Performance differences between academic spin-offs and non-academic start-ups: A comparative analysis using a non-parametric matching approach

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Abstract

How do academic spin-offs perform relative to other innovative start-ups? What are the factors that influence differences in their performance? Or do such performance differences exist at all? This study provides unique comparative evidence on the early performance of both types of entrepreneurial venturing. We apply non-parametric propensity score matching to address the potentially confounding influence of the endogeneity of academics' decision whether and when to engage in firm founding. Utilizing archival and survey data on 128 academic spin-offs and an equivalently matched group of 128 non-academic innovative start-ups in Germany, we find that firms involving academic founders experience a lower risk of default and achieve higher levels of innovative output in the first years of business operation. Results however do not suggest significant differences with respect to job-creation early after start-up. Moreover, the two sets of firms benefit differently from their initial resource endowment and strategic decisions. In particular, technological resources the founders contribute to their new venture and the market strategy at founding emerge as potential drivers of performance differences between academic spin-offs and other technology-based start-ups, whereas financial resources and founders' entrepreneurial human capital do not show differential effects.

Keywords: Academic entrepreneurship; Academic spin-off; New venture performance; Non-parametric matching

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INTRODUCTION

Over the past decades, academic entrepreneurship – i.e., scientists founding own firms in order to commercially exploit their research and inventions – has started to be considered a third mission in which higher education institutions engage, in addition to their more traditional mandates of research and teaching (Etzkowitz, 2004; Shane, 2004; Wright et al., 2007). The underlying rational for this is to be rooted in the impact that scientific research has on high-technology sectors and, more generally, on today's knowledge-based economy (Dosi, 1988; Mansfield, 1998; Rosenberg & Nelson, 1994). Businesses created by academic scientists, so-called academic spin-off companies, are widely seen as important contributors to economic development (e.g., by transforming the results of scientific research into new innovative products and services) and societal wealth (e.g., by creating highly innovative jobs) (Roberts, 1991; Shane, 2004). Not surprisingly, governments in most industrialized countries are explicitly targeting the creation and growth of business start-ups from the public science sector (OECD, 2003). Besides legislative changes (mostly adopting models from the US, such as the Bayh-Dole Act of 1980), a number of structural mechanisms have been put in place like technology transfer organizations (TTOs), science parks, industrial liaison offices, and incubators directed at supporting and promoting entrepreneurial activity in academia (Wright et al., 2007).

However, despite this growing acceptance of the importance of academic entrepreneurship for national economies (for a comprehensive review of the literature on this topic see Rothaermel, Agung, & Jiang, 2007), positions on the significance of academic spin-off companies for innovation, economic growth and industrial renewal compared to other types of entrepreneurial venturing vary greatly. On the one hand, a few empirical studies document the success of academic scientists when engaging in business creation (e.g., Rothaermel & Thursby, 2005; Shane, 2004; Zucker, Darby, & Armstrong, 2002). On the other hand, some studies show that academic spin-offs tend to stay small (Chiesa & Piccaluga, 2000; Zhang, 2009) and to grow less than other high-technology start-ups (Ensley & Hmieleski, 2005; George, Zahra, & Wood, 2002). Bonardo, Paleari, and Vismara (in press), while showing that an academic affiliation enhances the valuation of firms at the time of an IPO, also point out that over the long run science-based businesses do not outperform their non-academic counterparts, and even exhibit worse operating performance. More importantly, entrepreneurship scholars (e.g., Agrawal, 2006; Lacetera, 2009; Toole & Czarnitzki, 2007) have recently argued against drawing definitive conclusions from existing comparative analyses, unless the potential endogeneity of academic scientists' entrepreneurial career choice is appropriately controlled for. Accordingly, the type of businesses academics start would generally be different from those undertaken by other actors (e.g., by employees of existing companies), which might render any comparison between economic and innovative outcomes of firms that involve academic founders and firms that do not potentially misleading. Against this backdrop, we still lack a thorough understanding about the relative performance of academic spin-offs and other innovative start-ups or the factors that influence differences in their performance or if such performance differences exist. This study aims to help filling this void.

Building on previous research which posits that initial resource endowments and strategic decisions can have long-lasting effects on a start-up firm's future development (Barney, 1991; Boeker, 1989; Stinchcombe, 1965), we identify a number of key determinants of new venture performance, comprising technological resources, financial resources, entrepreneurial human capital and the market strategy at founding. We propose that, due to "genetic characteristics" of academic spin-off companies (Colombo & Piva, 2008), these performance determinants may position science-based businesses on growth paths that are different from those of other innovative start-ups. We test our propositions using multiple measures of economic performance (employment growth, default risk) and innovative performance (patent applications). In order to take account of the potential endogeneity of academic scientists' entrepreneurial decision, we follow recent recommendations in the statistical evaluation literature (Ho et al., 2007; Stuart, 2010) and apply non-parametric propensity score matching (Dehejia & Wahba, 2002; Rosenbaum & Rubin, 1983; 1985). We define the founding of an academic spin-off company as being subject to a "treatment" and create an adequate control group of innovative start-ups that have not been "treated", which is then used to disentangle performance differences between both types of business start-ups.

The paper is organized as follows. The next section sets out our hypotheses on growth and development of innovative new ventures in general, and on potential drivers of performance differences between academic spin-offs and other innovative start-ups in particular. Section 3 briefly discusses the endogeneity bias that might have confounded existing comparative analyses and motivates the analytical plan of the present paper. Section 4 is dedicated to the presentation of the data, the variables used, and the analytical strategy. The empirical analysis is presented in Section 5. Finally, Section 6 discusses our findings and concludes.

HYPOTHESES

As new venture performance in general is complex and multi-dimensional (Westhead & Birley, 1994), there appears to be no comprehensive theoretical approach which can adequately explain whether or not academic spin-offs indeed perform different from their non-academic counterparts. On the other hand, scholars claim that growth patterns of new businesses are not random and completely unpredictable; rather, "how and why firms grow" is systematically related to the characteristics of these firms and their environments (Delmar, Davidsson, & Gartner, 2003). This thinking is consistent with previous research which posits that initial founding conditions, available resources, and strategic decisions at start-up can have long-lasting effects on a firm's future development (Barney, 1991; Boeker, 1989; Stinchcombe, 1965). In the present study, we thus draw on this research to identify a set of key variables that are then investigated as potential drivers of performance differences between academic spin-off companies and other innovative start-ups. This set of variables comprises attributes of founders' entrepreneurial human capital (*entrepreneurial experience*, *industry experience*, *start-up team*) as well as the new ventures' financial resources (*start-up capital*), technological resources (*innovativeness*, *prior patent stock*), and market strategy at founding (*market breadth*). The underlying mechanisms through which these variables may affect new venture performance can be assumed to be the same for both categories of firms. We argue, however, that "genetic characteristics" of academic spin-off companies (Colombo & Piva, 2008) may either enhance or buffer these performance effects and, thus, may eventually position science-based businesses on growth paths that are different from those of other innovative start-ups. To explore these aspects in more detail, we first set out our hypotheses on the effects of initial resource endowments and market strategy on growth and development of innovative new ventures in general (denoted 1a, 2a, and so forth). This is followed by hypotheses on the differential effects of these variables in the specific case of academic spin-off companies (denoted 1b, 2b, and so forth).

Performance effects of technological resources

Shane and Stuart (2002) argue that the strength of a new venture's technological endowment at founding is an important predictor of its subsequent performance, since in most cases these companies do not have any complementary assets in place. Its technological resource base is likely to determine a start-up's tendency to engage in new idea generation, experimentation, and innovation activities resulting in new products and processes (Lee, Lee, & Pennings, 2001). A recent meta-analytical review (Rosenbusch, Brinckmann, & Bausch, 2010) demonstrates the importance of a start-up's innovation strategy. By offering innovative products, new ventures can benefit from customer loyalty, price premiums, and entry barriers for potential imitators, allowing them to successfully compete with established incumbent firms (e.g., Acs & Audretsch, 1990). Moreover, the accumulation of technological resources as captured, e.g., by firm founders' previous patent stock, signals the quality and strength of a new venture's intellectual property position and the potential to innovate to external stakeholders (Hsu & Ziedonis, 2007). On this ground, we formulate the following hypothesis:

Hypothesis 1a: There is a positive effect of technological resources on new venture performance.

Performance effects of financial resources

Generally, the amount of financial resources available at start-up increases the chances for a new venture to survive and grow (Brüderl et al., 1992; Holtz-Eakin et al., 1994). Financial capital provides a buffer against random shocks, such as market downturns or managerial mistakes. It also provides organizational slack, facilitating the pursuit of resource-intensive growth strategies (Cooper et al., 1994). Research suggest that in particular technology-based businesses are those most likely to be subject to capital market imperfections and, thus, to suffer from funding gaps whenever personal financial resources of the founders are limited (Carpenter & Petersen, 2002). Due to severe information asymmetries, key stakeholders, such as external financiers and customers, cannot readily observe the innovative new ventures' quality and prospects and thus may be reluctant to provide financial resources (Shane & Cable, 2002). The resulting funding gap leads these start-ups to invest substantially less and, thus, inhibit innovation, and delay, or even prevent firm growth. Therefore, we hypothesize that:

Hypothesis 2a: There is a positive effect of financial resources on new venture performance.

Performance effects of entrepreneurial human capital

Entrepreneurial human capital has been shown to be related to new venture survival and growth (Brüderl et al., 1992; Colombo & Grilli, 2005). For example, earlier entrepreneurial episodes, successful or not, may provide experience of operating a business and may thus be the best preparation for the current entrepreneurial role (Brüderl et al., 1992). Firm founders with entrepreneurial experience may also have developed commercial and social networks that provide access to financial resources and management talent (Mosley & Wright, 2007). Furthermore, industry-specific experience involving knowledge of competitive conditions and regulations specific to the new venture's industry sector, as well as previously established goodwill with customers, suppliers, and other stakeholders should help overcome the liability of newness (Cooper et al., 1994; Stinchcombe, 1965). Research has indicated that prior industry experience further allows entrepreneurs to identify emerging opportunities and position their new products and services accordingly (Shepherd & DeTienne, 2005). Based on the above arguments, we expect that:

Hypothesis 3a: There is a positive effect of entrepreneurial human capital on new venture performance.

Performance effects of market strategy at founding

The market opportunity a new venture faces at start-up is likely to be determined by the breadth of its target market (Clarysse et al., 2007; Heirman & Clarysse, 2004). The breadth of the target market may range from a specific niche market to an established mainstream market. In general, the entry of a new business into a market represents a strategic action that may initiate a retaliatory response from incumbent competitors. As a consequence, researchers advocate the niche strategy for technology-based start-ups (Porter, 1980; Roure & Maidique, 1986). Initially targeting a narrow market segment and serving a specific group of customers through differentiated products or services may create unique business opportunities too small to be of interest to larger, economies-of-scale oriented competitors (Porter, 1980). Hence, we thus assume that:

Hypothesis 4a: There is a positive effect of a lower breadth of the target market at founding on new venture performance.

Performance differences between academic spin-offs and other non-academic start-ups

Academic spin-off companies may enjoy significant advantages in exploiting their technological resources as they are endowed with greater absorptive capacity than their non-academic counterparts (Colombo, D'Adda, & Piva, 2010). Due to both the scientific background and the ”connectedness” of their founders in the scientific community, spin-off firms are claimed to be better equipped to recognize the value of external knowledge, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1990; Corolleur, Carrere, & Mangematin, 2004). In addition, marginal returns on internal investments in R&D are likely to be higher for academic spin-offs than for other innovative start-ups as a consequence of the technological specialization of their founders acquired in an academic setting (Colombo & Piva, 2008). We therefore expect that:

Hypothesis 1b: The positive effect of technological resources on new venture performance is enhanced for academic spin-offs compared to non-academic innovative start-ups.

Moreover, in the case of academic spin-offs, the detrimental effect of funding gaps might be less severe as the parent research organization may lower the new firms' initial financial needs (Colombo & Piva, 2008; George, Zahra, & Wood, 2002; Moray & Clarysse, 2005). For instance, many universities and research institutes offer expensive technical facilities and scientific equipment at subsidized costs or even direct financial support, such as loans that are free of interest for the first year. As part of their intellectual property policy, some parent research organizations may sustain the costs related to legal protection of the technological inventions their spin-off companies are based on. During the first business years, academic spin-offs may also benefit from reduced personnel costs as in most cases the founding partners are still employed at the university and may afford to offer their services to the new business below market prices. We therefore conclude that university support enables academic spin-offs to invest a larger amount of their initial financial resources in processes nurturing their growth and development than new ventures not backed by a parent organization. The corresponding hypothesis is formulated as follows:

Hypothesis 2b: The positive effect of financial resources on new venture performance is enhanced for academic spin-offs compared to non-academic innovative start-ups.

The fact that academic spin-offs are created by entrepreneurial teams prevalently composed of individuals who were formerly employed by public research organizations has a significant bearing on the entrepreneurial human capital resources available to the new venture (Samsom & Gurdon, 1993; Shane, 2004). Indeed, academic founding teams are likely to be unbalanced in terms of having a strong technological knowledge base, but lacking industry-specific and managerial competences (Colombo and Piva 2008; Ensley & Hmieleski, 2005). One way to fill this knowledge gap may be adding commercially-experienced team members, so-called "surrogate entrepreneurs" (Franklin, Wright, & Lockett, 2001). However, evidence suggests that the addition of external managers or business developers to the scientist team members does not necessarily add to the cognitive heterogeneity required to help the spin-off to grow (Vanaelst et al., 2006), and may even hamper new venture performance due to misunderstanding, distrust and conflicts among team members with managerial and scientific backgrounds (Cantner, Goethner, & Stuetzer, 2010). To conclude, their "genetic characteristics" may render academic spin-off companies less effective in translating entrepreneurial human capital of their founders into competitive advantage. Hence, we assume that:

Hypothesis 3b: The positive effect of entrepreneurial human capital on new venture performance is buffered for academic spin-offs compared to non-academic innovative start-ups.

For academic spin-off companies the most accessible market opportunity appears to be the provision of research-based consultancy or research services to customers. These activities are closest to the academic entrepreneur's former work at the public research organization and are unlikely to require demanding initial investments in physical infrastructure (Druilhe & Garnsey, 2004; Pérez & Sánchez, 2003). Prior research suggests that, for these types of new ventures, focusing on niche markets at start-up increases the chances of success to commercialize science-based technologies (Heirman & Clarysse, 2004). Once they have established market acceptance with their knowledge-intensive services and early products in a small market segment, the spin-off firms can use these first customers as a reference to go after broader markets in a relatively fast and low cost manner (Roberts, 1991). We therefore hypothesize that:

Hypothesis 4b: The positive effect of a lower breadth of the target market at founding on new venture performance is enhanced for academic spin-offs compared to non-academic innovative start-ups.

Overall, with respect to their performance in the first years after start-up, academic spin-offs may clearly benefit from its links with the parent research organization. The spin-off is able to access more resources in its early stages than a company set up by an independent entrepreneur (Rappert et al., 1999). The network and reputation of the research institute can further provide organizational legitimacy to the new venture and enhance its growth prospects (Stuart et al., 1999). Rothaermel and Thursby (2005) show that academic spin-offs benefit from strong ties to their parent research organization in terms of higher survival rates. Despite the potential benefits yielded by academic affiliation, scientific achievements do not necessarily go along with an inclination to successfully do business. It is stated that "academics do not make good entrepreneurs and the effective exploitation of their technology usually requires that the ownership of the technology and the managerial control are taken out of their hands at an early stage" (Stankiewicz, 1994, p. 101). Just as the theoretical debate is controversial, so is the available empirical evidence. Egeln et al. (2003), for instance, find that employment in the year of establishment is higher in academic spin-offs than that in other new technology-based firms, whereas Dahlstrand (1997) reveals an initial 10-year period after which academic spin-offs start to grow faster than their non-academic counterparts. Zhang (2009) concludes that academic spin-offs may remain small in the early years because they focus more on R&D activities. They may significantly grow in the long run after they have entered the stage of mass production. In fact, spin-offs from the public science sector have been shown to be more R&D-intensive than other innovative start-ups (Mustar, 1997). In many cases, up to 20% of their early sales are invested in R&D, confirming that what is usually spun off from public research are not "technologies-as-products" but rather R&D and technical problem-solving capabilities (Stankiewicz, 1994). Drawing from this evidence, we assume that:

Hypothesis 5: Academic spin-offs show a lower economic performance than non-academic innovative start-ups.

Hypothesis 6: Academic spin-offs show a higher innovative performance than non-academic innovative start-ups.

ENDOGENEITY BIAS IN PREVIOUS COMPARATIVE STUDIES

Entrepreneurship scholars have recently advised to take any strategic, organizational, and policy implications from existing comparative analyses with caution, unless the potential endogeneity of academic scientists' entrepreneurial career choice is appropriately controlled for (e.g., Agrawal, 2006; Lacetera, 2009; Toole & Czarnitzki, 2007). Arguably, the type of businesses academics start are generally different from those undertaken by non-academic entrepreneurs, which might render any comparison between economic and innovative outcomes of firms that involve academic founders and firms that do not potentially misleading. It is suggested that in order to understand the peculiarities of academic entrepreneurship as compared to more general entrepreneurship, one needs to consider the different rules and incentives to which academic scientists respond. While the primary goal of academics would be to gain scientific prestige and establish priority in discovery, which is done most efficiently through publication in scientific journals (Dasgupta & David, 1994; Stephan, 1996), industrial actors usually do not share the academic values of publishing and sharing knowledge. Instead, new knowledge is to be kept proprietary and exploited to achieve or sustain a competitive advantage (Nelson, 2004).

Lacetera (2009) proposes a theory of academic entrepreneurship, taking into account these aspects. The underlying economic model develops three key propositions of academic scientists' decision whether and when to undertake entrepreneurial activity: academic reluctance, project selection, and academic rush. According to the model, both academic scientists and industrial actors (e.g., researchers in corporate R&D departments) benefit from the monetary returns from research commercialization. In addition, academics, unlike industrial researchers, also derive direct utility from the research activities that precede commercialization, for example, in the form of publications and peer recognition. As a first result of the model, academic scientists are more reluctant to commercialize research because they may find it too costly to abandon the research activities that generate the highest peer recognition in the scientific community (i.e., *academic reluctance*). Involving academic scientists in a commercial project thus would imply the involvement of academic missions and objectives which may take priority over the focus on commercial success. In fact, it has been shown that new ventures are likely to grow faster if the academic founders initially give up on their commitments with the university such that the rules of the scientific community do not apply any longer (Doutriaux, 1987). Moreover, the model proposes that while industrial actors have incentives to commercialize any projects which offer (even marginal) non-negative returns, academic scientists tend to choose to participate only in those commercial projects which make it worthwhile for them to forego the direct recognition benefits of scientific research (i.e., *project selection*). Therefore, a self-selection mechanism is present, which is further consistent with research hinting at a lower risk-taking propensity of academic scientists compared to industrial actors (e.g., Bellante & Link, 1981; Özcan & Reichstein, 2009). Consequently, academics' higher opportunity costs of switching to entrepreneurship (due to the benefits of scientific research and the risk-less wage in public sector employment) would need to be covered by the expected profitability of the commercial project. Lastly, academic scientists and industrial actors may differ with respect to the timing of commercialization of a given project, that is academics may opt to commercialize an invention at some earlier point in time (i.e., *academic rush*). This would be the case if industrial actors find it profitable to engage in supplemental research activities prior to commercialization, whereas academic scientists would perceive the performance of this research as less rewarding in terms of scientific recognition, and would, therefore, prefer to move to commercialization activities right at the outset. This theoretical prediction concurs with the empirical finding that academic scientists indeed tend to start their companies when products are little more than "proof-of-concept" and some additional development effort is needed in order to attain commercial success (Jensen & Thursby, 2001; Shane, 2004).

These results, taken together, tell us that behavioral predispositions and belonging to the community of science might constitute potentially unobserved effects which may have driven the empirically observed performance differences between academic spin-offs and their non-academic innovative counterparts. In the present study, we aim to control for these confounding influences by taking account of differences between academic and independent entrepreneurs in a number of characteristics measured at the project phase prior to actual venture set-up. Therefore, we regard the founding of an academic spin-off company as being subject to a "treatment" in the sense of the statistical evaluation literature and compare them to innovative start-ups that have not been "treated". Applying non-parametric propensity score matching (PSM; Dehejia & Wahba, 2002; Rosenbaum & Rubin, 1983; 1985), we then create an adequate control group of innovative start-ups that are as similar to academic spin-offs as possible with respect to the project phase covariates measured at the level of the firm founders. Finally, with the matched sample, we test our hypotheses on performance differences between academic spin-offs and other innovative start-ups via regression analyses.

METHOD

This study is part of the Thuringian Founder Study (Thüringer Gründer Studie), an interdisciplinary research project on success and failure of innovative start-ups in the Federal State of Thuringia, Germany. Located in the center of Germany, Thuringia has experienced a process of convergence between old and new technologies since 1990 that led to a diversified industry structure ranging from food industry and automobile industry to science-based industries like biotechnology and (opto-)electronics. A broad spectrum of research organizations, like universities and non-university research institutions (e.g., Max Planck institutes, Fraunhofer institutes) further provides a fertile ground for the emergence of academic entrepreneurship.

Participants

In a first step of sample selection, we draw from the German trade register (Handelsregister) for commercial and private companies, recording 2971 technology-oriented or knowledge-based start-ups[1] founded between 1994 and 2006 in the German Federal State of Thuringia. From this list of firms, we selected a random sample of 2604 start-ups (which corresponds to 3671 firm founders). Founders of these firms were contacted by mail and telephone in order to recruit one founder per start-up (most likely the lead-entrepreneur in case of a founder team), resulting in a response rate of 24.5% (based on the number of start-ups). Note that an important advantage of this recruitment procedure is the possibility to interview founders whose companies were already closed down. Hence, there is no bias toward surviving or particularly successful firms. Finally, 639 structured face-to-face interviews were carried out in 2008. We had to exclude 76 cases as these were not genuinely new start-ups but subsidiaries or diversifications of existing companies. 13 cases were excluded where we had concerns over interview quality. Furthermore, we had to exclude 15 observations from the analysis due to incomplete data. This resulted in 535 valid cases.

Consistent with similar terms used in the literature, we define an academic spin-off as a company that was set up by university faculty, research staff or students who were still affiliated with or who had quite the parent research organization in order to commercially exploit their scientific ideas and research knowledge (e.g., Carayannis et al., 1998; Druilhe & Garnsey, 2004; Pirnay et al., 2003). Following this definition, 57 of the 535 interviewed firms

[1] Following Grupp *et al.* (2000), innovative industries are defined according to the average R&D investments at the firm-level. Hence, in innovative industries firms spend on average 3.5% of their turnover in R&D.

(corresponding to 11% of this sample) identified themselves as academic spin-offs.[2] We complemented this random spin-off sample with a non-random selection of firms spun off from universities and research institutes in Thuringia. The sampling of these companies was not based on particular criteria (e.g., industry sector or founding year), but was conducted in a quite informal way, asking staff of university technology transfer offices, management of business incubators, public business consultants, and previously interviewed scientist-entrepreneurs to identify other spin-off companies of which they are aware. 102 companies were additionally identified which met our definition of an academic spin-off. Of these, 72 founders were interviewed face-to-face in 2009 (response rate of 71%), adding to the 57 observations that were drawn from the random sampling.[3] In total, the final sample utilized in this study consists of n = 129 academic spin-off companies and n = 478 non-academic innovative start-ups.

Procedure

The structured interviews were carried out by the members of the research project. On average, an interview took one and a half hours. The interviews covered a broad set of questions regarding socio-demographic and psychological data of the entrepreneurs. Retrospective data were collected relating to events in the entrepreneur's life and the business history, covering the new venture creation process and the first three business years of the start-up[4]. Face-to-face interviews allowed to obtain information that respondents may be sensitive about providing, e.g., in a mail or phone survey. To overcome potential hindsight

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[2] Egeln, Gottschalk, and Rammer (2004) report similar estimates of spin-off activity in Germany. Drawing from a representative sample of start-ups in knowledge-intensive industries, they approximate that about 11% of these start-ups originated from German public research organizations.

[3] T-tests and χ^2-tests for all study variables revealed no significant differences between both spin-off sub-samples.

[4] The first business year is defined as the time when accounting started either because of obligations from the German trade register or because of first revenues. Thus, this definition does not necessarily correspond to the date of registration at the Handelsregister.

bias and memory decay of the interviewed entrepreneur (Davidsson, 2006), the members of the research project utilized mnemonic techniques drawn from the Life History Calendar method (Caspi et al., 1996).[5] This method has been shown to collect more valid and reliable retrospective information than traditional questionnaires (Belli et al., 2001; 2004).

Measures

Table 1 presents descriptions and coding for all study variables. Included are the matching variables, treatment and explanatory variables, dependent variables, and control variables.

Independent and treatment variable

Our treatment variable captures whether a new venture can be identified as an academic spin-off company. Following the definition of an academic spin-off used in this study, the new venture had to be developed by university faculty, staff or students (whether or not they were still affiliated with a public research organization) based on their own research.

Matching variables

To reduce the problem of endogeneity that may bias any comparative analysis of academic spin-offs and other innovative start-ups, we include several matching variables in the propensity score model used in the matching procedure. We draw from Lacetera's (2009) theory of academic entrepreneurship (and its propositions of academic reluctance, project selection, and academic rush) as well as from related empirical findings to identify appropriate matching variables that may influence academic scientists' entrepreneurial career choice and may also affect the outcome variables of interest.

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[5] A study-specific version of the Life History Calendar is employed, which is a data-collection tool established in sociological and psychological research. It is based on the principles of the autobiographic memory. This means that, in a first step, interviewees are asked about the timing of major life events, sequences, and transitions (e.g., marriage, birth of children, education, or vocational life). In a second step, these biographical key data served as memory anchors for the recall of the retrospective study variables.

With respect to the proposition of academic reluctance (i.e., the prevalence of peculiar missions and objectives other than entrepreneurial ones among the academic founders), the variable *payroll* measures whether the entrepreneurs founded the new venture while still working at a prior employer, i.e., either at a university (in the case of an academic spin-off) or at an incumbent company (in the case of a non-academic innovative start-up). Referring to the proposition of project selection (i.e., academic scientists' selection into the most profitable entrepreneurial projects), we aim to control for the entrepreneurs' risk-taking propensity. Building on recent research in vocational psychology which finds a positive relationship between an individual's entrepreneurial personality and the propensity to take risk (Nicholson et al., 2005) and further links certain personality traits to an entrepreneurial career choice (Zhao & Seibert, 2006), we consider the entrepreneurs' Big 5 personality traits (*conscientiousness*, *extraversion*, *agreeableness*, *openness*, *neuroticism*; Costa & McCrae, 1992) as well as their *entrepreneurial personality profile* (Schmitt-Rodermund, 2004; 2007) in the propensity score model. Finally, referring to the proposition of academic rush (i.e., an academic scientist will commercialize a certain project earlier than an industrial actor), we take account of the pre-founding efforts founders have invested in the development of the new venture's core product or service (denoted as *stage of new product development* in the tables). As recommended when conducting propensity score analysis (Caliendo & Kopeinig, 2008), all matching variables occur pre-treatment (i.e., in the project phase prior to actual venture set-up) or are fixed over time (e.g., Big Five personality traits, entrepreneurial personality profile).

Dependent variables

The present study seeks to compare academic spin-off companies with other non-academic innovative start-ups along three dimensions of economic and innovative performance. The first two performance measures refer to new ventures' economic performance and gauge employment growth and default risk. First, *employment growth* is operationalized as the number of full-time employees in the third business year.[6] Growth in employment is used as performance indicator because it signals the need for additional resources to meet customer demands. In addition, new venture growth and the resulting job creation is a desirable outcome from a macroeconomic perspective. Relative growth rates could not have been computed since most of the sampled firms started without any employees (for a similar approach see Baum & Silverman, 2004; Clarysse, Wright, & Van de Velde, accepted article). If a new venture did not reach its third business year we recoded the number of employees as zero. Note that "many owners/entrepreneurs for a variety of reasons report manipulated performance outcomes" (Sapienza, Smith, & Gannon, 1988, p. 46). In order to validate our information on employment growth, we were able to gather secondary data for 171 new businesses (corresponding to 28% of the complete sample) from two business information providers (Creditreform and Bureau van Dijk). A high correspondence between the information provided by the interviewees and the information we found in secondary data sources indicate validity of our employment growth measure (r = .87, p < .001).

Second, we use the credit rating index provided by Creditreform, Germany's major credit rating agency, to measure new firms' *default risk* three years after founding. Indeed, this rating index and new venture survival are highly correlated in the present sample (r = .58, p < .001). Creditreform has a comprehensive database at its disposal, comprising data on the financial standing of almost all German firms. Its rating takes into account financial and liquidity risk as well as structural risks like industry characteristics, competitive position, and productivity, along with "soft factors" such as payment history, volume of orders, firm development, and management quality (Czarnitzki & Kraft, 2007). Thus a rating reflects both currently observable firm characteristics and expectations regarding future development.

[6] Founders as well as board members (where applicable) are not counted as employees.

Originally, the credit rating score ranges from 100 to 600, with 100 corresponding to the best rating.

The third performance measure refers to innovative performance and captures a new venture's success in developing intellectual property. Accessing the database of the German Patent and Trademark Office (DPMA)[7], we count the *number of patent applications* which either the founder(s) (as inventor) or the new venture (as applicant) filed during the first four years of business operation. We focus on patent output because patents are tangible manifestations of firms' ideas, techniques, and products, and represent an important milestone in the innovation process within firms (DeCarolis and Deeds, 1999). Furthermore, patenting performance has frequently been used to measure innovative firm behavior in past research (e.g., Ahuja and Katila, 2001; Hall and Ziedonis, 2001).[8]

Control variables

The regression analyses are controlled for industry peculiarities (six dummy variables for the industry sectors) and possible temporal influences (four dummy variables for the start-up year) in our analyses.

[Insert Table 1 here]

Analytical strategy

7 Applying for a patent at the DPMA involves lower fees as compared to applications at, e.g., the European Patent Office (EPO). This implies that academic spin-offs, not being able or willing to bear the higher fees, will apply at the DPMA alone. However, applications at the EPO that cover the German territory will appear in the DPMA dataset as well. The German database can therefore be expected to be more complete.

8 A number of shortcomings of patents as a measure of a firm's innovative output should be mentioned (see Griliches, 1990, for an extended discussion of this topic). Most importantly, patent data might underestimate innovative firm performance as not all patentable inventions are patented. Firms may use other strategies to appropriate the benefits of their R&D efforts, such as secrecy, lead time, or complementary assets. Reasons for not patenting also include the lengthy application process relative to the duration of the innovation cycle or the perceived ease of inventing around a patent (Cohen et al., 2000)

We separate our analysis into two steps, as recommended by Ho et al. (2007) and Stuart (2010). First, we select well-matched groups of academic spin-offs and other innovative start-ups using non-parametric propensity score matching (PSM; Dehejia & Wahba, 2002; Rosenbaum & Rubin, 1983; 1985). Once we obtained matches, we run regression analyses on the matched sample. In a similar context, this approach has recently been used to investigate the effects of a firm's university affiliation on its valuation at IPO (Bonardo, Paleari, & Vismara, in press). Moreover, Fini (2010) explores the relationship between entrepreneurs' organizational affiliation and the enactment of their entrepreneurial intentions, using a previously matched sample of academic and industrial entrepreneurs.

In the present study, we conduct PSM to better compare the early performance of academic spin-off companies (treatment group) and other innovative start-ups (control group), which are likely to differ considerably on a number of covariates measured at the project phase prior to venture set-up (as discussed earlier). Conventional regression adjustment for these differences ignores that the two samples may not overlap sufficiently on the distribution of the project phase covariates to allow for meaningful comparison. Resulting estimates would rely heavily on model specification (i.e., on extrapolation), and can therefore be misleading (Heckman, Ichimura, & Todd, 1998; Imbens, 2004). To reduce model dependence, we preprocess the data set with PSM prior to regression analyses (see Ho et al., 2007). The objective of this approach is to identify an adequate control group of innovative start-ups that are as similar to academic spin-offs as possible in all project phase covariates. In that sense, we replicate the distribution of the covariates that would be expected if the status of an academic spin-off company could be randomly assigned to a group of new businesses. A key assumption when conducting PSM is that of strongly ignorable treatment assignment (also known as *strong ignorability*; Rosenbaum & Rubin, 1983). This assumption demands that (a) after conditioning on the measured project phase covariates, there is no hidden bias due to unmeasured confounders, and (b) for each firm in our data set the probability of treatment is strictly positive (i.e., each firm could have been identified as an academic spin-off company or not). Satisfying the first component of this assumption, termed unconfoundedness, requires that *all* relevant covariates that affect both treatment (i.e., the founding of an academic spin-off) and potential outcomes (i.e., new venture performance) are observed by the researcher. Clearly, unconfoundedness is a strong condition, which cannot be verified directly. We are confident in maintaining its credibility in our study, though, since the selection of matching variables is justified by theoretical and empirical research on academic entrepreneurship. A central aspect relating to the second component of strong ignorability is the common support or overlap condition which assures that for each treatment unit a comparable control unit can be identified.

With PSM we first estimate the predicted probability of treatment for each firm in our data set. A logit model is specified in which the set of measured project phase covariates is regressed on a dichotomous criterion variable indicating whether or not a firm is identified as an academic spin-off company (see Table A1 in Appendix A). The resulting propensity score collapses the project phase covariates into a single summary measure, in order to make matching more feasible. Different matching methods can be used to assign treatment units to control units on the basis of the estimated propensity score (for an overview see, e.g., Imbens, 2004; Smith & Todd, 2005). We use nearest-neighbor matching (without replacement), one of the most frequently used matching techniques, where a treatment unit is matched to the control unit with the closest propensity score. Those two matched units are then removed from the pool, and the matching procedure continues with the next treatment unit. Control units not chosen as a match for any treatment unit are discarded from subsequent analyses.

After preprocessing the data with PSM, we perform regression analyses on the matched sample. We rely on negative binomial regression to assess the effect of an academic background on a new venture's employment growth in the first three business years and on the number of patent applications in the first four years of business operation.[9] Moreover, we use OLS regression to assess the effect of the status of an academic spin-off on the default risk after the first three business years.

RESULTS

Establishing a control group of non-academic innovative start-ups

Figure 1 provides graphical diagnostics of the matching procedure. The left panel depicts the distribution of the propensity score for the original groups of academic spin-offs and non-academic control units. The vertical dashed lines indicate the region of common support, given by the overlap of the propensity score distribution between both samples. We determine the region of common support by comparing the minima and maxima of the propensity score. Imposing the common support restriction requires dropping one academic spin-off company and 27 non-academic control units.

[Insert Figure 1 here]

Table 2 compares academic spin-off companies and their non-academic innovative counterparts on the project phase covariates before and after matching. Before matching, founders of academic spin-offs were significantly more likely to have a wage job, i.e., at a university or research institute, next to setting up the new venture (as indicated by the variable payroll), and more likely to invest less time in the development process that eventually leads to market-ready products or services than founders of other innovative start-ups (as indicated by the variable stage of new product development). Regarding the Big Five personality traits,

9 Both performance measures, employment growth and number of patent applications, involve non-negative count data that exhibit overdispersion (i.e., the variance of each variable is larger than its mean). A likelihood ratio test indeed indicates overdispersion for both dependent measures, pointing to the inadequacy of employing the Poisson distribution for estimation. The Vuong (1989) test further rejects zero-inflated negative binomial models, suggesting that in both cases a standard negative binomial distribution fits the data better.

academic entrepreneurs scored significantly lower in conscientiousness and extraversion and higher in openness. Moreover, they had a less entrepreneurial personality profile than independent entrepreneurs. By contrast, after matching, there are no significant differences on any of the project phase covariates. Likewise, the right panel of Figure 1 shows that, after matching, the distribution of the propensity score for both groups is nearly equal.

The resulting matched sample thus consists of 128 academic spin-off companies and 128 matched non-academic control units. Overall, 351 firms were excluded from further analyses, either because their propensity score lied outside the region of common support or because they did not constitute suitable matching partners.

[Insert Table 2 here]

Preliminary analyses

Correlations between the variables used in the regression analyses are provided in Table 3. Table 4 shows their descriptive statistics. With respect to the outcome variables (employment growth, default risk, patent applications), we find that academic spin-offs do not create significantly more employment after the first three business years than non-academic innovative start-ups. Spin-off companies however seem to exhibit a lower default risk and to apply for more patents in the first years after start-up than their non-academic innovative counterparts, providing preliminary support for Hypotheses 6 and 7.

[Insert Table 3 here]

[Insert Table 4 here]

In addition, the figures for initial resource endowments and market strategy in Tables 3 and 4 reveal some differences between both types of innovative business creation. First of all, the businesses started by academic scientists possess a higher amount of technological resources (i.e., the founders of academic spin-offs have gathered a larger patent stock prior to actual venture set-up and more likely have invested in R&D activity during the venture creation phase as well as in the first three business years), whereas no such difference can be found for financial resources (as indicated by the variable start-up capital). Also, academic spin-offs and other innovative start-ups significantly differ with respect to the market strategy at founding (as indicated by the variable market breadth) since spin-off firms in our sample are more likely to target a niche market and serve a specific group of customers when starting business operations. Regarding the measures of entrepreneurial human capital, academic spin-offs more likely are set up by a team of founders. There are no significant differences between the founders of academic spin-offs and other start-ups with respect to entrepreneurial experience and industry experience.

Regression analysis

Regression results for the performance indicators investigated in this study are presented in Tables 5-7.

[Insert Table 5 here]

The analysis first is devoted to determinants of employment growth (Table 5). Model 1 includes all explanatory variables. We find that the amount of start-up capital ($B = 0.289$, $p < 0.01$) and the breadth of the target market at founding ($B = 0.294$, $p < 0.1$) positively predict the number of employees in the third business year, whereas the remaining variables do not show up significant. Models 2-5 introduce interaction terms involving the academic spin-off variable and the resource and strategy variables in order to identify potential drivers of performance differences between academic spin-off companies and non-academic innovative start-ups.[10] Results suggest a significant interaction effect between the status of an academic spin-off and the breadth of the target market at founding (Model 4; $B = -1.021$, $p < 0.01$).

[Insert Table 6 here]

Table 6 replicates the structure of analysis employed above using a firm's default risk three years after founding as dependent variable. Turning to Model 1, innovativeness of the new venture ($B = 21.942$, $p < 0.05$) and the breadth of its target market at founding ($B = 23.443$, $p < 0.1$) are relate to a higher risk of default. Moreover, the status of an academic spin-off company ($B = -29.569$, $p < 0.01$) significantly reduces the default risk. Model 2 also reveals a significant interaction effect between the status of an academic spin-off and the innovativeness of the new venture ($B = -54.355$, $p < 0.01$).

[Insert Table 7 here]

Finally, in Table 7, determinants of a new venture's success in developing intellectual property in the first four business years are investigated. According to our results in Model 1, founders' prior patent stock ($B = 0.044$, $p < 0.01$), new venture's innovativeness ($B = 1.336$, $p < 0.01$), start-up capital ($B = 0.161$, $p < 0.1$) and the status of an academic spin-off ($B = 0.637$, $p < 0.1$) emerge as positive predictors of the number of patent applications in the first four years of business operation. We also find significant interactions between the status of an academic spin-off and both the prior patent stock of the founders and the new venture's innovativeness (Model 2; $B = -3.448$, $p < 0.05$ and $B = -1.566$, $p < 0.05$, respectively).

[10] In order to test the interaction effects, we follow the guidelines by Aiken and West (1991) and use z-standardized variables to compute the interaction terms.

Furthermore, in Model 4, results suggest a significant interaction between the academic spin-off variable and the target market breadth at founding ($B = -1.836$, $p < 0.05$).

In sum, for our measures of *economic performance*, employment growth and default risk, the results do not provide support for Hypothesis 1a (technological resources do not predict employment growth and are positively related to default risk) and Hypothesis 3a (entrepreneurial human capital is neither related to employment growth nor to default risk). Furthermore, we find mixed support for Hypothesis 2a (financial resources show a positive effect on employment growth but do not predict default risk) and Hypothesis 4a (a lower breadth of the target market at founding positively predicts both employment growth and default risk). Mixed support is also provided for Hypothesis 5 as academic spin-offs do not show a higher employment growth but exhibit a lower default risk in the first business years. As regards *innovative performance*, measured via patent applications, the data provides support for Hypotheses 1a and 2a (the number of patent applications is positively predicted by technological resources and financial resources, respectively). Hypotheses 3a and 4a are not supported (entrepreneurial human capital and the target market breadth at founding do not show an effect on the number of patents applied for in the first four business years). Finally, there is support for Hypothesis 6 proposing the academic spin-offs achieve a higher innovative performance (i.e., a higher number of patent applications) than other innovative start-ups.

Figure 2 graphically depicts the identified interactions between the academic spin-off variable and the measures of initial resource endowments and market strategy for the purpose of interpretation. We use the SPost program ("prvalue" command) for Stata (Long and Freese, 2006) to obtain predicted values for the performance measures. Values are obtained separately for each interaction, holding the other measures at their means. Figure 2A shows that the positive effect of technological resources (i.e., the innovativeness of a new venture) on the default risk after the first three business years is enhanced for academic spin-offs compared to other technology-based start-ups. Figure 2B provides evidence for the enhancing effect of an academic background on the relationship between a lower target market breadth at start-up and employment growth in the subsequent business years. Hence, the corresponding Hypotheses 1b and 4b receive mixed support regarding *economic performance*. Similarly, Figures 2C, 2D, and 2E reveal an enhancing effect on the relationship between technological resources and the initial market strategy on the one side and *innovative performance* on the other side for firms that involve academic founders, supporting Hypotheses 1b and 4b. Hypotheses 2b and 3b do not receive support for either of the performance measures.

DISCUSSION AND CONCLUSION

This study provides comparative evidence on the early performance of academic spin-off companies and other non-academic innovative start-ups. Drawing on previous research on new venture growth and development, a set of relevant performance predictors is identified comprising firm founders' entrepreneurial human capital as well as the new venture's financial resources, technological resources, and market strategy at founding. We argue however that due to the "genetic characteristics" of academic spin-offs (Colombo & Piva, 2008), these performance predictors may position science-based businesses on growth paths that are different from those of their non-academic innovative counterparts.

In contrast to previous research comparing the performances of both kinds of entrepreneurial venturing, the present study aimed to control for the endogeneity of academic scientists' decision whether and when to engage in firm founding. According to Lacetera's (2009) theory of academic entrepreneurship, academics may pursue scientific motives rather than entrepreneurial ones when starting an own firm, may select the most promising commercial projects, and may not invest as much time in the development process that eventually leads to marketable products as independent entrepreneurs. Hence, the businesses academic scientists start might generally be different from those undertaken by non-academic entrepreneurs, which may render any comparison potentially misleading. We apply non-parametric propensity score matching (Dehejia & Wahba, 2002; Rosenbaum & Rubin, 1983; 1985) in order to take account of these aspects. This approach allows to select well-matched groups of academic spin-offs and other innovative start-ups that are as similar as possible with respect to a number of characteristics measured at the project phase prior to venture set-up. The resulting matched sample is then used to test our hypotheses.

Our work provides indications of potential drivers of performance differences between academic spin-off companies and non-academic innovative start-ups. Overall, the market strategy at founding and technological resources seems to have differential effects on the early performance of both types of new ventures. It appears that targeting a *niche market* may be the superior entry strategy for academic spin-offs. Our study suggests that spin-off firms pursuing a niche strategy significantly grow more in terms of employees after the first three business years compared to any kind of business start-up. In addition, these spin-offs are more successful in generating intellectual property as they apply for significantly more patents in the first four business years than other new ventures initially operating on an established mainstream market.

We also find that *innovativeness* of a new venture is significantly associated with a higher default risk after the first three business years. For academic spin-offs however this relationship does not seem to hold as they generally experience relatively lower, and thus better, credit ratings. While the finding for non-academic start-ups is in line with other research applying different measures of a firm's innovativeness (Czarnitzki & Kraft, 2004), our study hints at a buffering effect of an academic background on the default risk early after start-up. It might thus be that an academic affiliation signals reliability of the business idea to potential lenders which might then lead to lower expectations of default. As regards the number of patent applications, our results reveal that for both kinds of firms innovativeness in terms of R&D activity during the venture creation process as well as in the first three business year plays a relevant role. We find that highly innovative non-academic start-ups are more successful in developing intellectual property than highly innovative academic spin-offs, although this effect seems to be rather small.

Our study further provides interesting results regarding the relationship between the second measure of technological resources, *prior patent stock* of firm founders, and the innovative performance of academic spin-offs and other innovative start-ups. While for the latter type of firms, the number of patent applications in the first four business years may not be related to the patenting activities of founders prior to venture creation, it seems that academic spin-off companies are more likely to apply for patents when their IP position at founding is relatively weak. This expands the academic entrepreneurship literature which tends to assume that academic spin-offs are generally generating more innovative output than other types of start-ups. However, our finding indicates that in the case of a smaller patent stock, and therefore a weaker IP position, academic spin-offs might be more likely to apply for patents early after start-up in order to protect their innovative business idea from imitation and to secure a competitive advantage during the first business years. By contrast, spin-off firms drawing on a larger patent stock at start-up may be more reluctant to apply for further patents and to bear additional patenting costs.

In sum, the present study underscores the peculiarities of academic entrepreneurship, first, by indicating that firms created by academic scientists may indeed follow other grow paths than firms founded by independent entrepreneurs and, second, by providing hints as to what factors may account for differences in their performance. Our findings may thus aid in the design of policy measures specifically targeted at fostering research commercialization through creating entrepreneurial ventures.

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Table 1.

Description of Study Variables

Variable name	Description
Matching variables	
Big Five personality traits	We use the German 45-item questionnaire by Ostendorf (1990) to measure Big Five personality traits (conscientiousness, extraversion, agreeableness, openness, neuroticism) for both founders of academic spin-offs and independent entrepreneurs.[a] Participants had to rate perceived personality attributes using 9 bipolar adjective pairs with Likert scales ranging from 0 to 5 for each trait: *Conscientiousness* (α = .82), e.g., "lazy vs. diligent" *Extraversion* (α = .71), e.g., "uncommunicative vs. talkative" *Agreeableness* (α = .72), e.g., "good nature vs. cranky" *Openness* (α = .62), e.g., "conventional vs. inventive" *Neuroticism* (α = .76), e.g., "vulnerable vs. robust"
Entrepreneurial personality	Following Obschonka et al. (2010), the variable entrepreneurial personality captures an individual's match with an entrepreneurial personality pattern. The reference type of an entrepreneurial personality is characterized by the highest possible score (5) in extraversion, conscientiousness, and openness, and the lowest possible score (0) in agreeableness and neuroticism (see Schmitt-Rodermund, 2004, 2007). With regard to this reference type, we estimated the "goodness-of-fit" of each person's Big Five profile. First, we calculated each person's squared differences between the reference values and the personal values on each of the five scales. If a person, for instance, scored a 3 in neuroticism, the squared difference is 9 (because the reference value is 0). Second, the five squared differences were summed up for each person and, third, the algebraic sign of this sum was reversed (e.g., a value of 5 became -5). The resulting value served as the final variable entrepreneurial personality. The closer to 0 the values in this variable, the better the fit between an individual's Big Five personality profile and the defined entrepreneurial reference type.
Payroll	Dummy variable indicating whether the individual founder was still working at a prior employer (e.g., in a university, other company) at the time of venture set-up (0 = no; 1 = yes)
Stage of new product development	Stage of development of the core product / service at the time of venture set-up, ranging from 0 (early-stage), over 1 (close to market) to 2 (market-ready)
Treatment variable / Explanatory variable(s)	
Academic spin-off	Dummy variable indicating whether the new venture is an academic spin-off (0 = no; 1 = yes)
Prior patent stock	Number of patents which the founder(s) applied for either as inventor or applicant within five years prior to venture set-up
Innovativeness	Dummy variable indicating whether conducting R&D was a major activity during the venture creation process as well as in the first three business years (0 = no; 1 = yes)
Start-up capital	Seven categories capturing the total amount of financial capital available at the start of the first business year: (1) 1.000€ or less, (2) more than 1.000€ to 10.000€, (3) more than 10.000€ to 50.000€, (4) more than 50.000€ to 100.000€, (5) more than 100.000€ to 250.000€, (6) more than 250.000€ to 500.000€, (7) more than 500.000€
Market breadth	Dummy variable indicating the breadth of the target market at the time of venture set-up (0 = specific niche market; 1 = established mainstream market)
Start-up team	Dummy variable indicating whether more than one person was actively involved in the venture creation process and own or have owned a part of the new venture (0 = no; 1 = yes)
Entrepreneurial experience	Dummy variable indicating whether one (or more) founder(s) had launched another start-up prior to the first steps in the venture creation process (0 = no; 1 = yes)
Industry experience	Dummy variable indicating whether one (or more) founder(s) had acquired experience in the new venture's industry within the last three years prior to the first steps in the venture creation process (0 = no; 1 = yes)
Dependent variables	
Employment growth	Number of full-time employees at the end of the third business year
Default risk	Creditreform's rating index, ranging from 100 (best) to 600 (worst) (see explanation under Method/Sample and data collection/Secondary data and under Method/Measures/Dependent variables)
Patent applications	Number of patents which either the founder(s) (as inventor) or the new venture (as applicant) applied for during the first four business years

Control variables	
Sector-dummies	Six dummy variables indicating whether in the first three business years the new venture was active in (1) ICT, software, and picture processing, (2) (opto-)electronics and measurement instrumentation, (3) consumer/business services and consulting, (4) life sciences and medical engineering, (5) automation technology and mechanical engineering, (6) environmental technology, energy management, and solar technology, (7) other (0 = no; 1 = yes)
Year-dummies	Four dummy variables capturing the start of the first business year: (1) 1989-1994, (2) 1995-1998, (3) 1999-2001, (4) 2002-2008 (0 = no; 1 = yes)

Note. [a]The Big Five personality traits are measured as the individual's current traits. However, due to their high degree of stability over the life span (Caspi et al., 2005), we deemed these trait measures to be appropriate matching variables.

Table 2.

Comparison of Treatment Units (Academic Spin-offs) and Control Units (Non-Academic Start-ups) Before and After Matching on Matching Variables (Two-sided *t*-test)

Matching variables	Academic spin-offs[a,b] (*n* = 129)	Full control units[a] (*n* = 478)	Matched control units[b] (*n* = 128)
Conscientiousness	3.43	3.67***	3.44
Extraversion	3.09	3.23**	3.15
Agreeableness	3.17	3.10	3.13
Openness	3.34	3.17***	3.38
Neuroticism	1.37	1.37	1.42
Entrepreneurial personality profile	-22.56	-21.31**	-22.06
Payroll (0 = no; 1 = yes)	0.19	0.06***	0.18
Stage of new product development	1.09	1.30**	1.07

Note. [a] Part of the original sample (N = 607). [b] Part of the matched sample (N = 256). One treatment unit had to be discarded as its propensity score laid outside the region of common support (see upper panel in Figure 1).
**$p < .05$. ***$p < .01$.

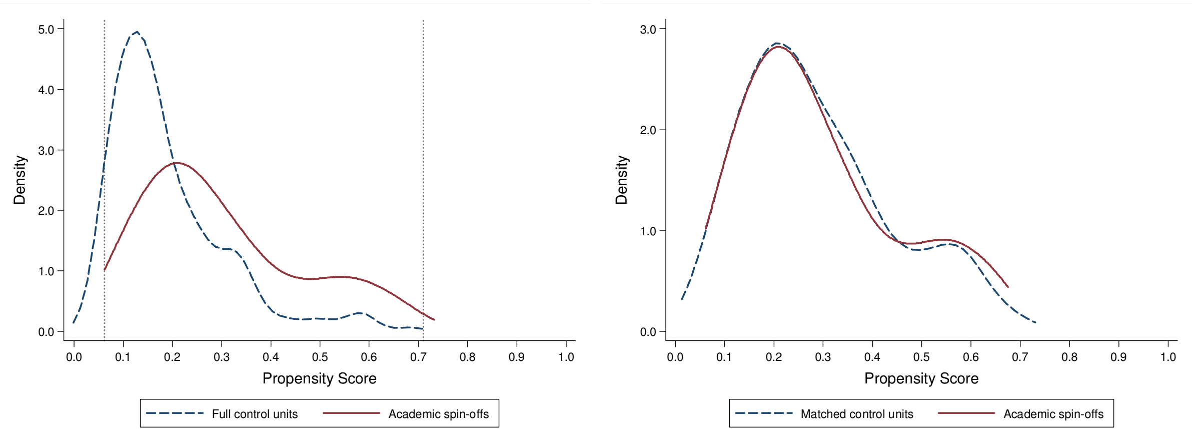

Figure 1.

Density distribution of the propensity score before matching (left panel; N = 607) and after matching (right panel; N = 256). The estimation is performed using a Gaussian kernel. The vertical dashed lines in the left panel indicate the region of common support.

Table 3.

Correlations between the Variables Used in the Regression Analyses

		1	2	3	4	5	6	7	8	9	10	11
1	Employment growth	–										
2	Default risk	-.06	–									
3	Patent applications	**.12**	-.04	–								
4	Academic spin-off (0 = no; 1 = yes)	-.08	**-.20**	**.20**	–							
5	Prior patent stock	.09	-.01	**.56**	**.19**	–						
6	Innovativeness (0 = no; 1 = yes)	-.08	.07	**.14**	**.37**	**.15**	–					
7	Start-up capital	**.45**	.06	**.22**	.05	**.27**	.09	–				
8	Market breadth (0 = niche market; 1 = mainstream market)	.11	**.15**	-.05	**-.22**	-.09	**-.17**	-.07	–			
9	Start-up team (0 = no; 1 = yes)	.07	-.02	.10	**.26**	.08	**.12**	.11	-.04	–		
10	Entrepreneurial experience (0 = no; 1 = yes)	**.13**	.04	.11	.00	**.12**	.07	**.18**	-.01	**.28**	–	
11	Industry experience (0 = no; 1 = yes)	-.02	-.03	-.01	.01	.08	.05	**.13**	-.09	.07	.04	–

Note. Correlations apply to the matched sample of academic spin-offs and their control units (N = 256). Bold numbers indicate statistical significance at $p < .05$.

Table 4.

Mean and Standard Deviation of the Variables Used in the Regression Analyses for the Sample of Academic Spin-offs and the Matched Sample of Control Units

	Variables	Academic spin-offs (n = 128)	Matched control units (n = 128)	Sample differences[a]
1	Employment growth	4.55 (5.62)	5.52 (6.62)	1.15
2	Default risk	271 (33.27)	298.50 (92.66)	2.94***
3	Patent applications	5.46 (16.41)	0.71 (2.47)	-5.74***
4	Prior patent stock	5.23 (16.43)	0.63 (2.27)	-5.27***
5	Innovativeness (0 = no; 1 = yes)	0.79 (0.41)	0.43 (0.50)	34.72***
6	Start-up capital	3.48 (1.61)	3.34 (1.42)	-0.74
7	Market breadth (0 = niche market; 1 = mainstream market)	0.11 (0.31)	0.28 (0.45)	12.03***
8	Start-up team (0 = no; 1 = yes)	0.85 (0.36)	0.63 (0.49)	17.00***
9	Entrepreneurial experience (0 = no; 1 = yes)	0.39 (0.49)	0.39 (0.49)	0.00
10	Industry experience (0 = no; 1 = yes)	0.87 (0.34)	0.86 (0.35)	0.03

Note. Standard deviations in parentheses. [a]Test statistics and significance levels are based on a t-test, a Mann-Whitney-U-test, or a χ^2-test as required.
***p < .01.

Table 5.

Negative Binomial Estimates of Employment Counts[a]

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B	SE	B	SE	B	SE	B	SE	B	SE
Hypotheses 1a – 4a										
Technological resources										
Prior patent stock	0.003	0.006	0.052	0.033	0.003	0.006	0.004	0.005	0.004	0.006
Innovativeness	-0.036	0.144	-0.090	0.187	-0.035	0.144	-0.056	0.141	-0.072	0.147
Financial resources										
Start-up capital	0.289 ***	0.044	0.270 ***	0.044	0.290 ***	0.060	0.309 ***	0.043	0.286 ***	0.045
Market strategy at founding										
Market breadth	0.294 *	0.160	0.307 *	0.160	0.293 *	0.161	-0.087	0.198	0.303 *	0.161
Entrepreneurial human capital										
Start-up team	0.199	0.160	0.207	0.161	0.199	0.162	0.295 *	0.161	0.218	0.207
Entrepreneurial experience	0.094	0.138	0.073	0.138	0.094	0.138	-0.027	0.140	0.112	0.158
Industry experience	-0.030	0.190	-0.013	0.191	-0.030	0.190	-0.064	0.186	0.213	0.273
Hypothesis 5										
Academic spin-off	-0.186	0.161	-0.409	0.255	-0.186	0.161	0.639 **	0.326	0.288	0.473
Hypotheses 1b – 4b										
Spin-off × Prior patent stock			-0.597	0.398						
Spin-off × Innovativeness			0.200	0.299						
Spin-off × Start-up capital					-0.004	0.129				
Spin-off × Market breadth							-1.021 ***	0.348		
Spin-off × Start-up team									-0.051	0.341
Spin-off × Entrepreneurial experience									-0.028	0.110
Spin-off × Industry experience									-0.468	0.395
Constant	0.863 ***	0.271	0.922 ***	0.271	0.860 ***	0.292	0.923 ***	0.269	0.699 **	0.298
Pseudo R^2	0.060		0.062		0.060		0.067		0.061	
χ^2	83.384 ***		86.477 ***		83.385 ***		92.189 ***		84.936 ***	
N	256		256		256		256		256	

Note. [a] All estimations include 5 industry sector dummies and 3 start-up year dummies. **p* < .10. ***p* < .05. ****p* < .01.

Table 6.

OLS Estimates of the Default Risk[a]

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B	SE	B	SE	B	SE	B	SE	B	SE
Hypotheses 1a – 4a										
Technological resources										
Prior patent stock	-0.089	0.391	-0.257	2.759	-0.009	0.397	-0.133	0.391	-0.146	0.400
Innovativeness	21.942 **	10.343	45.805 ***	13.765	21.974 **	10.337	23.538 **	10.382	22.975 **	10.528
Financial resources										
Start-up capital	3.965	3.481	4.466	3.469	8.445	5.323	3.530	3.487	3.988	3.522
Market strategy at founding										
Market breadth	23.443 *	12.646	27.754 **	12.613	22.778 *	12.652	36.017 **	15.515	22.010 *	12.730
Entrepreneurial human capital										
Start-up team	1.847	11.909	-0.264	11.813	-0.079	12.027	-0.182	11.969	9.114	15.144
Entrepreneurial experience	5.381	10.052	3.605	9.978	5.078	10.050	8.606	10.292	2.365	11.668
Industry experience	-12.713	15.351	-16.693	15.272	-13.377	15.353	-11.415	15.342	-34.726	23.306
Hypothesis 5										
Academic spin-off	-29.569 ***	11.203	6.647	18.806	-29.690 ***	11.197	-61.300 **	25.384	-49.697	34.917
Hypotheses 1b – 4b										
Spin-off × Prior patent stock			2.988	32.852						
Spin-off × Innovativeness			-54.355 **	20.987						
Spin-off × Start-up capital					-11.580	10.414				
Spin-off × Market breadth							37.961	27.265		
Spin-off × Start-up team									-18.618	24.792
Spin-off × Entrepreneurial experience									3.835	7.934
Spin-off × Industry experience									37.934	31.264
Constant	256.361 ***	23.243	248.139 ***	23.186	243.010 ***	26.148	253.112 ***	23.304	271.523 ***	27.506
Adjusted R^2	0.054		0.076		0.055		0.059		0.050	
F	1.76 **		1.97 **		1.73 **		1.78 **		1.58 *	
N	213		213		213		213		213	

Note. [a] All estimations include 5 industry sector dummies and 3 start-up year dummies. **p* < .10. ***p* < .05. ****p* < .01.

Table 7.

Negative Binomial Estimates of Patent Counts[a]

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B	SE	B	SE	B	SE	B	SE	B	SE
Hypotheses 1a – 4a										
Technological resources										
Prior patent stock	0.044 ***	0.017	0.329 ***	0.112	0.044 ***	0.365	0.046 ***	0.017	0.047 ***	0.015
Innovativeness	1.336 ***	0.357	2.206 ***	0.553	1.344 ***	0.017	1.265 ***	0.353	1.148 ***	0.355
Financial resources										
Start-up capital	0.161 *	0.095	0.187 **	0.094	0.181	0.361	0.197 **	0.094	0.183 *	0.094
Market strategy at founding										
Market breadth	0.193	0.441	0.128	0.444	0.189	0.162	-0.747	0.638	0.250	0.430
Entrepreneurial human capital										
Start-up team	0.435	0.398	0.317	0.393	0.421	0.442	0.555	0.398	-0.159	0.520
Entrepreneurial experience	0.298	0.319	0.204	0.318	0.300	0.409	0.059	0.332	0.585	0.370
Industry experience	-0.307	0.427	-0.662	0.427	-0.307	0.319	-0.392	0.421	1.278	0.948
Hypothesis 6										
Academic spin-off	0.618 *	0.357	1.402 **	0.668	0.629 *	0.427	2.077 ***	0.805	1.601	1.226
Hypotheses 1b – 4b										
Spin-off × Prior patent stock			-3.448 **	1.344						
Spin-off × Innovativeness			-1.566 **	0.730						
Spin-off × Start-up capital					-0.044	0.296				
Spin-off × Market breadth							-1.836 **	0.894		
Spin-off × Start-up team									1.200	0.772
Spin-off × Entrepreneurial experience									-0.346	0.258
Spin-off × Industry experience									-2.042	1.100
Constant	-4.439 ***	0.835	-4.964 ***	0.852	-4.512 ***	0.969	-4.145 ***	0.823	-5.585 ***	1.096
Pseudo R^2	0.171		0.190		0.171		0.177		0.180	
χ^2	135.203 ***		149.854 ***		135.225 ***		139.566 ***		142.087 ***	
N	256		256		256		256		256	

Note. [a] All estimations include 5 industry sector dummies and 3 start-up year dummies. *$p < .10$. **$p < .05$. ***$p < .01$.

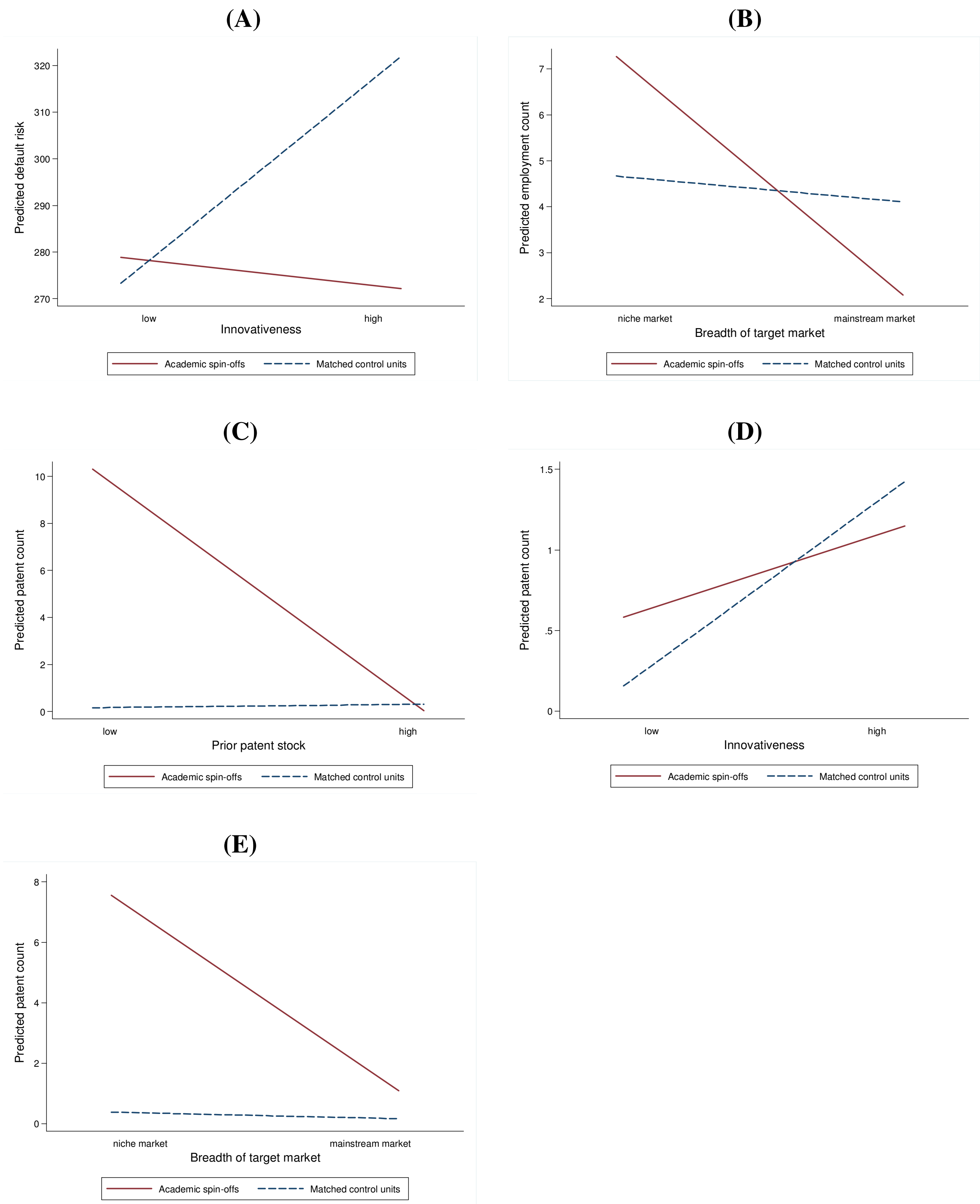

Figure 2:

Interaction Effects between the Status of an Academic Spin-off Company and the Performance Predictors

Appendix A

Table A1.

Logit Estimation of the Propensity Score

Dependent variable: Academic spin-off *(no/yes)*		
Conscientiousness	-0.753	(0.314)**
Extraversion	-0.458	(0.313)
Agreeableness	0.238	(0.484)
Openness	0.758	(0.288)***
Neuroticism	-0.186	(0.278)
Entrepreneurial personality	-0.005	(0.068)
Payroll *(no/yes)*	1.352	(0.309)***
Stage of new product development	-0.293	(0.122)**
Constant	-0.066	(2.598)
Pseudo R^2	0.101	
χ^2	63.34***	
N	607	

Note. Standard errors in parentheses.
$^{**}p < .05$. $^{***}p < .01$.