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The Patenting Behavior of Academic Founders

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The Patenting Behavior of Academic Founders

Sascha G. Walter, Arne Schmidt und Achim Walter

Abstract

This study explores why academic entrepreneurs patent their inventions before and after creating a firm. Drawing on start-up data combined with patent data, we specifically examine the impact of five, relatively under-researched factors (scientific field, pace of technological development, technological uncertainty, entrepreneurial orientation, and patent effectiveness). The study shows that some scientific fields, technological uncertainty, and patent effectiveness are positively related to patent propensity, both before and after founding. The effects of pace of technological development and entrepreneurial orientation were time-specific. Our study suggests that patenting by academic entrepreneurs is driven by special rationales and that prior research on full-time scientists and established firms does not necessarily generalize to them. We discuss the implications of our findings both in terms of contribution to the current literature and technology transfer policies.

1 Introduction

Scientists increasingly commercialize their inventions through firm formation. The decision to patent an invention (or not) can be seen as a critical part of this process. The researcher has to weigh up the fundamental tradeoff in patenting: Patents can safeguard the knowledge-base of a venture against early imitation by defining property rights over an invention but at the same time they can facilitate early imitation by disclosing critical information (Harter, 1994; Arundel, 2001; Kultti, Takalo, & Toikka, 2007). In this situation, a researcher who aims to commercially exploit his or her discovery faces two basic options. The first is to disclose the discovery to the research organization, let the technology transfer office (TTO) file a patent and (hope to) obtain a license prior to firm founding (Thursby & Thursby, 2002). This involves losing control over the invention. In the worst case scenario, any start-up

plans can be inhibited because not all research organizations license back to inventors (Shane, 2002). The other option is to conceal the discovery from the administration and create a venture without filing a patent prior to founding (Landry, Amara, & Saihi, 2007; Jensen, Thursby, & Thursby, 2003). This poses considerable ethical issues and legal risks (Bercovitz & Feldman, 2008). Thus - why and when do academic entrepreneurs patent?

Scholars have sought explanations for why some researchers patent more than others in characteristics of the individual, the research organization, and the firm. Empirical studies on individual characteristics have shown that scientists, who are male (Frietsch, Haller, Funken-Vrohling, & Grupp, 2009; Whittington & Smith-Doerr, 2005; Thursby & Thursby, 2005), older (Allen, Link, & Rosenbaum, 2007; Carayol, 2007; Stephan, Gurmu, Sumell, & Black, 2007), conduct more applied research (Sellenthin, 2009; Calderini, Franzoni, & Vezzulli, 2007), have published intensively (Dietz & Bozeman, 2005), and have gained more industry experience (D'Este & Perkmann, forthcoming; Meyer, 2006; Renault, 2006) are more likely to patent. Studies on characteristics of the research organization have observed higher patenting rates at institutions that facilitate patenting through active support (Baldini, 2009; Sellenthin, 2009; Calderini et al., 2007) and provide clear incentives by splitting revenues with inventors (Renault, 2006). Once the firm is founded, characteristics of the firm may also influence subsequent patenting behavior. Empirical studies indicate that firms which are large (Arora & Ceccagnoli, 2006; Brouwer & Kleinknecht, 1999), export-oriented (Arundel & Kabla, 1998), intensively conducting R&D (Brouwer & Kleinknecht, 1999; Scherer, 1983), and operating in certain industries (Brouwer & Kleinknecht, 1999; Arundel & Kabla, 1998; Mansfield, 1986) tend to more actively patent their inventions.

Extant studies on patenting have either considered scientists or established firms but have, to date, neglected academic entrepreneurs. Consequently, prior findings might not be generalizable to academic entrepreneurs for two reasons. First, they have to weigh up the interests of their (prospective) firms and interests of the research organization. Entrepreneurial rationales can collide with administrative regulations that stipulate disclosing and patenting inventions with commercial potential. If a secrecy strategy is vital for the new venture's success, some academic entrepreneurs might be motivated to bypass organizational routines. Others might decide to delay filing a patent until after the firm is founded. Second, the transition from the academic world that emphasizes open knowledge sharing and peer

recognition to the business world that emphasizes private property and profits might change the self-perception and strategic posture of academic entrepreneurs (Jain, George, & Maltarich, 2009). As a consequence, his or her preference for protecting intellectual property through patents might change.

This study explores empirically why academic entrepreneurs patent and how the advancement through the founding process changes drivers of patenting. To illuminate changes in patenting tendencies over time, our analysis covers two phases, including a three-year-period before and after venture creation, respectively. Specifically, we analyze (inter-temporal changes in) the effect of the scientific field, pace of technological development, technological uncertainty, entrepreneurial orientation, and patent effectiveness on the patent propensity of the founding team. A unique dataset of 260 technology start-ups combined with patent data, allows us to test our hypotheses in a context in which patenting is a critical strategic decision and substantial patentable know-how is involved.

This paper makes three contributions to the extant literature. First, it provides an empirical test of the impact of several influences on the patent propensity of a special group - academic entrepreneurs. Such a test bridges the divide between two literatures that have evolved in relative isolation and have either looked at scientists or incumbent firms. Second, the study shows that the pace of technological development, technological uncertainty, and entrepreneurial orientation, affect patent decisions. In doing so, it extends prior research that has paid little attention to these factors. Third, the study spans both the pre-founding and the post-founding phase, which facilitates detecting potential dynamics in the strength of these influences. The results complement prior research by showing that such changes are minimal. The paper is divided into five sections. In the next section, we review the extant literature and explain why the five influences should affect the likelihood that academic entrepreneurs patent their inventions. In the third section, we describe the dataset and methods used in this study. In the fourth section, we present the results and discuss their implications in the last section.

2 The different explanations

The extant literature on patenting has focused on full-time scientists or established firms. Academic entrepreneurs, in part, stand between both streams because they are entrepreneurially-minded scientists who create new firms to commercialize their research. Prior findings might, therefore, not generalize to them. As firm formation involves the challenge of converting an elementary idea to a profitable venture, other rationales may drive the patenting of academic entrepreneurs. The rationales could also change over time. Thus, analyzing patenting behavior throughout the founding process might yield new insights. Case-based research by Vohora et al. (2004) proposes five phases of start-up development. Drawing on this framework, we suggest that different drivers of patenting may prevail in the phases.

In the first phase, scientific research within academic institutions creates entrepreneurial opportunities. Many universities have adopted “pro-patent policies” to foster patenting of their employees’ inventions (Baldini, 2009). Moreover, academics increasingly seem to accept patenting as a legitimate activity that is compatible with other career interests (Bercovitz & Feldman, 2008). Thus, scientists in fields with patentable research should be more likely to file patents. In the second phase, the entrepreneurs and/or the TTO examine if the opportunity has sufficient commercial value to warrant further effort to exploit it. In fields with a high pace of technological development, patents can, in part, shield the start-up against uprisings competition, thereby helping to secure value from the invention (Hall & Ziedonis, 2001). Moreover, in situations of high technological uncertainty, effective patents often provide the time required to develop marketable applications from the core technology (Shane, 2004). In the subsequent phases, the venture acquires and deploys strategic resources, continuously optimizes its approach to identify, acquire and integrate requisite resources and finally attains sustainable returns. These phases are characterized by a steep learning curve leading the entrepreneurs to think and act more strategically. To the extent they adopt a more strategic posture, a growing entrepreneurial orientation may replace a previously more academic rationale in patenting. Moreover, the effectiveness of patent protection plays a key role throughout all phases (Shane, 2002).

Interviews with entrepreneurs and technology transfer officers also suggest that the five factors – scientific field, pace of technological development, technological uncertainty,

entrepreneurial orientation, and patent effectiveness – can drive patenting by members of the founding team. The subsections below provide more detailed arguments for why this should be the case. To explore changes over time, we consider both the pre- and post-founding phase.

2.1 Scientific field

We first consider the scientific field of the founding team members. Patenting can collide with traditional academic norms (Etzkowitz, 1998), involve the risk of receiving no (exclusive) license (Shane, 2002), or may be a suboptimal strategy for some start-ups (Arundel, 2001). This might lead some inventors not to patent. However, we argue that academic entrepreneurs from scientific fields that typically yield patentable results are more likely to patent for several reasons. First, for federally funded research, invention disclosure is stipulated by law and encouraged by many research organizations. Thus, academics patent to be eligible for future government grants and to comply with legal requirements. Royalty-sharing incentives, active support through technology transfer offices (TTO), and negligible costs also encourage inventors to patent (Bercovitz & Feldman, 2008).

Second, patents reflect research performance, thus academics engage in patenting to demonstrate their per se unobservable quality as a researcher. Scientists in a study by Göktepe-Hulten and Mahagaonkar (forthcoming), for instance, patented not primarily for immediate financial gains but to signal their achievement and to gain reputation in academia and industry. Such quality signals are central to the academic career system as they are directly linked to financial rewards, tenure, and promotions. While publishing is still regarded as the major mechanism for gaining scientific reputation and publication rates far exceed patent rates (Dietz & Bozeman, 2005), publishing and patenting provide different signals. A publication in a prestigious journal shows that the underlying research is novel to the scientific community and has substantial intellectual value, whereas a patent indicates that the research is novel to the industrial community and has potential commercial value. Empirical studies suggest that both are complementary rather than substitute activities for faculty members (Meyer, 2006; Van Looy, Callaert, & Debackere, 2006; Thursby & Thursby, 2005; Agrawal & Henderson, 2002) and that in many cases the same research can yield patents as well as publications (Jensen & Murray, 2005). Consequently, academics can draw on both strategies to position themselves on the market for academic positions. Because increased

technology transfer has become an articulated objective of the university administration (Etzkowitz, 1998), more directly applicable research may be desired. Patenting permits researchers to signal that they are capable of conducting such research.

Third, patents spur relationships with industry that provide access to critical resources. For scientists without venturing intentions, they serve as “chips to exchange” for supplementary funding, access to equipment, and insights applicable for academic research (Owen-Smith & Powell, 2001; Meyer-Krahmer & Schmoch, 1998).

If, as we argue above, academic entrepreneurs have a general motivation to patent, the patentability of their inventions should be the major restriction. However, some scientific fields, such as business or law, are not conducive to yielding patentable results. In contrast, other fields, such as natural science, medicine, engineering, and computer science, have higher patenting potential (Azagra-Caro, Carayol, & Llerena, 2006; Dietz & Bozeman, 2005). Founding teams composed of scientists from these fields should exhibit higher patenting rates than others. This rationale should prevail after founding because many academic entrepreneurs retain their self-view as researchers while engaging in commercialization activities (Jain et al., 2009). This explanation suggests that, *ceteris paribus*,

Hypothesis 1. The higher the number of founders from scientific fields with patenting potential, the more likely is the founding team to file patents prior to and after firm founding.

2.2 Pace of technological development

The second influence we consider is the pace of technological development that refers to the speed of technological changes in a technological field (sometimes also referred to as technological turbulence, e.g., Jaworski & Kohli, 1993). Scholars of technology evolution have argued that new technologies are often born in federally funded research organizations. With ongoing basic research, more researchers and firms become interested in the technology and refine it (Pavitt, 1984; Walsh, 1984). The pace of technological development grows and firms increasingly enter markets with products and services based on the technology. In the next phase, the technology matures, markets become saturated, and the entry rate declines- the pace of technological development drops again (Dosi, 1982; Gort & Klepper, 1982).

The pace of technological development should enhance the likelihood that academic entrepreneurs file patents for three reasons. First, TTOs tend to encourage patenting in rapidly-developing fields because the activity in the field indicates the potential value of an invention – a key criterion to patent. Firms in the field prove that marketable applications of the technology exist. They also serve as potential licensees, thereby increasing the prospect of generating revenues. Second, in times of rapid technological advances, niche markets emerge and offer a fertile ground for market entry by new firms (Tushman & Anderson, 1986). As industry rivalry increases and more competitors begin to work on the same technology, the threat of knowledge leakages and appropriation grows. New firms are therefore required to protect their core technology against imitation and secure their niche market through strong proprietary rights to key technologies (Hall & Ziedonis, 2001; Blind, Edler, Frietsch, & Schmoch, 2006). Third, in this situation, new firms are also increasingly competing with other newcomers for external funding and market shares. Thus, signaling technological quality through patents becomes more important to attract potential investors and customers (Levitas & McFadyen, 2009). Patents support the acquisition of external funding when the academic entrepreneurs have no other evidence of the commercial value of their invention (Hall, 2005). Consequently, *ceteris paribus*,

Hypothesis 2. The higher the pace of technological development, the more likely is the founding team to file patents prior to and after firm founding.

2.3 Technological uncertainty

The third influence, technological uncertainty, refers to the perceived degree to which the process of developing marketable products from the core technology is predictable and controllable. If technological uncertainty is high, the time, costs, and supportive technologies necessary to develop products cannot be foreseen. Often academic start-ups commercializing radical technologies are confronted with uncertainty and barriers that must be overcome to successfully introduce the technology to market (Bhide, 1994). Technological uncertainty should increase the likelihood that academic entrepreneurs file patents for three reasons. First, in many technology fields one firm alone cannot handle the research involved in developing

marketable products, but requires research partners from academia or industry. This poses considerable risks of knowledge-leakages. Patents are conducive to finding research partners and successfully collaborating in R&D as they establish clear proprietary rights over the shared knowledge (Hertzfeld, Link, & Vonortas, 2006; Arundel, 2001). Second, alternative IP protection strategies like secrecy or a time lead on competitors assume that firms quickly develop and market products to realize first-mover-advantages. In situations, where the time to yield marketable products and the number of resulting products is hardly predictable, such strategies appear to be less applicable. Patent protection allows academic entrepreneurs to experiment with different alternative designs of commercial applications for a technology and adopt it to market needs before competition sets in (Shane, 2001). Third, technological uncertainty lengthens time-to-market and increases the likelihood that the academic entrepreneurs do not discover marketable applications of the technology. Patents allow securing some minimum value from the technology even if product development fails. The arguments above suggest that, *ceteris paribus*,

Hypothesis 3. The higher the technological uncertainty, the more likely is the founding team to file patents prior to and after firm founding.

2.4 Patent effectiveness

The fourth critical influence examined in this study is patent effectiveness, this is the degree to which they protect against imitation and facilitate enforcing legal rights in the case of infringements. Patenting involves considerable risks because it requires the disclosure of critical information on an invention, thereby allowing competitors to learn about promising research areas or ways to patent around an invention (Arundel, 2001). Mazzoleni and Nelson (1998) state that “patents encourage and provide a vehicle for disclosure and, more generally, generate quick and wide diffusion of the technical information underlying new inventions”. Moreover, the potential of patents to secure economic value was found to vary across technological fields and industries (Arundel & Kabla, 1998; Schankerman, 1998). The decision to patent may therefore rest on the strength of patent protection relative to the risks involved. If patents are strong, imitation risks are reduced and patenting activities are more

actively pursued. This allows them to realize the advantages of patents, such as signaling towards customers and investors or giving time for product development (Shane, 2001). Conversely, if patents are weak, firms tend to rely on other strategies to protect their IP, such as secrecy or a time lead on competitors.

Empirical studies suggest the effectiveness of patents as one explanation for industry differences in patenting rates (Arundel & Kabla, 1998; Schankerman, 1998; Brouwer & Kleinknecht, 1999). Hall and Ziedonis (2001) found that the strengthening of the US patent rights in the 80s triggered an upsurge in patenting in the semiconductor industry. Arora and Ceccagnoli (2006) found a positive relationship between patent effectiveness and patent propensity of firms. According to other studies, patenting rates are higher in countries with strong patent systems characterized by effective enforcement mechanisms and few restrictions on patent rights (de Rassenfosse & van Pottelsberghe de la Potterie, 2009; van Zeebroeck, van Pottelsberghe de la Potterie, & Guellec, 2009).

As the technology is usually applicable for distinct possible applications in different industries (e.g. Gans & Stern, 2003; Gruber, MacMillan, & Thompson, 2008), we expect the patent effectiveness in the technological field of the idea the start-up is based upon to influence the propensity to patent prior firm founding. After firm founding, we expect the patent effectiveness of the industries the start-up has consequently entered to influence patenting behavior. Thus we posit that, *ceteris paribus*,

Hypothesis 4. The higher the patent effectiveness in a technological field (industry), the more likely is the founding team to file patents prior to and after firm founding.

2.5 Entrepreneurial orientation

The fifth explanation for variation in the patent propensity of academic entrepreneurs is entrepreneurial orientation - this is the processes, structures, and behaviors of firms that are characterized by innovativeness, proactiveness, and risk taking (Covin & Slevin, 1989; Miller & Friesen, 1983). Innovativeness reflects the tendency of a firm to actively support new ideas, novelty, experimentation, and creative solutions in pursuit of competitive advantage. Risk-taking involves a firm's tendency to take business-related chances regarding strategic actions

in uncertain environments. Proactiveness is a firm's tendency to anticipate and act on future needs by introducing new products and services ahead of the competition (Covin & Slevin, 1989; Lumpkin & Dess, 1996). While a broad stream of research has linked entrepreneurial orientation to business performance (Rauch, Wiklund, Lumpkin, & Frese, 2009), it should also increase the patent propensity of academic entrepreneurs after firm founding.

Entrepreneurial-oriented firms tend to compete on the basis of their technological skills in the belief that successful innovation emanates from effective R&D (Atuahene-Gima & Ko, 2001). They strive for a technology leadership rather than a follower strategy (Lumpkin & Dess, 1996), which drives them to dedicate a higher share of their expenses to R&D than other firms (Renko, Carsrud, & Brännback, 2009). Because of their focus on an exploratory, risk-seeking approach to innovation, such firms are likely to be the first to arrive at new inventions that can be protected by patents. Moreover, patent protection creates favorable conditions to experiment with new technologies in a pursuit for more creative product applications (Shane, 2001). Firms with well-protected technological bases can therefore follow a more aggressive growth strategy with a lower risk of knowledge leakages. Patents help to “stake claims” in the market and defend a “pole position” in a possible technology race that many start-ups have at the outset. Finally, entrepreneurial-oriented firms were found to increase their innovation capacity by forming effective alliances (Marino, Strandholm, Steensma, & Weaver, 2002). Patents are a signaling device to attract potential partners and prepare a successful collaboration (Hertzfeld et al., 2006; Arundel, 2001). These arguments propose that, *ceteris paribus*,¹

Hypothesis 5. The higher the entrepreneurial orientation, the more likely is the founding team's start-up to file patents after firm formation.

¹ The extant literature has defined entrepreneurial orientation on the group- or firm-level. Consequently, we restrict Hypothesis 5 to the post-founding phase.

3 Methods

3.1 Sample and procedure

This study examines a combination of survey and patent data. We surveyed start-ups created to exploit technology from publicly funded research institutions in Germany, including universities, universities of applied science, and research institutions within the Fraunhofer Society, Helmholtz Association, Leibniz Science Association, and Max-Planck Society (see Krabel und Müller, 2009 for a description). After gathering contact information from technology transfer offices, print media, the internet and annual reports from research institutions, we contacted 542 start-ups via phone to arrange interview appointments. To include only firms with the potential to patent, we confirmed that the underlying business model was based on a technological invention developed by the founders in the research organization. Trained interviewers then conducted 288 face-to-face interviews with one member of the founding teams. Data on patent effectiveness was collected from patent attorneys in Germany. We sent a standardized questionnaire to 2,417 individuals listed in the directory of German patent attorneys. Of those, 190 usable questionnaires were returned (8%). On average, the respondents had worked for 9.59 years (s.d. 8.82) as patent attorney and for 14.87 years (s.d. 10.33) in patent-related fields.

Patent data came from the database “PATSTAT” (version 09/2008) provided by the European Patent Office. We considered patent applications by members of the founding team in the pre-founding phase (three full years prior to incorporation) and patent applications by the start-up itself in the post-founding phase (three full years after incorporation). The final dataset consisted of 260 start-ups, of which 120 (60) had filed patents prior (after) incorporation. Technological fields included software/simulation (33%), biotechnology (23%), electronics (22%), nanotechnology/new materials (10%), and others (12%). The average venture had been in business for five years (mean = 4.93; s.d. = 2.34), had three founders (mean = 3.27; s.d. = 1.90), and employed eleven full-time equivalents (mean = 11.29; s.d. = 12.61). This sample profile is comparable to related studies in the field (Nerkar & Shane, 2003; Hmieleski & Baron, 2009).

3.2 Measures

3.2.1 Dependent variables

Patent propensity refers to the tendency of an individual or a group to file patents for inventions. In line with the extant literature (e.g., Brouwer & Kleinknecht, 1999), we adopted two alternative measures for the pre- and post-founding phase. The first is a dummy variable for the mere existence of patent applications by the founding team or start-up (0 = no patents filed, 1 = patents filed). It reflects the founding team's willingness to use patents at all. The second is the number of patent family applications. A patent family comprises all patent applications based on the same invention in different jurisdictions.² Grouping patent applications into families avoids redundant counts by considering the same invention only once in our data (Lettl, Rost, & von Wartburg, 2009). This measure captures the extent to which the founding team opts for patents. As it substantially deviates from normal distribution, we used a natural log transformation.

3.2.2 Independent variables

Information on the *scientific field* was gathered by asking for the type and field of the highest degree of all founding team members. We considered four fields in our analysis that typically yield patentable research outcomes (natural science, engineering, medicine, and computer science). The *pace of technological development* in a start-up's technological field was - like all other items, unless stated otherwise - measured on a 7-point Likert-scale (1 = "does not apply at all"; 7 = "applies fully and completely"). We derived our four item measure based on Sood and Tellis (2005). The scale describes the extent of research conducted in a specific technological field and the frequency of technological change. One item of the original scale was deleted during scale purification. The measure is reliable at an alpha of 0.78. An overview of all items and validity information is presented in the Appendix A. We developed a scale for *technological uncertainty* through a procedure proposed by

² To be considered as part of the same DocDB simple family, a patent application has to claim exactly the same priority applications. There may be exceptions from this rule if the European Patent Office classifies a patent application to a DocDB simple family due to face validity.

Rossiter (2002), as no directly applicable established measure was available. This resulted in three reflective items conceptually based on the work of Bhidé (1994) and Shane (2004: 186-190). The measure is reliable at an alpha of 0.77.

To measure *patent effectiveness*, patent attorneys rated the degree to which patents reliably protect against imitation and grant enforceable rights in several technological fields and industries (7-point Likert-scale; 1 = “very low effectiveness”, 7 = “very high effectiveness”). For technological fields, descriptive statistics (presented in Appendix B) and results from a factor analysis indicated the presence of two groups with low and high value, respectively. Since considering all fields in the regression analyses posed multicollinearity problems, we decided to use a dummy instead. Start-ups in the field of software & simulation (mean 3.73, s.d. 1.55) and production & management techniques (mean 3.63, s.d. 1.57) received a value of 0 for low effectiveness, whereas start-ups in the remaining fields received a value of 1 for high effectiveness. While the start-ups in our sample were only active in one technological field, they sometimes operated in more than one industry. In this case, the average rating was chosen. In extending prior operationalizations (e.g. Arora & Ceccagnoli, 2006), our measure prevents the threat of a common method bias by surveying patent attorneys rather than firms directly.

To operationalize dimensions of *entrepreneurial orientation*, we derived our own measures based on the established Covin and Slevin (1989) scale. To acknowledge the special situation of start-ups, we adjusted some items of the original scale that referred to established firms to the context of new firms. For, instance, the item “[my firm] typically initiates actions which competitors then respond to” was replaced by the item “our company undertakes great efforts to find new applications for our core technologies and to open new markets for our existing products/services.” As the dimensionality of the construct is an area of ongoing debate (Rauch et al., 2009), we decided to factor-analyze the items to confirm the original three-factor solution. After dropping items with a factor loading of a less than 0.40, the three dimensions innovativeness (2 items), proactiveness (3 items), and risk-taking (2 items) emerged, with alpha levels of 0.75, 0.64, and 0.70, respectively. The sum of these dimensions forms the final measure for entrepreneurial orientation.

3.2.3 Control variables

To isolate the effect of our predictor variables, we inserted several control variables that might affect patent propensity. Recent legislative changes, such as the Bayh-Dole Act from 1980 in the US, entitle research organizations to commercialize their employee's inventions, providing direct incentives to promote patenting. The German equivalent is the *Employee's Inventions Act* (EIA, *Arbeitnehmererfindungsgesetz*; see Harhoff & Hoisl, 2007 for an outline). A dummy variable coded 1 if the start-up was founded after 2001 and 0 for those founded before, controls for the impact of the act. Two research societies, Fraunhofer Society and Max-Planck Society, have established centralized patenting offices for all, geographically dispersed member organizations. Such centralization facilitates patenting if it leads to economies of scale, accelerates the process, and increases the quality of services offered. Alternatively, it discourages patenting if the geographic distance constrains the patenting process and complicates motivating inventors to patent. We therefore controlled for *centralized support* with a dummy variable that is coded 1 if the mother organization of the firm had a centralized patenting office and 0 for those that do not.

As larger start-up teams possess more resources to develop patentable inventions, we controlled for *team size* in terms of the number of founders in the pre-founding phase and the number of R&D employees in the post-founding phase. *Start-up experience* is likely to shape the tendency to patent because it permits academics to test the efficacy of patents and the entrepreneurial role. We therefore included a dummy variable that was coded 1, if at least one member of the founding team had previously started a company and 0 if no member had. *Market potential* refers to the extent to which marketable applications can be drawn from a core technology. Inventions with higher commercial value are more likely to result in patents (Bercovitz & Feldman, 2008). Market potential was measured with two reflective items and is reliable at an alpha of 0.76. *Expert knowledge* describes the extent to which the core technology of the start-up was based on tacit knowledge of the founding team. Such knowledge is often seen as a prerequisite for pursuing a secrecy strategy, as an important alternative to patenting (Arundel, 2001). The three-item measure was reliable at an alpha of 0.71. Patents are conducive to *venture capital* investments as they secure value of the firm and signal technological quality (Wright, Lockett, Clarysse, & Binks, 2006). The same rationale might drive venture capitalists on the board of new ventures to encourage patenting. Thus, we

inserted a dummy variable coded 1 if one or more venture capitalists held a stake in the start-up's equity and 0 if no one had.

4 Results

Table 1 provides the descriptive statistics and correlation matrix. Table 2 displays the regression results. Calculations of the variance inflation factor (VIF) reveal no serious multicollinearity problems ($VIF < 2.05$).³ Diagnostic checking confirms that the assumptions of regression analysis are met.

Please insert Table 1 and 2 about here

Hypothesis 1 suggests a positive relationship between the number of founders from scientific fields with patenting potential and patent propensity. The models indicate that founding teams with a higher number of researchers from natural science and medicine are more likely to patent than those teams with many scientists from engineering and software & simulation. This result provides some support for Hypothesis 1. According to Hypothesis 2, patent propensity increases with the pace of technological development. Our findings differ across time: In the pre-founding phase, a significant impact on the number of patents ($\beta = .11$, $p < .05$) and a weakly significant impact on the existence of patents was found ($\text{Exp}(B) = 1.21$, $p < .10$). In the post-founding phase, the effects were not significant. Thus, Hypothesis 2 received some support.

As stated in Hypothesis 3, we expected that a higher technological uncertainty would result in a higher patent propensity. This is consistently confirmed across all models, lending

³ Logistic regression does not include collinearity statistics. We therefore relied on VIF statistics provided by linear regression analysis after testing for non-linearity in the logit.

strong support for Hypothesis 3. We stipulated a positive impact of patent effectiveness on patent propensity in Hypothesis 4. Consistent with our expectations, the patent effectiveness in the technological field was positively related to both the existence of patents ($\text{Exp(B)} = 5.54, p < .001$) and the number of patent family applications ($\beta = .36, p < .001$). The results for patent effectiveness in the industry were similar ($\text{Exp(B)} = 1.70, p < .01$; $\beta = .12, p < .05$, respectively). Hypothesis 4 therefore received strong support. For the post-founding phase, Hypothesis 5 predicts a positive impact of entrepreneurial orientation on patent propensity. The proposed relationship was positive and significant for the number of patent family applications ($\beta = .14, p < .05$), but only weakly significant for the existence of patents ($\text{Exp(B)} = 1.11, p < .10$). This lends some support to Hypothesis 5.

With regard to our control variables, EIA was negatively related to patent propensity ($\text{Exp(B)} = -.94, p < .01$; $\beta = -.23, p < .001$), suggesting a decline in patenting in the aftermath of the act. In the post-founding models, the number of patent family applications was significantly related to start-up experience ($\beta = -.13, p < .05$), market potential ($\beta = .12, p < .05$), and venture capital ($\beta = .19, p < .001$). Moreover, we performed several test for all models to check the robustness of our findings. First, we redid the analyses restricting the pre-founding and post-founding phase to two years before and after incorporation. The results showed no substantial differences regarding the main findings. Second, we added a variable for the share of inventors who left academia to work full-time for the start-up. The variable reflects the extent to which members of the founding focus on academic or business careers. As the pattern of our results did not change substantially, but model fit decreased, we removed the variable again.

5 Discussion

This article examined five influences on the patent propensity of academic founding teams before and after incorporation- the scientific field, technological uncertainty, pace of technological development, patent effectiveness, and (only after firm founding) entrepreneurial orientation. Using data from 260 technology-based start-ups in Germany combined with patent information from the PATSTAT database, we find that these influences

are positively related to the tendency to file patents. Controlling for various confounding influences, academics were more likely to patent when the search for marketable applications of the firm's core technology was highly uncertain, the technological field was rapidly changing, the founding team operated in fields with strong patent protection, and the start-up was high in entrepreneurial orientation. Moreover, the pattern of results did not substantially differ between the pre-founding and the post-founding phase. Thus, the same influences seem to drive patenting before and after incorporation. One exception is the pace of technological development which is significant only in the pre-founding phase.

5.1 Limitations

This study is not without limitations. First, it illuminates a relatively short time period of three years before and after incorporation to detect changes in the rationale for patenting. Although in this phase the ground for the future of the start-up may be laid, we have little insight into how patenting behavior develops after that. Future research is therefore necessary to advance our knowledge of how and whether the patent propensity of academic entrepreneurs changes and affects patent policies of their growing start-ups.

Second, sampling solely from research organizations in Germany may yield results that are mostly generalizable to this context. Country differences, such as variations in jurisdiction, university regulations, or the routines of technology transfer, might generate different conditions for patenting, and may therefore affect patent propensity. While we have no a priori reason to believe that the findings would fail to apply to other country settings, the empirical investigation addressed only one setting. Consequently, the generalizability of our results to other country settings is questionable until future research proves otherwise.

Third, our study does only examine patent applications without considering other characteristics of patents. Thus, we have no information on which patents are actually granted. Similar data limitations precluded controlling for the economic value of patents. Future research could draw on such data to investigate to what extent patenting is driven by economic or other rationales.

Fourth, our dataset contains no information on which of the patents filed in the pre-founding phase were actually licensed-back and used by the start-up. Although our pre-

founding models address patenting by the founders in general, not only for the purpose of starting a business, such information could help to disentangle patents filed to create licensing revenues from patents filed to prepare venturing activities. However, our interviews with the founders indicate that the majority of patents filed within three years prior to incorporation were actually used by the new venture.

5.2 Implications for research

The results of this study have useful implications for different research areas. Many scholars have observed that academic researchers do not solely patent for monetary, but also for non-monetary reasons, e.g. to establish industry relationships or to gain prestige within the scientific community. This partly explains why many researchers file patents in areas in which patents typically possess less economic value as the underlying inventions are often incremental improvements of existing technologies or products (Owen-Smith & Powell, 2001; Dietz & Bozeman, 2005). However, our study provides no conclusive results for academic entrepreneurs. Future research should therefore examine whether they are driven by more academic or more entrepreneurial rationales when patenting. At least our finding for the negative impact of founding experience indicates that prior exposure to the business world might change their patenting behavior.

In addition, academic entrepreneurs are more likely to patent their inventions prior to founding if the pace of technological development is high, enabling them to protect prospective niches and to obtain venture capital. This finding extends the work by scholars of technological change who have established a link between technology life cycles and firm formation rates (Shane, 2001) by demonstrating that the development phase of a technology also influences the decision to patent. Contrary to our predictions, the relationship between the pace of technological development and patenting was not significant in the post-founding phase. One possible explanation for the unexpected finding is that the founders construct patent fences to prepare the market entry. After incorporation they focus on commercial activities, while further R&D activities resulting in patentable inventions are neglected within the time scope of our study.

The results also indicate that in situations of high technological uncertainty when the time and resources required to develop marketable applications from the core technology are hardly predictable, academic entrepreneurs are more likely to file patents. In prior studies, incumbent firms were found to prefer alternative protection strategies, such as lead time advantage (Blind et al., 2006) or secrecy (Arundel, 2001), to patent protection. In contrast, our findings suggest that such strategies are less applicable for new firms facing high technological uncertainty as they must swiftly develop and market products, but these firms cannot forecast the development time.

In Addition, our study adds to the literature on entrepreneurial orientation. Strategic management scholars have linked the construct to business performance (Rauch et al., 2009), but more recent studies failed to show its impact on firms' product innovativeness (Renko et al., 2009). As our findings indicate the context of technology start-ups, entrepreneurial orientation is positively related to the tendency to patent. Consequently, founding teams high in entrepreneurial orientation seem to focus on inventions with higher patenting potential or patent more aggressively to secure a strong position in the technological field or market.

The result that patent effectiveness drives patenting by academic entrepreneurs demonstrates the importance of strong intellectual property protection in commercializing academic inventions. Entrepreneurship research has already shown that a broad patent scope increases new firm value (Lerner, 1994) and the probability of licensing to non-inventors (Shane, 2002). However, university inventors were found to also patent in fields with weak patent protection, when pursuing academic interests (Owen-Smith & Powell, 2001; Dietz & Bozeman, 2005). While academic entrepreneurs have to balance academic and entrepreneurial career requirements, this study provides evidence that their patenting decision is driven by an economic rationale of patent effectiveness.

Finally, the study shows that three influences – scientific field with patenting potential, technological uncertainty, and patent effectiveness – significantly affect patenting before and after incorporation. Although some effect sizes slightly increase in the post-founding models, the overall change of these influences over time is low. The finding that the patenting rationale of academic entrepreneurs is relatively stable within a three-year period around incorporation is consistent with findings by Jain et al. (2009) that scientists largely preserve their academic role identity when engaging in commercial activities. Given the limited time

scope of our study, future research could examine whether and how these patenting rationales change in the long run. Our study provides a first step to bridging the divide between the two literatures on university and firm patenting, as we examine academic entrepreneurs transiting from the academic to the business world.

5.3 Implications for practice

This study also offers several practical implications. Several states have passed acts to stimulate patenting and research commercialization at publicly-funded institutions. Our results show that after the passage of the German Employees' Invention Act, academic entrepreneurs are less likely to patent inventions prior to incorporation. As an explanation, some prospective entrepreneurs might delay the patent application until after incorporation to prevent the threat of not receiving (exclusive) licenses. However, inspection of the data shows that this is not the case for the start-ups in our sample. They seem to prefer to avoid patenting at all in the aftermath of the act. This raises questions on whether such acts yield opposing effects and how policy-makers can align the interests of academic entrepreneurs and research organizations.

The results for the relative, temporal stability of some influences could motivate academic entrepreneurs to reflect upon their rationales for patenting. The start-up success may, in part, depend on the extent to which they adopt the "rules of the game" in the business world. Consequently, academic entrepreneurs should ensure that academic influences do not impede with firm interests in patenting start-up technology.

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Table 1: Descriptive statistics and correlations^a

Variable	MW	SA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Patents (t ₀) ^b	.46	.50	-																			
2. Patents (t ₁)	.25	.44	.63***	-																		
3. Num. of patents (ln, t ₀)	.71	.94	.82***	.66***	-																	
4. Num. of patents (ln, t ₁)	.34	.67	.55***	.87***	.73***	-																
5. Field natural science	1.23	1.43	.30***	.30***	.32***	.34***	-															
6. Field medicine	.18	.60	.17**	.19**	.18**	.16**	-.03	-														
7. Field engineering	.93	1.31	-.09	-.07	-.10	-.08	-.40***	-.18**	-													
8. Field computer science	.31	.86	-.14*	-.11 ^t	-.14*	-.13*	-.22***	-.09	-.09	-												
9. Pace of techn. development	3.73	1.41	.13*	.09	.14*	.12 ^t	.09	.02	.01	-.04	-											
10. Technological uncertainty	3.60	1.41	.15*	.23***	.16*	.21***	.08	-.03	.08	-.01	.01	-										
11. Patent effect. (techn. field) ^c	.63	.48	.36***	.34***	.38***	.32***	.28***	.22***	-.13*	-.39***	-.01	-.07	-									
12. Patent effect. (industry)	4.99	1.03	.31***	.26***	.30***	.23***	.16*	.21***	-.07	-.25***	.05	-.01	.44***	-								
13. Entrepreneurial orientation	13.91	3.21	.20**	.17**	.23***	.23***	.07	-.13*	.13*	-.02	.07	.10 ^t	-.03	.08	-							
14. EIA ^d	.35	.48	-.19**	-.16**	-.24***	-.20**	-.12 ^t	-.07	.15*	.05	.00	-.20**	.09	.01	-.10	-						
15. Institutional support ^e	.22	.42	.10	.09	.13*	.10	.06	-.08	.12 ^t	-.04	.19**	.09	-.03	.05	.06	-.04	-					
16. Team size	3.27	1.90	.06	.06	.10	.08	.24***	.09	.29***	.21***	.12 ^t	.15*	-.10	-.15*	.03	-.03	.10 ^t	-				
17. Number of R&D employees	.83	.24	.09	.02	.03	-.01	-.02	.06	.06	.00	-.04	.10	.13*	.09	-.02	.26***	.00	-.05	-			
18. Start-up experience ^f	.37	.48	-.02	-.08	-.02	-.11 ^t	-.02	.01	.04	.19**	-.02	.03	-.09	-.09	.07	.05	.03	.23***	.02	-		
19. Market potential	5.24	1.51	.03	.08	.08	.15*	-.07	.02	.11 ^t	-.01	.18**	-.08	.03	.01	.16*	-.02	.04	-.02	.03	-.01	-	
20. Expert knowledge	5.07	1.39	.13*	.10	.14*	.12 ^t	.07	-.05	.10	-.02	-.08	.03	.07	.04	.24***	-.01	.11 ^t	-.03	.02	-.03	.17**	-
21. Venture capital ^g	.19	.39	.19**	.19**	.32***	.29***	.12*	.08	-.08	-.05	.07	.02	.14*	.10 ^t	.17**	-.16**	.19**	.07	-.04	.02	.12*	.01

^a n = 260. ^b t₀ = pre-founding phase, t₁ = post-founding phase; coding: 1 = at least one patent filed, 0 = else. ^c Coding: 1 = high effectiveness, 0 = else. ^d Coding: 1 = firm founded after EIA in 2001, 0 = else. ^e Coding: 1 = centralized patenting, 0 = else. ^f Coding: 1 = start-up experience, 0 = else. ^g Coding: 1 = at least one venture capitalist holds stakes in firm equity, 0 = else. ^t p < .10, * p < .05, ** p < .01, *** p < .001 (two-tailed test).

Table 2: Regression Results of patent propensity prior to and after firm founding^a

	Pre-founding phase					Post-founding phase				
	Patents ^b			Number of patents (ln)		Patents ^b			Number of patents (ln)	
	B	S.E.	Exp(B)	b	S.E.	B	S.E.	Exp(B)	b	S.E.
Field natural science	.47 **	.16	1.61	.25 **	.05	.50 ***	.13	1.64	.31 ***	.03
Field medicine	.59 *	.29	1.81	.14 *	.09	.81 **	.27	2.26	.17 **	.06
Field engineering	.24	.17	1.28	.10	.05	.16	.15	1.17	.06	.03
Field computer science	.31	.22	1.36	.10	.07	.08	.28	1.08	.03	.05
Pace of techn.development	.19 ^t	.11	1.21	.11 *	.04	.08	.12	1.08	.03	.03
Technological uncertainty	.23 *	.11	1.26	.11 *	.04	.45 ***	.13	1.57	.18 ***	.03
Patent effect. (techn. field) ^c	1.71 ***	.36	5.54	.36 ***	.12					
Patent effect. (industry)						.53 **	.19	1.70	.12 *	.04
Entrepreneurial orientation						.11 ^t	.06	1.11	.14 *	.01
Employee's invention act (EIA) ^d	-0.94 **	.32	.39	-.23 ***	.11					
Centralized support ^e	.42	.36	1.52	.10 ^t	.12					
Team size	-.11	.10	.90	-.04	.04					
R&D employees						-.11	.73	.90	-.03	.15
Start-up experience ^f	.06	.31	1.06	.01	.11	-.50	.37	.61	-.12 *	.08
Market potential						.16	.13	1.17	.12 *	.02
Expert knowledge						.07	.14	1.07	.03	.03
Venture capital ^g						.59	.41	1.81	.19 ***	.09
Nagelkerke R ²	.34					.36				
Correct predictions (%)	72.70					81.90				
adj. R ²				0.28					0.28	

^a n = 260. ^b Coding: 1 = at least one patent filed, 0 = else. ^c Coding: 1 = high effectiveness, 0 = else. ^d Coding: 1 = firm founded after EIA in 2001, 0 = else. ^e Coding: 1 = centralized patenting, 0 = else. ^f Coding: 1 = start-up experience by at least one founder, 0 = else. ^g Coding: 1 = at least on venture capitalist holds stakes in firm equity, 0 = else.

^t p < .10, * p < .05, ** p < .01, *** p < .001 (two-tailed test).

Appendix A – Items

	Factor loading	t-Value
Pace of technological development ($\alpha = .78$, CR = .78, AVE = .48)		
Many companies conducted research within my company's technology field.	.53	8.48
The number of companies conducting their own R&D in my company's technology field was growing rapidly.	.58	9.38
Many groups of researchers in public research institutions were active in my company's technology field.	.86	14.98
The number of groups of researchers in public institutions conducting research in my company's technology field was growing rapidly.	.76	12.98
Technological uncertainty ($\alpha = .77$, CR = .80, AVE = .60)		
It was easy to understand, which other technologies our company required besides our core technology to create marketable products (r).	.41	6.72
The time to develop our core technology to marketability could be clearly estimated. (r)	.94	16.23
The costs to develop our core technology to marketability could be clearly estimated. (r)	.84	14.87
Innovativeness ($\alpha = .75$, CR = .76, AVE = .62)		
Our company has introduced many new products or services over the past three years.	.70	8.89
Changes in products or service lines have usually been quite dramatic.	.87	10.08
Proactiveness ($\alpha = .64$, CR = .70, AVE = .44)		
Our company undertakes great efforts to find new applications for our core technologies and to open new markets for our existing products/services.	.65	9.89
Our company introduces new technologies and methods for the production of our products/services long before our competitors do so.	.62	9.46
My company typically waits until other companies introduce new products/services to the market before introducing new products/services. (r)	.72	10.95
Risk-taking ($\alpha = .70$, CR = .71, AVE = .55)		
Over the past three years, our company has engaged in very many high-risk projects with chances of very high returns.	.73	7.76
Our company has emphasized taking bold, wide-ranging and capital-intensive actions in positions itself and its products/services over the past three years.	.75	7.84
Market potential ($\alpha = .76$, CR = .78, AVE = .65)		
The breadth of potential applications for the core technology was enormous.	.68	8.90
Applications for the core technology had enormous market potential.	.91	10.48
Expert knowledge ($\alpha = .71$, CR = .77, AVE = .53)		
Members of the founding team were considerably involved in technological breakthroughs in my company's technological field.	.75	12.16
Knowledge about the operational principles of my company's core technology was widely disseminated in the scientific community. (r)	.68	11.05
Competitors were able to very quickly learn about the core technology from public sources (books, journals, internet, etc.) to the point of being able to implement it. (r)	.74	12.00

r = reverse coded, α = Cronbach's Alpha; CR = Composite Reliability; AVE = Average Variance Explained; Model fit: $\chi^2/df = 1.59$; GFI = .92; AGFI = .89, RMSEA = .05

Appendix B – Descriptive statistics for patent effectiveness

Technological fields				Industries			
	n ¹	Mean	s.d.		n ¹	Mean	s.d.
microelectronics	157	5.31	1.30	construction	168	4.71	1.51
microsystems	147	5.44	1.22	chemicals	182	6.01	1.04
molecular electronics	137	5.06	1.38	computers and office machines	175	3.97	1.59
nanotechnology	153	5.48	1.26	electrical engineering	175	5.54	1.14
new materials	166	5.84	1.10	energy	154	5.09	1.24
photonics	136	5.24	1.27	optics and precision engineering	166	5.67	1.09
prod. and management techniques	148	3.63	1.57	aviation	150	5.01	1.40
software & systems	155	3.74	1.55	mechanical engineering	184	5.94	.99
biotechnology	159	5.71	1.16	health care	190	5.99	.99
				communications	160	5.03	1.25
				pharmaceuticals	178	6.37	.89
				automotive	161	5.58	1.28

¹ The respondents only evaluated their fields of expertise.