at their 25th and 75th percentiles, respectively).

5.2 Robustness checks: testing for survivorship bias

The use of survey information implies a potential survivorship bias in data that may intervene in the investigated relationship. To examine the extent of this bias, we focused on the RITA 2000 sample. This sample, composed of 401 firms, was selected according to the same criteria and strategy that were used for the RITA 2004 sample (see Colombo *et al.*, 2004). Of these firms, 101 exited the sample in the 2000-03 period. The fraction of EURJV participating firms in the subsample of surviving firms was slightly lower than in the exited firms' subsample (9.3% and 9.9%, respectively). A χ^2 test showed that the difference between the two subsamples was not statistically significant at any conventional confidence levels ($\chi^2(1) = 0.03$).

More importantly, to directly test for a possible survivorship bias, we adapted to our specific framework the standard Wooldridge's (1995) variable addition test for selection bias in panel data (see also Baltagi 2003) and a more recent methodology proposed by Semykina and Wooldridge (2006) that extends the previous one in allowing the test in the presence of unobserved heterogeneity and endogenous regressors.[12] In particular, based on the RITA 2000 sample, we

[12] We followed as closely as possible, given our data constraints, the two mentioned test approaches of Wooldridge (1995) and Semykina and Wooldridge (2006). In particular, since we are estimating a single probit equation of firm exit

estimated a probit model on firm exits in the 2000-03 period conditional on survival up to the end of 1999; the dependent variable in this model is the hazard rate of exit of sample firms in the 2000-03 period. The independent variables of this sample-selection model include founders' human capital variables (i.e., technical-scientific and economic-managerial university-level education and professional and managerial experience), firm-specific characteristics (e.g., firm size and age in 1999), and industry and geographical controls. We then used the estimated coefficients of this model to compute an inverse Mill's ratio control factor for firm exit in time *t* for each of the 265 firms included in the sample under consideration in the present work.[13] This time-varying ratio was then inserted as a control for survivorship bias in the TFP equation, which was then estimated both by the within-group (WG) estimator and by an instrumental variable approach such as GMM-SYS as required by Wooldridge (1995) and Semykina and Wooldridge (2006), respectively.[14] This additional variable aims at controlling for the unobserved heterogeneity that affects both a firm's probability of being sampled in 2004 and its productivity performance (see Winship and Morgan, 1999; Greene, 2003). The estimates of Models a2 and a3 shown in Table A1 in the Appendix—Model a1 shows the results of the WG estimates of the specification without controls for selectivity bias added for comparison purposes—indicate that the coefficient of the inverse Mill's ratio is not statistically significant, excluding the presence of any remarkable survivorship bias. Comparison of the estimates of Models a1 and a2 also suggests that the inclusion of the control for firm exit does not greatly influence our results.

(see *infra* in the main text), the only major simplification we are forced to implement in our setting with respect to Wooldridge's original framework and its subsequent extension is to assume that the impact of each determinant of firm exit does not vary over time.

[13] Formally (see also Winship and Morgan, 1999; Greene, 2003): $\lambda_{itEXIT} = \frac{-\phi(\psi' w_{it})}{\Phi(\psi' w_{it})}$, where w_{it} is the vector of independent variables of the probit model on firm exit; and $\phi(\cdot)$ and $\Phi(\cdot)$ are, respectively, the density and distribution functions of the standard normal.

[14] Note that: (1) step 2 (see also Baltagi, 2003) of Wooldridge's (1995) procedure applies a pooled OLS estimator only on the sample of selected firms using WG transformed variables; this translates in our framework in implementing a WG estimator only on the survived firms; and (2) the inverse Mill's ratio in Semykina and Wooldridge's (2006) version

6 - Discussion and conclusions

In this article we have investigated the *treatment effect* of the formation of a particular type of international R&D alliance—R&D collaborations funded by the EU—on the performance of NTBFs as measured by their TFP. In particular, we have analyzed whether this effect is contingent on the type and country of partner firms. For this purpose, we considered the EURJVs established by a large sample of Italian NTBFs observed over the 10-year period from 1994 to 2003, and we resorted to GMM-SYS estimates.

The article provides several new insights. NTBFs with more collaborations performed better than other comparable NTBFs. More interestingly, the greater the number of countries in which industrial partners are located and the closer these countries are to worldwide knowledge sources, the more positive the effect of the R&D alliances on firm performance. Conversely, collaborative ties with research organizations do not provide similarly beneficial effects, at least in the short term (for similar results see Medda *et al.*, 2005; Nieto and Santamaria, 2009). Taken together, these results indicate that the creation of a wide network of international R&D alliances *potentially* provides NTBFs with great benefits. However, whether these potential benefits are realized or not crucially depends on the selection of *suitable partners*. Previous studies on alliances inspired by the competence-based perspective (Teece, 1986; Ahuja, 2000; Gans and Stern, 2003) have argued that alliances are an important mechanism for enlarging the competence endowment on which NTBFs rely. In this article, we have gone a step further. Drawing on the view recently proposed by literature on global strategic networks that proximity to worldwide knowledge is an increasingly crucial characteristic of countries over and beyond their local endowment of resources (Nachum *et al.*, 2008), we have documented that industrial partners of international R&D collaborations that are located in proximity to world knowledge sources provide a bridging effect that is beneficial to NTBFs. In other words, alliance partners create an indirect link with these knowledge sources,

of the test is treated as an exogenous covariate. We thank Dr. Anastasia Semykina for personal communication made making them more accessible to NTBFs. Without these links, world knowledge would remain largely inaccessible to these firms.

We are aware that this study has some limitations, which open up opportunities for future research. Although the availability of longitudinal detailed data for a quite large number of NTBFs clearly is a strength of this article, only a few NTBFs entered in EURJVs over the observation period. This is probably the most important limitation of the present study. To further check the robustness of our results, additional analyses on samples including a greater number of NTBFs that were involved in international R&D alliances would be useful. Further analysis would also provide the opportunity to examine whether the *bridging role* of industrial partners that was highlighted in this study is contingent on firm- and alliance-specific characteristics. Moreover, it would be worthwhile extending the analysis of the effects on firm performance of partners' characteristics to such aspects as the size and international dispersion of their operations. For instance, one may wonder whether partnering with multinational enterprises that have developed their own global networks embedded in a variety of countries due to the multiple locations of their subsidiaries engenders different, possibly stronger bridging effects to the advantage of NTBFs. Second, we focus here on Italian NTBFs. This raises the issue of whether our results are generalizable to other countries. In particular, because of its sectoral specialization, Italy does not have a strong innovation system in high-tech sectors. Therefore, having access to world technological knowledge is probably even more important for Italian NTBFs than for NTBFs located in countries with more favorable local knowledge endowments. Italian NTBFs generally suffer from binding resource and financial constraints (see, e.g., Colombo and Grilli, 2007; Bertoni, Colombo, and Croce, 2009). This makes the bridging effect provided by alliance partners even more important. Thus, this study should be replicated in countries with business and financial environments more favorable to NTBFs. Third, one may also want to investigate whether the results we obtained here—notably

available to the authors confirming this as the correct procedure.

those relating to the location of alliance partners—extend to other types of alliances. For instance, we have found here that proximity of EURJVs' partners to world markets and labor resources does not play a significant role. However, whether this type of proximity is important in other alliances, such as commercial alliances, remains an open question. Lastly, we consider the use of TFP as a strength of the present work. Nevertheless, it would be interesting to make a step further and examine what precisely are the sources of the positive effect on the efficiency of NTBFs of the establishment of international alliances with industrial partners (e.g., whether it mainly is a demand or supply-side effect).

In spite of the above limitations, this study extends our understanding of the international alliances of NTBFs considerably. Moreover, it has implications for both owner-managers of NTBFs and policymakers. Baum *et al.* (2000) summarizes the prescription of their study for NTBFs' owner-managers in the following statement: 'Do not go it alone.' While we share their view, we add another prescription: 'Select suitable teammates.' High-tech start-ups that aim to overcome their lack of internal competencies through a network of alliances need to carefully select their partners. In doing so, NTBFs' owner-managers should not only consider the specialized competencies their alliance partners possess, but also the proximity of partners' countries to worldwide dispersed sources of knowledge. Of course, building an effective network of alliance partners is a managerial challenge. In particular, it is often difficult for an NTBF to signal its attractiveness to firms it would like to team with, especially if it does not have adequate patent activity (Stuart *et al.*, 1999; Stuart, 2000) or does not have a portfolio of successful new products (Rothaermel, 2002). Under these circumstances, being backed by a *sponsor*, such as a reputable VC investor, may be of great help (see e.g., Colombo *et al.*, 2006; Hsu, 2006).

Our study also gives interesting indications to policymakers. First and foremost, it suggests that the R&D collaborations funded by the EU—when they were properly designed—have improved the efficiency of the NTBF sector. From this standpoint, it is fundamental to recognize the importance of the bridging role toward world knowledge sources played by these collaborations. In addition, our findings argue in favor of the effort made by the European Commission (EC) in the last decade to stimulate European NTBFs and small firms to participate in EU-funded R&D projects. More specifically, since the launch of the EU´s Sixth Framework Programme (FP6), special small-scale actions such as the Specific Targeted Research Projects (STREPs) have encouraged small- and medium-sized enterprises (SMEs) to initiate their own projects. Substantial funds have been allocated to such measures. Moreover, the network of National Contact Points providing information and assistance to potential participants was expanded by the EC in 2007. This resulted in an increase in both SME requests for funding and SME participation in EU-funded research projects toward the target 15 percent set by the EC. However, we believe there is room for further improvements in this area. In particular, policy schemes helping NTBFs in finding suitably located alliance partners could be very beneficial for these firms. Different schemes may serve this purpose. On the one hand, business innovation centers, science parks, and incubators could support tenant NTBFs in their network building activity. In fact, firms incubated in science parks and business innovation centers have been found to participate in EURJVs more often than off-incubator firms (Colombo and Delmastro, 2002).[15] On the other hand, we mentioned above that NTBFs face serious adverse selection problems in searching for alliance partners. These problems are alleviated for VC-backed firms. Hence, in countries where the VC sector is still underdeveloped, policy measures that make it easier for NTBFs to obtain financing from reputable VC investors may have the indirect beneficial effect of facilitating the formation of international alliances with suitably located partners. Policy schemes that selectively give grants to innovative NTBFs in the very early stages of their existence—if they are administered by reputable governmental bodies—could provide a similar certification effect (Lerner, 1999; Colombo,

[15] However, whether on-incubator location has any effect on choices by tenant firms concerning type of partners involved in EURJVs remains to be tested. Hence, whether these organizations help NTBFs in joining forces with suitable partners is questionable.

Giannangeli, and Grilli, 2009). A strength of this type of scheme (that has, so far, gone quite unnoticed) is that they could help the beneficiary NTBFs find suitable alliance partners, which in turn would positively affect firm performance.

7 - References

Acs ZJ, Morck R, Yeung B. 1999. Productivity growth and firm size distribution. In *Entrepreneurship, Small- and Medium-Sized Enterprises and the Macroeconomy*. Acs ZJ, Carlsson B, Karlsson C, (eds). Cambridge University Press: Cambridge, U.K.

Aghion P, Blundell R, Griffith R, Howitt P, Prantl S. 2009. The effects of entry on incumbent innovation and productivity. *Review of Economics and Statistics* **91**: 20-32.

Aitken BJ, Harrison AE. 1999. Do domestic firms benefit from direct foreign investment? Evidence from Venezuela. *American Economic Review* **89**: 605-618.

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

Alfaro L, Kalemli-Ozcan S, Volosovych V. 2008. Why doesn't capital flow from rich to poor countries? An empirical investigation. *The Review of Economics and Statistics* **90**: 347-368.

Almeida P, Kogut B. 1999. Localization of knowledge and the mobility of engineers in regional networks. *Management Science* **45**(7): 905-918.

Andersson U, Forsgren M. 2000. In search of centre of excellence: network embeddedness and subsidiary roles in multinational corporations. *Management International Review* **40**: 329-350.

Andersson U, Forsgren M, Holm U. 2002. The strategic impact of external networks: subsidiary performance and competence development in the multinational corporation. *Strategic Management Journal* **23**(11): 979-996.

Ahuja G. 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* **21**(3): 317-343.

Baltagi BH. 2003. *Econometric Analysis of Panel Data* (2nd edn). John Wiley & Sons, Chichester, U.K.

Baum JAC, Calabrese T, Silverman BS. 2000. Don't go it alone: alliance network composition and start-ups' performance in Canadian biotechnology. *Strategic Management Journal* **21**(3): 267-294.

Baum JAC, Silverman BS. 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology start-ups. *Journal of Business Venturing* **19**(3): 411-436.

Becchetti L, Trovato G. 2002. The determinants of growth for small- and medium-sized firms. The role of the availability of external finance. *Small Business Economics* **19**(4) 291-306.

Becker GS. 1975. *Human Capital*. National Bureau of Economic Research: New York.

Bellone F, Musso P, Nesta L, Quéré M. 2008. Market selection along the firm life cycle. *Industrial and Corporate Change* **17**: 753-777.

Benfratello L, Sembenelli A. 2006. Foreign ownership and productivity: is the direction of causality so obvious? *International Journal of Industrial Organization* **24**(4): 733-751.

Bernard A, Jensen JB, Schott PK. 2006. Survival of the best fit: exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants. *Journal of International Economics* **68**: 219-237.

Bertoni F, Colombo MG, Croce A. 2009. The effect of venture capital financing on the sensitivity to cash flow of firm's investments. *European Financial Management*. Forthcoming.

Betz F. 1996. Industry-university partnerships. In *Handbook of Technology Management*, Gaynor G (ed). McGraw-Hill: New York;.

Birley S. 1984. Finding the new firm. *Proceedings of the Academy of Management Meetings* **47**: 64-68.

Blalock G, Gertler PJ. 2007. Welfare gains from Foreign Direct Investment through technology transfer to local suppliers. *Journal of International Economics* **74**(2): 402-421.

Blundell R, Bond S. 1998. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics* **87**: 115-143.

Blundell R, Bond S. 2000. GMM estimation with persistent panel data: an application to production functions. *Econometric Reviews* **19**(3): 321-340.

Bond S. 2002. Dynamic panel data models: a guide to micro data methods and practice. *Portuguese Economic Journal* **1**: 141-162.

Bower JD. 1993. Successful joint ventures in science parks. *Long Range Planning* **26**(6): 114-120.

Brush TH, Bromiley P, Hendrickx M. 2000. The free cash flow hypothesis for sales growth and firm performance. *Strategic Management Journal* **21**(4): 455-472.

Cantwell JA, Piscitello L. 2008. Increasing openness: the coevolution of MNEs' innovation strategies, location, and business networks. Paper presented at the annual meeting of the Strategic Management Society, Cologne, Germany.

Castellani D, Zanfei A. 2006. *Multinational Firms, Innovation and Productivity*. Edward Elgar Publishing Ltd.: Cheltenham, U.K.

Chemmanur T., Nandy D. 2006. How do Spin-offs Increase Efficiency? A Look Inside the Black Box. Working paper, Boston College.

Chemmanur T, Krishnan K, Nandy D. 2008. How does venture capital financing improve efficiency in private firms? A look beneath the surface. Working paper, Boston College and York University.

Cingano F, Schivardi F. 2004. Identifying the sources of local productivity growth. *Journal of the European Economic Association* **2**(4): 720-742.

Colombo MG, Delmastro M. 2002. How effective are technology incubators?: Evidence from Italy. *Research Policy* **31**(7): 1103-1122

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

Colombo MG, Grilli L. 2007. Funding gaps? Access to bank loans by high-tech start-ups. *Small Business Economics* **29**(1-2): 25-46.

Colombo MG, Giannangeli S, Grilli L. 2009. Public subsidies and the growth of high-tech start-ups: assessing the impact of selective and automatic support schemes. Working paper, Politecnico di Milano.

Colombo MG, Grilli L, Piva E. 2006. In search for complementary assets: the determinants of alliance formation of high-tech start-ups. *Research Policy* **35**: 1166-1199.

Colombo MG, Piva E. 2008. Strengths and weaknesses of academic start-ups: a conceptual model. *IEEE Transactions on Engineering Management* **55**(1): 37-49.

Crepon B, Duguet E, Mairesse J. 1998. Research, innovation, and productivity: an econometric analysis at the firm level. *Economics of Innovation and New Technology* **7**(2): 115-158.

Deeds DL, Hill CWL. 1996. Strategic alliances and the rate of new product development: an empirical study of entrepreneurial biotechnology firms. *Journal of Business Venturing* **11**(1): 41-55.

Driffield N, Du J, Girma S. 2008. Optimal geographic diversification and firm performance: evidence from the U.K. *Journal of Productivity Analysis* **30**: 145-154.

Eisenhardt KM, Schoonhoven CB. 1996. Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms. *Organization Science* **7**: 136-150.

European Commission. 2007. *Supporting SMEs Participation in Research Framework Programmes*. Office for Official Publications of the European Communities: Luxembourg.

Forsgren M, Holm U, Johanson J. 2005. *Managing the Embedded Multinational. A Business Network View*. Edward Elgar: Cheltenham, U.K.

Gans JS, 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.

Girma S, Görg H, Strobl E. 2007. The effect of government grants on plant-level productivity. *Economics Letters* **94**: 439-444.

Girma S, Görg H, Strobl E, Walsh F. 2008. Creating jobs through public subsidies: an empirical analysis. *Labour Economics* **15**: 1179-1199.

Grant R. 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal* **17**: 109-122.

Greene WH. 2003. *Econometric Analysis* (5th edn). Prentice Hall: Upper Saddle River, NJ.

Griliches Z, Mairesse J. 1998. Production functions: the search for identification. In *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, Strøm S (ed). Cambridge University Press: Cambridge, U.K.; 169-203.

Gulati R. 1998. Alliances and networks. *Strategic Management Journal* **19**(4): 293-317.

Gulati R. 2007. *Managing Network Resources. Alliances, Affiliations, and Relational Assets*. Oxford University Press: Oxford, U.K.

Gulati R, Nohria H, Zaheer A. 2000. Strategic networks. *Strategic Management Journal* **21**(3): 203-215.

Hall BH, Link AN, Scott JT. 2001. Barriers inhibiting industry from partnering with universities: evidence from the Advanced Technology Program. *Journal of Technology Transfer* **26**: 87-98.

Hall BH, Link AN, Scott JT. 2003. Universities as research partners. *Review of Economics and Statistics* **85**(2): 485-491.

Hall BH, Mairesse J. 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics* **65**: 263-293.

Hansen LP. 1982. Large sample properties of generalized method of moments estimators. *Econometrica* **50**: 1029-1054.

Hennart JF. 2000. Transaction costs theory and the multinational enterprise. In *The Nature of the Transnational* (2nd edn), Pitelis C, Sugden R. (eds). Routledge: London, U.K.

Hennart JF, Zeng M. 2002. Cross-cultural differences and joint venture longevity. *Journal of International Business Studies* **33**: 699-716.

Hsu DH. 2006. Venture capitalists and cooperative start-up commercialization strategy. *Management Science* **52**(2): 204-219.

Hsu DH, Ziedonis RH 2007. Patents as quality signals for entrepreneurial ventures. Paper presented at the Danish Research Unit on Industrial Research (DRUID) Summer Conference, Copenhagen, Denmark.

Jaffe A, Trajtenberg M, Henderson R. 1993. Geographical localisation of knowledge spillovers, as evidenced by patent citations. *Quarterly Journal of Economics* **58**: 577-598.

Javorcik BS. 2004. Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *American Economic Review* **94**: 605-627.

Lavie D. 2006. The competitive advantage of interconnected firms: an extension of the resource-based view. *Academy of Management Review* **31**(3): 638-658.

Lavie D. 2007. Alliance portfolios and firm performance: a study of value creation and appropriation in the U.S. software industry. *Strategic Management Journal* **28(12)**: 1187-1212.

Lavie D, Miller SR. 2008. Alliance portfolio internationalisation and firm performance. *Organization Science* **19**(4): 623-646.

Lee C, Lee K, Pennings JM. 2001. Internal capabilities, external networks, and performance: a study on technology-based ventures. *Strategic Management Journal* **22**(6/7): 615-640.

Leiponen A. 2005. Skills and innovation. *International Journal of Industrial Organization* **23**(5-6): 303-323.

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

Levinsohn J, Petrin A. 2003. Estimating production functions using inputs to control for unobservables. *Review of Economic Studies* **70**(2): 317-342.

Link AN, Siegel DS. 2007. *Innovation, Entrepreneurship, and Technological Change.* Oxford University Press, U.S.A.

McEvily B, Zaheer A. 1999. Bridging ties: a source of firm heterogeneity in competitive capabilities. *Strategic Management Journal* **20**(12): 1133-1156.

Medda G, Piga C, Siegel DS. 2005. University R&D and firm productivity: evidence from Italy. *Journal of Technology Transfer* **30**: 199-205.

Nachum L, Zaheer S, Gross S. 2008. Does it matter where countries are? Proximity to knowledge, markets and resources, and MNE location choices. *Management Science* **54**: 1252-1265.

Nieto MJ, Santamaria L. 2009. Technological collaboration: bridging the innovation gap between small and large firms. *Journal of Small Business Management*. Forthcoming.

Olley GS, Pakes A. 1996. The dynamics of productivity in telecommunications equipment industry. *Econometrica* **64**: 1263-1297.

Oxley JE. 1997. Appropriability hazards and governance in strategic alliances: a transaction cost approach**.** *The Journal of Law, Economics, and Organization* **13**: 387-409.

Parisi ML, Schiantarelli F, Sembenelli A. 2006. Productivity, innovation, and R&D: Micro evidence for Italy. *European Economic Review* **50**(8): 2037-2061.

Pavcnik N. 2003. Trade liberalization, exit, and productivity improvements: evidence from Chilean plants. *Review of Economic Studies* **69**: 245-76.

Penrose ET. 1959. *The Theory of the Growth of the Firm*. Basil Blackwell: Oxford, U.K.

Pisano G. 1990. The R&D boundaries of the firm: an empirical analysis. *Administrative Science Quarterly* **35**(1): 153-176.

Pisano GP. 1991. The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. *Research Policy* **20**: 237-249.

Rothaermel FT. 2002. Technological discontinuities and interfirm cooperation: what determines a start-up's attractiveness as alliance partner? *IEEE Transactions on Engineering Management* **49**(4): 388-397.

Rothaermel FT, Deeds DL. 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. *Strategic Management Journal* **25**(3): 201-221.

Rothaermel FT, Deeds DL. 2006. Alliance type, alliance experience, and alliance management capability in high-technology ventures. *Journal of Business Venturing* **21**(4): 429-460.

Santoro MD, Gopalakrishnan S. 2000. The institutionalization of knowledge transfer activities within industry-university collaborative ventures. *Journal of Engineering and Technology Management* **17**: 299-319.

Semykina A, Wooldridge JM. 2006. Estimating panel data models in the presence of endogeneity and selection: theory and application. Working paper, Michigan State University.

Shan W, Walker G, Kogut B. 1994. Interfirm cooperation and start-up innovation in the biotechnology industry. *Strategic Management Journal* **15**(5): 387-394.

Schilling MA. 2009. Understanding the alliance data. *Strategic Management Journal* **30**(3):233-260.

Smarzynska B. 2004. Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *The American Economic Review* **94**(3): 605-627.

Stuart TE. 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. *Strategic Management Journal* **21**(8): 791-811.

Stuart TE, Hoang H, Hybels RC. 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. *Administrative Science Quarterly* **44**: 315-349.

Stuart TE, Sorenson O. 2007. Strategic networks and entrepreneurial ventures. *Strategic Entrepreneurship Journal* **1**(3/4): 211-227.

Teece DJ. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy. *Research Policy* **15**: 285-305.

Van Biesebroeck J. 2007. Robustness of productivity estimates. *Journal of Industrial Economics* **55**: 529-569.

Walker G, Kogut B, Shah W. 1997. Social capital, structural holes and the formation of an industry network. *Organization Science* **8**(2): 109-125.

Windmeijer F. 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics* **126**: 25-51.

Winship C, Morgan SL. 1999. The estimation of causal effects from observational data. *Annual Review of Sociology* **25**: 659-706.

Wooldridge JM. 1995. Selection corrections for panel data models under conditional mean independence assumptions. *Journal of Econometrics* **68**: 115-132.

Zaheer A, Bell G. 2005. Benefiting from network position: firm capabilities, structural holes, and performance. *Strategic Management Journal* **26**(9): 809-825.

Zucker LG. 1986. Production of trust: institutional sources of economic structure 1840-1920. In *Research in Organizational Behavior*, Staw BM, Cummings LL (eds). JAI Press: Greenwich, CT; 53-111).

Table 1. Distribution of sample firms and firms involved in EU-funded research joint ventures (EURJVs), by industry and geographical area

	Sample firms		**Firms involved in EURJVs**		**EURJVs participation rate**
	N. (a)	%	N. (b)	%	(b)/(a)%
Industry					
ICT manufacturing	57	21.5	6	25.0	10.5
Robotics and automation equipment	25	9.0	2	8.3	8.0
Biotechnologies, pharmaceutics, and advanced materials	14	5.3	3	12.5	21.4
Software	92	30.0	9	37.5	9.8
Internet and telecommunications services	77	29.1	4	16.6	5.2
Total	265	100.0	24	100.0	9.0
Geographic area					
Northwest	128	48.3	7	29.2	5.5
Northeast	65	24.5	4	16.7	6.2
Central	43	16.2	10	41.7	23.2
South	29	10.9	3	12.5	10.3
Total	265	100.0	24	100.0	9.0

Table 2. Characteristics of EURJVs in which sample firms participated from 1994 to 2003

	Mean	S.D.	Min.	Max.
Number of EURJVs per firm (calculated only for the NTBFs that have participated in one or more EURJVs)	3.3	3.3	1.0	15.0
Number of partners per EURJV	9.3	13.1	1.0	94.0
Number of industrial partners per EURJV	3.9	6.8	0.0	58.0
Number of academic partners per EURJV	3.6	8.9	0.0	77.0
Number of other partners per EURJV	1.8	1.9	0.0	10.0
Number of foreign countries in which partners are located per EURJV	3.7	2.7	1.0	21.0
Number of foreign countries in which industrial partners are located per EURJV	1.9	1.7	0.0	10.0
Number of foreign countries in which academic partners are located per EURJV	1.9	2.6	0.0	18.0
Number of foreign countries in which other partners are located per EURJV	1.1	1.2	0.0	5.0

Table 3. Definitions of explanatory variables

Variable	Definition
Participation in EURJVs	
$NumberEURJVs_{it}$	Number of EURJVs in which NTBF *i* participates at year *t*
$SqNumberEURJVs_{it}$	Squared value of the number of EURJVs in which NTBF *i* participates at year *t*
$CountriesIndustrialPartners_{it}$	International heterogeneity of the portfolio of industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*, measured by the number of foreign countries where they are located
$SqCountriesIndustrialPartners_{it}$	Squared value of the measure of the international heterogeneity of the portfolio of industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$CountriesAcademicPartners_{it}$	International heterogeneity of the portfolio of academic partners involved in the EURJVs in which NTBF *i* participates at year *t*, measured by the number of foreign countries where they are located
$CountriesOtherPartners_{it}$	International heterogeneity of the portfolio of other (i.e., nonindustial and nonacademic) partners involved in the EURJVs in which NTBF *i* participates at year *t*, measured by the number of foreign countries where they are located
$IndustrialPartnerPerCountry_{it}$	Number of industrial partners involved in the EURJVs in which NTBF *i* participates at year *t* divided by the number of foreign countries where they are located
$AcademicPartnerPerCountry_{it}$	Number of academic partners involved in the EURJVs in which NTBF *i* participates at year *t* divided by the number of foreign countries where they are located
$OtherPartnerPerCountry_{it}$	Number of other partners involved in the EURJVs in which NTBF *i* participates at year *t* divided by the number of foreign countries where they are located
Proximity variables	
$KnowledgeProx_{it}$	Average value of the rescaled measures of proximity to knowledge (Nachum *et al.*, 2008) of the countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$MktProx_{it}$	Average value of the rescaled measures of proximity to market (Nachum *et al.*, 2008) of the countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$ResourceProx_{it}$	Average value of the rescaled measures of proximity to resources (Nachum *et al.*, 2008) of the countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$KnowledgeHomeCountry_{it}$	Average value of the R&D expenses in the home countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$MktHomeCountry_{it}$	Average value of the market size, operationalized by purchasing power parity (PPP) per capita GDP in the home countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
$ResourceHomeCountry_{it}$	Average value of the labor resources, operationalized by the number of people of working age, in the home countries of the industrial partners involved in the EURJVs in which NTBF *i* participates at year *t*
Firm and founder characteristics	
Age_{it}	Number of years since firm's foundation at year *t*
$Patent_{it-1}$	Patent stock of NTBF *i* at year $t-1$. Calculated as: $Patent_{t-1} = (1 - 0.15)Patent_{t-2} + NPatent_{t-1}$, where 0.15 is the Griliches constant depreciation rate of the patent stock and $NPatent_{t-1}$ is the number of granted patents which were applied by NTBF *i* at year $t-1$

$DIVC_{it-1}$	One for firms that up to year *t-1* have obtained venture capital financing from an independent financial intermediary
$DCVC_{it-1}$	One for firms that up to year *t-1* have obtained corporate venture capital financing
$DebtOnAssets_{it-1}$	Debts to total assets ratio at year *t-1*
$CFOnSales_{it-1}$	Cash flow to sales ratio at year *t-1*
$NFounders_{i}$	Number of founders
$EcoEducation_{i}$	Number of years of founders' university education in economics and management
$TecEducation_{i}$	Number of years of founders' university education in technical and scientific fields
$SpecWorkExp_{i}$	Number of years of work experience gained by founders in the same sector of NTBF *i* before the firm's foundation
$OthWorkExp_{i}$	Number of years of work experience gained by founders in other sectors than the one of NTBF *i* before the firm's foundation
$LocDevelop_{i}$	Value of the index measuring regional infrastructures in 1992 (mean value among Italian regions = 100; source, Centro Studi Confindustria, 1991)
$DASU_{i}$	One for academic start-ups (i.e., firms with at least one founder with previous research work experience in a university or other public research organization), and zero otherwise

Table 4. Descriptive statistics of explanatory variables of econometric models

Variable	**Number of observations**	**Mean**	**S.D.**	**Min.**	**Max.**
$NumberEURJVs_{it}$	1,532	0.107	0.556	0.000	7.000
$SqNumberEURJVs_{it}$	1,532	0.320	2.618	0.000	49.000
$CountriesIndustrialPartners_{it}$	1,532	0.111	0.582	0.000	8.000
$SqCountriesIndustrialPartners_{it}$	1,532	0.350	3.103	0.000	64.000
$CountriesAcademicPartners_{it}$	1,532	0.124	0.652	0.000	7.000
$CountriesOtherPartners_{it}$	1,532	0.067	0.368	0.000	4.000
$IndustrialPartnerPerCountry_{it}$	1,532	0.091	0.482	0.000	7.250
$AcademicPartnerPerCountry_{it}$	1,532	0.068	0.323	0.000	4.048
$OtherPartnerPerCountry_{it}$	1,532	0.056	0.273	0.000	2.250
$KnowledgeProx_{it}$	1,532	0.010	0.072	0.000	1.000
$MktProx_{it}$	1,532	0.048	0.198	0.000	1.000
$ResourceProx_{it}$	1,532	0.020	0.095	0.000	1.000
$KnowledgeHomeCountry_{it}$	1,532	0.085	0.384	0.000	2.830
$MktHomeCountry_{it}$	1,532	0.001	0.005	0.000	0.029
$ResourceHomeCountry_{it}$	1,532	1.497	6.835	0.000	55.869
Age_{it}	1,532	8.569	5.518	1.000	23.000
$Patent_{it-1}$	1,532	0.124	0.680	0.000	9.000
$DIVC_{it-1}$	1,532	0.033	0.179	0.000	1.000
$DCVC_{it-1}$	1,532	0.073	0.260	0.000	1.000
$DebtOnAssets_{it-1}$	1,532	0.699	0.193	0.046	1.572
$CFOnSales_{it-1}$	1,532	0.054	0.286	-4.388	3.617
$NFounders_{i}$	1,532	2.973	1.956	1.000	21.000
$EcoEducation_{i}$	1,532	0.217	0.711	0.000	4.000
$TecEducation_{i}$	1,532	2.131	2.292	0.000	8.000
$SpecWorkExp_{i}$	1,532	4.106	5.849	0.000	23.000
$OthWorkExp_{i}$	1,532	7.861	8.454	0.000	49.000
$LocDevelop_{i}$	1,532	114.673	32.533	0.000	174.700
$DASU_{i}$	1,532	0.113	0.317	0.000	1.000

Table 5. Effects of the characteristics of EURJVs on total factor productivity of new technology-based firms

		Model 1	**Model 2**	**Model 3**	**Model 4**
	$EURJV_{it}$				
γ_1	$NumberEURJVs_{it}$	-	-0.108 (0.436)	0.265 (0.118)**	0.250 (0.240)
γ_2	$SqNumberEURJVs_{it}$	-	0.049 (0.060)	-	-
γ_3	$CountriesIndustrialPartners_{it}$	-	0.456 (0.660)	0.436 (0.168)**	0.733 (0.255)***
γ_4	$SqCountriesIndustrialPartners_{it}$	-	-0.009 (0.074)	-	-
γ_5	$CountriesAcademicPartners_{it}$	-	-0.278 (0.158)*	-0.273 (0.140)*	-0.084 (0.145)
γ_6	$CountriesOtherPartners_{it}$	-	-0.035 (0.190)	-0.061 (0.263)	-0.176 (0.213)
γ_7	$IndustrialPartnerPerCountry_{it}$	-	-	-	-0.531 (0.281)*
γ_8	$AcademicPartnerPerCountry_{it}$	-	-	-	-0.236 (0.444)
γ_9	$OtherPartnerPerCountry_{it}$	-	-	-	1.105 (0.439)**
	$Proximity_{it}$				
β_1	$KnowledgeProx_{it}$	-	3.929 (2.183)*	3.878 (1.725)**	3.276 (1.532)**
β_2	$MktProx_{it}$	-	0.276 (1.823)	-0.304 (0.785)	-1.393 (0.995)
β_3	$ResourceProx_{it}$	-	-3.506 (3.455)	-3.046 (2.341)	-2.426 (2.048)
β_4	$KnowledgeHomeCountry_{it}$	-	-	-	-

β_5	$MktHomeCountry_{it}$	-	-	-	-
β_6	$ResourceHomeCountry_{it}$	-	-	-	-
λ	Age_{it}	0.041 (0.010)***	0.032 (0.011)***	0.029 (0.011)***	0.031 (0.010)***
	$\boldsymbol{Z_{it}}$				
δ_1	$Patent_{it-1}$	0.051 (0.129)	0.107 (0.110)	0.092 (0.105)	0.103 (0.081)
δ_2	$DIVC_{it-1}$	1.506 (0.686)**	0.998 (0.729)	1.013 (0.687)	0.995 (0.612)
δ_3	$DCVC_{it-1}$	-0.560 (0.522)	0.139 (0.436)	0.148 (0.440)	0.112 (0.268)
δ_4	$DebtOnAssets_{it-1}$	0.607 (0.286)**	0.624 (0.275)**	0.604 (0.285)**	0.611 (0.276)**
δ_5	$CFOnSales_{it-1}$	0.395 (0.221)*	0.402 (0.222)*	0.436 (0.205)**	0.385 (0.197)*
δ_6	$NFounders_i$	0.014 (0.030)	-0.000 (0.009)	-0.001 (0.030)	-0.006 (0.030)
δ_7	$EcoEducation_i$	0.101 (0.070)	0.084 (0.072)	0.080 (0.072)	0.093 (0.070)
δ_8	$TecEducation_i$	0.014 (0.028)	-0.004 (0.026)	-0.004 (0.026)	0.009 (0.025)
δ_9	$SpecWorkExp_i$	0.015 (0.011)	0.010 (0.012)	0.010 (0.012)	0.011 (0.012)
δ_{10}	$OthWorkExp_i$	0.000 (0.009)	-0.000 (0.009)	-0.002 (0.009)	-0.000 (0.009)
δ_{11}	$LocDevelop_i$	0.003 (0.002)*	0.003 (0.002)*	0.003 (0.002)*	0.002 (0.002)*
δ_{12}	$DASU_i$	-0.304 (0.197)	-0.278 (0.241)	-0.273 (0.221)	-0.302 (0.210)
α	Constant	-1.297 (0.296)***	-1.157 (0.288)***	-1.139 (0.285)***	-1.115 (0.272)***
	Wald tests				
	H_0: $EURJV_{it}=0$	-	23.91 (6)***	18.19 (4)***	28.79 (7)***
	H_0: $Proximity_{it}=0$	-	7.28 (3)*	19.25 (3)***	22.83 (3)***
	H_0: $\gamma_1=\gamma_2=0$	-	5.76 (2)*	-	-
	H_0: $\gamma_3=\gamma_4=0$	-	6.61 (2)**	-	-
	Observations	1532	1532	1532	1532
	Groups	265	265	265	265
	Hansen test	36.85 (43)	43.54 (109)	45.13 (107)	41.82 (108)
	AR(1)	-3.35***	-3.24***	-3.17***	-3.27***
	AR(2)	-1.15	-1.18	-1.21	-1.16

Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Estimates are obtained through a two-step GMM-SYS estimator with finite sample correction for standard errors in accordance with Windmeijer (2005). Standard deviation in round brackets; degrees of freedom in square brackets. The EURJV vector is considered endogenous while all other variables are exogenous. To limit possible finite sample bias and potential distortions by measurement errors (e.g., Bond 2002) we restrict moment conditions of endogenous variables to the interval t-3 and t-4. Estimates employ extraneous information provided by additional exogenous instruments capturing NTBFs' sectoral propensities to participate in EURJVs and invest in R&D and engineering activities.

APPENDIX

Table A1. Test for survivorship bias: within-group (WG) and generalized method of moments system (GMM-SYS) estimates

		Model a1 (WG estimator)	Model a2 (WG estimator)	Model a3 (GMM-SYS estimator)
	$EURJV_{it}$			
γ_1	*$NumberEURJVs_{it}$*	0.081 (0.034)**	0.089 (0.039)**	0.259 (0.122)**
γ_2	*$CountriesIndustrialPartners_{it}$*	0.070 (0.049)	0.069 (0.048)	0.431 (0.165)***
γ_3	*$CountriesAcademicPartners_{it}$*	0.073 (0.051)	0.073 (0.051)	-0.276 (0.139)**
γ_4	*$CountriesOtherPartners_{it}$*	0.071 (0.057)	0.079 (0.061)	-0.073 (0.248)
	$Proximity_{it}$			
β_1	*$KnowledgeProx_{it}$*	2.210 (0.900)**	2.236 (0.908)**	3.945 (1.779)**
β_2	*$MktProx_{it}$*	-0.374 (0.400)	-0.424 (0.395)	-0.209 (0.743)
β_3	*$ResourceProx_{it}$*	-1.843 (1.161)	-1.843 (1.167)	-3.148 (2.431)
λ	*Age_{it}*	0.030 (0.006)***	0.014 (0.028)	0.030 (0.012)**
	Z_{it}			
δ_1	*$Patent_{it-1}$*	-0.025 (0.028)	0.001 (0.035)	0.104 (0.103)
δ_2	*$DIVC_{it-1}$*	-0.857 (0.652)	-0.829 (0.573)	1.069 (0.639)
δ_3	*$DCVC_{it-1}$*	0.280 (0.234)	0.455 (0.324)	0.126 (0.563)
δ_4	*$DebtOnAssets_{it-1}$*	0.533 (0.155)***	0.537 (0.173)***	0.637 (0.284)**
δ_5	*$CFOnSales_{it-1}$*	0.441 (0.149)***	0.443 (0.155)***	0.427 (0.190)**
δ_6	*$NFounders_i$*	-	-	-0.003 (0.030)
δ_7	*$EcoEducation_i$*	-	-	0.076 (0.068)
δ_8	*$TecEducation_i$*	-	-	-0.003 (0.026)
δ_9	*$SpecWorkExp_i$*	-	-	0.010 (0.012)
δ_{10}	*$OthWorkExp_i$*	-	-	-0.002 (0.009)
δ_{11}	*$LocDevelop_i$*	-	-	0.003 (0.002)
δ_{12}	*$DASU_i$*	-	-	-0.279 (0.218)
δ_{13}	*$InverseMillsRatio_{it}$*	-	-2.372 (3.778)	0.055 (0.245)
α	*Constant*	-0.650 (0.149)***	-3.937 (5.184)	-1.059 (0.520)**
	Wald tests			
	H_0: *$EURJV_{it}=0$*	3.49 (4)***	3.37 (4)***	19.87 (4)***
	H_0: *$Proximity_{it}=0$*	8.28 (3)***	7.83 (3)***	16.98 (3)***
	Observations	1532	1507	1507
	Groups	265	261	261
	Hansen test	-	-	44.64 (105)
	AR(1)	-	-	-3.17***
	AR(2)	-	-	-1.21

Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Estimates are obtained through a two-step GMM-SYS estimator with finite sample correction for standard errors in accordance with Windmeijer (2005). Standard deviation in round brackets; degrees of freedom in square brackets. The EURJV vector is considered endogenous while all other variables are exogenous. To limit possible finite sample bias and potential distortions by measurement errors (e.g., see Bond 2002) we restrict moment conditions of endogenous variables to the interval t-3 and t-4. Estimates employ extraneous information provided by additional exogenous instruments capturing NTBFs' sectoral propensities to participate in EURJVs and invest in R&D and engineering activities.