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

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Abstract

This paper investigates how patents held by new ventures affect their ability to attract venture capital (VC) financing. We argue that investors are faced with great uncertainty and therefore rely on patents as signals when they try 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 a hazard rate analysis, we find that in the presence of patents, VC financing occurs earlier. Our results suggest that VCs pay attention to patent quality, financing ventures with high quality patents faster. Revealed quality has a mixed effect. Whereas we find that patent oppositions increase the likelihood of receiving VC, we do not find that the ultimate grant decision spurs VC financing. Presumably 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.

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

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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 not directly observable, external parties have to base their decision on observable attributes that are presumably correlated with the unobserved quality of the venture (Stuart et al. 1999). Hence, observable characteristics may serve as signals when the prospects of young companies are being evaluated.

Prior studies investigated the impact of various signals on external parties' appraisal of a venture. These include founder history (e.g., Eisenhardt and Schoonhoven 1990, Burton et al. 2002) and affiliations with prominent partners (e.g., Carter et al. 1998, Stuart et al. 1999, Gulati and Higgins 2003, Hsu 2006). In this research we examine the role of patents as quality signals for obtaining venture capital (VC) financing. Patents help companies to appropriate returns from investment in R&D, facilitate the licensing of technologies (e.g., Gans et al. 2002, Häussler 2007) and shorten time to IPO (Stuart et al. 1999). Previous literature also showed 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 2007), on VC valuation (Lerner 1994) and on the likelihood of attracting a prominent VC investor (Hsu and Ziedonis 2007).

Our study extends this literature in an important manner, since these previous studies (1) only focus on the impact of patenting on companies that had already obtained VC financing and (2) do not account for the "quality" of patents. By analyzing the informational content of patents, we are able to investigate the signal-interpreting expertise of the VCs. This is an aspect of signaling that has not been studied, 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).

To test our conjectures about signaling, we draw upon a unique survey dataset of 190 VC-seeking German and British biotechnology companies founded after 1989. For these companies, we have identified all patents filed at the European Patent Office (EPO). We provide an in-depth analysis of references contained in the search reports of these EPO patents. Contrary to patent references from the US Patent and Trademark Office (USPTO) which are largely listed in the application document, EPO references in search reports are fully controlled by the examiner and therefore more objective. We use these references to compute citation counts and to identify patents that lack novelty and inventive step. We complement our empirical analysis with interview evidence from VCs.

Overall, our empirical analysis demonstrates that companies' patenting activities have consistent and cogent effects on the timing of VC financing. Having at least one patent application increases the hazard of obtaining VC financing by 97%. 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 occur after the investment decision has been made, indicating that investors are well capable of distinguishing between patented inventions of low and high quality. Conversely, our results do not suggest that patent indicators induced by the patent examiner, e.g., novelty assessment, influence VCs' investment decision. Investigating subsequent patent events, we find that opposition events are taken as positive signals by VCs. Apparently, VCs prefer to finance endeavors with high commercial potential, where oppositions are more likely to occur. Presumably 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.

Our study makes a number of contributions. First, we extend the literature by providing evidence that patents help to reduce informational asymmetries in the investor-entrepreneur relationship. We argue that patents exert a signaling function which helps to overcome the constraining effects of ventures' liabilities of newness (Stinchcombe 1965). While recent research has shown that patenting activity influences investor valuation (Hsu and Ziedonis 2007, Mann and Sager 2007, Baum and Silverman 2004), we show that patents are also 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 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 more importantly, into the interpretation ability of the receiver, i.e., investor. We find that VCs are capable of detecting high-quality patent applications long before that assessment is confirmed by citations or examination outcomes. This enhances the effectiveness of patents as signals. This result also suggests that VCs often make well grounded decisions. 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 learn that VCs differentiate between the news values of subsequent patent events. Whereas patent grants do not show an additional effect, presumably due to VCs' good ability to interpret the application document, 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. Here we extend previous literature, which focuses on the signaling value of patent oppositions for stock market value (Harhoff, Häussler, Schirge 2007), by providing evidence for the value of oppositions as a signal for the VC financing decision.

The second contribution this research makes is to add to the literature on the economic effect of patents. While patent protection comes at the social expense of enhanced market power and the potential blocking of technological developments (Heller and Eisenberg 1998), we show that patents support the market entry of entrepreneurial companies. Our research suggests that patents constitute an attractive signaling mechanism for ventures which helps to overcome the liabilities of newness and, in turn, increases the level of market competition.

Our results have important implications for policy-makers as well as for practitioners. This paper supports the notion that patents have an import effect in facilitating entry while at the same time providing incentives for innovation. This runs against the common wisdom that patents, while supporting innovation, do so at the cost of economic efficiency (Hall 2007). 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 the due diligence process.

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 signals is 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. 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. Patents may be considered such an accomplishment, signaling a company's technical abilities. The value of patents 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. 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

Following the contribution of Spence (1973), 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. 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). The independent evaluating character of the patent office gives 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 have been found to be linked to the stock market value of 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 when uncertainty pervades attempts to evaluate ventures.

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 based in the US (MacMillan 1985) and for VCs based in Germany (Brettel 2002). 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 patents as quality signals, we would like 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., Teece, 1998; Gans et al. 2002), increase the attractiveness of companies as acquisition targets (Cockburn and Wagner 2007) and enable VCs to recover a salvage value from failing companies. 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”.

Recently, a few scholars have shed light on some aspects of the role of patents for VC financing. Hsu and Ziedonis (2007) find a positive effect of patents on investor 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. Prominent partners also have a positive influence on valuation. 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 and pre-IPO financing defined as VC financing and private placements. Patent grants also have a positive, but smaller, effect.

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 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.

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: Once startups have filed patent applications, the likelihood of obtaining VC financing increases.

This hypothesis serves as the starting point of our evaluation. 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.

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 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.

We emphasize that VCs may be able to obtain a reasonably precise assessment of patent quality before that quality is revealed publicly. At some point in time, however, the patent system reveals some of the quality aspects of a patent application. This may occur when the search report is made public, when the patent is granted or 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. The examiner at the patent office writes a search report in which she includes her view on the underlying prior art and if this is likely to affect the novelty of the patent under examination. The patent examiner might be viewed as a third party certifier (see Stuart et al. 1999). While Harhoff, Hoisl and Webb (2005) demonstrate that there is low (insignificant) correlation between the patent examiner's opinion on novelty and the perceived patent value, the view of the patent examiner might be a valuable signal for the VC in the investment decision, since the patent examiner determines the scope of the patent and whether the patent is ultimately granted. Hence, the examiner's assessment should be related to the objective quality of the patent.

The company only benefits from patent protection if its application is ultimately granted. A grant means that the company's invention is sufficiently new to warrant protection. A granted patent should therefore have a higher value to a VC than a mere patent application. Thus we presume that a VC takes the grant decision into account when making its investment decision.

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 patents, we presume that a patent opposition signals the presence of a valuable technology to the VC. An opposition event may again cause doubts about the legal situation, or it may confirm that other parties have a commercial interest in the technology addressed in the patent.

A natural corollary to our second hypothesis is:

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 events considered for hypothesis 3 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. To investigate revealed quality we make use of the exact timing of the patent-related information. We include the information starting from the quarter in which the information was published.

3 Field of Study and Data

3.1 The Biotechnology Setting

The biotechnology industry provides an attractive setting to study the impact of patents on the VC financing decision for several reasons. First, the R&D process, by its very nature, is highly uncertain and complex. Companies have to undergo a hazardous cost-intensive and long-winding road with unanticipated relapses that obstruct the development of products. Thus, new biotechnology start-ups are particularly risky and uncertain investments.

Second, the development process requires the companies to access a range of human and capital resources. 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). However, as VCs are already involved in an early development stage of the company (Hsu and Ziedonis 2007), they face challenges in assessing the potential of their investment candidates. In such situations, the quality of the ventures cannot be observed directly.

Therefore investors have to look for signs or certifications that are thought to correlate with the underlying but unobservable quality.

Third, patenting activity is of particular importance in biotechnology. Cohen et al. (2000) have shown that patents provide the primary mechanism for protecting intellectual property. As such, biotechnology companies are often portrayed as engaging in patent races (Reynolds 2000). While some scholars highlight that patented technology is extremely difficult to circumvent (Lerner 1995), pointing to an anti-commons problem (Heller and Eisenberg 1998), recent research has suggested that the picture is more nuanced (Adelman and DeAngelis 2006). For example, Walsh et al. (2007) demonstrate that patents are not perceived to block development of biotechnological tools. Arguing in favor of patents as protection mechanisms, previous studies assert that patents facilitate the acquisition of complementary assets (Pisano 1990) and increase the likelihood of cooperative commercialization (Gans et al. 2002, Häussler 2007). Moreover, patents can confer intrinsic value due to the property right. Patents are a well known R&D output measure (Griliches 1990) and thus of particular importance in an industry in which R&D output is perceived to be highly correlated with the future value of companies. In addition, patents might signal that a technology has been developed to a certain stage, speeding up the process that leads to IPO (Stuart et al. 1999). Previous research shows that patent activities are an important signal at the stock market (Austin 1993; Harhoff, Häussler and Schirge 2007).

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. Compared to the US, the biotechnology industry in these two European countries started with a backlog of several years. Of particular note was a very restrictive Genetic Engineering Act in Germany, which impeded the development of the biotechnology industry until the Act was amended in the mid 90s. The German government has subsequently recognized the huge potential of biotechnology and introduced new technology policies which created a wave of biotechnology companies (Casper 2000, Haagen et al. 2007).

3.2 Data Sources

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 total possible sample of 346 German and 343 British core biotechnology companies was identified for the survey. 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 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.[1] 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. We test for non-response bias by comparing early and late responses (Armstrong and Overton 1977). A series of t-tests for independent samples failed to identify significant differences between early and late respondents, providing evidence that non-response bias is unlikely to be a problem in this study.

The second step was to compile all patents filed at the European Patent Office. We use information from an EPO patent database and from EPO search reports in order to account for the quantity and quality of company patents.

An issue we want to discuss is a possible sample selection bias. 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

[1] 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 example is companies that received a large amount of money, e.g., from business angels.

since 1991. We observe companies that have gone out of business and companies still in business. 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. While one can nearly never rule out selection bias, 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.

3.3 Variable Definitions

The dependent variable in our analysis is the time of first VC financing. It is a dummy variable equal to one if the company has already received VC financing and zero otherwise. The variable is measured in quarters. The last quarter observed in the data is 4/2005. A company is right-censored if it has not obtained VC financing by this date.

The independent variables can be divided into patent related information and other company characteristics. All patent related variables are measured on a quarterly basis. *Dummy application* is equal to one if the company has applied for at least one patent. We also investigate the influence of the number of patents a company has. *Application stock* is the cumulative number of patent applications. For the empirical analysis we use the natural logarithm of the stock variable. We increase the stock by one before calculating the logarithm in order not to lose observations for companies without patent applications.

A precise assessment of patent quality requires a time-consuming assessment by legal, technical and business experts. A rough proxy variable can be obtained by using citation measures. European patents undergo a particularly rigorous examination process; if patents receive citations from subsequent patents (i.e., in the search reports for these patents), then they are presumably particularly relevant and of high quality. A positive relationship between number of citations received and the private economic value of patents has been shown by Harhoff et al. (1999). Jaffe et al. (2000) 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. Thus, *Av. citations, incl. self* is defined as the total number of citations received divided by application stock. Citations are counted from the publication of the application for a period of three years. *Av. citations, excl. self* is defined analogously but excludes self citations. Since we use the citation measure as a proxy for anticipated patent quality, we include the full number of citations for each patent from the quarter of its application onwards.

X-Type references/application stock is the total number of x references divided by the application stock of the company. The European Patent Office classifies references into several categories. An x reference means that a claimed aspect of the invention cannot be considered novel and thus does not deserve patent protection. Applications with a high share of x references can be considered as weak applications or as applications with low novelty. This indicator differs from the average number of citations in that it is not related to economic patent value (Harhoff et al. 2006). As an alternative indicator for novelty we calculate the number of x references to the patent literature divided by the number of claims (*X-Type references / claims*). We divide by the number of claims because patents with more claims typically contain more references.

We also 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. It is therefore an indicator of the importance of the underlying literature. Impact factors have been determined for the 120 most important journals in the area of biotechnology according to the ISI Citation Index.[2] 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.

Dummy grant is equal to one if the company has at least one granted patent. *Dummy application no grant* is one if the company has made at least one application but no application has yet been granted. *Share grant* is the share of patent applications that have already been granted at the respective quarter.

[2] 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.

Share opposition gives 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. Even though only granted patents can receive an opposition, we divide by the application stock and not by the grant stock to get an indication of the share of current technological developments that are affected by the opposition.

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 was 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. *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 German Private Equity and Venture Capital Association (BVK 2007); data for the UK is taken from the British Private Equity and Venture Capital Association (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 after founding. 69% percent of observations within the sample 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 with a higher number of citations and a higher degree of 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. 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.

The timing of events is displayed in Figure 2. 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. The Figure suggests that 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 time period into quarter-year spells.

The hazard of obtaining VC financing is defined as:

$$h(t_i) = \frac{\text{prob. that company i receives VC financing in quarter t}}{\text{prob. that company i has not received VC financing until quarter t - 1}}$$

The hazard is 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 in the following form:

$$h(t_i) = h_0(t)*\exp(x_i\beta)$$

$h_0(t)$ is the baseline hazard, which is estimated non-parametrically and can take any form. The covariates x_j have a multiplicative influence on the baseline hazard, i.e. the covariates have a constant influence over time. Companies that have not received VC financing by the time of the survey are treated as right censored.

4.2 *Empirical Results*

4.2.1 Patents as Signals

The regression results shown in Table 3 shed light on whether companies with patents receive VC financing faster. We observe 190 companies for a total of 3001 quarters. Models 1 to 3 show the results of the Cox proportional hazard model, whereas model 4 is a parametric hazard model with a log-logistic distributional assumption.

The baseline model 1 includes only variables describing venture quality differences and environmental conditions. In models 2 to 4 we add the patent variables. Model 2 shows the result for the variable *Dummy application.* In the Cox model a positive coefficient indicates that companies receive VC financing faster, a negative coefficient means the opposite. The variable *dummy application* has a positive coefficient that is significant at the 1% level. Having at least one patent application increases the hazard of obtaining VC financing by 97%, which is a substantial increase. At the time of first VC financing 60% of companies have at least one application. The results of model 3 suggest that the number of patent applications matters as well. An increase of the application stock by one standard deviation increases the hazard of obtaining VC financing by 50%. We therefore find strong support for our hypothesis 1 that patent applications reduce the time to first VC financing.

In order to get a better understanding of the time reduction achieved by patents, we estimate a parametric hazard model with a log-logistic distributional assumption (model 4). The dependent variable of this model is the natural logarithm of time. In contrast to the Cox proportional hazard model, a positive coefficient indicates an increase in time to VC financing and a negative coefficient a reduction in time to VC financing. Companies with at least one patent application obtain VC financing on average 78% faster than companies without patents.

Companies with a larger portfolio of technical capabilities receive VC financing faster.[3] 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

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

result can be an indication that VCs target companies where they can make a large difference. However, the coefficient is not significant.

Our control for the supply side conditions in the VC market, *early stage financings*, has the expected 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.

We investigated whether patent applications have different influences in Germany and the UK. The interaction between *Dummy application* and *German company* turns out to be insignificant.[4] An interaction between *Dummy application* and the age of the company measured in quarters is also insignificant. This result is also an indication that the proportional hazard assumption of the Cox model is justified.

We calculated specifications with different sets of 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 identical results. 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 leads to identical results.

4.2.2 Anticipated Quality

The regressions in Table 4 shed light on the influence of the quality of patents for obtaining VC financing. We use the average number of citations received as a proxy for the economic value of the patents. The results of models 1 and 2 show that companies with more highly cited patents receive VC financing faster. For the size and the significance level of the effect it does not matter whether self citations are included or not. The coefficient of *ln application stock* decreases slightly when we control for the average number of citations but remains significant at the 1% level. The results provide support

[4] 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 entered the market turned out to be insignificant.

for our second hypothesis: Companies with patents of higher anticipated quality receive VC financing faster.

Our results show that VCs are able to differentiate between patent applications of higher and lower quality. Citations are a measure that VCs cannot observe at the time of their decision. Hence, VCs are able to independently judge the quality of the patents since they have a good knowledge about the industry. The results support the view of VCs as a “source of selection” of companies (Baum and Silverman 2004).

4.2.3 Revealed Quality

Several quality dimensions of a patent application can be deduced from the search report, in which a patent examiner includes her view on the novelty of the patent under examination. A higher value of the variable *x-type references/application stock* indicates a lower degree of novelty. Lower novelty decreases the time to VC financing, but the effect is only marginally significant at the 11% level. The alternative novelty variable x-*type references/claims* also shows a negative, but not significant, influence. Since novelty and the number of received citations can be correlated, we also estimate a specification including both factors (results not reported). We find that the influence of citations is not diminished by controlling for novelty. The science base of the patent application also has no significant influence. Companies with applications that refer to publications in more prestigious scientific journals do not receive VC financing faster.[5]

Results of Table 5 show whether subsequent patent events, i.e., grants and oppositions, have an influence on the financing decision. In column (1) we calculate separate effects for patent applications that have not yet resulted in a grant and for granted applications. The dummy variable indicating that a company has at least one grant has a higher coefficient and its influence is more precisely measured than the dummy variable indicating the pending status, but the difference between the coefficients is not significant (p-value of 27%). The results in column (2) point in a similar direction. The number of patent applications matters, but the share of applications that have already been granted has no

[5] 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.

additional influence. These results have three possible interpretations: First, grants often come very late in the life cycle of companies. VCs therefore know that they cannot base their investment decisions on grants. Second, a grant is very likely to occur. Companies with at least one application at the time of first VC financing have a median of three applications. If the average grant rate at the EPO of 66% is assumed, then the probability that no patent will be granted is only 3.6%. Presumably VCs take more of a portfolio perspective and thus attach less importance to each individual patent. Third, 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 on when VC financing is first granted.

Some companies apply for a patent at both the EPO and the USPTO. The USPTO is known to grant patents faster on average than the EPO. 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 (results not reported).

We also investigate the influence of oppositions. Companies receive VC financing faster if a higher share of their patent applications received an opposition from a third party. 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 evidence for hypothesis 3 is mixed, in that not all dimensions of revealed quality have an influence on the financing decision. We find a weak influence of information from the search report, no influence of grants and a strong influence of oppositions.

At this point we want to raise an issue that is worth discussing. 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 firms 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 29,000. A rational company will only patent if it sees a benefit in doing so. We therefore conclude that a patent application cannot be reduced to a mere indicator of the technological progress of a company.

4.3 Interview Evidence

Empirical work alone is 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 2007). Therefore, we have undertaken five in-depth interviews with VCs from Germany and the United Kingdom to complement our analysis. In selecting our interview partners we were interested in getting the views of different types of VCs. Therefore, we have interviewed investment managers of early stage, late stage and corporate VCs. 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 thing we learned from our interview partners is that *both* the protection and the quality signaling functions of patents are of great importance for the VC. 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 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 mathematical and therefore difficult for VCs to read. To overcome this, they use well-paid technical experts and patent lawyers to evaluate the patents. Overall, it is therefore not clear whether patent information reduces the costs of the due diligence process.

Third, our interviewees indicated that the VCs evaluate patents and related documents very carefully, although there are slight differences among VCs. One of our VCs gave us a list with 35 criteria on which a hired technology expert in the field of the biotechnology firm should base his evaluation of the patent portfolio. Another interviewee said that they have no standardized patent due diligence. When asking about the relevance of 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 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 on whether there is something valuable based on the patent 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 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. All in all, our interviews suggest that patents provide valuable information and help to reduce uncertainty by enabling the VC to better judge the quality of the technology.

5 Conclusion

5.1 Theoretical Implications

Our paper provides contributions to three 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), whether this results from selection or nurturing is left open. 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 2007, Mann and Sager 2007, Lerner 1994), we show that patents are already important for the financing decision.

We provide a contribution to a second strand, the signaling literature, which is closely connected to the entrepreneurship literature. The signaling literature is interested in observable attributes that help to reduce information asymmetries when directly observable measures of quality are not available (Spence 1984; Stuart, Hoang and Hybels 1999). In our paper, we demonstrate that patents act as quality signals in 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 patents and the ability of the VC to read signals. Using citation counts, we find that VCs are quite good at evaluating the quality of patents from as early as the application document. This result increases the importance of patents as quality signals rather than just binary signals. This finding is complemented by our interviews. These revealed 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. In addition, third party evaluations are of particular importance in the signaling literature (Stuart, Hoang and Hybels, 1999). In this context, the patent system is very helpful since it allows us to learn about third party evaluation of patents. It gives insights into the patent examiner’s evaluation inscribed in the search report and the novelty assessment for the final grant decision. It also provides some indication of whether the patent threatens the commercial potential of competitors, if we pay attention to oppositions. We find that an opposition is a very strong signal for the commercial potential of a company. Therefore, a patent opposition positively influences the probability of financing. In that respect we add to the findings of Harhoff, Häussler, and Schirge (2008), who document that the stock market reacts to patent oppositions. We only find a weakly significant effect (11%) that suggests the patent examiner evaluation impacts the financing decision of VCs. This might be explained by the very weak correlation between the patent examiner's evaluation and the commercial value of a patent (Harhoff, Hoisl, and Webb 2006). In addition, the ultimate grant decision appears not to have an effect on the financing decision. This might be explained by (1) the skewed distribution of the patent value (Harhoff, Scherer, and Vopel 1999), (2) the relative high grant rate of 66% at the European Patent Office, and (3) the importance of the patent portfolio in a VCs assessment, which reduces the meaning of a single patent.

Finally, we contribute to the literature on the economic effects of patents. Patents are often criticized for undermining competition by impeding market entry of new ventures. 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, speak against the competition suppressing view, by suggesting a pro-competitive role of patents. We posit that patents fulfill a role that goes beyond the traditional role of protecting from imitation. For start-ups patents act as quality signals. Patents have a social value if they allow better companies to signal their value and help them to obtain funding. Hence, patents have a pro-competitive role in that they foster innovation by facilitating the acquisition of external resources.

5.2 Practical Implications

Besides extending the literature, the results have important implications for practitioners and public policy. Our results show that patents are an effective mechanism to transfer information. As such, startup managers can use patents to overcome the "liability of newness". Our detailed analysis on how various patent metrics influence the VC investment decision provides some insights for companies interested in obtaining VC.

With regards to public policy, this study implies that the role patents fulfill has been completely underestimated. They reduce information asymmetries and positively influence market entry by startups. 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 to decrease the cost of evaluation and enable firms with high quality patents to receive financing faster.

5.3 Limitations and Future Research

One issue we want to raise is generalizability. 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) has suggested 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. However, Hall and Ziedonis (2001, 110) report that, for ventures in the semiconductor industry, one of the most important roles of patents appeared to be "securing capital from private investors in the startup phase".

Previous research has shown that affiliations with prominent partners are important quality signals (e.g., Stuart, Hoang and Hybels 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.

Furthermore, future research could identify if the investor's due diligence varies systematically with investor attributes, e.g., size, investment focus. 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 patents function as important signals for obtaining VC finance. It would also be interesting to know how costly it is for companies to send the signal, a question our analysis cannot answer.

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)
Dependent variable	hazard	hazard	hazard	hazard
Model	Cox	Cox	Cox	Cox
Sample	alive	dead	alive	dead
Dummy application	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
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%.

Tables and Figures

Table 1: Descriptive Statistics Patent Variables

	VC financed firms			Non VC financed firms		
Variable	Obs	Mean	St. Dev.	Obs	Mean	St. Dev.
Dummy application	1411	0.69	-	1595	0.37	-
Dummy grant	1411	0.09	-	1595	0.05	-
Application stock #	976	5.12	6.65	584	3.32	3.45
Av. citations, incl. self #	976	1.54	3.33	584	0.87	0.92
Av. citations, excl. self #	976	1.38	3.16	584	0.81	0.85
X-type references/ application stock #	976	0.91	1.07	584	1.33	1.40
X-type references/ claims #	976	0.06	0.08	584	0.08	0.10
Impact factor of scientific literature #	976	1.71	3.26	584	0.54	1.50
Share grant #	976	0.04	0.15	584	0.04	0.14
Share opposition #	976	0.01	0.05	584	0.001	0.01

Note: The statistics refer to the first 16 quarters after founding. # The statistics are given for companies with at least one patent application.

Table 2: Descriptive Statistics Control Variables

	VC financed firms			Non VC financed firms		
Variable	Obs	Mean	St. Dev.	Obs	Mean	St. Dev.
Technological capabilities	87	2.16	1.31	103	1.69	1.04
Years to market entry	87	5.37	3.88	103	3.96	3.57
Spin-out science	87	0.61	-	103	0.53	-
Spin-out company	87	0.06	-	103	0.12	-
Independently founded	87	0.33	-	103	0.35	-
German company	87	0.63	-	103	0.59	-
Founded ‘90 - ’95	87	0.09	-	103	0.14	-
Founded ‘96 - ‘99	87	0.39	-	103	0.23	-
Founded ‘00 - ’02	87	0.46	-	103	0.49	-
Founded ‘03 - ‘05	87	0.06	-	103	0.14	-

Note: These variables are time-invariant, therefore one observation is available per company.

Table 3: Hazard Models – Patents as Signals

	(1)	(2)	(3)	(4)
Dependent variable	hazard	hazard	hazard	log time
Model	Cox	Cox	Cox	log-logistic
Dummy application		0.677***		-0.776**
		(0.233)		(0.344)
Ln application stock			0.441***	
			(0.123)	
Technical capabilities	0.232***	0.213**	0.182**	-0.464***
	(0.085)	(0.086)	(0.086)	(0.137)
Years to market entry	0.053*	0.043	0.046	-0.077*
	(0.028)	(0.029)	(0.029)	(0.043)
Early stage financings	0.001**	0.001**	0.001**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
Spin-out science	-0.081	-0.125	-0.164	0.369
	(0.243)	(0.245)	(0.247)	(0.369)
Spin-out company	-0.439	-0.434	-0.572	0.857
	(0.488)	(0.489)	(0.492)	(0.653)
Founded '90 - '95	-0.473	-0.416	-0.444	1.241**
	(0.456)	(0.453)	(0.458)	(0.616)
Founded '96 - '99	0.136	0.237	0.206	-0.106
	(0.247)	(0.250)	(0.249)	(0.369)
Founded '03 - '05	0.223	0.103	0.146	-0.387
	(0.493)	(0.497)	(0.496)	(0.643)
German company	-0.023	-0.099	-0.080	0.001
	(0.274)	(0.276)	(0.276)	(0.404)
Observations	3001	3001	3001	3001
Pseudo R-squared	0.03	0.04	0.04	
Chi2	22.8	31.5	34.6	37.54
Log likelihood	-412.2	-407.9	-406.3	-238.8

Note: Standard errors in parentheses. Coefficients not hazard ratios shown. Gamma for log-logistic: 1.10 * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Hazard Models – Quality of Patents I

	(1)	(2)	(3)	(4)	(5)
Dependent variable	hazard	hazard	hazard	hazard	hazard
Model	Cox	Cox	Cox	Cox	Cox
Ln application stock	0.414***	0.415***	0.535***	0.498***	0.429***
	(0.126)	(0.126)	(0.134)	(0.132)	(0.130)
Av. citations, incl. self	0.042**				
	(0.020)				
Av. citations, excl. self		0.043**			
		(0.021)			
X-type references/appl. stock			-0.252+		
			(0.158)		
X-type references/claims				-2.343	
				(2.135)	
Impact factor of scientific lit.					0.021
					(0.066)
Technical capabilities	0.187**	0.187**	0.184**	0.177**	0.183**
	(0.086)	(0.086)	(0.086)	(0.086)	(0.086)
Years to market entry	0.047	0.047	0.047	0.046	0.044
	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)
Early stage financings	0.001**	0.001**	0.001**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Spin-out science	-0.131	-0.132	-0.208	-0.198	-0.174
	(0.250)	(0.250)	(0.248)	(0.248)	(0.249)
Spin-out company	-0.526	-0.528	-0.600	-0.559	-0.562
	(0.494)	(0.494)	(0.492)	(0.492)	(0.493)
Founded '90 - '95	-0.484	-0.482	-0.512	-0.478	-0.455
	(0.458)	(0.458)	(0.464)	(0.462)	(0.459)
Founded '96 - '99	0.164	0.164	0.175	0.192	0.208
	(0.252)	(0.252)	(0.251)	(0.249)	(0.249)
Founded '03 - '05	0.167	0.165	0.126	0.124	0.147
	(0.497)	(0.496)	(0.499)	(0.498)	(0.497)
German company	-0.096	-0.097	-0.106	-0.093	-0.083
	(0.277)	(0.277)	(0.278)	(0.277)	(0.277)
Observations	3001	3001	3001	3001	3001
Pseudo R-squared	0.04	0.04	0.04	0.04	0.04
Chi2	37.3	37.3	37.7	36.0	34.7
Log likelihood	-405.0	-405.0	-404.8	-405.6	-406.3

Note: Standard errors in parentheses. Coefficients not hazard ratios shown, + significant at 11%, * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Hazard Models – Quality of Patents II

	(1)	(2)	(3)
Dependent variable	hazard	hazard	hazard
Model	Cox	Cox	Cox
Dummy application no grant	0.617**		
	(0.241)		
Dummy grant	1.016***		
	(0.380)		
Ln application stock		0.430***	0.431***
		(0.127)	(0.125)
Share grant		0.333	
		(0.824)	
Share oppositions			8.452**
			-3.422
Technical capabilities	0.204**	0.184**	0.164*
	(0.086)	(0.086)	(0.087)
Years to market entry	0.044	0.045	0.045
	(0.029)	(0.029)	(0.029)
Early stage financings	0.001**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)
Spin-out science	-0.165	-0.178	-0.190
	(0.248)	(0.249)	(0.247)
Spin-out company	-0.486	-0.587	-0.575
	(0.493)	(0.495)	(0.492)
Founded '90 - '95	-0.423	-0.443	-0.618
	(0.454)	(0.457)	(0.485)
Founded '96 - '99	0.194	0.193	0.203
	(0.252)	(0.250)	(0.249)
Founded '03 - '05	0.087	0.132	0.136
	(0.498)	(0.498)	(0.496)
German company	-0.114	-0.095	-0.140
	(0.276)	(0.279)	(0.281)
Observations	3001	3001	3001
Pseudo R-squared	0.04	0.04	0.05
Chi2	32.6	34.8	38.8
Log likelihood	-407.3	-406.3	-404.3

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

Figure 1: Applied Patents per Quarter

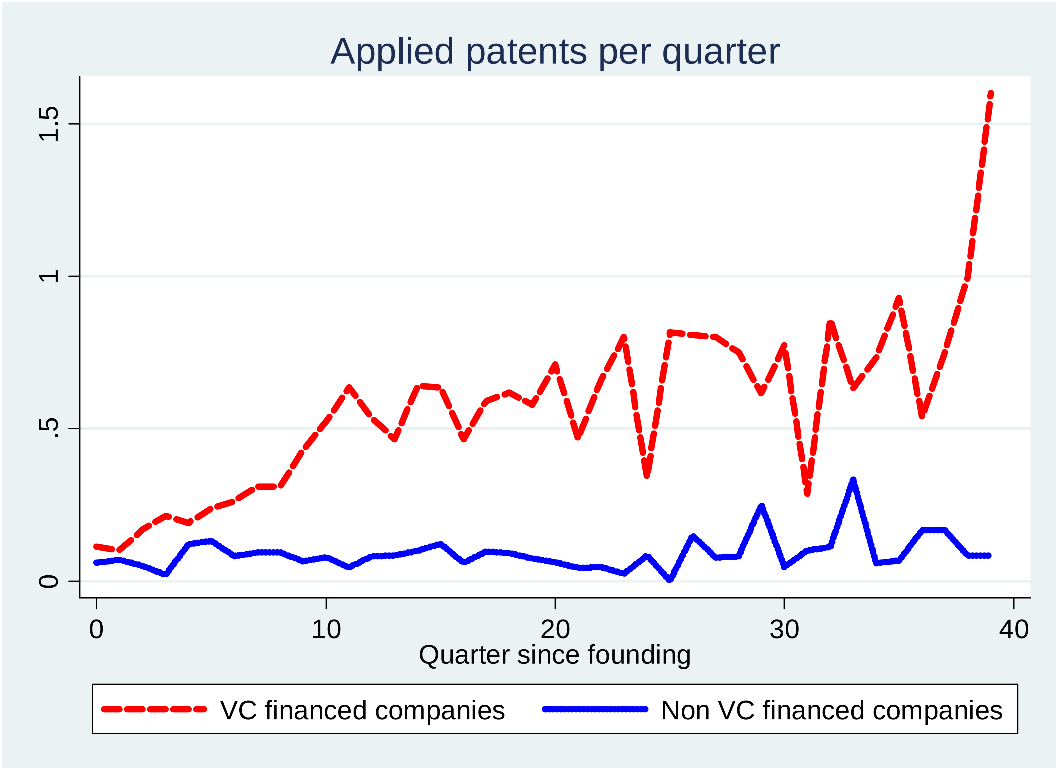
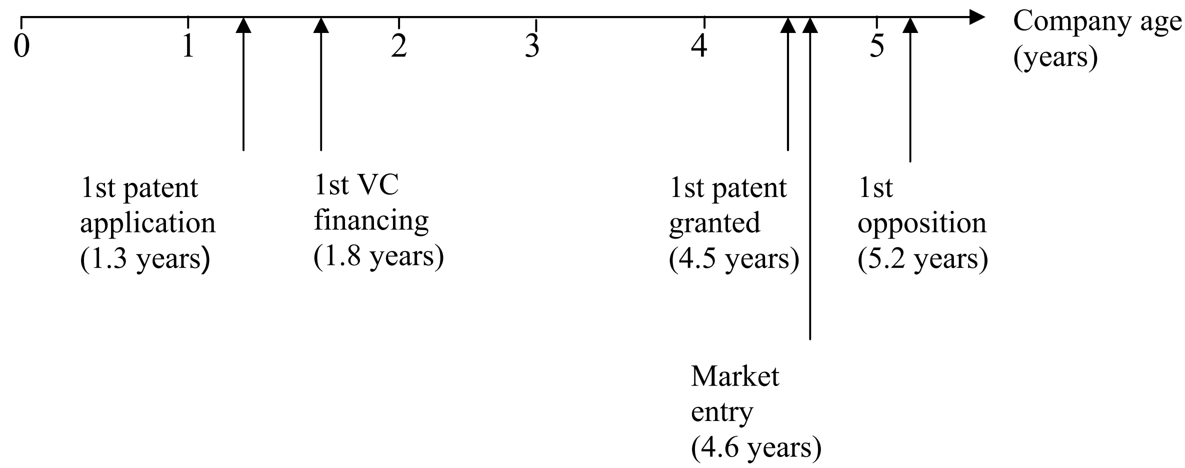


Figure 2: Timing of Events



Note: Average number of years given in parentheses.

References

Adelman, D.E., K.L. DeAngelis. 2006. Patent metrics: The mismeasure of innovation in the biotech patent debate. *Arizona Legal Studies Discussion Paper* No. 06-10.

Amit, R., L., Glosten, E. Muller. 1990. Entrepreneurial ability, venture investments, and risk sharing. *Management Science* **36** 1232-1245.

Anand, B.N., M.J. Piskorski 2000. Resources, Power and Prestige: Formulation of Structural Inequality in Social Exchange Networks. Harvard Business School Working paper.

Anderson, P. 1999. Venture capital dynamics and the creation of variation through entrepreneurship. In: Baum J.A., McKelvey, B. (eds), *Variation in Organization Science: In Honor of Donald T. Campbell*. Sage, Thousand Oaks, CA, pp. 137-153.

Armstrong, J.B., T.S. Overton. 1977. Estimating Non-reponse bias in mail surveys. *Journal of Marketing Research* **14** 396-402.

Austin, D.H. 1993. An event study approach to measuring innovative output: The case of biotechnology. *American Economic Review* **83** 253-258.

Baum, J.A.., B.S. Silverman. 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. *Journal of Business Venturing* **19** 411-436

Brettel, M. 2002. Entscheidungskriterien von Venture Capitalists, Eine Empirische Analyse im internationalen Vergleich. *DBW* **62** 305-325.

Burton, M.D., J. Sorensen, C. Beckman. 2002. Coming from good stock: Career histories and new venture formation. *Research in the Sociology of Organizations* **19** 229-262.

BVCA. 2007. Report on Investment Activity 2006. British Private Equity and Venture Capital Association. London. UK.

BVK. 2007. BVK Statistik. Das Jahr 2006 in Zahlen. German Private Equity and Venture Capital Association. Berlin. Germany. several issues.

Carter, R.B., F.H. Dark, A.K. Singh. 1998. Underwriter reputation, initial returns and long run performance of IPO stocks. *Journal of Finance* **53** 285-311.

Casper, S. 2000. Institutional adaptiveness, technology policy, and the diffusion of new business models: The case of German biotechnology. *Organization Studies* **21**(5) 887-914.

Casper, S., R. Whitley. 2004. Managing competences in entrepreneurial technology firms: A comparative institutional analysis of Germany, Sweden and the UK. *Research Policy* **33** 89-106.

Cockburn, I., M. MacGarvie. 2007. Patents, Thickets and the Financing of Early-Stage Firms: Evidence from the Software Industry, *NBER Discussion Paper*. No. 13644.

Cockburn, I., S. Wagner. 2007. Patents and the Survival of Internet-related IPOs, *NBER Discussion Paper*. No. 13146.

Cohen, W.M., R.R. Nelson, J.P.Walsh. 2000. Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or Not), *NBER DP No. 7552*.

Eisenhardt, K.M., C.B. Schoonhoven. 1990. Organizational growth: Linking founding team, strategy, environment, and growth among U.S. semiconductor ventures, 1978-1988. *Administrative Science Quarterly* **35** 504-529.

Freeman, J.H. 1999. Venture Capital as an Economy of Time. R. Leenders, S. Gabbay, eds. *Corporate Social Capital*, Kluwer, Boston, MA, 460–482.

Gans, J. S., Hsu, D. H. and Stern, S. (2002), When does start-up innovation spur the gale of creative destruction?. *RAND Journal of Economics* **33** 571-586

Griliches, Z. 1990. Patent statistics as economic indicators: A survey. *Journal of Economic Literature* **28** 1661-1707.

Gulati, R., M.C. Higgins. 2003. Which ties matter when? The contingent effects of interorganizational partnership on IPO success. *Strategic Management Journal* **24** 127-144.

Haagen, F., C. Häussler, D. Harhoff, G. Murray. 2007. *Finding the path to success: The structure and strategies of British and German biotechnology firms*. LMU: Munich.

Häussler, C., D. Harhoff, M. Schirge. 2007. Stock market reactions to patent oppositions in biotechnology and pharmaceutical. Working Paper.

Häussler, C. 2007. The determinants of cooperative commercialization in German and British biotechnology. Working Paper.

Hall, B.H. 2007. Patents and innovation (and competition). in: OECD (eds.) Competition, patents and innovation. Directorate for financial and enterprise affairs, Competition committee. 243-251

Hall, J., C. Hofer. 1993. Venture capitalists' decision criteria in new venture evaluation. J*ournal of Business Venturing* **8** 25-42.

Hall, B.H., G. Thoma, S. Torrisi. 2007. The market value of patents and R&D: Evidence from European firms. *NBER Working Papers* 13426.

Hall, B.H., R.H. Ziedonis, R. 2001. The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995. *RAND Journal of Economics* **32** 101-128

Harhoff, D., K. Hoisl, C. Webb. 2006. European patent citations – How to count and how to interpret them, mimeo.

Harhoff, D., F. Narin, F.M. Scherer, K. Vopel. 1999. Citation frequency and the value of patented inventions. *Review of Economics and Statistics* **81** 511-515.

Harhoff, D., M. Reitzig. 2004. Determinants of opposition against EPO patent grants – The case of biotechnology and pharmaceuticals. *International Journal of Industrial Organization* **22** 443-480.

Hayes, D.L. 1999. What the general intellectual property practitioner should know about patenting business methods. *Computer Lawyer* **16** 3-18.

Heller, M.A., R.S. Eisenberg. 1998. Can patents deter innovation? The anticommons in biomedical research. *Science* 280 698-701.

Hellmann, T. and Puri, M. (2000), The Interaction Between Product Market and Financing Strategy: The Role of Venture Capital, *Review of Financial Studies* **13** 959-984

Heil, O., T.S. Robertson. 1991. Toward a theory of competitive market signalling: A research agenda. *Strategic Management Journal* **12** 403-418.

Hsu, D.H. 2006. Venture capitalists and cooperative start-up commercialization strategy. *Management Science* **52**(2) 204-219.

Hsu, D., R.H. Ziedonis. 2007. Patents as quality signals for entrepreneurial ventures, mimeo.

Jaffe, A.B., M. Trajtenberg, M. Fogarty. 2000. Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors, American Economic Review, Papers and Proceedings, 90, 215-218

Kortum, S., J. Lerner. 2000. Assessing the contribution of venture capital to innovation. *RAND Journal of Economics* **31** 674-692

Lanjouw, J. O., M. Schankerman. 2004. Patent quality and research productivity: Measuring innovation with multiple indicators. *Economic Journal* **114** 441-465.

Lemley, M.A. 2000. Reconceiving patents in the age of venture capital. *Journal of Small and Emerging Business Law* **4** 137-148.

Lemley, M.A. 2001. Rational ignorance at the patent office, ***95*** *Northwestern University of Law Review* 1495.

Lerner, J. 1994. The importance of patent scope: an empirical analysis. *RAND Journal of Economics* **25** 319-333.

Long, C. 2002. Patent signals. *University of Chicago Law Review* **69** 625-679.

MacMillan, I. C., R. Siegel, P.N. Subbanarasimha. 1985. Criteria used by venture capitalists to evaluate new venture proposals. *Journal of Business Venturing* **1** 119-128.

MacMillan, I.C., L. Zemann, P.N. Subbanarasimha. 1987. Criteria distinguishing successful from unsuccessful ventures in the venture screening process. *Journal of Business Venturing* **2**, 123-137.

Mann, R.J. 2005. Do patents facilitate financing in the software industry?, Texas Law Review **83** 961-1030

Mann, R.J., T.W. Sager. 2007. Patents, venture capital, and software start-ups. *Research Policy* **36** 193-208.

Ndofor, H.A., E. Levitas. 2004. Signalling the Strategic Value of Knowledge. *Journal of Management* **30** 685-702.

OECD 2005. *A framework for biotechnology statistics*. OECD, Paris.

Pisano, G.P. 1990. The R&D boundaries of the firm: An empirical analysis. *Administrative Science Quarterly* **35** 153-176.

Reynolds, T. 2000. Gene patent race speeds ahead amid controversy. J*ournal of the National Cancer Institute* **92**(3)184-186

Shane, S., T. Stuart. 2002. Organizational endowments and the performance of university start-ups. *Management Science* **48** 154-170.

Shepherd, D.A., R. Ettenson, A. Crouch. 2000. New venture strategy and profitability: A venture capitalist's assessment. *Journal of Business Venturing* **17** 1-20.

Spence, M. 1973. Job market signaling. *Quarterly Journal of Economics* **87** 355-374.

Stinchcombe, A.L. 1965. Social Structure and Organizations. In: J.G. March (ed), *Handbook of Organizations*. Rand McNally: Chicago, pp. 142-193.

Stuart, T. E., H. Hoang, R.C. Hybels, R. C. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. *Administrative Science Quarterly* **44** 315-349.

Teece, D. 1998. Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets. *California Management Review* **40**(3) 55-79.

Walsh, J.P., W.M. Cohen, C. Cho. 2007. Where excludability matters: Material versus intellectual property in academic biomedical research. *Research Policy* **36**(8) 1184-1203.

Zott, C., Q.N. Huy. 2007. How entrepreneurs use symbolic management to acquire resources. *Administrative Science Quarterly* **52** 70-105.