DO ACADEMIC ENTREPRENEURS PATENT THEIR SECRETS? AN EMPIRICAL INVESTIGATION OF PATENT RATIONALES

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ABSTRACT

This study explores why academic entrepreneurs seek patents for their inventions before and after spin-off creation. Specifically, we examine (1) the relative impact of academic, business, and entrepreneurial rationales and (2) changes in patent propensity throughout the founding process. Findings based on 160 technology spin-offs combined with patent data show that some academic and business rationales, but also entrepreneurial rationales (technological uncertainty, tacit knowledge) affect patent propensity. Surprisingly, academic entrepreneurs with patents prior to founding patented less after founding. We discuss the implications of our results both in terms of contribution to the current literature and technology transfer policies.

INTRODUCTION

Sooner or later, academic entrepreneurs have to make the critical decision to seek patents for their invention or not. Patents can safeguard the knowledge-base of a new venture against early imitation by defining property rights over an invention (Harter, 1994). They serve as signals of expertise (Arundel, 2001), attract venture capital (Wright, Lockett, Clarysse, & Binks, 2006; Mann & Sager, 2007), support inter-firm partnering (Hertzfeld, Link, & Vonortas, 2006), and, if effective, yield substantial competitive advantage (Kaiser, 2009; Song, Podoynitsyna, van der Bij, & Halman, 2008). On the other hand, patents require to disclose critical information, thereby facilitating early imitation (Arundel, 2001; Kultti, Takalo, & Toikka, 2007). Patenting consumes considerable time and money. It can also be a suboptimal strategy for spin-offs because, in case of infringements, many new ventures may lack the resources necessary to effectively litigate and enforce their rights (Arundel, 2001; Lanjouw & Schankerman, 2004). Given this fundamental tradeoff, when and why do academic entrepreneurs patent?

Prior research on patenting has focused on the starting and end point of the founding process, being the full-time scientist (Azoulay, Ding, & Stuart, 2007; D'Este & Perkmann, forthcoming; Dietz & Bozeman, 2005; Meyer, 2006; Sellenthin, 2009) or the established firms (Arundel & Kabla, 1998; Brouwer & Kleinknecht, 1999; Mansfield, 1986). Academic entrepreneurs constitute an intermediate group. They transit from the academic world emphasizing open knowledge sharing and peer recognition to the business world emphasizing private property and profits. They have to balance academic and entrepreneurial career interests. This may include resolving conflicts of interests in patenting between the home university and the prospective venture. The founding process can therefore yield important changes regarding self-perception (Jain, George, & Maltarich, 2009), strategic posture (Hoang & Gimeno, 2010), and, as we suspect, preference for patents. To date, however, relatively little is known about whether and why academic entrepreneurs seek patents and how their patenting propensity changes over time. This is surprising, given that employing the wrong rationales – for instance, patenting for academic reputation (Göktepe-Hulten & Mahagaonkar, forthcoming) when a secrecy strategy should be pursued – may seriously compromise a spin-off's long-term survival.

Our study explores empirically why academic entrepreneurs seek patents in the founding phase (three full years prior to and after incorporation of their ventures) – a time when the ground for the future of the spin-off is laid and possible effects of the "scientist-to-entrepreneur-metamorphosis" may become most visible. We focus on two important aspects. The first is the relative effect of influences suggested in the literatures on patenting by full-time scientists (academic rationales), patenting by established firms (business rationales) and influences particularly relevant to new ventures (entrepreneurial rationales). The second aspect is the impact of role changes and learning. Specifically, we argue that academic entrepreneurs who more readily adopt the entrepreneurial role, as reflected in high entrepreneurial orientation, are more likely to seek patents. We also propose that academic entrepreneurs with a preference for patents professionalize their patenting over time, thus seek more patents after than prior to founding. A unique dataset from 160 technology spin-offs from public universities 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 extends the literature on multiple fronts. First, the study provides an empirical test of established, partly competing influences on the patent propensity of a special and neglected 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. The results demonstrate that patenting by academic entrepreneurs is only limitedly driven by well-known academic and business rationales, but also by relatively unexplored rationales, including technological uncertainty and tacit knowledge. Second, scholars of industrial patenting have argued that technological competition should increase patenting (Arora & Ceccagnoli, 2006). The finding of an inverted U-shaped relationship in this study suggests that patenting is no attractive option for academic entrepreneurs when technological competition is very low or very high. Third, the relationship between entrepreneurial orientation and business performance is well-established (Rauch, Wiklund, Lumpkin, & Frese, 2009). This study extends the literature by linking entrepreneurial orientation to patent propensity.

THE DIFFERENT EXPLANATIONS

In our model, academic entrepreneurs face two basic options. The first is to seek patents. In the pre-founding phase, some jurisdictions permit the inventor to independently file a patent (Sellenthin, 2009), others entitle research organizations to do so on behalf of their employees (e.g. the Bayh-Dole Act, Henderson, Jaffe, & Trajtenberg, 1998). The inventor is then required to disclose the discovery, let the organization decide whether to patent and, in case, obtain a license prior to firm founding. Otherwise, he or she can patent in his or her own name. In the post-founding phase, academic entrepreneurs have full discretion over patenting the spin-off's inventions. The second option is not to seek patent protection and rely on alternative appropriation mechanisms instead. Despite potential legal and ethical risks (Bercovitz & Feldman, 2008), academic entrepreneurs might decide to conceal a discovery from the administration when patenting is not regarded as an appropriate strategy or an institutional patenting infrastructure is lacking or ineffective (Baldini, 2009). Indeed, many faculty members do not disclose their inventions (Bercovitz & Feldman, 2008; Landry, Amara, & Saïhi, 2007; Jensen, Thursby, & Thursby, 2003). Sometimes even universities avoid official regulations and let researchers exploit inventions themselves (Sellenthin, 2009). The subsections below provide arguments why academic entrepreneurs should seek patents for academic, business, and entrepreneurial rationales and why their patent propensity should change over time.

Academic rationales

Institutional publication performance refers to the impact of publications by researchers affiliated with the organization and should be positively related to patent propensity. Often the same research is patentable and publishable (Agrawal & Henderson, 2002). Publications and patents are increasingly seen as complementary rather than substitute activities (Fabrizio & Di Minin, 2008; Meyer, 2006; Thursby & Thursby, 2005; Van Looy, Callaert, & Debackere, 2006). Patents serve as an extra publication from the same research, thereby helping to gain reputation in academia and industry (Agrawal & Henderson, 2002; Göktepe-Hulten & Mahagaonkar, forthcoming). Moreover, universities emphasizing publication excellence typically attract, recruit, and train high-quality researchers. They provide a context in which reputation building through publications is valued. Yet, scholarly publications are also an important information source for the industry (Cohen, Nelson, & Walsh, 2002). Complying with publication norms therefore requires academic entrepreneurs to patent, in order to prevent unintended knowledge flows. Prior studies confirmed a positive relationship between patenting and the impact, but not the number of publications (Baldini, 2009; Calderini, Franzoni, & Vezzulli, 2007; Carayol, 2007; Landry et al., 2007). Thus, ceteris paribus,

> *Hypothesis 1a: The higher the institutional publication performance, the more likely are academic entrepreneurs to seek patents.*

Institutional research focus. Universities concentrating on applied research receive more of their research budget from industry than other organizations (Henderson et al., 1998). We argue that such a focus is positively related to patenting propensity. The sponsor can encourage researchers to strive for commercially-oriented discoveries and align their research to the needs of the industry (Landry et al., 2007). Applied research is more likely to results in patentable inventions that are readily applicable to industrial problems and have commercial value (Di Gregorio & Shane, 2003). Supporting this argument, Sellenthin (2009) reported a positive relationship between conducting applied research and patenting. Moreover, industrial funding was found to raise patenting propensity (Carayol, 2007; Dietz & Bozeman, 2005; Landry et al., 2007). Thus, ceteris paribus,

> *Hypothesis 1b: The stronger the institutional focus on applied research, the more likely are academic entrepreneurs to seek patents.*

Institutional patenting experience refers to a university's cumulative experience in patenting and should increase the founders' willingness to seek patents. Academic entrepreneurs pursuing a patenting strategy are interested in filing high-quality patents that secure competitive advantage and prevent competitors from inventing around the patent (Arundel, 2001). Bayh-Dole-like acts have empowered many universities to decide on the content of patents for disclosed inventions (Harhoff & Hoisl, 2007). Although some institutions, particularly top universities in the US (Shane, 2002), offer advanced support in patenting, this is not always the case for other institutions and/or countries. Findings for Italy, for instance, suggest that a lack of support by the university administration hinders patenting (Baldini, 2009). Similarly, researchers and universities in Germany were found to avoid the public infrastructure (Sellenthin, 2009). For academic entrepreneurs, disclosing inventions can thus pose a considerable risk that the university files low-quality patents. If no other information on the institutions' patenting competence is available, cumulative experience serves a quality signal. Experienced institutions have developed knowledge about effective patenting in a learning-by-doing process (Mowery, Sampat, & Ziedonis, 2002; Owen-Smith & Powell, 2003). They may be less likely to "make the same mistake twice" and may provide better support, thereby increasing the founders' confidence in patenting via the organization. Indeed, studies have shown that scientists in institutions with more patenting experience (Calderini et al., 2007) and greater support (Sellenthin, 2009) tend to patent more actively. Thus, ceteris paribus,

> *Hypothesis 1c: The higher the institutional patenting experience, the more likely are academic entrepreneurs to seek patents.*

Business rationales

Inter-firm partnerships. Many spin-offs need external partners to further develop and market applications from the core technology. Arm-length cooperations can lead to unintended knowledge spillovers between the parties, posing considerable risks for technology-based spin-offs (Alvarez & Barney, 2001). Patents provide a means to keep the other side from appropriating and/or using such knowledge by establishing clear property rights over the shared knowledge (Arundel, 2001). Moreover, patents facilitate treating a firm's knowledge as a documented, formalized, and tradable asset (Brouwer & Kleinknecht, 1999), thereby helping to negotiate and manage such partnerships. Patents belong to the most frequently used mechanism to protect technologies brought to and created in R&D collaborations (Hertzfeld et al., 2006). Thus, ceteris paribus,

> *Hypothesis 2a: The more extensive inter-firm partnerships, the more likely are academic entrepreneurs to seek patents.*

Export orientation refers to the share of sales due to exports. Spin-offs entering foreign markets require effective safeguards of their technologies as they face additional competition in a new, unknown environment. They often have no prior information on exchange partners which causes problems of information asymmetry and raises the risk of opportunistic behavior. In line with this argument, Ivus (2010) found that stronger property rights increased the quantity of exports into developing countries. Similarly, Arundel and Kabla (1998) observed a higher patent propensity of firms that sell products on foreign markets. Thus, ceteris paribus,

> *Hypothesis 2b: The higher the export orientation, the more likely are academic entrepreneurs to seek patents.*

Technological competition captures the intensity of rivalry in a technological field (Arora & Ceccagnoli, 2006) and should have an inverted U-shaped relationship with patenting. At low levels of competition, founders may perceive the threats of knowledge leakages and appropriation as too low to justify considerable investments of time and money involved in patenting. With uprising competition, more competitors begin to work on the same technology and the risks associated with rivalry, such as knowledge leakages, grow. Academic entrepreneurs are increasingly 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). Moreover, new firms are also increasingly competing with other newcomers for external funding and market shares. In this situation, signaling technological quality through patents becomes more important to attract potential investors and customers (Hall, 2005; Levitas & McFadyen, 2009). As technological competition continues to grow, the intensified research activity in the field accelerates technological progress, thereby reducing the life time of established technologies. The time to reap the benefits of patents declines and patenting becomes a less attractive alternative. Academic entrepreneurs begin to carefully weigh benefits and costs of employing a patenting strategy. When competition exceeds a certain level, the life time of a technology becomes too short to warrant extensive investments in patenting. This leads founders to consider alternatives to patents. The above arguments suggest that the motivation to patent increases with technological competition to a certain level, a tipping point, and then drops again – an inverted U-shaped relationship. Consequently, ceteris paribus,

> *Hypothesis 2c: The relationship between technological competition and academic entrepreneurs' tendencies to seek patents is inverted U-shaped.*

Entrepreneurial rationales

Technological uncertainty describes 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 from the core technology cannot be foreseen. Technological uncertainty is an aspect particularly salient to academic entrepreneurs: While most established, large firms possess a mix of new and mature technologies that allow to balance cash flows between different units, academic spin-offs are typically dependent on commercializing one new technology without having supplementary income from other businesses (Bhide, 1994). Technological uncertainty should increase patent propensity. Alternative IP protection strategies like secrecy or 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, in turn, allows academic entrepreneurs to experiment with different designs of commercial applications for a technology and adopt it to market needs before competition sets in (Shane, 2001). Furthermore, technological uncertainty lengthens time-to-market and increases the likelihood that the academic entrepreneurs do not discover marketable applications of the technology. Patents allow to secure some minimum value from the technology even if product development fails. Thus, ceteris paribus,

> *Hypothesis 3a: The higher the technological uncertainty, the more likely are the academic entrepreneurs to seek patents.*

Tacit knowledge comprises knowledge tied to the senses, tactile experiences, intuition, unarticulated mental models, or implicit rules of thumb (Nonaka & von Krogh, 2009). It tends to be highly personal and difficult to transfer (Polanyi, 1966). In established firms, different individuals possess critical tacit knowledge, manage and own the firm, causing agency problems. Firms often patent to safeguard against knowledge losses when key R&D employees quit to join or start a rival (Kim & Marschke, 2005). In contrast, academic entrepreneurs combine tacit knowledge about the core technology and ownership of the spin-off. Tacit knowledge should also be positively related to patent propensity, but for different reasons. First, given their expertise, scientists high in tacit knowledge are more likely to arrive at novel and non-obvious discoveries, possibly applicable to patent protection. Often such knowledge cannot be completely codified or scientists have few incentives to do so because returns to codification are below returns to time invested in further research (Zucker, Darby, & Armstrong, 2002). Nevertheless, filing at least some patents permits the entrepreneurs to reap key benefits from patenting, such as building reputation (Blind et al., 2006) or attracting venture capital (Wright et al., 2006). Even if these patents fail, sufficient tacit knowledge is left to shield the venture's knowledge base against imitation. Second, tacit knowledge can complement patents, thereby providing a more effective shield against imitation. Many core technologies are based on more than one patentable invention. Founders high in tacit knowledge can employ a hybrid protection strategy by patenting one (part of an) invention and keeping another one secret (Arundel, 2001). If competitors require both parts to imitate a technology, the technology is safe as long as one safeguard holds. Thus, ceteris paribus,

> *Hypothesis 3b: The higher the tacit knowledge, the more likely are the academic entrepreneurs to seek patents.*

Transition effects

Learning to patent. The founding phase is a time of comprehensive learning (Cope, 2005; Ravasi & Turati, 2005). We argue that academic entrepreneurs learn to patent more strategically over time, thus should patent more intensively after than prior to founding. Fully preparing for the challenges of entrepreneurship is difficult (Cope, 2005). Many entrepreneurs have little prior knowledge on effective patenting and have to acquire such expertise through experience (Ravasi & Turati, 2005) or social ties (Davidsson & Honig, 2003). Effective institutional support is not always available (Baldini, 2009; Sellenthin, 2009). This can lead the founders to initially file, alone or together with the research organization, weak or too few patents. As the experience of the founders grows over time, some receive a first feedback on the effectiveness of their patents. Moreover, an increasing number of actors with patenting expertise becomes involved in the founding process. Some spin-offs, for instance, receive support from venture capital firms, some move into science parks that foster an exchange with other start-ups. Learning by doing or learning from social ties can show the inadequacy of prior patenting. The need for a more elaborate patenting strategy may become obvious. This often involves filing more patents, for instance, to build effective patent portfolios (Blind, Cremers, & Mueller, 2009) or patent fences (Reitzig, 2004). Thus, ceteris paribus,

> *Hypothesis 4a: Academic entrepreneurs with patent applications in the pre-founding phase will patent more intensively after than prior to founding.*

Entrepreneurial orientation. Academic entrepreneurs differ in the speed and extent of adjusting to business norms (Hoang & Gimeno, 2010; Jain et al., 2009). We argue that founders who more readily adopt entrepreneurial roles, as reflected in high entrepreneurial orientation, are more likely to seek patents. Entrepreneurial orientation is defined as the processes, structures, and behaviors of firms that are characterized by innovativeness, proactiveness, and risk taking (Covin & Slevin, 1989; Miller & Friesen, 1983). Entrepreneurial-oriented founders 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" on the market and defend a "pole position" in a possible technology race that many spin-offs have at the outset. Thus, ceteris paribus, *Hypothesis 4b: The higher the entrepreneurial orientation, the more likely are the academic entrepreneurs to seek patents after founding.*

METHODS

Sample and procedure

This study combines survey and patent data. Survey data came from face-to-face interviews with academic entrepreneurs. We contacted 524 technology spin-offs via phone to request interview appointments. Of these, 288 agreed to participate. Trained interviewers then conducted interviews with one founder of each spin-off. Analyses reveal no significant differences between participating and non-participating firms in terms of age, size, and technological field. After excluding firms not based on technology, older than ten years, and not originated in public universities, the final sample comprised 160 spin-offs. Patent data came from the database "PATSTAT" (version 09/2008) provided by the European Patent Office (EPO). We searched for patent applications in two periods, the pre-founding phase (three full years prior to incorporation) and the post-founding phase (three full years after incorporation). Incorporation was chosen as a dividing line as it enables the academic entrepreneurs to patent in the name of the spin-off. 48 (36) spin-offs had filed patents prior (after) incorporation. Technological fields included software/simulation (32%), biotechnology (23%), electronics (19%), nanotechnology/new materials (11%), and others (15%). The average venture had been in business for five years (mean = 4.99; s.d. = 2.22), had three founders (mean = 3.19; s.d. = 1.61), and employed eleven full-time equivalents (mean = 10.54; s.d. = 12.46).

Measures

Dependent variables. Patent propensity refers to the tendency of an individual or a group to seek patents for inventions. Following Brouwer and Kleinknecht (1999), we adopted two alternative measures. The first is a dummy variable for the mere existence of applications (0 = no patents filed, 1 = patents filed). It reflects the 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. 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 academic entrepreneurs opt for patents. In the pre-founding phase, we considered patent applications based on a founder's invention and either filed by a founder or the university. The database contained no information on which of university patents were actually licensed back and used by the spin-off. We therefore inspected the content of the patents and included only those patents matching the spin-off's core technology. In the pre-founding phase, we searched for patent applications by the spin-off.

Independent variables. To measure *institutional publication performance*, we computed citation counts from the Web of Science, an established source also used in prior studies (e.g. Azoulay et al., 2007). Our search included journal articles published by university researchers within five full years prior to the spin-off's incorporation. Following Calderini et al. (2007), we operationalized *institutional patenting experience* as the total number of patents filed by the institution within the five-years-period, excluding patents co-filed by industry partners. *Focus on applied research* was captured as the EURO value of industry funding per professor of each university, a measure similar to Di Gregorio and Shane (2003). We gathered data from surveys by the Federal Statistical Office (Series 11-4.3.2, e.g. Statistisches Bundesamt, 2010). *Network size* was measured as the number of collaborations with research organizations and competitors. Compared to prior measures (e.g. Arundel, 2001), we added competitors as they are important research partners able to quickly absorb and use partner knowledge (Dussauge, Garrette, & Mitchell, 2000). *Export orientation* was captured as percentage of sales due to export.

Technological competition in a spin-off's technological field was - like all following items, unless stated otherwise - measured on a 7-point Likert-scale (1 = "does not apply at all"; 7 = "applies fully and completely"). Our measure (4 items, $\alpha = .78$) is based on Sood and Tellis (2005) and describes the extent of research conducted in a specific technological field, as reflected in the number of active institutions. Our measure for *technological uncertainty* (3 items, $\alpha = .77$) was conceptually based on the work of Bhide (1994) and Shane (2004: 186-190). We derived an own measure for *tacit knowledge* (3 items, $\alpha = .71$) that captures the extent to which the founders were experts in their fields and knowledge about the core technology was available via external sources. *Entrepreneurial orientation* was operationalized similar to Covin and Slevin (1989). Because the original scale referred to established firms, we adjusted some items to the context of spin-offs. As the dimensionality of the construct is an area of ongoing debate (Rauch et al., 2009), we factor-analyzed the items to confirm the original three-factor solution. After dropping items with a factor loading of a less then 0.40, the three dimensions innovativeness (2 items, $\alpha = .75$), proactiveness (3 items, $\alpha = .64$), and risk-taking (2 items, $\alpha = .70$) emerged. The sum of these dimensions forms the final measure for entrepreneurial orientation. An overview of all items and validity information is available from the corresponding author.

Control variables

We controlled for a number of influences, including *team size* (number of founders) in the pre-founding phase and the number of *employees* in the post-founding phase, *share of full professors*, *industry experience* (number of years the founders had worked in the industry), *start-up experience* (1 = "at least one founder had previously started a company", 0 = else), *market potential* (2 items, $\alpha = .76$), *patent effectiveness* (rated by patent attorneys on a 7-point Likert-scale; 1 = "very low effectiveness", 7 = "very high effectiveness"), *venture capital* (1 = "at least one venture capitalist holds stakes in firm equity", 0 = else), the spin-off's *R&D intensity* (share of employees working full time in R&D), and *share of full-time entrepreneurs*, being inventors who left academia to work full-time for the spin-off.

RESULTS

Table 1 provides the descriptive statistics and correlation matrix. Tables 2 and 3 display the regression results. Since our dependent variables are dummies and counts of scores, we used binary logistic regression and negative binomial regression to estimate our models, respectively. The likelihood-ratio test for overdispersion suggests that a poisson regression is no adequate alternative. Calculations of the variance inflation factor (VIF) reveal no serious multicollinearity problems (VIF < 1.62). Diagnostic checking confirms that the assumptions of regression analysis are met.

Please insert Tables 1, 2 and 3 about here

Models 1 and 2 tested academic rationales. Hypothesis 1a suggests a positive relationship between institutional publication performance and patent propensity. No significant effect was found for the existence and number of patent applications (H1a not supported). According to Hypothesis 1b, patent propensity increases with institutional patenting experience. The effect was significant and positive for both outcomes (H1b supported). As stated in Hypothesis 1c, we expected a positive relationship between a university's focus on applied research and patent propensity, whereas the effect was not significant (H1c not supported). Models 3 and 4 examine business rationales. Hypothesis 2a predicts a positive relationship of network size with patent propensity. The effect was significant and positive for the number of applications, but insignificant for the existence of applications (H2a partly supported). Hypothesis 2b proposes that export orientation has a positive influence on patent propensity. The effect is not significant for both dependent variables (H2b not supported). In Hypothesis 2c, we suggested an inverted U-shaped relationship between technological competition and patent propensity, which is confirmed for existence of applications (H2c partly supported). We investigated entrepreneurial rationales for the pre-founding (Models 5 and 6) and post-founding phases (Models 7 and 8). Hypothesis 3a predicted that a higher technological uncertainty results in a higher patent propensity. This is confirmed for both outcomes in the post-founding phase, but not in the pre-founding phase (H3a partly supported). Hypothesis 3b predicts a positive influence of tacit knowledge on patent propensity. Again, the effects were positive and significant for both dependent variables only in the post-founding phase (H3b partly supported). We also examined how transiting from academia to business affects patent decisions. Hypothesis 4a proposed that a faster adoption of the entrepreneurial role, as reflected in higher entrepreneurial orientation, increases patent propensity. The effect was significant and positive for the number, but not for the existence of patent family applications (H4a partly supported). Hypothesis 4b, finally, suggested that academic entrepreneurs with at least one patent prior to founding intensify patenting after founding. Given the non-normal distribution of the data, we used a non-parametric Wilcoxon signed-rank test to examine this relationship. Of the 48 spin-offs, 11 applied for more patents, 34 for fewer patents, and 3 for the same number of patents. The rank test suggests a decreasing tendency to file patents ($Z = -2.83$, $p < .01$). This result also holds when we control for start-up experience and patent effectiveness.

DISCUSSION

This article examined why academic entrepreneurs seek patents for their inventions in the founding phase and how their patent propensity changes over time. Using data from 160 technology-based spin-offs from public universities in Germany combined with patent information from the PATSTAT database, we find that a mix of academic, business, and entrepreneurial rationales shapes patent propensity. Controlling for various confounding influences, academic entrepreneurs were more likely to seek patents when their home universities were well experienced in patenting, technological competition was at a moderate level, the spin-off engaged extensively in inter-firm partnerships, the search for marketable applications of the firm's core technology was highly uncertain, and the founders had accumulated comprehensive tacit knowledge. Moreover, academic entrepreneurs high in entrepreneurial orientation patented more extensively. Contrary to our expectations, founders with at least one patent prior to founding, patented less after founding.

Limitations

This study is not without limitations. First, it illuminates a relatively short period of three years before and after incorporation to detect changes in patenting decisions. While the pre-founding results were robust to extending the timeframe to five and seven years, data limitations do not allow us to test this for the post-founding phase. 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 the growing spin-offs. Second, sampling solely from universities in Germany may yield results that are mostly generalizable to this context. Country differences, such as variations in jurisdiction, university regulations, university experience with technology commercialization, and routines of technology transfer, might generate different conditions for patenting, thereby affecting 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.

Implications for research

Our findings are important to several strands of scholarly research because they identify academic entrepreneurs as a group with specific patenting rationales. One strand of research has shown that individual and institutional influences explain patenting by full-time scientists (e.g. Dietz & Bozeman, 2005). Another strand has shown that organizational and environmental characteristics account for patenting by established firms (e.g. Arundel & Kabla, 1998). This study shows that academic entrepreneurs, while sharing some of the rationales with both groups, seek patents for specific, often overlooked rationales: technological uncertainty and tacit knowledge. By examining academic entrepreneurs in transition from the academic to the business world, our paper provides a first step to bridge the divide between the two literatures on patenting in research organizations and firms. The finding of a curvilinear relationship of technological competition with patent propensity indicates that academic entrepreneurs are more likely to patent their inventions at moderate levels of competition. This observation extends the work in the field of technological change that has established a link between technology life cycles and firm formation rates (Shane, 2001) by demonstrating that technological rivalry also influences the decision to patent. Moreover, it points to one possible explanation why scholars of industrial patenting have suggested a positive, but found a negative relationship between technological competition and patent propensity (Arora & Ceccagnoli, 2006). Moreover, the unexpected finding that academic entrepreneurs with at least one patent prior to founding patented less after founding warrants further investigation. One possible explanation lies in the role of the university administration: Institutional regulations or pressures might have led some founders to disclose and (let the university) patent their inventions in the pre-founding phase, although individual preferences or strategic considerations suggested otherwise. After founding, they therefore reduce or stop patenting efforts. This argument is consistent with our finding that the entrepreneurial rationales examined here significantly influence patenting only after founding. As a second explanation, the post-founding phase might draw the entrepreneurs' attention to activities not conducive to yield patentable inventions. This could include activities such as acquiring venture capital, matching prototypes to customer needs, or establishing production facilities. Finally, entrepreneurship scholars have regarded patent effectiveness as an important influence on firm formation rates (e.g. Lowe, 1993; Shane, 2001). The decision to patent may therefore be closely linked to the decision to create a technology spin-off. An alternative perspective is proposed in this paper: The patent propensity of academic entrepreneurs is influenced by various, partly competing rationales and might be time-variant. The results, indeed, confirm that many founders do not seek patents at all within the founding phase. Moreover, the patent propensity changes throughout the founding process and is affected by different rationales thereby indicating that he creation of academic spin-offs is not inevitably linked to considerations of patentability.

Implications for practice

This study also offers several practical implications. Given the various rationales at play, academic entrepreneurs are encouraged to critically reflect on their patenting rationales and whether these rationales are adequately balanced. The specific results also point them to the importance of incorporating the level of technology competition in their patent decisions. In fields of moderate competition, the benefits from patenting may justify the costs and risks involved. The opposite may be the case in fields of very low or very high competition. Moreover, our findings for tacit knowledge indicate that entrepreneurs high in such knowledge are in an advantageous position: They could run a mixed patent-secrecy strategy by codifying some of their knowledge in patents and keeping other parts secret as a complementary safeguard. This approach enables them to reap major benefits associated with patenting, while taking fewer risks compared to less knowledgeable colleagues. The results for technological uncertainty suggest that when the time and resources needed to develop marketable products from the core technology is hardly predictable, academic entrepreneurs should consider patent protection, as in this situation pursuing alternative protection strategies may be often difficult or ineffective. The principal results also remind university policy-makers that patenting may not always be in the best interest of technology spin-offs. Conflicts of interest could lead academic entrepreneurs to conceal discoveries from the administration or technology transfer offices to patent technology, when patenting is a suboptimal strategy for the spin-off. This suggests to consider alternative ways to claim ownership in inventions, for instance, by taking equity in the new venture.

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Table 1 – Descriptive Statistics and Correlations.[a]

Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10
1. Patents (t_0)[b]	.30	.46	.00	1.00	-									
2. Patents (t_1)	.23	.42	.00	1.00	.40***	-								
3. Num. of patents (t_0)	.88	1.96	.00	12.00	.98***	.42***	-							
4. Num. of patents (t_1)	1.03	3.99	.00	44.00	.40***	.99***	.27***	-						
5. Inst. publication performance	11.34	9.28	.00	5.17	-.05	-.01	.06	-.01	-					
6. Inst. patenting experience	.58	2.58	.00	23.60	-.05	-.08	.19*	.00	.02	-				
7. Focus on applied research	49.69	46.89	.04	197.74	.03	.14^{t}	.18*	.02	-.01	.08	-			
8. Network size (ln)	1.82	.84	.00	5.04	.06	.09	.02	.01	.07	-.06	-.07	-		
9. Export orientation (ln)	.12	.19	.00	.69	.06	.16*	-.02	.00	.00	-.02	-.03	.11	-	
10. Technological competition	3.68	1.41	1.00	7.00	.07	.05	.01	.17*	-.02	-.08	-.09	.09	-.01	-
11. Technological uncertainty	3.61	1.38	1.00	7.00	.08	.27***	.10	.09	.01	.07	-.07	.00	.14^{t}	-.09
12. Tacit knowledge	5.05	1.35	1.00	7.00	.03	.09^{t}	.09	.14^{t}	-.13^{t}	.01	.05	.12	.05	-.06
13. Entrepreneurial orientation	13.89	3.12	3.50	21.00	.12	.20**	.09	.18*	-.05	.02	.14^{t}	.13^{t}	.19*	.00
14. Team size	3.25	1.97	1.00	14.00	.13	.20**	.16*	.08	.04	-.08	.01	.10	-.06	.17*
15. Industry experience	8.47	11.67	.00	8.00	.09*	.02	.21**	.04	.01	-.03	.00	.18*	-.04	.00
16. Share of professors	.13	.22	.00	1.00	.16*	.09	.08	.00	-.07	-.09	-.05	.04	.01	.07
17. Patent effect. (techn. field)	.64	.48	.00	1.00	.32***	.28***	.25**	.18*	-.05	.06	.00	.20*	.07	-.02
18. Patent effect. (industry)	4.96	1.03	3.00	6.37	.26***	.21**	.18*	.16*	.00	.05	.14^{t}	.01	.25**	.03
19. Market potential	5.26	1.48	1.50	7.00	.03	.02	.03	.10	-.08	-.15^{t}	.05	.20*	-.16*	.21**
20. Start-up experience	.36	.48	.00	1.00	.17*	-.06	.15^{t}	-.06	.02	-.15	-.14^{t}	.08	-.22**	-.02
21. Number of employees (ln)	1.45	.93	.00	4.39	-.03	.16^{t}	.05	.27***	-.01	-.03	-.04	.18*	.19*	.09
22. Venture capital	.15	.36	.00	1.00	-.01	.07	.00	.09	.11	-.09	-.05	-.07	.03	-.04
23. R&D intensity	.81	.22	.16	1.00	.08	.00	.06	-.03	-.07	.02	.07	-.12	-.10	-.09
24. Share of full-time entr.	.49	.40	.00	1.00	-.02	.01	.02	-.06	-.03	.01	.15^{t}	.07	.11	.01

[a] $n = 160$, ^{t} $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed test). [b] t_0 = pre-founding phase, t_1 = post-founding phase.

Table 1 (continued) – Descriptive Statistics and Correlations.[a]

Variable	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Patents (t_0)[b]														
2. Patents (t_1)														
3. Num. of patents (t_0)														
4. Num. of patents (t_1)														
5. Inst. publication														
6. Inst. patenting experience[d]														
7. Focus on applied research[e]														
8. Network size (ln)														
9. Export orientation (ln)														
10. Technological competition														
11. Technological uncertainty	-													
12. Tacit knowledge	-.11	-												
13. Entrepreneurial orientation	.01	.24**	-											
14. Team size	.24**	-.04	-.02	-										
15. Industry experience	-.05	.05	.14[t]	.30***	-									
16. Share of professors	-.08	.07	.03	-.08	-.05	-								
17. Patent effect. (techn. field)[f]	.04	.18*	.03	-.13	-.01	.04	-							
18. Patent effect. (industry)	.03	.05	.14[t]	-.12	-.18*	.01	0.47***	-						
19. Market potential	-.18*	.14[t]	.15[t]	.03	.03	.11	0.03	0.00	-					
20. Start-up experience[g]	-.02	.06	.09	.21**	.40***	.04	0.01	-0.05	0.02	-				
21. Number of employees (ln)	.06	-.06	.21**	.17*	.01	.02	-0.11	0.07	0.09	0.06	-			
22. Venture capital[h]	.05	.01	.18*	-.07	-.08	.10	0.06	0.09	0.03	0.02	0.14[t]	-		
23. R&D intensity	.21**	.00	.04	-.09	-.09	.09	0.11	0.09	-0.06	-0.06	-0.64***	-0.11	-	
24. Share of full-time entr.	-.12	-.10	.11	-.09	-.08	-.23**	-0.13[t]	0.02	0.09	0.07	0.26***	0.01	-0.20*	-

[a] n = 160, [t] $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed test). [b] t_0 = pre-founding phase, t_1 = post-founding phase.

Table 2 – Results for Regression Analyses of Academic and Business Rationales.[a]

	Pre-founding phase				Post-founding phase			
	Patents[b]		Num. of patents		Patents[b]		Num. of patents	
	Model 1		Model 2		Model 3		Model 4	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Academic rationales								
Inst. publication performance	0.01	0.02	0.02	0.02				
Inst. patenting experience	0.18**	0.07	0.10**	0.04				
Focus on applied research	0.01	0.01	0.01	0.01				
Business rationales								
Network size (ln)					0.31	0.29	0.50*	0.25
Export orientation (ln)					0.09	1.07	-0.40	1.12
Technological competition					1.62*	0.81	1.24t	0.73
Technological competition^2					-0.20*	0.10	-0.14	0.09
Control variables								
Team size	0.28*	0.13	0.37**	0.12				
Industry experience	0.01	0.02	-0.01	0.01				
Share of professors	1.85*	0.85	1.43*	0.59				
Patent effectiveness	2.00***	0.50	1.84***	0.46	0.53*	0.22	0.61**	0.19
Market potential	-0.01	0.14	0.01	0.11	0.02	0.15	0.18	0.14
Start-up experience	0.76t	0.43	0.35	0.34	-0.29	0.49	-0.42	0.41
Number of employees (ln)					0.87*	0.31	1.41***	0.27
Venture capital					0.48	0.61	1.39**	0.53
R&D intensity					3.29*	1.17	4.61***	1.30
Share of full-time entrepreneurs					-0.10	0.49	-0.27	0.54
Log Likelihood	-79.36		-173.92		-73.39		-165.03	
Chi-square	154.44		214.26		138.17		226.23	
Pseudo-R^2	0.19		0.16		0.14		0.27	

[a] n = 160, [t] $p < .10$, [*] $p < .05$, [**] $p < .01$, [***] $p < .001$ (two-tailed test). [b] t_0 = pre-founding phase, t_1 = post-founding phase.

Table 3 – Results for Regression Analyses of Entrepreneurial Rationales.[a]

	Pre-founding phase				Post-founding phase			
	Patents[b]		Num. of patents		Patents[b]		Num. of patents	
	Model 5		Model 6		Model 7		Model 8	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Entrepreneurial rationales								
Technological uncertainty	0.07	0.15	0.09	0.14	0.57**	0.20	0.44**	0.17
Tacit knowledge	-0.02	0.15	0.06	0.13	0.42*	0.18	0.58***	0.14
Entrepreneurial orientation					0.09	0.07	0.14*	0.06
Control variables								
Team size	0.22 t	0.14	0.26*	0.13				
Industry experience	0.02	0.02	0.00	0.01				
Share of professors	1.60 t	0.84	1.09 t	0.66				
Patent effectiveness	1.97***	0.48	1.82***	0.41	0.49*	0.22	0.58**	0.22
Market potential	-0.02	0.14	-0.02	0.11	0.05	0.15	0.14	0.11
Start-up experience	0.61	0.42	0.10	0.33	-0.37	0.50	-0.53	0.46
Number of employees (ln)					0.71*	0.33	0.84***	0.24
Venture capital					0.02	0.68	0.48	0.47
R&D intensity					2.12 t	1.18	1.64 t	0.96
Share of full-time entr.					0.45	0.58	-0.10	0.63
Log Likelihood	-82.15		-180.93		-67.57		-155.99	
Chi-square	152.20		269.52		147.33		286.03	
Pseudo-R^2	0.16		0.13		0.21		0.31	

[a] n = 160, [t] $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed test). [b] t_0 = pre-founding phase, t_1 = post-founding phase.