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Firms' genetic characteristics and competence-enlarging strategies: A comparison between academic and non-academic high-tech start-ups

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ABSTRACT

This paper argues that academic high-tech start-ups exhibit peculiar "genetic characteristics" that leave an enduring imprint on firm development. We formulate a series of hypotheses on the effects of such genetic characteristics on the post-entry strategies that academic high-tech start-ups adopt to enlarge their initial competence endowments. In the empirical section, we use matched-pair statistical techniques and run several regressions to test the theoretical hypotheses. Our findings contribute to the literature on the antecedents of the strategies adopted by academic high-tech start-ups. They also allow us to derive implications for academic entrepreneurs, university managers and policy makers.

1. Introduction

The establishment of start-ups aimed at commercially exploiting the technological knowledge generated within public research organisations is an increasingly popular option to create wealth from the results of academic research (Siegel et al., 2003; Vohora et al., 2004; Wright et al., 2004). Since the 1990s, intense competition has developed among universities and other public research organisations to increase the formation rate of high-tech firms, and many scholars have analysed the conditions and strategies for start-up *creation* (Chrismann et al., 1995; Davenport et al., 2002; Di Gregorio and Shane, 2003; Upstill and Symington, 2002). Despite the efforts of their parent research organisations, the financial returns from this form of commercialisation of academic research have generally been below expectations (Wright et al., 2003). In particular, it has been highlighted that these firms tend to remain small (Degroof and Roberts, 2004).

Designing effective policies to support the growth of start-ups generated by public research organisations requires an in-depth understanding of the characteristics of these firms at the time of their founding and their post-entry strategies. The present paper aims to help develop such understanding. Previous studies have recognised that the firms originated in the public research domain exhibit some peculiarities that make them distinct from other high-tech start-ups (Clarysse and Moray, 2004; Ensley and Hmieleski, 2005). However, little insight exists about the effects of such characteristics on the post-entry strategies adopted by these firms. Hence, here we intend to take a step towards filling this gap by comparing start-ups generated by public research organisations with other new high-tech ventures.

We focus attention on a special category of firms originated from the public research environment: academic start-ups, defined here as new technology-based firms (NTBFs) created by academics, i.e., (full-time or part-time) personnel of public research organisations and Ph.D. students who were actively involved in academic research immediately before founding the firm.[1] Sometimes, these firms are based on university intellectual property, or they involve the parent organisation as a shareholder. Sometimes, the relationship with the parent organisation is weaker or even non-existent. What makes these firms special is that, being created by academics, they inherit from their founders *genetic characteristics* that clearly differ from those of other NTBFs (Colombo and Piva, 2008). Moreover, relying on Stinchcombe's (1965) imprinting argument, we posit that, because of these genetic characteristics, the strategies

[1] We focus here on firms with a founding team composed (at least in part) of academic inventors because they seem to be more numerous than spin-offs (or spin-outs) founded by external entrepreneurs, as some empirical studies have suggested. For instance, Lowe (2002) considered technologies licensed by the University of California to newly created firms; the majority of these licenses were to academics that licensed their own inventions back from the university to found a new firm. Zucker et al. (2002) showed that 80% of the 10 most highly valued biotech companies in 1994 reported at least one scientist from one of the top 112 universities on their managerial teams when they went public. These academics had been holding these positions since the creation of their respective companies.

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adopted by academic start-ups in the years after foundation, with the aim of enlarging their initial competence endowments, are likely to diverge from those of other NTBFs.

These differences are condensed in a set of theoretical hypotheses that are tested in the empirical section of the paper. For this purpose, we first consider a sample composed of 64 Italian academic NTBFs and compare it to a matched control sample composed of non-academic NTBFs, with matching based on a variant of the propensity score method. The comparison relates to the investment and alliance strategies of firms. We also document differences in the human capital characteristics of the founders of the firms included in the two groups. Second, we estimate several econometric models on the antecedents of firms' internal investments and collaborative strategies. These regressions allow us to control for the possible existence of a survivorship bias.

The empirical analysis provides compelling evidence that academic and non-academic NTBFs have different initial competence endowments and adopt different strategies to enlarge these endowments. These results contribute to the theoretical debate on high-tech entrepreneurship and have interesting implications for academic entrepreneurs, officers of parent research organisations and policy makers.

The paper proceeds as follows. In the next section, we introduce the theoretical background and the hypotheses to be tested. We then describe the methodology of the empirical analysis. In the subsequent section, we illustrate the results of the statistical tests realised with matched-pair techniques and the estimates of the econometric models. A discussion of the main findings and their implications in the last section concludes the paper.

2. Theory and hypotheses

2.1. Theoretical background: the imprinting of the genetic characteristics of academic start-ups

Since the seminal work by Stinchcombe (1965), several studies have argued that conditions existing at the formation stage of a firm leave an enduring imprint on its post-entry evolution. Founding conditions include environmental characteristics (e.g., market size, market growth and concentration) and the initial resources and competencies embedded in both the technology and the entrepreneurial team (Bamford et al., 1999). In this work, we focus attention on the latter aspect. Relying on arguments inspired by the competence perspective, we contend that high-tech NTBFs inherit from their founders "genetic characteristics" that shape their initial competence endowments. These characteristics subsequently influence the strategies that these firms adopt to enlarge such competence endowments.[2]

In the early years after foundation, the competencies of an NTBF largely coincide with the skills and knowledge of its founders (Cooper and Bruno, 1977; Feeser and Willard, 1990). In the very uncertain business environment typical of high-tech industries, entrepreneurial judgement[3] has an idiosyncratic, non-contractible nature. Therefore, in accordance with Knight's (1921) "cephalisation principle", when an individual spots a new business opportunity, the best option available to exploit it is to start a new venture (see Alvarez and Barney, 2002; Foss, 1993). In addition, successful exploitation of this opportunity requires the integration of complementary, context-specific knowledge (e.g., knowledge relating to complementary technologies and managerial and commercial knowledge) that is generally dispersed among different individuals. Although, in principle, these "specialists" might by hired by the new firm, their knowledge is more efficiently coordinated and protected if they are members of the founding team and have a stake in the firm's future profits. As a corollary, the human capital characteristics of founders, that determine what these people know and are able to do, crucially influence the firm's initial competence endowment (for a similar argument relating to start-ups originated from academic institutions, see Lockett et al., 2005).

However, a firms initial competence endowment is often limited and insufficient for successful business development. Therefore, in the early stages, NTBFs struggle to enlarge their endowments through suitable internal investments. The support offered by alliances with third-party organisations is also extremely important, because it provides access to competencies and resources NTBFs lack and cannot build in isolation (Gans and Stern, 2003).[4]

We claim that academic and non-academic NTBFs exhibit different genetic characteristics because, as previous studies suggest, the composition of their respective founding teams differ. The teams of academic NTBFs seldom include individuals with prior professional experience in the private sector (Chiesa and Piccaluga, 2000; O'Boyle, 1984). Conversely, they tend to be composed of academics who work on similar research topics. This peculiar team composition is a result of the background of academic founders and the context they start their firm in. Indeed, the formation of firms' founding teams is mainly driven by the similarity of personal characteristics and prior social network ties among individuals (Ruef et al., 2003). In particular, individuals are naturally attracted by partners who have similar education and occupation (Lazarsfeld and Merton, 1954; McPherson et al., 2001). These similarities increase mutual understanding, thus favouring the formation of entrepreneurial teams. Furthermore, social network ties, especially work relations (Aldrich et al., 2002), influence the composition of founding teams. In fact, individuals who share the same work environment, are more likely to develop trust in their competencies and mutual behaviour. They also have more opportunities to discuss the possibility of jointly launching a new venture.

These arguments help explain why academic entrepreneurs rarely team up with individuals who are salaried employees or (owner-)managers of other firms. This clearly influences the human capital of academic NTBFs' founding teams, as reflected by both education and work experience. The resulting differences between academic and non-academic NTBFs are almost self-evident. First, the founding teams of the former companies, due to the presence of academics, will exhibit higher levels of education than those of the latter ones. In fact, all academic scientists have graduated from universities, and they often have achieved a Ph.D. degree, as this is a fundamental requirement for a career in the public research system. Second, the founding teams of academic NTBFs will also have greater experience with research accumulated in academic laboratories but, on average, they will exhibit less industry work experience, both in technical and commercial functions, than those of other NTBFs. Third, academic NTBFs' founding teams are likely to lack the "leadership experience" (Brüderl et al., 1992) that can be obtained either through a managerial position in another firm

[2] Here, we focus only on the strategies aimed at developing the technological, commercial and managerial competencies of high-tech start-ups, as they are particularly important for firms' survival and growth. In fact, as is suggested by competence-based theories (Grant, 1996), competencies are inherently difficult to reproduce because of their tacit nature, and thus, they are potentially a key source of sustainable competitive advantages.

[3] The term "entrepreneurial judgement" refers to an individual's beliefs about how his (her) knowledge and skills can be combined with other resources so as to create value. Due to environmental uncertainty, these beliefs are very difficult to share with others (Shane and Venkataraman, 2000).

[4] Another strategy aimed at enlarging the initial competence endowment consists of acquiring companies that possess the competencies that NTBFs lack. Nevertheless, NTBFs' limited financial resources usually prevent these firms from following this strategy, at least in the first years after foundation.

or in prior self-employment episodes. Therefore, among academic NTBFs, there will be a lack of competence in how to manage a new firm (entrepreneur-specific knowledge).[5]

The differences between academic and non-academic NTBFs also regard the social contacts of the founding teams. Being part of the scientific community, academic founders will exhibit more numerous and stronger ties within academia than will founders external to the public research environment (Murray, 2004). Furthermore, academic founders often keep their positions in the parent research organisation even after foundation of a new venture (Roberts, 1991). Thus, it is easier for them to maintain and enlarge this social network. Conversely, their network of social contacts with private firms, especially in the commercial function, is likely to be less developed than the one of founders of non-academic NTBFs.

As a result of the genetic characteristics inherited from founders, academic NTBFs have competence endowments at foundation that are different from the ones non-academic NTBFs have. They have greater (and more effective) scientific and technological competencies than their non-academic counterparts, but smaller (and less effective) commercial and managerial competencies. In the following section, we will analyse the strategies that academic and non-academic NTBFs can adopt to close their knowledge gap, and we will highlight how these strategies are shaped by the different genetic characteristics of these two types of firms.

2.2. The impact of the genetic characteristics of academic start-ups on competence-enlarging strategies

After entry, NTBFs can adopt two types of strategies to enlarge their initial competence endowments: they can make internal investments and establish collaborative relationships with third-party organisations.

2.2.1. Internal investments

Let us first discuss the differences between academic and non-academic NTBFs with respect to their internal investment strategies. For this purpose, we take inspiration from the standard micro-economic production theory. In a stylised "competence-based production function" framework, we assume that NTBFs use two key competence inputs to produce their output: (i) technical and scientific competencies, and (ii) commercial and managerial competencies. The same amount of output in terms of value added can be produced using a different mix of the two competence inputs.[6] Given the amount of one type of competence that is used in production, the amount of output that firms produce increases with the amount of the other competence, but at a decreasing rate. Hence, as the amount of one type of competence increases, firms need to give up a greater amount of that competence in return for the other type of competence so as to produce the same amount of output, i.e., the competence iso-quant curve is downward sloped.

The first graph of Fig. 1 shows the competence endowments at foundation of an academic and a non-academic NTBF (indicated by points A_1 and NA_1, respectively). In line with the arguments illustrated in Section 2.1, the academic NTBF possesses a greater amount of technical and scientific competencies and a smaller amount of commercial and managerial competencies than does the non-academic NTBF. For the sake of simplicity, we initially assume that the unit cost of each type of competence is the same for the two types of NTBFs, and we consider two NTBFs that, in spite of the difference in their initial competence endowments, are located on the same competence iso-cost curve (curve C_1).

To enlarge their initial competence endowments, both NTBFs need to decide the amount of (i) technological and scientific competencies, and (ii) commercial and managerial competencies to be acquired. We assume that firms choose the competence endowment that maximises their profits, given the resources available. NTBFs usually suffer from financial constraints (Carpenter and Petersen, 2002; Hall, 2002) that bound the amount of investments. Moreover, firms' owner-managers can often devote limited time to the search for and acquisition of additional competencies. In the following, we assume that such resource constraints do not engender any differences between academic and non-academic NTBFs with respect to the adoption of internal investment strategies. Accordingly, after entry, the two firms under consideration will move to the competence iso-cost curve C_2, with $C_2 > C_1$. If the marginal product of each type of competence were the same for the two firms, the optimal mix of technical and scientific competencies, and commercial and managerial competencies would also be the same. The competence mix at equilibrium, indicated by point $A_2 = NA_2$ in Fig. 1, would be the one that equates the ratio of the marginal products of the two types of competencies with the ratio of their unit costs (i.e., in point $A_2 = NA_2$, the competence iso-quant and iso-cost curves have the same slope). Under these circumstances, to move from the initial competence endowment to the equilibrium competence mix, an academic NTBF would acquire a greater amount of commercial and managerial competencies ($\Delta CM^A > \Delta CM^{NA}$) and a lower amount of technical and scientific competencies ($\Delta TS^A < \Delta TS^{NA}$) than would a non-academic NTBF. Following this line of reasoning, one might conclude that academic NTBFs are likely to invest more in commercial and managerial functions than are their non-academic counterparts, and they are likely to invest less in technical and scientific functions.

The arguments illustrated above hold true under the assumption that the marginal product and unit cost of each type of competence is the same for academic and non-academic NTBFs. Due to the diverse genetic characteristics of these two types of firms, this assumption is quite implausible. First, the marginal product of the technological and scientific competencies is greater for academic NTBFs than for their non-academic counterparts because of the technical and scientific prowess of the former type of firms. The opposite holds true for commercial and managerial competencies. It follows that the (negative) slope of the competence iso-quant curves is smaller for academic NTBFs than for non-academic NTBFs (i.e., the competence iso-quants of academic NTBFs are flatter; compare the dashed and dotted competence iso-quant curves in the second graph of Fig. 1). Second, the competence iso-cost curves are steeper for academic NTBFs than for non-academic ones. Hiring highly qualified individuals with technical and scientific competencies is likely to be easier for academic NTBFs, thus lowering the cost of these types of competencies. On the one hand, the personal contacts of the founders of these firms in the academic community lower the costs of the search for educated technical personnel, especially among recent graduates and researchers (Downes and Eadie,

[5] Actually, in their academic careers, the founders of academic NTBFs may have developed skills relating to the management of research teams. Whether these skills are fungible to the management of an NTBF is questionable due to the idiosyncrasies of public research organisations. It is also likely to depend on the specific institutional characteristics of the public research systems in different countries (e.g., prevailing sources of financing of public research organisations, evaluation procedures and recruiting mechanisms of research personnel). It is fair to recognise that in Europe (and especially in Italy), the institutional characteristics of public research organisations widely diverge from those of private firms.

[6] Of course, the *type* of output (i.e., the products and services) produced by firms that have a different mix of the competence inputs will differ even if the *amount* of output is the same. For instance, firms may produce highly innovative products that require a great amount of technological and scientific competencies, or they may produce more conventional products while providing customers with sophisticated customer care and after-sale services that require a great amount of commercial and managerial competencies.

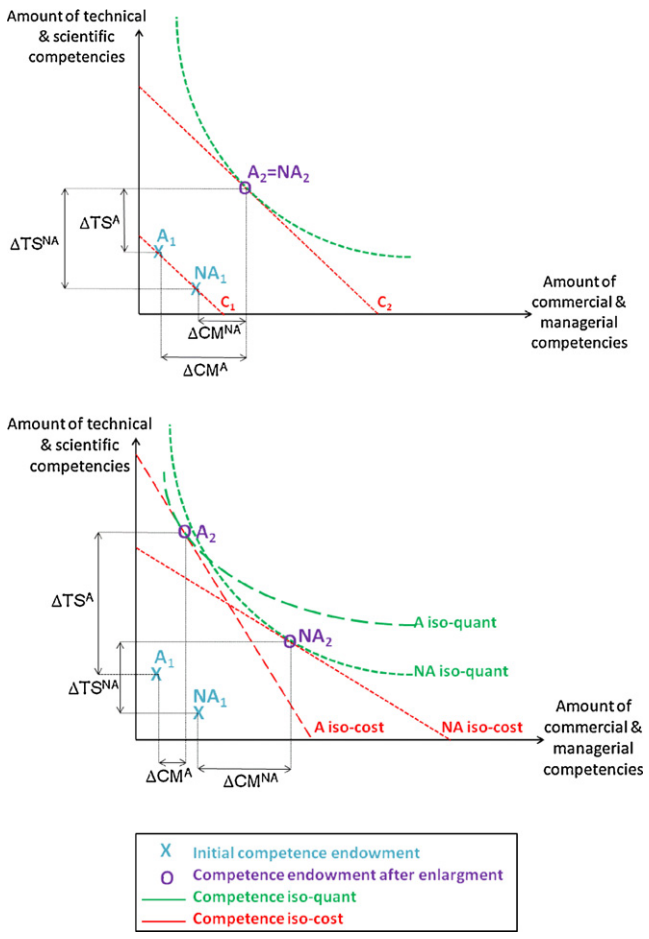

Fig. 1. The initial competence endowments of an academic NTBF (A) and a non-academic NTBF (NA) and their enlargement through internal investments.

1997; Murray, 2004). On the other hand, as scientists usually have a "taste for science" (Dasgupta and David, 1994; Merton, 1973), they are likely to prefer employment in more science-oriented firms (Stern, 2004). Therefore, they will be less reluctant to accept an employment offer from an academic NTBF than from a non-academic NTBF and may even be prepared to swap a higher salary for greater personal intrinsic rewards. The opposite again holds true regarding the costs of the search for and acquisition of additional commercial and managerial competencies.

Therefore, given the amount of available resources, an academic NTBF will choose an optimal competence mix that differs from the one chosen by a non-academic NTBF. The two equilibrium competence mixes are indicated by points A_2 and NA_2 in the second graph of Fig. 1, respectively. The academic NTBF will use relatively more scientific and technological competencies and less commercial and managerial competencies than will the non-academic NTBF. Hence, one obtains: $\Delta TS^A > \Delta TS^{NA}$ and $\Delta CM^A < \Delta CM^{NA}$. This means that the founders of academic NTBFs shape their companies in their own images, further specialising them in technical and scientific functions (i.e., a competence-deepening effect), rather than correcting for their own competence weaknesses through investments in commercial and managerial functions.

These arguments lead us to formulate the following hypotheses.

Hypothesis H1 *(:).* Academic NTBFs place relatively greater emphasis than non-academic NTBFs on internal investments in technical and scientific functions and less emphasis on internal investments in commercial functions.

Hypothesis H2 *(:).* Academic NTBFs hire a relatively greater number of educated technical personnel than non-academic NTBFs.

2.2.2. Alliances

Alliances with third parties may also be instrumental to enlarging NTBFs' initial competence endowments.[7] For the sake of simplicity, we will assume here that an NTBF establishes an alliance if the benefits of collaborating exceed the associated opportunity costs.[8] These benefits and costs vary according to the objective of the alliance and the nature of the partner. In the following, we will consider four alliance types: technological and commercial alliances with public research organisations and technological and commercial alliances with other firms. We will compare the benefits and costs (namely, the transaction costs associated with the search for partners and the appropriability hazards generated by the collaborations, and the costs of managing alliance operations) of these alliance types for academic and non-academic NTBFs.

Let us first consider *technological alliances with public research organisations*. We predict that the propensity of academic NTBFs to establish this type of alliance is unequivocally greater than the propensity of non-academic NTBFs, as for the former type of firms, the benefits are greater, and the costs are lower.

As to the benefit side, public research organisations are key external sources of information for new ideas and innovation

[7] Alliances may be aimed at inter-organisational learning and internationalisation of partner competencies (explorative alliances). Alternatively, they may simply allow a firm to use the services of partners' competencies (or assets) with no learning involved (exploitative alliances). Be they exploratory or exploitative, both forms of alliances allow firms to enlarge the set of competencies on which they rely (Grant and Baden Fuller, 2004).

[8] Therefore, we implicitly assume that if an NTBF intends to establish a collaboration, there is always a partner wishing to team up with it.

completion (e.g., Cohen et al., 2002) and potentially bring to a technological alliance knowledge that is rarely available in the private sector (Leyden and Link, 1999). However, whether partner firms are able to make the best use of this knowledge depends on their *absorptive capacity* (Cohen and Levinthal, 1990, p. 128). Zahra and George (2002) make a distinction between "potential" and "realised" absorptive capacity. Potential absorptive capacity refers to the ability to *identify* relevant knowledge produced by external sources (*acquisition*) and to analyse, process, interpret, and understand this knowledge (*assimilation*). Realised absorptive capacity consists of the ability to modify and adapt external knowledge, combine it with existing and internally generated knowledge (*transformation*), and transform this combined knowledge into a competitive advantage (*exploitation*). We claim that, as a consequence of the superior technical and scientific prowess of the founding teams of academic NTBFs and these firms' greater post-entry internal investments in technical and scientific activities, academic NTBFs find it easier to identify and further develop promising scientific results developed by partner public research organisations and to understand how to use them for commercial purposes than non-academic NTBFs. Because of their superior *potential absorptive capacity*, the benefits they can reap from technological collaborations with public research organisations are greater than those that can be obtained by non-academic NTBFs.

In addition, academic NTBFs have lower costs of searching for academic partners than other NTBFs. An immense amount of research is conducted by many public research organisations that are dispersed around the world. The quality of this research is highly variable, and its commercial value is uncertain. Moreover, it is fundamental for a firm to obtain early access to the most promising scientific research so as to negotiate with the public research organisation on more favourable terms. As was mentioned earlier, the founders of academic NTBFs are more deeply embedded within the scientific community than are their non-academic peers. These links in the research environment make it easier for academic NTBFs to spot high-quality scientists in public research organisations who are interested in establishing collaborative technological relationships with them.

Academic NTBFs also enjoy lower costs of managing the operations of these alliances. The fact that academic founders belong to the same social network as the research staff of public research organisations facilitates information communication and coordination of inter-organisational activity. It also helps to create a community of intent between partners, helping them to better align their goals and to develop trust (Das and Teng, 1998), which in turn makes the conduct of the personnel involved in the alliance more predictable (Johansson et al., 2005).

Lastly, the first-hand knowledge possessed by academic founders of the goals and operations of public research organisations and the existence of trust between alliance partners reduce the appropriability hazards that are usually engendered for private firms by collaborations with public research organisations (Leyden and Link, 1999; Link and Scott, 2005).

Hypothesis H3 *(:).* Academic NTBFs are more likely to establish technological alliances with public research organisations than are non-academic NTBFs.

Conversely, it is questionable whether academic NTBFs are more likely to establish *commercial alliances with public research organisations* than non-academic NTBFs. On the one hand, the search and management costs of this type of collaboration are lower for academic NTBFs than for non-academic ones, for the same reasons as those illustrated above. However, the genetic characteristics of academic NTBFs reduce the benefits of this type of collaboration. These alliances are aimed at commercialising technological artefacts and knowledge developed by partner research organisations. Clearly, the lack of commercial competencies and assets of academic NTBFs reduces the pay-off of these collaborations.

Let us now consider *alliances with other firms*. Regarding *technological alliances*, it is questionable whether academic NTBFs have a greater propensity than their non-academic counterparts to establish this type of collaborative relationship. On the one hand, the benefits for academic NTBFs are likely to be greater than those reaped by non-academic NTBFs. The alliance literature has emphasised the synergistic gains that alliance partners can realise by combining complementary assets and capabilities (Teece, 1986; Gans and Stern, 2003). There may indeed exist considerable gains in combining the superior scientific and technological expertise of academic NTBFs with the application-oriented, industry-specific technological competencies possessed by other private firms. On the other hand, the costs of this type of collaboration for academic NTBFs are likely to be greater than for non-academic NTBFs. In particular, the transaction costs arising from appropriability hazards are likely to be greater for academic NTBFs. Due to their genetic characteristics and post-entry internal investments in research, academic NTBFs are more likely to possess state-of-the-art technological knowledge than non-academic NTBFs. Moreover, this knowledge is likely to be their only (potential) source of competitive advantage. Therefore, unintended knowledge leakages to and opportunistic behaviour by partner firms can be very detrimental for academic NTBFs, especially if the partner possesses the complementary technological and commercial assets that are needed to commercially exploit the technological knowledge of the academic NTBF. As to the remaining costs, the partner search costs incurred by academic NTBFs depend on the degree of integration between the public research system and the private sector and may vary across different countries and technological fields. The less entrepreneurial the public research system, the larger the search cost disadvantage for academic NTBFs. A similar reasoning applies to alliance management costs.

Following similar arguments, we cannot make any prediction about the relative propensity of academic and non-academic NTBFs to establish *commercial alliances with other firms*. Again, these alliances are especially beneficial for academic NTBFs, as they allow these firms to obtain access to specialised commercial assets and competencies (e.g., a trained sale force, marketing competencies, distribution channels and a brand name) that are complementary to their internal technical and scientific competencies. The commercial assets and competencies that are generally possessed by large incumbent firms cannot be effectively accessed by NTBFs through arm's length arrangements due to high transaction costs. Moreover, time and financial constraints often prevent NTBFs from acquiring them or building them in isolation (Teece, 1986; Gans and Stern, 2003; Colombo et al., 2006). However, the costs that academic NTBFs incur in establishing commercial alliances with other firms are again likely to be higher than those incurred by non-academic NTBFs. First, searching for suitable partners in commercial alliances is likely to be more difficult for the founders of academic NTBFs, as they have a less developed network of commercial contacts than the non-academic founders of other NTBFs. Second, the costs of managing a commercial alliance are greater as a consequence of the lack of commercial and managerial work experience of academic founders.

3. Methodology of the field analysis

3.1. The sample of academic start-ups

In this section, we will describe the sample of academic NTBFs and the procedure that was used to build it. In the following section, we will illustrate the matching procedure that was used to build

the control sample composed of non-academic NTBFs. Both samples were extracted from the 2004 release of the RITA (Research on Entrepreneurship in Advanced Technologies) database developed at the Department of Management, Economics and Industrial Engineering of Politecnico di Milano.

The RITA database was created in 2000 and was updated and extended in 2002 and 2004. The development of the 2004 release of the database went through a series of steps. First, the Italian firms that were established after 1980, remained independent until 2003 and operated in high-tech sectors, both in manufacturing and services, were identified. For the construction of this target population, a number of sources were used.[9] These included lists provided by national industry associations, on-line and off-line commercial firm directories, and lists of participants in industry trades and expositions. Information provided by the national financial press, specialised magazines, other sectoral studies, and regional Chambers of Commerce was also considered. Altogether, 1974 firms were selected for inclusion in the database: 123 academic NTBFs and 1851 non-academic NTBFs. For each firm, a contact person (i.e., one of the owner-managers) was also identified. Second, a questionnaire was sent to the contact person of each target firm either by fax or by e-mail in the first semester of 2004. The first section of the questionnaire provides detailed information on the human capital characteristics of firms' founders. The second section comprises further questions concerning the characteristics of the firms, including their alliance activities. In particular, firms were asked to provide the following information.

- *Characteristics of the founders*. We collected data relating to the educational attainments and prior work experience of each founder, classified according to the functional activity (e.g., R&D, production, or sales), hierarchical position and sector of activity of the employer.
- *Characteristics of the workforce*. We measured the skill level of the workforce by the share of graduate employees (i.e. employees with a university degree) in the total workforce. In addition, firms indicated the distribution of the workforce by type of activity (i.e., technical activities, commercial activities and other activities). They also indicated whether they hired one or more salaried managers.
- *Alliances*. Firms were asked whether they established commercial and/or technological alliances with other companies and public research organisations. They also indicated whether they purchased R&D and other technical services from these latter organisations.

Lastly, answers to the questionnaire were checked for internal coherence by research assistants and were compared with data provided by firms' annual reports and websites. In several cases, phone or face-to-face follow-up interviews were conducted with firms' owner-managers. This final step was crucial to obtain missing data and ensure that data were reliable.[10]

We received 550 questionnaires, 64 of them relating to academic NTBFs. This corresponds to more than half of the initial population of academic NTBFs. χ^2 tests show that there are no statistically significant differences between the distributions of the 64 sample firms across industries and regions and the corresponding distribution of the 123 RITA academic NTBFs from which the sample was drawn ($\chi^2(3) = 0.173$ and $\chi^2(2) = 0.354$, respectively). Therefore, the dataset used in this work provides a reasonably adequate test bed of the theoretical hypotheses illustrated in Section 2.

As is usual in studies that use survey-based data, the analysis presented in this paper suffers from a survivorship bias that might have significant consequences for our study. For instance, if the characteristics of the founders and the competence-enlarging strategies adopted by firms differed between the NTBFs that ceased operations or were acquired by/merged with other companies before 2003 and those that survived as independent firms until 2003, this might bias the results of the empirical analysis. The matched-pair analysis that is described in the following section does not control for the alleged effects of the survivorship bias. For these reasons, we will also present the results of the estimates of several econometric models that include an inverse Mills ratio type of control variable, with the aim of at least partially correcting for the survivorship bias.

3.2. Matching procedure

To provide empirical evidence on the differences between academic and non-academic NTBFs with respect to firms' genetic characteristics and to test the theoretical hypotheses, we resorted to a matched-pair analysis. We compared the 64 sample academic NTBFs with twin non-academic NTBFs. To control for other possible differences in the founding conditions, we included in the latter sample NTBFs founded in environments similar to those of the 64 academic NTBFs. We did so by resorting to a variant of the propensity score method (Bryson et al., 2002; Imbens, 2004). Following Rosenbaum and Rubin (1983), matching was based on an index (the propensity score) that reflects the probability of "participating in a treatment program". A firm "participates in the treatment program" if it is an academic NTBF.

Thus, the first task in matching was the estimation of the participation model, i.e., the probability of firm i being an academic NTBF. Using data relating to the sample of 550 NTBFs, we estimated participation in the treatment program through a logit model:

$$P(\mathrm{ASU}_i = 1) = F(\mathrm{Age}_i, R_i, I_i) \quad (1)$$

which includes the firm's age at the survey date and variables relating to firm's area of localisation (R_i) and industry of operation (I_i). Variables R_i were measured at the regional or county level. Variables I_i relate to ten manufacturing and six service industries.[11] Note that, following Bryson et al. (2002), the regressors in the logit model should have included variables that can drive "participation in the treatment program" and affect the results of the subsequent analyses on matched samples. As we had no expectations with respect to which variables might influence the firm's probability of being an academic NTBF, we simply included the latter variables (see Table A1 in the Appendix).

The estimation of the participation model (illustrated in Table A2 in the Appendix) allowed us to calculate the propensity score (i.e., the fitted value from the logit model) for each

[9] Combining information from several sources was necessary as, unfortunately, data provided by official national statistics do not allow for obtaining a reliable description of the universe of Italian NTBFs. The main problem is that in Italy, most individuals who are defined as "self-employed" by official statistics actually are salaried workers with atypical employment contracts. On the basis of official data, such individuals cannot be distinguished from entrepreneurs that created new firms. Moreover, independent firms cannot be distinguished from subsidiaries of other firms, as corporate ownership data are not available.

[10] Note that for only three firms, the set of owner-managers at survey date did not include at least one of the founders of the firm. For these firms, information relating to the human capital characteristics of the founders was checked through interviews with firms' personnel so as to be sure that it did not relate to current owner-managers.

[11] The ten manufacturing industries are: aerospace, computers, electronic components, telecommunication equipment, optical, medical and electronic instruments, robotics, automation equipment, biotechnologies, pharmaceuticals and advanced materials. The six service industries are: e-commerce, internet service providers, web-based services, telecommunication services, software and multimedia content.

Table 1
Sectoral and geographical composition of the academic start-ups and control samples.

	Academic NTBFs		Other NTBFs	
	No. of firms	%	No. of firms	%
Sector				
Aerospace	1	1.6	0	0.0
ICT manufacturing[a]	9	14.1	11	17.2
Robotics and automation equipment	8	12.5	7	10.9
Biotechnologies, pharmaceutics and advanced materials	3	4.7	3	4.7
Software	18	28.1	18	28.1
Internet and telecommunication services	22	34.4	23	35.9
Multimedia content	3	4.7	2	3.1
Total	64	100.0	64	100.0
Geographic area				
Northwest	27	42.2	27	42.2
Northeast	18	28.1	26	40.6
Centre	16	25.0	5	7.8
South and islands	3	4.7	7	10.9
Total	64	100.0	64	100.0

[a] ICT manufacturing includes the following industries: computers, electronic components, telecommunication equipment, and electronic, medical and optical instruments.

firm. Then we paired each academic NTBF with the non-academic NTBF with the closest propensity score value (nearest neighbour method). Actually, in building the control sample, we adopted a variant of propensity score matching (for a similar approach, see Puhani, 1998). We first split the firms under consideration into two sub-groups that included manufacturing and service firms, respectively. Then we performed the matching separately for either group. This allowed us to place greater emphasis on the firm's industry. This variable is of great importance, as manufacturing firms substantially differ from service ones with respect to several aspects that are studied in the statistical analysis (e.g., the qualification of the workforce and its distribution across different activities). Thus, exact matching on this variable limits the risk that our results are driven by a selection bias (Heckman et al., 1997, 1998). To check whether the participation model has been adequately specified to balance the characteristics of the treatment and the comparison groups, we tested whether the samples of academic NTBFs and non-academic NTBFs were significantly different in the mean values of the variables that entered the participation model (Rosenbaum and Rubin, 1983. For an empirical application of the balancing test, see Dehejia and Wahba, 1998). The absence of statistically significant differences between the two samples suggests that the matching was successful (see Table A3 in the Appendix).[12]

The distribution of the academic NTBFs and the control sample by industry and geographic region is illustrated in Table 1. The table reveals that sample academic NTBFs mainly operate in Internet and telecommunication services (34.4% of the sample) and software (28.1%). As for the geographical distribution, sample academic NTBFs are mainly located in the Northwest of Italy (42.2% of the sample); conversely, the number of academic NTBFs founded in southern, less developed regions is visibly lower (4.7%).

The sample of academic NTBFs was then compared with the control sample along a series of dimensions through statistical tests. We resorted to *t*-tests for continuous variables and Mc Nemar tests for dummy variables. Due to the presence of missing values for some variables, the number of observations considered in the tests varies. As we test multiple measures, we adjusted *p*-values upward to reduce the chance of incorrectly declaring a statistical significance (Bland and Altman, 1995; Tukey, 1977). We resorted to the adjustment suggested by Tukey et al. (1985), as many of the variables we compare are correlated.

The definition of the variables used in the statistical analysis is provided in Table 2, while the findings of the tests are presented in Sections 4.1 and 4.2.

3.3. The econometric models

Using a matched-pair analysis to test our hypotheses has a clear advantage: misspecification biases are eliminated. Indeed, this technique does not require us to specify the functional form of the competence-enlarging strategies' equations. However, the matched-pair analysis exhibits a major weakness. As we mentioned above, it does not allow controlling for the possible presence of a survivorship bias.

To overcome such a weakness, we resorted to the estimates of ten econometric models, one for each of the variables reported in Table 2 in the "competence-enlarging strategies" group. Each model relates one of the ten variables to a set of regressors common to all models. These regressors include a dummy equal to one for academic NTBFs (*DASU*). In all models, a positive (negative) and significant coefficient for *DASU* indicates that the genetic characteristics of academic NTBFs lead the value of the dependent variable to be significantly higher (lower) for academic NTBFs than for other NTBFs. The set of regressors also includes age at the survey date, industry and location, and a factor that aims to correct (at least partially) for survivorship bias.

To build the latter factor, we adopted a two-stage estimation procedure (see Heckman, 1979). In stage one, we considered the RITA 2000 sample. This sample is composed of 25 academic NTBFs and 376 non-academic NTBFs identified when the RITA database was created (see Colombo et al., 2004 for a detailed description of this sample). We do have exit data for these firms in the 2000–2003 period. Out of the 25 ASUs, two (8.0%) ceased operations, and two (8.0%) were acquired by/merged with other firms. Out of the 376 non-academic NTBFs, 46 exited the sample due to failure (corresponding to a 12.2% share), and 36 were acquired (9.6%). We then estimated the probabilities of ceasing operations and being acquired in the 2000–2003 period conditional on survival until the end of 1999 (i.e., the hazard rates) through two probit models. The independent variables of both models included (i) two measures of founders' education and four measures of their work experience (*TechEducation*, *EcoEducation*, *TechWorkExp*, *ComWorkExp*,

[12] We also built a second control sample adopting nearest-neighbour matching based on the propensity score, without distinguishing manufacturing firms from those that operate in services. The results of the statistical tests confirm the findings that are presented in Section 4. For the sake of synthesis, they are not reported in the paper. They are available from the authors on request.

Table 2
Variables used in the statistical analysis.

Variable	Description
Characteristics of the founding teams	
Graduated	Number of graduated founders (i.e., founders having a university degree)
PhD	Number of founders having a Ph.D. degree
Education	Total number of years of education of founders
EcoEducation	Total number of years of economic and managerial university education of founders
TechEducation	Total number of years of scientific and technical university education of founders
SpecWorkExp	Total number of years of work experience of founders in the same sector of the start-up before firm's foundation
TechWorkExp	Total number of years of technical work experience of the founders in the same sector of the start-up before firm's foundation
ComWorkExp	Total number of years of commercial work experience of the founders in the same sector of the start-up before firm's foundation
GenWorkExp	Total number of years of work experience of the founders in other sector than the one of the start-up before firm's foundation
DFounderManager	One for firms with one or more founders with a prior management position in another firm
DFounderEntrepreneur	One for firms with one or more founders with a previous self-employment experience
Competence enlarging strategies	
%Tech	Percentage of employees working in R&D and other technical functions
%Comm	Percentage of employees working in commercial functions
%GraduatedEmployees	Percentage of graduated employees (i.e., employees having a university degree)
DManager	One for firms with one or more salaried managers (except owner-managers)
DTechAllianceResOrg	One for firms that have established one or more technological alliances with public research organisations
DCommAllianceResOrg	One for firms that have established one or more commercial alliances with public research organisations
DTechAllianceFirm	One for firms that have established one or more technological alliances with other companies
DCommAllianceFirm	One for firms that have established one or more commercial alliances with other companies
DConsultingResOrg	One for firms that have acquired consultancy services from public research organisations
DEUProjects	One for firms that have been involved in one or more research projects funded by the European Union

GenWorkExp, *DFounderManager*; see Section 4.1 for a description); (ii) two dummy variables aimed at signalling, respectively, the firms that received a venture capital investment by 2000 (*DVC1999*) and academic NTBFs (*DASU*); (iii) firm age (*Age1999*) and size (*LEmployees1999*), measured by the (log of the) number of employees at the end of 1999; (iv) an index capturing infrastructure development in the province in which the focal NTBF is located (*Infrastructure*) and (v) sectoral dummies (the results of these estimates are available from the authors on request).

In stage two, we predict the likelihood of firm exit in year t conditional on survival until the end of year $t-1$. To do so, we use the coefficients of the probit models estimated in stage one. We assume that the determinants of both failure and acquisition do not change over time. Hence, the coefficients of the equations on the likelihood of failure and acquisition in any year are assumed to equal those of the equations that we estimated for the 2000–2003 period. Under this assumption, and making the additional assumption that the two types of events under consideration here are not correlated, the hazard rate of firm exit is calculated as the sum of the hazard rates of firm failure and acquisition. We then computed the inverse Mills ratio of firm exit as the integral of the yearly hazard rate of exit from firm foundation to survey date. This inverse Mills ratio is the last factor we included in the set of regressors of the ten models described above.

4. Empirical results

4.1. Genetic characteristics

We have argued that academic and non-academic NTBFs inherit different "genetic" characteristics from their founders. This section is devoted to the analysis of the characteristics of the founding teams of the two categories of firms. Although we use the firm as our unit of analysis, variables are built departing from individual-level data. These data regard 377 entrepreneurs: 196 of them founded the 64 sample academic NTBFs, and the remaining 181 founded the 64 twin non-academic NTBFs. The findings of the statistical analysis show that, in accordance with our arguments, the human capital of the founders of academic NTBFs differs from that of other high-tech entrepreneurs.

As is evident from Table 3, the founding teams of academic NTBFs exhibit greater education levels than those of other NTBFs. The mean value of the sum of the years that founders spent in formal education (*Education*) and the mean number of founders who have graduated from a university (*Graduated*) are considerably higher in the academic NTBF sample than in the control one (53.09 against 39.87, and 2.05 vs. 1.54, respectively). Moreover, the mean number of founders who have a Ph.D. degree (*PhD*) is six times higher (0.66 vs. 0.11). All of these differences are found to be statistically significant (with adjusted p-value of 0.02, 0.00 and 0.00, respectively).

Regarding the nature of the education received by founders, the founding teams of academic NTBFs exhibit greater specialisation in technical and scientific fields. The mean value of the total number of years of university-level technical education of academic NTBFs' founders (*TechEducation*) is 10.94, compared to 4.77 for other NTBFs, with the difference again being significant (adjusted p-value: 0.00). Conversely, no difference is found with respect to years of university-level economic and managerial education (*EcoEducation*).[13]

We also consider the work experience of firms' founding teams. The results of the tests are generally in line with prior studies in that they show that the founding teams of academic NTBFs lack

[13] *EcoEducation* measures years spent towards the attainment of degrees in economics, management, and political sciences, while *TechEducation* reflects years spent obtaining degrees in engineering, chemistry, physics, geology, mathematics, biology, medicine, pharmaceutics, and computer science. To properly judge the effective level of competencies of founders, we consider the minimum length of time necessary to attain a certain degree. To attain an Italian graduate degree in economics, management, political sciences and most scientific degrees four years of studies are requested, while five years is the minimum time for a degree in engineering and chemistry. Master and Ph.D. programs require one and three additional years, respectively, independently of the specific field.

Table 3
The founding conditions: results of statistical tests on the matched samples.

Variable	No. of firms	Academic NTBFs	Other NTBFs	Adjusted *p*-value	*p*-value
Graduated[a]	124	2.03	1.09	0.000***	0.000***
PhD[a]	128	0.66	0.11	0.006***	0.001***
Education[a]	124	53.09	39.87	0.017**	0.003***
EcoEducation[a]	122	1.14	1.40	0.998	0.672
TechEducation[a]	122	10.94	4.77	0.000***	0.000***
SpecWorkExp[a]	118	2.14	9.27	0.006***	0.001***
TechWorkExp[a]	120	1.35	5.65	0.028**	0.005***
ComWorkExp[a]	122	0.82	1.93	0.751	0.218
GenWorkExp[a]	118	2.60	8.29	0.324	0.067*
DFounderManager[b]	120	21.7%	33.3%	0.644	0.167
DFounderEntrepreneur[b]	110	25.4%	49.1%	0.153	0.029**

* $p < .10$; ** $p < .05$; *** $p < .01$.
[a] *t*-test between the two categories (academic and non-academic NTBFs).
[b] Mc Nemar test between the two categories (academic and non-academic NTBFs).

industry-specific human capital. The mean values of the sum of years of prior professional experience of founders in firms that operate both in the same sector of activity of the NTBF (*SpecWorkExp*) and in other sectors (*GenWorkExp*) are lower in the academic NTBF sample (2.14 vs. 9.27, and 2.60 vs. 8.29, respectively. The adjusted *p*-values are equal to 0.00 for the former variable but only to 0.32 for the latter one). In particular, a large difference exists between the two categories of firms as to *TechWorkExp*, the total number of years of work experience gained by founders in the R&D, design, and engineering departments of firms that operate in the same sector of the NTBF under consideration (1.35 vs. 5.65, adjusted *p*-value: 0.00). Conversely, the industry-specific professional experience gained in commercial functions (*ComWorkExp*) is small in both samples.

In addition, the founding teams of academic NTBFs exhibit lower entrepreneurial and managerial experience than those of other NTBFs. In fact, the presence of serial entrepreneurs, i.e., individuals who have had previous entrepreneurial experiences (*DFounderEntrepreneur*), in the founding team is less frequent among academic NTBFs (25.4% as opposed to 49.1%), with the difference being close to statistical significance (adjusted *p*-value: 0.16; *p*-value: 0.03). Regarding the presence among the founders of one or more individuals with a managerial position in another firm prior to the establishment of the new venture (*DFounderManager*), the difference between academic NTBFs and other NTBFs, although quite large, is not significant (21.7% vs. 33.3%).

Altogether, the empirical analysis confirms the evidence provided by prior studies on the peculiarities of the founding teams of academic NTBFs. Our claim is that academic NTBFs inherit from their founders specific genetic characteristics that differ from those of non-academic NTBFs and differently influence the competence-enlarging strategies these firms adopt after foundation.

4.2. Competence-enlarging strategies

In this section, we discuss both the results of the statistical analyses on the matched samples (reported in Table 4) and the estimates of the 10 econometric models described in Section 3.3 (reported in Table 5) to spot the differences in the competence-enlarging strategies adopted by academic and

Table 4
Competence enlarging strategies: results of statistical tests on the matched samples.

Variable	No. of firms	Academic NTBFs	Other NTBFs	Adjusted *p*-value	*p*-value
%Tech[a]	116	54.2%	51.2%	0.563	0.136
%Comm[a]	116	16.8%	19.1%	1.000	0.928
%GraduatedEmployees[a]	94	54.9%	34.9%	0.033**	0.006***
DManager[b]	128	7.8%	21.9%	0.312	0.064*
DTechAllianceResOrg[b]	112	51.8%	26.8%	0.061*	0.011**
DCommAllianceResOrg[b]	112	23.2%	14.3%	0.898	0.332
DTechAllianceFirm[b]	112	37.5%	37.5%	1.000	1.000
DCommAllianceFirm[b]	112	60.7%	62.5%	1.000	1.000
DConsultingResOrg[b]	70	31.4%	22.9%	0.989	0.549
DEUProjects[b]	128	18.8%	1.6%	0.017**	0.003***

* $p < .10$; ** $p < .05$; *** $p < .01$.
[a] *t*-test between the two categories (academic and non-academic NTBFs).
[b] Mc Nemar test between the two categories (academic and non-academic NTBFs).

Table 5
Competence enlarging strategies: regressions with controls for the survivorship bias.

Model	Dependent variable	Type of model	No. of firms	Coefficient and std. error of *DASU*
1	*%Tech*	Double censored tobit	489	0.032 (0.040)
2	*%Comm*	Double censored tobit	489	−0.001 (0.026)
3	*%GraduatedEmployees*	Double censored tobit	497	0.482 (0.056)***
4	*DManager*	Probit	507	−0.361 (0.364)
5	*DTechAllianceResOrg*	Probit	476	0.982 (0.210)***
6	*DCommAllianceResOrg*	Probit	476	0.645 (0.231)***
7	*DTechAllianceFirm*	Probit	476	0.200 (0.198)
8	*DCommAllianceFirm*	Probit	476	0.151 (0.202)
9	*DConsultingResOrg*	Probit	363	1.191 (0.244)***
10	*DEUProjects*	Probit	507	0.899 (0.247)***

* $p < .10$; ** $p < .05$; *** $p < .01$.

non-academic NTBFs. Note that, for the sake of synthesis, in Table 5 we show only the estimated coefficients of *DASU*.

All of the results of the matched-pair analysis are confirmed by the estimates of the econometric models. The statistical significance of the results is greater for the econometric estimates, perhaps as a consequence of the larger size of the sample of non-academic NTBFs.

Hypotheses *H1* and *H2* regard the recourse to internal investments to enlarge the firm's initial competence endowment. They contend that academic NTBFs place more emphasis than other NTBFs on internal investments in technical activities and less emphasis on investments in commercial activities and that they have a superior ability to attract better-educated technical human resources, respectively. To test the former hypothesis, we considered the distribution of a firm's workforce across different functional activities. Specifically, we examined the percentage of employees working in R&D, design and engineering functions (*%Tech*) and in commercial functions (*%Comm*). Both the matched-pair analysis and the estimates of the models controlling for the survivorship bias indicate that the percentage of employees in commercial functions is lower among academic NTBFs, while the percentage of employees in technical functions is higher. However, the differences between academic and non-academic NTBFs are not significant. Hence, we conclude that hypothesis *H1* is not supported.

To test hypothesis *H2*, we considered the share of graduated employees in the total workforce (*%GraduatedEmployees*). In accordance with our expectations, the findings of both types of analysis reveal that academic NTBFs employ more educated individuals than other NTBFs. The share of graduate employees is indeed higher for academic NTBFs than for twin companies (54.9% vs. 34.9%, adjusted *p*-value: 0.03), and the coefficient of *DASU* is positive and significant at 1% in Model 3. Note that although we can argue that academic NTBFs rely more intensively than other NTBFs on the labour market of skilled human resources, we do not know the distribution of graduate employees by university degree. We may only presume that most of them have technical competencies as a consequence of both the privileged relations of the founders of academic NTBFs with graduates in technical disciplines and the slightly greater share of employees assigned to technical functions. To gain further insight into this issue, we considered whether the firms hired one or more salaried managers. This is captured by the dummy variable *DManager*. No difference is found with respect to this variable in the matched-pair analysis. Moreover, the coefficient of *DASU* in Model 4 is negative, although not significant. These results indicate that academic NTBFs do not enjoy any advantage over other NTBFs in hiring professional managers. They are consistent with the view that the advantage of academic NTBFs in hiring qualified personnel is confined to technical positions.

Regarding competence enlargement through the establishment of alliances, we considered whether firms ever established technological and commercial alliances with public research organisations (*DTechAllianceResOrg* and *DCommAllianceResOrg*) and other firms (*DTechAllianceFirm* and *DCommAllianceFirm*). Our analysis shows that, in accordance with hypothesis H3, academic NTBFs are significantly more prone to establish technological alliances with public research organisations. More than half of academic NTBFs established this type of alliance, while only 27% of non-academic NTBFs did so (adjusted *p*-value: 0.06; *p*-value: 0.01). This result is confirmed by the positive coefficient of *DASU* (significant at 1%) in Model 5. The estimates of the econometric models reveal that academic NTBFs are also more likely to establish commercial alliances with public research organisations, as the positive coefficient of *DASU* (significant at 1%) in Model 6 indicates. Conversely, we do not find any significant difference between academic and non-academic NTBFs with respect to the propensity to establish alliances with other firms, either of a technological or commercial nature. To gain further insights into NTBFs' competence-enlarging strategies, we also considered the purchase of technical consultancy services from public research organisations (*DConsultingResOrg*) and the participation in collaborative research projects funded by the European Union (*DEUProjects*). These projects aim at performing pre-competitive research in collaboration with international partners, among which there frequently are public research organisations. Again, the results indicate that academic NTBFs are significantly more inclined than their non-academic peers to engage in these activities.

Let us briefly discuss the effect of the survivorship bias. Altogether, the results regarding the coefficient of the inverse Mills ratio control clearly show that it is important to control for survivorship, a task that is rarely undertaken in the entrepreneurship literature (for exceptions, see Colombo and Grilli, 2010; Delmar and Shane, 2006; Eckhardt et al., 2006). The coefficient of this control variable is negative and statistically significant in Models 4, 5, 9, and 10. This points to the presence of unobserved factors that (i) are positively (negatively) correlated with a firm's likelihood of exit and (ii) are negatively (positively) correlated with the recruiting by firms of salaried managers, the establishment of technological alliances with and the purchase of consultancy services from public research organisations and the participation in EU-funded international research projects. Conversely, the coefficient of the inverse Mills ratio control is positive and significant in Model 2. This indicates that unobserved factors that lead to an increase (decrease) of the likelihood of exit are positively (negatively) correlated with the share of the firm's workforce employed in commercial functions.

Finally, in order to gain further insights in the link between the genetic characteristics of academic and non-academic NTBFs and the competence enlarging strategies of these two types of firms, we have also included in our econometric models indicators for the education level and work experience of firms' founders (see Table A4 in the Appendix). This allows us to directly test whether these human capital characteristics of founders are responsible for the differences in the competence-enlarging strategies of academic and non-academic NTBFs that we have detected.[14] Remind that academic NTBFs' founding teams exhibit greater university level education in technical and scientific fields, but smaller industry-specific technical work experience. In Models 3, 9, and 10, the coefficient of *TechEduc* is positive and significant. This suggests that the greater education of academic founders in technical and scientific fields leads academic NTBFs to be more prone to hire educated personnel, to purchase technical consultancy services from public research organisations and to participate in EU-funded research projects than their non-academic counterparts. Conversely, *TechWorkExp* exhibits a negative and significant coefficient only in the *DTechAllianceResOrg* equation. Moreover, the coefficient of *DASU* is still positive and significant at 1% in Models 3, 5, 9, and 10. These results suggest that the differences between academic and non-academic NTBFs with respect to the internal investments strategies and the collaborations with public research organisations that have been highlighted earlier, are not fully explained by the differences between these two types of firms in the years and type of university level education and prior work experience of the founders. The coefficient of *DASU* is also significant (at 5%) in Model 2. Here, its negative sign indicates that, in accordance with hypothesis H1, academic NTBFs place a lower emphasis than non-academic NTBFs on internal investments in commercial functions. The lack of significance of *TechEducation* and *TechWorkExp* indicates that this difference is not engendered by the differences between academic

[14] We are indebted to an anonymous reviewer for this suggestion.

and non-academic NTBFs with respect to the education and prior work experience of the founders. Thus, the lower emphasis on investments in commercial function is probably a consequence of genetic differences between academic and non-academic NTBFs in other dimensions (e.g., in founders' networks of personal contacts).

5. Discussion and conclusions

In this paper, we have adhered to the view inspired by the competence perspective that academic NTBFs inherit from their founders "genetic" characteristics that differ from those of other NTBFs. Then, following Stinchcombe's (1965) imprinting argument, we have claimed that these genetic characteristics exert a persistent influence on firms' post-entry competence-enlarging strategies. In particular, we expect academic NTBFs to be more inclined than non-academic NTBFs to make internal investments in technical activities and to establish technological alliances with public research organisations, and less inclined to invest in commercial activities. In the empirical section of the paper, we have examined data on Italian academic and non-academic NTBFs, and we have resorted to both matched-pair statistical techniques and the estimation of several econometric models that included a control for survivorship bias in the set of covariates. Our empirical findings confirm the evidence provided by previous studies (e.g., Ensley and Hmieleski, 2005) suggesting the existence of genetic differences between academic and non-academic NTBFs associated with the composition of their founding teams. The founders of academic NTBFs exhibit greater technical and scientific education but have less industry-specific technical work experience than do their non-academic counterparts. Moreover, they lack leadership experience, because before the firm's foundation, they seldom had managerial positions in other companies or were involved in other self-employment episodes. More interestingly, our findings show that the peculiar genetic characteristics of academic NTBFs differently shape the strategies they adopt to enlarge their initial competence endowments with respect to other NTBFs. Academic NTBFs enjoy an advantage in hiring qualified personnel, presumably for technical positions, while they are relatively less prone than their non-academic counterparts to make human capital investments in the commercial function. Moreover, their external collaboration strategies clearly differ from those of other NTBFs. They are more inclined than other NTBFs to establish technological alliances with and purchase technical services from public research organisations and to participate in pre-competitive international collaborative research projects. In other words, academic NTBFs use internal investments and external collaborative relations to further improve their technological and scientific competencies. Conversely, contrary to conventional wisdom, they do not exhibit a greater propensity than do their non-academic peers to resort to alliances with other firms or to make internal investments in the commercial function, so as to counterbalance the lack of industry-specific and managerial competencies of their founders.

We think that the findings illustrated in this paper are interesting, because they both contribute to the theoretical debate on high-tech entrepreneurship and are very informative for academic entrepreneurs, officers of public research organisations and policy makers.

In terms of theory development, our analysis provides fresh insights into two literature streams. First, we contribute to the literature on academic entrepreneurship. Research on university-based ventures has focused on the founding team's composition (in relation to founders' education profile, business experience, and affiliation) and the founders' human capital to explain firm performance differentials (see Rothaermel et al., 2007 for a review). Here, we focus on founding teams to explain differences in firm strategies, and we show that founders' human and social capital also affect competence-enlargement internal investments and alliance formation. Moreover, as firms' strategies clearly influence firms' outcomes, our results suggest that the effect of founders' genetic characteristics on performance is both direct, as prior studies have shown, and indirect, i.e., mediated by strategy. Second, we contribute to the imprinting literature. Prior studies discussed the impact of founding conditions on firm organisation (e.g., Baron et al., 1996, 1999; Hannan et al., 1996), behaviour and performance (e.g., Bamford et al., 2004). Here, we show that founding conditions also exert an imprint on firm strategies.

In spite of the merits of this study, we are aware of its limitations. First and foremost, we were forced to consider academic NTBFs as a homogenous group. Previous studies have argued that NTBFs' strategies are shaped by the characteristics of their technological and business environments (e.g., Bruneel et al., 2011). Further research work is needed to understand whether and how such characteristics moderate the effects of academic NTBFs' genetic characteristics on their post-entry competence-enlarging strategies. For instance, we expect the propensity of academic NTBFs to deepen their technological and scientific specialisation to be magnified in sectors characterised by tight appropriability of technology, high technological opportunities and control of specialised commercial assets by large incumbent firms (e.g., in biotechnologies). Such a propensity may also be moderated by the firm's age. As Geroski et al. (2010) have shown, the impact of founding conditions, although persistent, is likely to decrease as time goes by. Thus, one may wonder how rapidly the imprint of academic NTBFs' genetic characteristics fades away over time and whether this process is eventually accelerated by disruptive organisational changes, such as the receipt of venture capital finance. Finally, all firms that were analysed in this work are located in a single country with specific institutional characteristics. In Italy, the public research system is historically quite disconnected from the private sector. This clearly influences the social contacts of academic entrepreneurs and, in turn, may affect the alliance strategies adopted by academic NTBFs. Thus, it would be interesting to extend this comparative analysis to other countries to check whether national institutional characteristics of the public research system influence the genetic characteristics and post-entry competence-enlarging strategies of academic NTBFs.

An important strength of this study is that our findings have interesting managerial and policy implications. We have shown that the superior technical education and research experience of the founders leads academic NTBFs to adopt strategies that further improve their technological and scientific competencies. This specialisation is at the same time an asset and a liability for these firms. For academic NTBFs that follow a business model aimed at entering the "market for products" and, therefore, develop, produce and sell their own products and services, it clearly represents an obstacle because it prevents these firms from acquiring the commercial and managerial competencies that would be required to compete successfully with incumbent firms. Founders of these firms should recognise that because of firms' genetic characteristics, an alternative strategy is to specialise in technical activities while shaping firms' operations as first-class "R&D laboratories". Rather than entering the "market for products", they can enter the "market for technologies" (Arora et al., 2001), especially if the appropriability regime of technology is tight. Alternatively, they may want to enter the "market for assets" and try to become an attractive acquisition target for large incumbent companies that are endowed with the specialised complementary assets and competencies necessary to commercially exploit the innovative products and technologies academic NTBFs have developed.

In addition, officers of technology transfer offices and incubators and policy makers should be aware that, because of the genetic

characteristics of academic NTBFs, these firms are naturally prone to adopt a business model aimed at deepening their technological and scientific competencies. Therefore, they should concentrate their support on helping academic NTBFs (i) to sell their technological artefacts and disembodied technical knowledge to incumbent firms that are better positioned to commercially exploit these technologies, and (ii) to become the target of an acquisition on the part of these firms. They should also recognise that academic NTBFs are not well equipped to implement a high-growth business model, which requires substantial investments in the commercial function of the business and sophisticated managerial skills that lie beyond the area of expertise of academic founders. To successfully implement this type of business model, academic NTBFs should undergo a genetic mutation of their competencies. Again, officers of public research organisations may facilitate this mutation through coaching (Clarysse and Moray, 2004) or promoting changes in the owner-manager team through the advent of a surrogate entrepreneur (Franklin et al., 2001).

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Appendix A.

Tables A1–A4.

Table A1
Variables used in the matching process.

Variable	Description
DASU	One for academic start-ups
Age	Number of years since firm's foundation
Variables related to firm's localisation	
Infrastructure	Value of the index measuring regional infrastructures in 1992 (mean value among Italian regions = 100)
%GeoPublicFinanced	Percentage of RITA firms that obtained public subsidies out of all RITA firms in the region in which the focal firm was located
Variables related to firm's sector of activity	
%SectoralTech	Percentage of employees working in R&D and other technical functions out of the total workforce in the firm's sector of activity (source: ISTAT)
Appropriability	Mean value of the answers of RITA NTBFs' owner-managers to questions concerning the appropriability of technology in the firm's sector of activity measured through a likert scale from 1 (weak appropriability) to 6 (strong appropriability)
Competition	Mean value of the normalised answers of RITA NTBFs' owner-managers to questions concerning the degree of competition in the firm's sector of activity

Table A2
Estimates of the participation model.

		DASU
a_0	*Constant*	3.578 (4.167)
a_1	*Age*	−0.102 (0.030)***
a_2	*Infrastructure*	0.198 (0.006)**
a_3	*%GeoPublicFinanced*	0.007 (0.002)**
a_4	*%SectoralTech*	2.724 (1.475)*
a_5	*Appropriability*	−2.122 (1.107)*
a_6	*Competition*	−1.711 (0.754)**
	No. of observations	528
	Log-likelihood	−167.242

*$p < .10$; **$p < .05$; ***$p < .01$.

Table A3
Results of the t-tests performed to identify differences between the academic start-ups and control samples in the mean values of the variables that entered the participation model.

Variable	No. of firms	Academic NTBFs	Other NTBFs	p-value
Age	128	6.76	7.48	0.284
Infrastructure	128	124.49	124.03	0.901
%GeoPublicFinanced	128	46.62	47.17	0.957
%SectoralTech	128	0.38	0.37	0.604
Appropriability	128	3.97	3.96	0.584
Competition	128	−0.06	−0.04	0.623

*$p < .10$; **$p < .05$; ***$p < .01$.

Table A4
Competence enlarging strategies: regressions with controls for the survivorship bias and founder-specific characteristics.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
DASU	0.035	−0.062**	0.199***	−0.077	1.061***	0.225	0.339	0.061	0.924***	1.203***
	(0.045)	(0.029)	(0.049)	(0.304)	(0.254)	(0.275)	(0.246)	(0.256)	(0.289)	(0.309)
EcoEducation	−0.006	0.019*	0.089***	0.192*	−0.079	0.138	0.078	0.018	0.098	−0.198
	(0.016)	(0.010)	(0.017)	(0.090)	(0.101)	(0.096)	(0.083)	(0.084)	(0.137)	(0.145)
TechEducation	0.007	0.002	0.068***	0.012	0.038	0.089**	−0.010	0.049	0.097**	0.076*
	(0.006)	(0.004)	(0.007)	(0.039)	(0.036)	(0.041)	(0.034)	(0.035)	(0.044)	(0.044)
TechWorkExp	−0.002	−0.002	−0.005	0.017	−0.040**	−0.031	0.015	0.022	−0.043	0.008
	(0.003)	(0.002)	(0.003)	(0.017)	(0.017)	(0.023)	(0.014)	(0.015)	(0.027)	(0.023)
ComWorkExp	−0.005	0.007**	0.000	−0.009	−0.047*	0.005	−0.017	0.031	−0.051	−0.081*
	(0.004)	(0.003)	(0.005)	(0.026)	(0.026)	(0.030)	(0.023)	(0.025)	(0.035)	(0.044)
GenWorkExp	−0.001	0.000	−0.003	0.009	−0.024*	0.010	−0.003	−0.007	−0.013	−0.032*
	(0.002)	(0.001)	(0.002)	(0.012)	(0.013)	(0.014)	(0.011)	(0.011)	(0.014)	(0.017)
DFounderManager	−0.014	0.044	0.020	0.163	0.008	−0.047	−0.191	0.099	0.264	−0.097
	(0.044)	(0.028)	(0.048)	(0.251)	(0.244)	(0.306)	(0.235)	(0.242)	(0.284)	(0.416)
Other Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
No. of observations	431	431	435	441	413	378	413	413	309	442

The dependent variables are the following. Model 1: *%Tech*; Model 2: *%Comm*; Model 3: *%GraduatedEmployees*; Model 4: *DManager*; Model 5: *DTechAllianceResOrg*; Model 6: *DCommAllianceResOrg*; Model 7: *DTechAllianceFirm*; Model 8: *DCommAllianceFirm*; Model 9: *DConsultingResOrg*; Model 10: *DEUProjects*. The description of the founder-specific variables is provided in Table 2. *GenWorkExp* is the total number of years of work experience gained by founders in other sectors than the start-up's one before firm's foundation.
*$p < .10$; **$p < .05$; ***$p < .01$.

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