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To Be Financed or Not…- The Role of Patents for Venture Capital Financing

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Abstract

This paper investigates how patent applications and grants held by new ventures improve their ability to attract venture capital (VC) financing. We argue that investors are faced with considerable uncertainty and therefore rely on patents as signals when trying to assess the prospects of potential portfolio companies. For a sample of VC-seeking German and British biotechnology companies we have identified all patents filed at the European Patent Office (EPO). Applying hazard rate analysis, we find that in the presence of patent applications, VC financing occurs earlier. Our results also show that VCs pay attention to patent quality, financing those ventures faster which later turn out to have high-quality patents. Patent oppositions increase the likelihood of receiving VC, but ultimate grant decisions do not spur VC financing, presumably because they are anticipated. Our empirical results and interviews with VCs suggest that the process of patenting generates signals which help to overcome the liabilities of newness faced by new ventures.

Keywords: patents, venture capital, intellectual property rights, R&D, biotechnology

JEL classification: O30, O34, L20, L26, G24

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1. Introduction

A critical endeavor of any entrepreneurial venture is to mobilize the resources necessary to build a successful company (Stinchcombe 1965). Entrepreneurs have to convince external resource holders of the growth potential of their company. Because the quality of a venture is often not directly observable, external parties have to base their decision on observable attributes that are correlated with the unobserved quality of the venture (Stuart et al. 1999). Observable characteristics may serve as signals when the prospects of young companies are being evaluated.

We examine the role of patents[1] as quality signals for VC financing. Patents are known to help companies to appropriate returns from investment in R&D, facilitate the commercialization of technology (e.g., Gans et al. 2002, Dechenaux et al. 2008, Haeussler 2008) and shorten time to IPO (Stuart et al. 1999). While some studies have shown a positive impact of the patent stock of high-technology companies on the amount of VC financing received (e.g., Baum and Silverman 2004, Mann and Sager 2007, Hsu and Ziedonis 2008), on VC valuation (Lerner 1994) and on the likelihood of attracting a prominent VC investor (Hsu and Ziedonis 2008), a thorough understanding of whether and how patents support the venture in attracting VC at all, is still missing.

In this study, we examine how the existence and "quality" of patents filed and held by young ventures influence VC decision making. By analyzing the informational content of patents, we are able to explore the role of the VC's expertise in interpreting signals.[2] This is an aspect of signaling that has not been studied before, although the effectiveness of the signaling mechanism depends crucially on the recipients' ability to interpret the signal accurately (Heil and Robertson 1991, Ndofor and Levitas 2004). We also examine the impact of patent examination and of reactions by rivals (opposition) on the VC's funding decision. The patent system may create signals of startup quality at various stages of the patenting process. The role of the different types of "approval" received from the patent office has not been studied in earlier work.

Based on the extant literature, we develop a set of hypotheses and then draw upon a unique survey dataset of 190 VC-seeking German and British biotechnology companies founded after 1989. From the survey, we have comprehensive information on the technologies used by the startups and on the strength of their technological capabilities. Furthermore, we have also

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[1] When we refer to patents, we include filed applications and patent grants under this term. Reference to *either* applications *or* grants is used when the distinction matters for our results.

[2] A definition of the term "signal" follows in section 2. We use the term "patents as signals" as a short-hand expression for any signals that may emerge from the patenting process, including the preparation of a patent application.

identified all patent applications filed and all patent grants received by these companies at the European Patent Office (EPO). We use data from the search reports of EPO patents to compute citation counts and to identify patents that may lack novelty and inventive step. Following a "pin factory" approach (see Borenstein et al. 1998), we complement our econometric results with information from interviews with VCs. The unique combination of survey data, official patent records and interviews strengthens the validity of our results.

Our empirical analysis demonstrates that companies' patenting activities have consistent and cogent effects on the timing of VC financing. Having filed at least one patent application reduces the time to the first VC investment by 76%. An increase of the application stock by one standard deviation is associated with a 50% increase in the hazard of obtaining VC financing. When we investigate the quality of patents, which we measure with received citations, we find that ventures with higher patent quality receive VC faster. This is important because the citations largely occur *after* the investment decision has been made, indicating that investors are well capable of distinguishing between patented inventions of low- and high-quality at an early stage. Conversely, there is only weak evidence that patent indicators generated by the patent examiner (e.g., assessment of the patent's novelty and inventive step[3]) affect the hazard rate. Due to the investors' ability to determine the quality of inventions from the information in patent applications, the final grant decision shows no additional effect on the time to VC financing. We also find that opposition events increase the hazard of receiving VC finance. Apparently, opposition by competitors is taken as a *positive* signal by VCs. We conclude (and confirm in our interviews) that VCs prefer to finance endeavors with high commercial potential, where oppositions are more likely to occur.

Our study seeks to make two main contributions. First, we extend the literature by providing evidence that signals generated in the patenting process help to reduce informational asymmetries in the investor-entrepreneur relationship. We argue that patenting exerts a signaling function which helps to overcome the constraining effects of ventures' liabilities of newness (Stinchcombe 1965). We document that patenting is important for the general VC investment decision and that they help firms to attract VC faster than would be possible without patents. Contrary to other studies, we do not simply focus on patents as binary signals, but elaborate on the process of patenting, on the information content of patents and the signal-reading ability of VCs. This allows us to gain insights into the venture's ability to emit such a signal, but even

[3] The criterion of "inventive steps" used at the European Patent Office corresponds to "nonobviousness" as used by the USPTO.

more importantly, into the ability of the investor to interpret such signals. We find that VCs are capable of detecting high-quality patent applications long before the assessment is confirmed by citations or examination outcomes. This enhances the effectiveness of patenting as a signal-generating process. This finding extends the literature on the “scout” function of VCs (Baum and Silverman 2004) by demonstrating that VCs are able to identify valuable technology with considerable precision. Furthermore, we find that a patent opposition boosts investors’ interest in the company. The signal “opposition” may be interpreted by the investor as evidence that the company is developing a technology of high commercial value (see Harhoff et al. 2008).

Second, this research adds to the literature on the economic effects of patents. The classical view of patents asserts that patents foster incentives for innovation, but that they do so at the social expense of enhanced market power and the potential blocking of technological developments (Heller and Eisenberg 1998). Our results show that patenting also support the entry of entrepreneurial companies. As Hall (2007) has noted, patents may in this context be the source of a favorable welfare contribution, since they encourage innovation and the creation of new industries or the emergence of specialization in value chains. Our research suggests that patents do indeed constitute an attractive instrument which helps young ventures to overcome the liabilities of newness and, in turn, facilitates market entry while at the same time providing incentives for innovation.

Our results have important implications for the practice of technology management and financing. For biotechnology ventures as well as for advisors and investors, the findings confirm that patents convey important information about the company and that they deserve considerable attention in due diligence processes. While preparing a patent application is costly and requires some disclosure of private information to the public, ventures should not underestimate the signaling value of patents as they help in acquiring funding and may also help keeping investors patient and enthusiastic about the venture.

2. Theoretical Framework

VCs need to make their investment decisions under a high degree of uncertainty. Technology start-ups are difficult to evaluate since they do not have a track record which outsiders can use to evaluate their potential, they are often years away from first revenues, their assets are mostly intangible and they are plagued by a high failure rate. These perils have led VCs to spend a great deal of effort in seeking and assessing signals of ventures’ growth potential (Amit et al. 1990, Hall and Hofer 1993) and have driven entrepreneurs to undertake symbolic action to gain legitimacy (Zott and Huy 2007).

The value of signaling lies in reducing information asymmetries (Spence 1973) as well as minimizing information costs (Long 2002). In general, the literature has identified three broad categories of signals that are relevant for technology-based startups. Signals of the first type include educational background as well as founder history (Eisenhardt and Schoonhoven 1990, Burton et al. 2002, Shane and Stuart 2002). The second group includes signals in the form of attributes of parties affiliated with a person or organization (e.g., Stuart et al. 1999). The third category includes previous accomplishments of the startup company. Patent grants and even patent applications may be considered such an accomplishment, signaling a company's technical abilities. The value of signals generated during the patenting process is that they reduce information asymmetries between the VC and the new and unproven company seeking capital and that they minimize information costs for the financiers. Even a patent application which has not been approved yet by a patent office may constitute such a signal. The preparation of patent applications requires effort and time, since applicants have to follow strict guidelines and need to include technical information in a very structured manner. This allows individuals familiar with the patent application requirements to quickly assess the strengths and weaknesses of an invention and of the technology employed by the startup. While previous research has extensively elaborated on the first two categories, our study investigates whether patents are a meaningful signal in the entrepreneur-investor relationship.

Patents as Signals

We define a signal as a characteristic that is correlated with company performance, but is easier to observe than the underlying causal factors influencing performance.[4] Patents generally fit this definition well. A patent is a voluntary, readily observable attribute of a patentee, which is costly for the patentee to obtain (Long 2002). This is particularly true for European patents which are – on average – 5 to 10 times more expensive than USPTO patents. The independent evaluation by the patent office may lend credibility to the patent as a signal; and credibility is a central element of how well a signal is received (Heil and Robertson 1991). Patents suggest that a company has developed its technology to a certain extent and that it has "defined and carved out a market niche" (Lemley 2001, 1505). Moreover, patents appear to have a *causal* effect – ownership and loss of ownership (e.g., in litigation) show a strong impact on the stock market value of

[4] We note that this is *not* the exact notion of "signals" used by Spence (1973) in his pioneering work where performance need not be correlated with the activity by which signalling is achieved.

companies (e.g., Hall et al. 2007). Hence, patents might act as observable indicator of the unobservable promise and quality of a venture's technology in the presence of uncertainty.

The relevance of patents for companies attempting to obtain financial resources, especially in their early stages, has previously been noted in the literature (Hayes 1999, Lemley 2000). A product that is proprietary or can otherwise be protected is an important selection criterion for VCs (MacMillan 1985). Hence, it can be expected that companies in need of capital will be informed about the potentially helpful role of patents and will try to obtain patents if the cost of doing so is not too high for them.

Before we further discuss the role of the patenting process for generating quality signals, we need to point to the value of patents as property rights. Patents increase appropriability and thus provide incentives for innovation. In addition, patents facilitate the licensing of technology (e.g., Gans et al. 2002). They increase the attractiveness of companies as acquisition targets (Cockburn and Wagner 2007) and enable VCs to recover a salvage value from failing companies. However, scholars have also documented that "patent strength" varies between industries in such that in most industries patents are less featured than other means of protecting innovations, such as mover advantages or secrecy (Levin et al. 1987).

While a large strand of literature has investigated the traditional view of patents as a means of protecting intellectual property, Long (2002, 625) notes that scholars have overlooked the informational function of patents which "may be more valuable to the rights holder than the substance of the rights". Moreover, the information that is relevant to a financier may not just come from the grant event, but from other aspects of the patenting process. Recently, a few scholars have shed light on some aspects of the role of patents for VC financing. Hsu and Ziedonis (2008) find a positive effect of patents on investors' estimates of company value for a sample of VC financed semiconductor startups. They find larger effects for early funding rounds, where information asymmetry is at its largest. In addition, patents are particularly valued by more prominent VC investors. Lerner (1994) also documents a positive influence of patents on company valuation. Mann and Sager (2007) investigate correlations between the availability of patents and performance indicators, such as number of financing rounds, total investment received, exit status, late-stage financing and longevity. Without taking the timing of events into account, they generally find positive correlations. However, having a patent before the first instance of VC financing is not significantly related to any of the performance variables. Baum and Silverman (2004) examine selection criteria used by VCs and subsequent company performance. They find a positive association between patent applications at the USPTO and pre-IPO financing defined as VC financing and private placements. Patent grants also have a positive, but smaller effect than patent applications.[5]

The existing literature has largely focused on companies with VC financing and on subsequent performance measures such as IPO, company profitability etc. Evidence on whether patents play a role in the initial selection decision of VCs is still scarce. Our hypotheses focus on the financing decision made by VCs and on the impact that patent applications, anticipated patent quality and revealed patent quality have on this decision. By distinguishing between anticipated quality (i.e., quality as revealed later in the examination process) and observable, i.e., revealed quality in our estimations, we can draw conclusions about the signal interpreting capabilities of the VC. This distinction will turn out to be important in our results.

The Role of Patent Applications and of Application Quality

Our most basic hypothesis presumes a relationship between the existence of a patent application and VC investment. We suggest:

> ***Hypothesis 1:*** As startups file patent applications, the hazard of obtaining VC financing increases.

This hypothesis serves as the starting point of our evaluation. The filing of patent applications may signal two aspects: first, that the startup has matured sufficiently to consider the commercial utilization of the technology it has been working on; and second, that it is willing to invest in the protection of its technology. Thus, a supportive result of this hypothesis is subject to various caveats. A clearer picture may emerge once the quality of the application is considered in more detail. Harhoff et al. (1999), among others, have shown that patent value has a very skew distribution with most granted patents being of little value. Hence, patents might signal that an innovation is novel, but not necessarily that it has commercial value. VCs will therefore have to evaluate the private value of a patent in order to assess the potential return from a venture investment. To do so, VCs will have to invest in their own signal-reading expertise (Heil and Robertson 1991) or, alternatively, they may hire external experts, such as patent attorneys, to evaluate the legal and technical foundations of a given patent application. In either case, the patent application may serve as a reasonably standardized format containing technical information on the startup's invention. VCs will act as "scouts" in selecting companies (Baum

[5] While Baum and Silverman do not comment on this aspect, the use of USPTO data limits the study to applications that were ultimately granted, since publication occurs only at grant. Conversely, our EPO data allow us to trace unsuccessful applications as well as successful ones which became granted patent rights.

and Silverman 2004), and they will be more likely to make an investment if applications are anticipated to have high-quality. Thus, we hypothesize:

Hypothesis 2: The higher the *anticipated* quality of a startup's patent application, the more likely the startup is to receive VC financing.

Revealed Quality and Third-Party Evaluation of Patents

In the previous hypothesis we emphasize that VCs may be able to obtain a reasonably precise assessment of patent quality *before* that quality is revealed publicly. A public revelation may occur (i) when the search report is made public, (ii) when the patent is granted or (iii) when the patent is opposed. Besides relying on their own interpretation of the patent document, VCs can also base their decision on these objective evaluations within the patent system, but the associated delay in decision-making has negative consequences: the VC may lose the investment to another rival, or the pre-money valuation of the startup may increase. How this tradeoff is resolved is largely an empirical question. If the VC wants to take "official" information into account it can use information included in the patent office's search report in which the examiner includes her view on the underlying prior art. This initial assessment is likely to affect the scope of the patent once granted, and it may therefore affect the financing descision (unless the information is correctly anticipated).

Moreover, a granted patent will have a higher value to a VC than a mere patent application because the grant offers higher certainty concerning the scope and the strength of patent protection.[6] However, if the VC has inspected the patent application and has come to a positive assessment with sufficient confidence, then the grant event is unlikely to elicit further actions by the VC.

Information on the patent's quality may also be revealed by opposition activity. In the first nine months after the grant of a patent, any third party can file an opposition at the European Patent Office. An opposition from a competitor can indicate that the company possesses especially valuable technology. If the technology were worthless, competitors would not bother to incur the costs of opposition (Harhoff and Reitzig 2004). However, an opposition also indicates that the patent faces a threat of revocation. The VC therefore needs to take a closer look to find out whether the patent will likely be upheld. An opposition can have a positive or a negative influence on the availability of VC. Since we are elaborating on the signaling character of

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[6] Gans et al. (2008) argue that such uncertainties are important in practice. They find that the hazard rate for concluding a cooperative licensing agreement increases significantly after the patent has been issued, since the grant clarifies the patent's claims. Note that certainty is never fully achieved, since the patent may later be challenged in litigation, or – at the European Patent Office – even earlier in opposition proceedings.

patents, we presume that a patent opposition signals the presence of a valuable technology to the VC. Statistically, the VC can expect that the patent is revoked in one third of the cases, while the opposition is rejected or the patent is maintained in amended form in the remaining two thirds of cases (Harhoff and Reitzig 2004).A natural corollary to our second hypothesis is therefore:

Hypothesis 3: The higher the *revealed* quality of a startup's patent application, the more likely the startup is to receive VC financing.

All of the three events considered for hypothesis three can be regarded as signals that are generated by a third party, i.e., the patent office and competitors, and might provide additional information on the actual value of a patent.

3. Field of Study and Data

3.1. The Biotechnology Setting

The biotechnology industry provides an attractive setting for studying the impact of patents on the VC financing decision for several reasons. The R&D process in biotechnology is highly uncertain and complex, and companies need to access a broad range of human resources and capital. Among the capital resources, venture capital is often viewed as the key gatekeeper for ventures (Shepherd et al. 2000), facilitating the successful acquisition of additional resources (Stuart et al. 1999, Anand and Piskorski 2000). Furthermore, patenting activity is of particular importance in biotechnology. Cohen et al. (2000), *inter alia*, have shown that intellectual property rights are an important means for protecting innovation in the life sciences. Our investigation takes this function as given and focuses on the information content of patents for venture capital funding decisions.

3.2. Data Sources

We study the role of patents for financing in the German and British biotechnology industry. After the US, these two countries are home to the largest number of biotechnology companies world-wide. Our database for this study draws from two data sources. First, we build on a survey conducted among German and British biotechnology companies in 2006. The survey population is composed of all companies active in the bio-pharmaceutical sector according to the OECD definition (OECD 2005). Companies not founded in one of the two countries or subsidiaries of foreign companies, and companies solely offering services or supplying products without conducting research were excluded from the sample. A population of 346 German and 343 British core biotechnology companies was identified. Of those, 162 German and 118 British companies were successfully interviewed face-to-face with a preformatted and tested questionnaire. The objective of the current analysis is to shed light on the role of patents for VC financing. Therefore we excluded companies that were – according to our survey responses - not interested in VC financing, either because they do not want to give up control of the company or they are not in need of VC financing.[7] We thus have a homogenous sample of companies as basis for our analysis. Moreover, we only include companies that were founded after 1990. Our analysis is based on 116 German and 74 British companies that match our criteria and for which we have all the data needed to test our hypotheses. 87 of these companies received VC financing; 103 did not. The second step was to compile data on all patents filed by these companies at the European Patent Office. We use information from an EPO patent database and from EPO search reports in order to operationalize our variables for the quantity and quality of company patents.[8]

3.3. Variable Definitions

The dependent variable in our analysis is the time of first VC financing. The variable is measured on a quarterly basis. The last quarter observed in the data is 4/2005. The variable is coded as a dummy equal to one if the company has received VC financing and zero otherwise. Data on a company is right-censored if the company has not obtained VC financing by the date of the survey.

The independent variables can be divided into patent related information and other company characteristics. All patent related variables are measured on a quarterly basis. The dummy variable *patent application* is equal to one if the company has applied for at least one patent in the current or in a previous quarter. We also investigate the influence of the number of patents a company has. *Application stock* is the cumulative number of patent applications filed at the EPO. For the empirical analysis we use the natural logarithm of the stock variable, since we assume that additional patent applications will have a decreasing marginal effect on the hazard rate.[9] We increase the stock by one before calculating the logarithm in order not to lose observations for companies without patent applications.

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[7] Companies might not be in need of venture capital, for example, when they follow a hybrid business model in which they provide service or supplier activities for third parties in order to finance their own R&D efforts. Another case would be companies that received a large amount of money, e.g., from business angels.

[8] Sample selection bias may constitute a problem in our data. In our sample we did not account for companies that had failed and therefore exited the market. To rule out the possibility that this severely affects our results, we compiled a second data set with all German biotechnology companies founded since 1991. We observe companies that have gone out of business and companies still in business. The Online Appendix 1 presents the dataset and shows the results for the effect of patents on the likelihood of obtaining VC for companies that are still in the market as well as for companies that failed. From this calculation we learn that the core effects, i.e., that patents facilitate VC financing, are robust in both samples. The robustness in the effects of the patenting variable in the additional calculation greatly increases our confidence in our study and particularly in its contribution.

[9] Biotechnology firms frequently file a set of secondary patents to safeguard the results of primary patents further. These secondary patents will not be as important to the VC as the primary ones.

As an approximate measure of patent we use the number of citations received by a given patent application. European patents undergo a rigorous examination process. If patents receive citations from subsequent patents (i.e., in the search reports for these subsequent patents), then they are presumably particularly relevant as prior art. Several studies have shown that there is a positive relationship between number of citations received and the private economic value of patents.[10] Thus, *average number of citations* is defined as the total number of citations received, divided by application stock. We use the citation count to measure the impact of the VC's anticipation of patent quality. Citations are counted from the publication of the application (which occurs 18 months after priority) for a period of three years, but we introduce the full three-year count from the filing date onwards. If VCs anticipate quality prior to its "official" confirmation, then this variable should have a positive impact on the funding hazard.

We derive two measures of *revealed* quality from the search reports published by the European Patent Office. The prior art references in the search report are allocated to one of several categories. An X reference means that a claimed aspect of the invention cannot be considered novel or inventive, and that the claim may thus not deserve patent protection. We compute the variable *X-Type references/application stock* as the total number of X references divided by the application stock of the company. Applications with a high share of X references can be considered applications with low novelty or inventive step. Harhoff and Wagner (2006) show that such applications are particularly likely to be refused or withdrawn at the EPO.

As a second measure of revealed quality based on search reports, we include an indicator for whether the invention builds on scientific breakthroughs. The impact factor of s*cientific literature* gives the average impact factor of the journals that are cited as references to the non-patent literature in the search report. It is therefore an indicator of the importance of the scientific underlying literature. Impact factors have been determined for the 120 most important journals in the area of biotechnology according to the ISI Citation Index.[11] The indicators for novelty and for scientific importance are derived from information in the search report. These indicators are used in the analysis starting from the quarter in which the search report was published, since we use them as measures for revealed quality.

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[10] See Harhoff et al. (1999), Harhoff et al. (2003) and Gambardella et al. (2008) using European patent citations. Jaffe et al. (2005), using USPTO citations, find a positive relationship between both the economic and technological importance of a patent as indicated by the inventor and the number of citations the patent received.

[11] In 31% of the referenced literature the patent examiner listed as the source not the journal name but the name of the database the article was downloaded from. In these cases we assumed an impact factor of one because we could not determine the real impact factor of the journal in which the article was published. Calculating the model without these articles does not change the sign or significance of coefficients.

The dummy variable *grant* is equal to one if the company has at least one granted patent. The variable *share granted applications* is the share of patent applications that have already been granted at the time of the respective quarter. These variables are used to test the impact of the grant information.

Share of opposed patents is our fourth measure of revealed quality and indicates the share of the patent applications that received an opposition. It is calculated as the total number of oppositions received divided by the application stock. Oppositions are measured at the quarter in which they occur divided by the patent application stock in that specific quarter.

The regressions also contain controls for company characteristics. All company characteristics are defined with reference to the time of founding. We can thereby exclude the possibility that company characteristics have been changed by the intervention of the VC. *Technical capabilities* proxies for the skill set of the employees. It is defined as the number of biotechnical methods a company is working with at the time of foundation, e.g., DNA, proteins and molecules or cell and tissue culture. Up to nine methods are possible. *Years to market entry* covers how many years the company thought to be away from market entry at the time of founding. Market entry is defined as achieving the first turnover with a product. Turnover due to selling of services is excluded. The variable has two interpretations. A larger value can indicate a higher demand for external financing, since the company needs to sustain a longer period of R&D. A larger value can also be a measure of uncertainty, since a longer time to market means that the technology is less developed and that the prospects of the company are more uncertain.

Spin-out science is a dummy variable indicating that the company is a spin-out from a university or a publicly funded research institute. *Spin-out company* indicates a spin-out from a private-sector company. The base category is independently founded companies. We also include controls for the founding period. We cover the periods 1990-1995, 1996-1999 and 2003-2005 (*founded '90 – '95*, etc.) with 2000-2002 being the base category – a time period of decline in the stock markets. *German company* is a dummy indicating that the company is based in Germany as opposed to the UK.

Finally, the regressions include the number of early stage VC financings as a proxy for the supply conditions in the market for VC financing (*early stage financings*). The early stage financings are comprised of seed and start-up financings. Data for Germany is taken from the annual statistical publication of the German Private Equity and Venture Capital Association 'BVK Statistik' (BVK 2007); data for the UK is taken from the statistical publication of the British Private Equity and Venture Capital Association 'Report on investment activity 2006'

(BVCA 2007). The average number of early stage financings over the sample period 1990-2005 is 401 for Germany and 307 for the UK.

3.4. Descriptive Statistics

The descriptive statistics in Table 1 show pronounced differences in the patenting activities of VC financed and non VC financed companies. The statistics are calculated for the first 16 quarters (4 years) after founding. 69% percent of firms within the group of VC financed companies have at least one patent application, whereas this share is substantially lower, at 37%, for non VC financed companies. VC financed companies have a larger application stock. There are also differences in the characteristics of the patent portfolios. VC financed companies have portfolios of applications with a higher number of citations and a lower number of X references, indicating higher quality of patent applications with regard to inventive step and novelty. Furthermore, their patents build on scientific literature with a greater impact factor.

The share of observations with at least one granted patent is also higher for VC financed companies, although at 9%, it is still quite low. The share of already granted patents is the same for both groups, but VC financed companies have a higher share of patents that received an opposition.

The differences between VC financed and non VC financed companies are further explored in Figure 1. For all quarters after founding, VC financed companies have a higher average number of patent applications. But Figure 1 does not take the timing of the VC financing into account. Hence, it is not possible to deduce from the figure whether applications help companies to obtain VC or whether VC financed companies patent more.

On average, companies apply for the first patent at the age of 1.3 years. For companies that obtain VC financing during the sample period, the first VC investment deal is closed five months later. Interestingly, the first patent grant is only obtained at the age of 4.5 years, shortly before market entry. This already suggests that actual patent grants may have only a limited influence on VC financing. The average company obtains VC financing long before the first patent is granted.

Further differences in company characteristics are explored in Table 2. VC financed companies have capabilities in more technical areas and are further away from market entry at founding. Spin-outs from universities or publicly funded research institutions have a higher probability of being VC financed. However, the probability of VC financing is almost identical for German and British companies. Companies founded during or shortly before the boom period of VC financing ('96-'99) have a higher probability of obtaining VC financing.

4. Multivariate Study

4.1. Methodology

Using a proportional hazard model with time-varying covariates, we estimate the effect of a company's patenting activities on the hazard of acquiring VC financing in a specific quarter. From the date of founding onward, the companies are "at risk" of a VC investment. To accommodate time-varying covariates, we split the complete time period into quarter-year spells. The hazard of obtaining VC financing is defined as the probability of obtaining VC financing in the current period given that no VC financing has been received up to the previous period. Our main interest is to investigate how patent related variables influence this hazard. The Cox proportional hazard model accommodates the influence of covariates by multiplying the baseline hazard by a function of observables. The hazard function itself is estimated non-parametrically and can take any form. Companies that have not received VC financing by the time of the survey are treated as right censored.

4.2. Empirical Results

Our hazard rate results are shown in Table 3 and shed light on whether companies with patent applications or grants receive VC financing faster than those without patents. We observe 190 companies for a total of 3001 quarters. Our estimation strategy is as follows. We present estimates from Cox proportional hazard models in which we include our patenting variables as well as control variables for founding years, economic environment and type of spinout. We also include two additional control variables based on our survey responses and demonstrate that the inclusion of these does not lead to reduced or less significant coefficients for our patenting variables.

Column (1) shows results for a specification with a dummy variable for the incidence of any patent applications and a metric variable for the number of citations received. In the Cox model a positive coefficient indicates that companies receive VC financing faster, a negative coefficient means the opposite. The variable *application (0/1)* has a positive coefficient which is significant at the 1% level. The coefficient of the citation variable is significant at the 10% level. Moreover, our control variables for technical capabilities, years to market entry and early stage financings have the expected positive sign, but only two of them (technical capabilities and early stage financings) are significant, both at the 5% level. None of the other control variables have a significant coefficient in this initial specification.

In column (2), we add the application stock variable to the specification. The results clearly show that application stock is a better predictor of VC timing than the simple application dummy. This result is important since it confirms that the time variant stock variable matters in the Cox model while the (largely) time invariant dummy variable is not statistically relevant once the stock variable is included. We therefore maintain the stock of applications and drop the dummy variable in all other models.

The results from column (3) provide first of all strong support for our hypothesis 1: an increase in the number of patent applications is associated with a reduction of the time to first VC financing. While the hazard estimate cannot be interpreted directly in terms of time, we also estimated a parametric accelerated failure time model based on a log-logistic distributional assumption (not shown in Table 3). Estimates from this model indicate that companies with at least one patent application obtain VC financing on average 78% faster than companies without patents. Increasing the patent application stock by one standard deviation (from 5.12 to 11.77 patent applications) reduces the time to the first financing round by 50%.

Moreover, the citation variable becomes significant at the 5% level in column (3): companies with highly cited patents receive VC financing faster than firms with infrequently cited patent applications. Thus, our second hypothesis also receives support. Citations are a measure that VCs typically cannot observe at the time of their decision. VCs are apparently able to differentiate between patent applications of higher and lower quality before an official assessment is available. These results support the view of VCs as a “source of selection” of companies (Baum and Silverman 2004).

In column (4), additional variables describing the revealed quality of the application stock are introduced in order to test hypothesis 3: the number of *X-type references/application stock*, the average *impact factor of scientific literature* referenced in the search report, a dummy variable for the first patent grant – *grant (0/1)* - and the *share of opposed patents*. There is only weak evidence that the information in the search report matters for the timing of VC finance. A higher value of the variable X-*type references/application stock* indicates a lower degree of novelty and/or inventive step. The results in column (4) show that concerns about novelty and/or inventive step increase the time to VC financing, but the effect is only marginally significant at the 10% level. There is no evidence that companies whose patents build on publications in particularly prestigious scientific journals receive VC financing faster than applicants with more mundane patents.

The results also indicate that the grant information does not have any explanatory power – in column (4), the coefficient of the grant dummy is estimated very imprecisely. We cannot reject the null hypothesis that grants do not matter for the funding decisions. In order to ascertain that the latter result is not driven by misspecification of the functional form, we include in model 5 the share of granted applications instead of the dummy variable. The result is again negative – grant-related variables do not impact the hazard of the financing event. This result confirms once more that VCs presumably anticipate most of the information about the quality of the venture's patent applications prior to examination and patent grant. Due to the investors' ability to determine the quality of inventions from the information in patent applications (see hypothesis 2), the final grant decision shows no additional effect.

In models 4 and 5, we also investigate the influence of oppositions. As the results show, companies receive VC financing faster if a higher share of their patent applications are opposed by third parties. Oppositions can indicate that the company possesses a valuable technology that competitors would like to use as well. Thus, the occurrence of an opposition informs the VC about the commercial potential of a patent. The effect size of oppositions is considerable. Taking the average portfolio with five applications, one opposition has the same effect as roughly 5 citations. To summarize, the evidence for hypothesis three is mixed, in that not all dimensions of revealed quality have an influence on the financing decision. We find a rather weak influence of information from the search report, no influence of grants and a strong influence of oppositions. The latter result is probably due to the fact that oppositions cannot be anticipated as well as the quality of the patent application. The opposition event thus creates new information that is then taken into account in subsequent financing decisions.

The results in column (6) test the possibility that the citation variable may dominate the influence of our variables derived from the search report. In that case, the variables *X-type references/application stock* and *impact factor of scientific literature* should have significant coefficients once we drop the citation variable. However, that is not the case – the results are largely unchanged. The X-type reference variable is marginally significant, but none of the other results change. Taking the specification in column (5) as our reference point, we find that the X-type reference variable, the impact factor variable and the variable indicating the share of granted patents are even jointly insignificant (χ^2=2.83 (3 dof), p=0.42).

Some of the coefficients of our control variables in Table 3 are of interest in their own right. Since the results are fairly robust across specifications, we focus on the coefficient estimates in column (5). Companies with a larger set of *technical capabilities* receive VC financing faster.[12] The variable *years to market entry* has a positive coefficient. Companies that have to undergo a longer development phase have a higher need for capital and presumably benefit more from the advice VCs give. The result can be an indication that VCs target companies where they can make a large difference. However, the coefficient is only marginally significant. Our control for the supply side conditions in the VC market, *early stage financings*, has the expected, statistically significant influence. The sample companies receive VC financing faster if more companies are financed in a given year. The additional control variables for type of founding, founding period and home country appear to be of no importance. That also applies to the country dummy - German and UK firms do not display different timing patterns. Even the interaction between the dummies *application* and *German company* turns out to be insignificant.[13] An interaction between the dummy variable *application* and the age of the company measured in quarters is also insignificant. This latter result is also an indication that the proportional hazard assumption of the Cox model is justified.

We also estimated additional specifications which included further control variables. Evidence by Hellman and Puri (2000) shows that more innovative companies have a higher likelihood of being VC financed. We controlled for the innovator strategy (i.e., how innovative the most promising technology of the company is) and obtained similar results to those in column (5). We do not use this control in the reported specifications, since it is measured at the time of the survey and thus might be influenced by the VC itself. Inclusion of a dummy for whether a company is active in the field of therapeutics did not reveal statistically significant results either.

Finally, since the timing of information is important for identification of effects in our model, we performed a number of robustness checks.[14] First, instead of computing the grant variables based on the actual grant date, we obtained information as to when the EPO informed the patent applicant about its intention to grant a patent. In none of these specifications did the grant variable become significant. Second, we took into account the granting dates of US patents. Many companies in our sample apply for a patent at both the EPO and the USPTO. For our sample period, the USPTO was known to grant patents faster on average than the EPO. See

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[12] We experimented with a quadratic form for this variable to test for benefits of specialization, but found no significant influence of the squared term.

[13] We also experimented with interaction terms of *dummy application* with *years to market entry*. We expected a positive coefficient since the patent signal could be stronger in environments with higher uncertainty, but found no significant difference. Similarly, an interaction of *dummy application* with a dummy for companies that have already achieved positive sales turned out to be insignificant.

[14] The estimates described here are available upon request.

Harhoff and Wagner (2006) for details on patent examination lags. The USPTO granted patent applications which were equivalents to our EP patents after roughly 3 years whereas the EPO granted patents in our sample after 4.8 years. We ran additional regressions using the earliest grant date for patents applied for at both offices. We found a higher coefficient for the grant variable, but the influence of grants was not more precisely estimated. Third, we experimented with other patent indicators. We did not find a significant influence on the time to VC financing for the number of references (also separate for references to patent literature and references to non-patent literature), the share of references to non-patent literature, or the average number of claims.

While these robustness checks support our interpretation of the estimates in Table 3, it is nonetheless worthwhile to discuss potential alternative explanations for our results at this point. Can we be sure that our effects are driven by the hypothesized patent signaling rather than unobserved differences between companies that happen to correlate with patents? One could argue that patents are just a sign that a company has reached a certain development stage. We address this issue by using several variables that control for differences in quality between companies. We have also restricted our sample to companies that have applied for VC financing and companies with R&D of their own. This should reduce the effect of differences in company strategy. In addition, patenting in the biotechnology sector comes very early in the development stage of products (e.g., in drug discovery and preclinical stage). Therefore, a patent does not say much about how fast a company makes progress in the development process. In addition, patents are costly. The costs for an EPO patent amount to about Euro 32,000.[15] A rational company will only patent if it sees a benefit in doing so. In separate regressions (available upon request), we also show that dropping the variables which are most likely to be correlated with unobservables – our survey information on technical capabilities and time to market– does not diminish the coefficients of our patenting variables by much. We therefore conclude that the evidence in support of our signaling hypothesis appears to be fairly strong. But we go one step further towards validation and compare our interpretation to statements from venture capitalists.

4.3. Interview Evidence

Econometric results alone are often not sufficient to distinguish between the traditional protection function of patents and their function as quality signals (Stuart et al. 1999, Hsu and Ziedonis 2008). Therefore, we have undertaken five in-depth interviews with VCs from Germany and the United Kingdom to complement our analysis in the "pin factory" tradition. In selecting our interview partners we were interested in getting the views of different types of VCs. We have interviewed investment managers of early stage, late stage VCs and a corporate VC. The aim of these interviews was to gain insights into the importance of patents for the financing decision and detailed information on the patent due diligence.

The first insight we gained from our interview partners is that *both* the protection and the quality signaling functions of patents are of great importance for VCs. One of the interviewees highlighted that "patent applications signal that companies have done their homework". We also learned from our interview partners that companies are well aware of the importance VCs attach to patent applications and the importance of applying for a patent prior to entering into negotiations.

Second, we were interested in learning from our interview partners whether patents are able to convey information at a relatively low cost. This potential advantage of patents has been mentioned in the literature (Long 2002, 647). Our interview partners suggested that patent documents offer information on the technology in a condensed and standardized format which helps in the due diligence process. Nevertheless, patent applications are often quite technical and formal and therefore difficult for VCs to read. To overcome this, they use highly specialized technical experts and patent lawyers to evaluate the patents. Patents may not reduce the costs of the due diligence process, but they provide precise information on the technology.

Third, our interviewees indicated that the VCs evaluate patents and related documents very carefully, although there are considerable differences among VCs. One of our VCs gave us a list with 35 criteria on which hired technology experts in the field of the biotechnology firm should base their evaluation of the patent portfolio. Another interviewee said that they have no standardized patent due diligence. When asking about the relevance of information contained in the search report, we find a large heterogeneity among VCs. Whereas one VC appeared to be very interested in the information from the search report "(…) to see what the examiner thinks, to learn who is also working in this area and how the prior art limits the possibilities of the company under consideration", another VC with similar size and investment focus rarely makes use of search reports. When we asked about the importance of the grant decision, we learned that patent grants are preferred but are not particularly important for the investment decision, since VCs "(…) are able to decide whether there is something valuable based on the patent application document". In addition, VCs highlighted that, particularly in biotechnology, the picture that emerges from evaluating the entire patent portfolio is relevant, while the appraisal of a single

[15] See http://www.european-patent-office.org/epo/new/costs_ep_2005_de.pdf. (last download December 15, 2008).

patent is less meaningful. When shedding light on patent oppositions, our interviews revealed that an opposition signals to the VC that a third party is interested in the technology and, thus, that there is commercial opportunity. The opposition positively influences the financing decision when the patent is perceived to be strong or if the company is able to make commercial use of the third party's interest, e.g., by licensing or selling the patent to the opposing party. The VC may abandon the investment opportunity if the commercial potential of the start up is severely endangered by the opposition.

5. Implications and Conclusion

5.1. Theoretical Implications

Our paper provides contributions to several strands of literature. First, we extent a growing body of literature on entrepreneurial management by showing that patents help companies to overcome the liabilities of newness by facilitating access to external financial resources. While previous literature observed that VC financed ventures are more active in patenting compared to non VC financed companies (Kortum and Lerner 2000), it was left open whether this results from selection or nurturing. Our results provide evidence in favor of selection. While recent research has shown that investors pay attention to patent portfolios in their valuation decision (Hsu and Ziedonis 2008, Mann and Sager 2007, Lerner 1994), we show that the patenting process affects the financing decision.

As a contribution to the signaling literature, we demonstrate that in the course of patenting, important signals are created which have impact on the venture-investor relationship. In contrast to other studies, we do not only focus on patents as binary signals but elaborate on the information content of the patenting process and the ability of the VC to read signals. Using citation counts, we find that the quality of applications affects VC behavior even before the quality is confirmed by outside parties. Our interviews confirm that VCs invest in their signal-reading expertise by making efforts to stay informed about available patent information and by hiring external experts to evaluate the patent portfolios of potential investments. Moreover, the patent system can provide confirmation of whether the patent has commercial potential – being subject to opposition enhances the likelihood of receiving VC. However, we find only weak evidence suggesting that the patent examiner's assessment impacts the financing decision of VCs. Nor does the ultimate grant decision have an effect on the financing decision. This result is not too surprising, given the long lags in the examination process at the major patent offices – VCs simply may not have the time to wait for approval by the patent office. Instead, they evaluate the patent application themselves, anticipating the quality later certified by the patent office. Taking these results together, the role of patenting is rather complex – the patenting process itself generates information that is helpful to investors, but it is not simply the patent grant itself that is recognized by VCs.

We also contribute to the literature on the economic effects of patents. Patents will typically be a barrier to entry. For example, Cockburn and MacGarvie (2007) find a lower entry activity in markets more affected by patent thickets. In addition, they report that companies operating in markets with denser thickets experience a delay in the first funding by external investors. Our results, however, suggest that the phenomenon is more complex: by facilitating entry of VC-financed startups, patents also serve a pro-competitive role. For start-ups the patenting process generates valuable quality signals which help them to obtain funding. While this aspect has been discussed by some scholars (e.g., Hall and Ziedonis 2001), it still deserves further attention.

5.2. Practical Implications

Besides extending the scientific literature, our results have important practical implications for management and public policy. We show that patent documents are effective instruments for the transfer of information. Ownership of patents (or patent applications) is associated with faster acquisition of VC. Thus, investing in intellectual property will effectively support startup founders and managers to overcome the liability of newness. Our detailed analysis on how various patenting events and metrics affect the VC investment decision provides crucial insights for companies interested in obtaining VC. Faced with resource constraints, start-ups often have a choice between pursuing patent grants or investing in additional applications. Our results suggest that improvements to the application stock and its quality are of particular relevance for VC acquisition purposes. Naturally, patent grants will matter for obtaining actual protection, but they do less so for the raising of capital. These results can also help to shape the patenting strategy of start-up companies. Firms often need to determine the optimal time for submitting a patent application. Refining the application prior to filing may yield broader scope and better protection. Delaying the filing may raise the danger of being pre-empted by rivals. We find that the trade-off also applies in the context of raising VC – both quantity and quality matter. The patenting strategy of a start-up should be a task for the top management as it can be of crucial importance for the further development of the company. Our results have also implications for VCs who can make use of patents in order to learn about the start-up's technology. Our results show that VCs tend to anticipate patent quality. Some VCs may profit from making further investments in this capability and should invest in their patent reading ability.

With regards to public policy, this study implies that the role patents serve is rather complex. Patents may reduce information asymmetries between financiers and founders, and they may therefore positively influence market entry by start-ups. This finding points to an important economic role of the patent system which is not yet reflected in the current debate on the “optimal” patent system but should not be ignored. Second, our findings point to a discussion on how the signaling role of patents can be actively promoted. The challenge for patent offices is to think about how patent information can be provided faster and in a clearer form such as to enable firms with high-quality technologies to receive financing faster.

5.3. Limitations and Future Research

Various caveats need to be taken into account when considering our results. First, there is a question of external validity. This study investigated the importance of patents for obtaining VC financing in one industry. It would be interesting to know whether the revealed effects are also present in industries other than biotechnology. In biotechnology, patent protection plays a very important role (Cohen et al. 2002). Whether the signaling role of patents differs in importance from industry to industry is not clear from previous findings. Mann (2005) suggests that the importance of patents for the financing decision varies by sector with the software sector, for example, exhibiting an unusually low importance of patents. Hall and Ziedonis (2001, 110) study the patenting behavior of ventures in the semiconductor industry and find that one of the most important roles of patents appears to be “securing capital from private investors in the start-up phase”. Furthermore, Arora et al. (2008) document that the patent premium is high in industries like drugs, biotechnology and medical instruments and low in industries like electronics. It is left to future research to determine how strongly these effects are influenced by the signaling role of patents. A second issue concerns potential omitted variable biases. Previous research has shown that affiliations with prominent partners are important quality signals (e.g., Stuart et al. 1999; Hsu 2006). Ideally we would like to control for these quality signals in our analysis, since it is possible that these signals are correlated with patenting. Unfortunately, our survey data does not include information about the prominence of a company’s affiliates and it is not possible to obtain this information from publicly available data sources.

Given our results, it seems particularly promising to explore how investors structure their due diligence processes in order to decipher signals as fully as possible. In this project we have conducted interviews with only a handful of companies, so we cannot draw conclusions regarding institutional differences in patent due diligence. Nevertheless, we think that it would be a worthwhile endeavor to conduct a large scale study. We found evidence that patenting functions as an important signal-generating process for obtaining VC finance. It would also be interesting to know how costly it is for companies to generate the signals, and to separate the value of the signal from the value of the exclusion right. We leave these questions to be explored in future research.

Tables and Figures

Table 1: Descriptive Statistics of Time-Variant Patent Variables

	VC financed firms			Non VC financed firms			Diff. mean
Variable	Obs	Mean	St.Dev.	Obs	Mean	St.Dev.	p-value
application (0/1)	1411	0.69	-	1595	0.37	-	0.000
grant (0/1)	1411	0.09	-	1595	0.05	-	0.000
application stock	976	5.12	6.65	584	3.32	3.45	0.000
average number of. citations	976	1.54	3.33	584	0.87	0.92	0.000
X-type references/application stock	976	0.91	1.07	584	1.33	1.40	0.000
X-type references/claims	976	0.06	0.08	584	0.08	0.10	0.000
impact factor of scientific literature	976	1.71	3.26	584	0.54	1.50	0.000
share granted applications	976	0.04	0.15	584	0.04	0.14	0.944
share opposed patents	976	0.01	0.05	584	0.001	0.01	0.002

Note: The statistics refer to the first 16 quarters after founding. # The statistics are given for companies with at least one patent application. For the dummy variables the last column shows the two-sample test of proportion.

Table 2: Descriptive Statistics of Time-Invariant Control Variables

	VC financed firms			Non VC financed firms			Diff. mean
Variable	Obs	Mean	St. Dev.	Obs	Mean	St. Dev.	p-value
technological capabilities	87	2.16	1.31	103	1.69	1.04	0.006
years to market entry	87	5.37	3.88	103	3.96	3.57	0.009
spin-out science (0/1)	87	0.61	-	103	0.53	-	0.297
spin-out company (0/1)	87	0.06	-	103	0.12	-	0.156
independently founded (0/1)	87	0.33	-	103	0.35	-	0.793
German company (0/1)	87	0.63	-	103	0.59	-	0.574
founded ‘90 - ’95 (0/1)	87	0.09	-	103	0.14	-	0.345
founded ‘96 - ‘99 (0/1)	87	0.39	-	103	0.23	-	0.019
founded ‘00 - ’02 (0/1)	87	0.46	-	103	0.49	-	0.627
founded ‘03 - ‘05 (0/1)	87	0.06	-	103	0.14	-	0.073

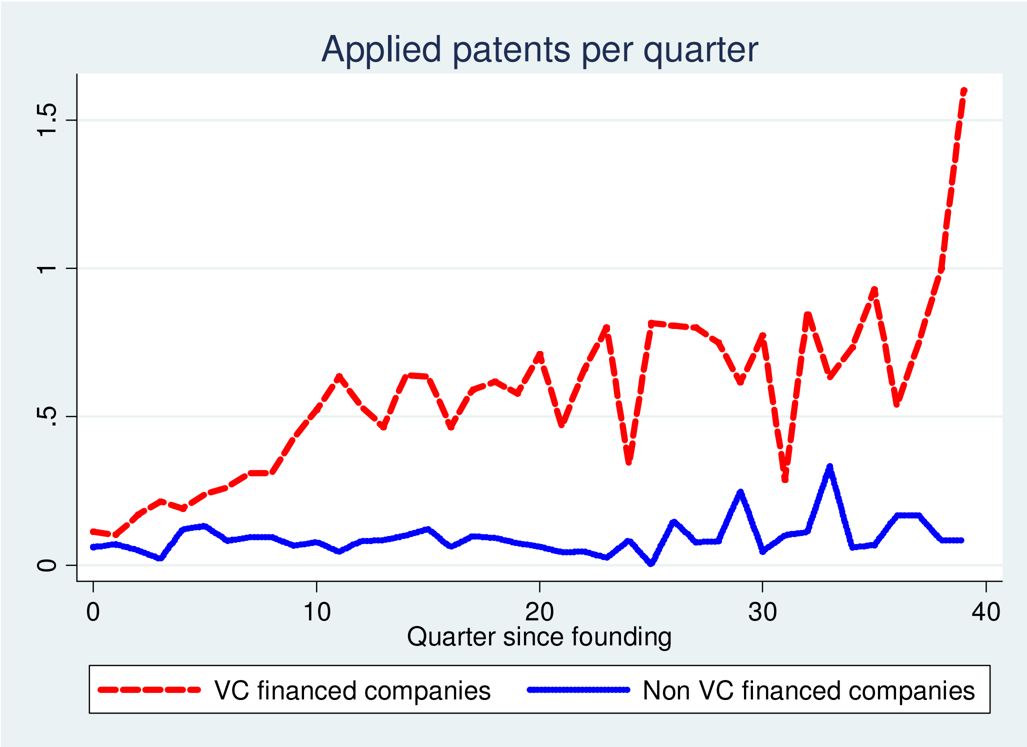
Note: These variables are time-invariant, therefore one observation is available per company. For the dummy variables the last column shows the two-sample test of proportion.

Table 3: Cox-Hazard Models

Variable	(1)	(2)	(3)	(4)	(5)	(6)
application (0/1)	0.597**	0.042				
	(0.240)	(0.381)				
ln application stock		0.396**	0.413***	0.601***	0.537***	0.564***
		(0.200)	(0.126)	(0.176)	(0.154)	(0.152)
average number of citations	0.037*	0.041*	0.042**	0.038*	0.039*	
	(0.021)	(0.021)	(0.020)	(0.020)	(0.020)	
X-type references/appl. stock				-0.286*	-0.271*	-0.276*
				(0.166)	(0.164)	(0.164)
impact factor of scientific lit.				-0.076	-0.065	-0.065
				(0.116)	(0.114)	(0.115)
grant (0/1)				-0.302		
				(0.459)		
share granted applications					0.035	0.007
					(0.956)	(0.969)
share opposed patents				9.369**	8.401**	8.676**
				(3.726)	(3.581)	(3.585)
technical capabilities	0.219**	0.187**	0.186**	0.173**	0.172**	0.167*
	(0.086)	(0.087)	(0.086)	(0.087)	(0.088)	(0.087)
years to market entry	0.0449	0.047	0.047	0.052*	0.0514*	0.0504*
	(0.029)	(0.029)	(0.029)	(0.030)	(0.031)	(0.030)
early stage financings	0.0011**	0.0012**	0.0012**	0.0013**	0.0013**	0.0013**
	(0.006)	(0.0006)	(0.006)	(0.0006)	(0.0006)	(0.0006)
spin-out science	-0.0932	-0.131	-0.132	-0.165	-0.185	-0.216
	(0.248)	(0.250)	(0.250)	(0.256)	(0.257)	(0.253)
spin-out company	-0.399	-0.522	-0.526	-0.568	-0.585	-0.629
	(0.491)	(0.496)	(0.494)	(0.495)	(0.497)	(0.495)
founded '90 - '95	-0.459	-0.480	-0.483	-0.720	-0.715	-0.680
	(0.454)	(0.459)	(0.458)	(0.496)	(0.495)	(0.495)
founded '96 - '99	0.191	0.168	0.165	0.158	0.123	0.165
	(0.253)	(0.254)	(0.252)	(0.260)	(0.256)	(0.253)
founded '03 - '05	0.132	0.163	0.167	0.146	0.135	0.113
	(0.497)	(0.498)	(0.497)	(0.498)	(0.499)	(0.499)
German company	-0.110	-0.099	-0.097	-0.168	-0.172	-0.155
	(0.276)	(0.278)	(0.277)	(0.284)	(0.286)	(0.285)
Observations	3001	3001	3001	3001	3001	3001
Chi2	33.6199	37.3574	37.3451	45.1678	44.7227	42.2897
log likelihood	-406.9	-405.0	-405.0	-401.1	-401.3	-402.5

Note: Standard errors in parentheses. Coefficients, not hazard ratios shown.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 1: Quarterly Patent Applications by Company Type



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Online Appendix

Appendix 1. Robustness Check Selection

We compiled an additional data set to check for the robustness of our results with regard to a possible selection bias. This calculation is based on information on all German biotechnology companies that were founded after 1990. The information is obtained from Creditreform, Germany's largest credit rating agency. We restricted the sample to biotechnology companies with a focus on human biotechnology and excluded companies that are only active as suppliers, service companies or consultants. The Creditreform database contains basic company level data such as number of employees, legal form, industry and ownership structure, and other information usually gathered by credit rating agencies.

We identified 543 biotechnology companies, of which 142 had already gone out of business. Companies are deemed to go out of business if they end their activities involuntarily (bankruptcy) or voluntarily. Companies that were taken over by other companies are not counted as closures if their legal entity was not deleted. For over 95% of the closed companies, going out of business was not related to a take-over. Whether a company received VC investment or not is established from the ownership structure information in the dataset. 112 companies in the sample received VC financing; 37 of these are already out of business. 61% of the VC financed companies had applied for at least one patent at the time of financing. Companies with applications have, on average, applied for 4.3 patents (median 3) at the time of financing. The mean size at foundation is 8.9 employees (median 2).

Table A1 displays the results from the time-to-VC financing models. A time period comprises six months. Model (1) and (3) include only companies that are still alive whereas models (2) and (4) report the results for the companies that went out of business. The results suggest that the patenting activities (at least one patent in models (1) and (2) as well as the application stock in models (3) and (4)) reduce the time to first VC financing for companies that are still alive as well as for companies that have already failed. The similar results for both company groups give us confidence that the results of our main data set are not distorted by selection bias.

Table A1: Hazard Models – Alternative Data Source

	(1)	(2)	(3)	(4)
Model	Cox	Cox	Cox	Cox
Sample	alive	dead	alive	dead
application (0/1)	1.810***	1.208***		
	(0.249)	(0.351)		
ln application stock			0.771***	1.162***
			(0.115)	(0.239)
ln employees	0.053	0.032	-0.023	-0.011
	(0.088)	(0.146)	(0.091)	(0.144)
early stage financings	0.002***	0.003***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
founded '90 - '95	-0.763	-1.619*	-0.680	-1.451*
	(0.556)	(0.849)	(0.558)	(0.837)
founded '00 - '04	-0.098	0.396	0.051	0.328
	(0.285)	(0.405)	(0.288)	(0.408)
Observations	4744	1409	4744	1409
Firms	401	142	401	142
Pseudo R-squared	0.11	0.13	0.09	0.16
Chi2	95.58	45.99	77.00	54.71
Log likelihood	-372.3	-148.3	-381.6	-143.9

Note: Standard errors in parentheses. Coefficients not hazard ratios shown * significant at 10%; ** significant at 5%; *** significant at 1%.