How patenting informs VC investors
– the case of biotechnology

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ABSTRACT

This paper investigates how information generated during the patenting process affects the ability of start-ups to attract VC financing. We argue that not only patent applications should be considered, but that instead the entire examination process at the patent office generates valuable information. We test our hypotheses using a sample of biotechnology companies that seek venture capital. We find that the filing of patent applications is positively related to VC financing. Moreover, the examination process generates valuable information via search reports, citations and opposition procedures. The patenting process thus supports investors in updating their expectations regarding the quality of start-ups.

Keywords: venture capital, patenting, biotechnology

EFM classification code: 810, 800

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1 Introduction

The quality of intangible assets, such as know-how, business concepts and technologies is often more difficult to assess for outsiders than for insiders (Lev, 2001). To limit the perils of asymmetric information, economic agents need to communicate the quality of their projects or ventures to investors, potential partners and customers. We are particularly interested in how entrepreneurs communicate quality to venture capitalists (VCs) as external providers of equity, since VC financing is among the most important forms of financing for startups with high growth potential (Gompers and Lerner, 2004). Previous studies have shown that founders use a variety of mechanisms to signal quality, e.g., through forming an alliance with a prominent partner (Stuart, Hoang and Hybels, 1999), their industrial and entrepreneurial experience (Eisenhardt and Schoonhoven, 1990; Burton, Sorensen, and Beckman, 2002; Hsu, 2007), certain top management team characteristics (Zhang and Wiersema, 2009; Higgins and Gulati, 2006), or by choosing a particular board composition (Certo, 2003). Several authors have pointed out that technology-based startups may also want to utilize patent rights to communicate the quality of their underlying technologies to investors (e.g., Lemley, 2000; Mann and Sager, 2007; Hsu and Ziedonis, 2011, Conti et al., 2013). However, the relationship between the information generated by the patenting process and VC- financing has turned out to be a complex one. In our paper, we seek to contribute to the literature by presenting a framework in which the filing of a patent application is a signal which informs investors' expectations in terms of a venture's prospects. This aspect is not novel. But going beyond previous studies, we argue that subsequent processes at the patent office generate a flow of information which allows investors to update the initially formed expectations.

This emphasis on the emergence of new information sets our paper apart from the literature. So far, the literature in this field has mainly relied on a static interpretation of signaling theory

(Spence, 1973) as its conceptual foundation. We suggest complementing this perspective by taking subsequent information processes into account which allow dynamic updating of expectations formed by the initial signal.

Our theoretical discussion suggests that once companies reach a quality threshold (e.g., in the development of their invention), they can inform third parties about their quality by filing patent applications. VCs should be able to observe the actions of the patent applicant and draw conclusions from these actions. Explanatory power should therefore reside with the filing of applications. However, over time, the patent office will generate additional information pertaining to the quality of the patent. Moreover, if competitors oppose a patent grant, they may also become engaged in the information updating process. If information of this type affects VC financing in a major way, the entire patenting process appears relevant for our understanding of how information asymmetries are reduced over time.

Empirically, we utilize a unique survey dataset of 190 VC-seeking German and British biotechnology companies to test our theoretical reasoning. The survey provides us with comprehensive information on the technologies used by the startups, the riskiness of the ventures, the origin of the startups and their target market. We have also identified all patent applications filed and all patent grants received by these companies. The ventures in our sample predominantly file their applications at the European Patent Office (EPO). For these EPO patent applications, a particularly rich set of data is available, which contains information from search reports and from the EPO's opposition procedure. We assemble from these data sources a panel dataset and employ hazard-rate models with time-varying covariates to test our hypotheses. Our results suggest that the information generated in the course of the patenting process is indeed useful to VCs, and that positive information from the patent system significantly increases the hazard of VC financing, while negative information reduces it.

Following a 'pin factory' approach (see Borenstein, Farrell, and Jaffe, 1998), we complement our econometric results with information from interviews with VCs. Both our estimates and the qualitative results support our assumption that patent applications *per se* significantly impact VC financing. But subsequent information generated in the course of the patenting process also contributes to explaining VC financing events by allowing VCs to update the expectations formed initially. This is true even after controlling for the fact that VCs can anticipate information by carefully reading the patent application. Based on our theoretical framework and empirical results, we develop a number of implications and recommendations.

2 Theory and Hypotheses

2.1 Signals for Forming and Subsequent Information for Updating Expectations

Spence (2002, 407) characterizes signals as 'things one does that are visible and that are in part designed to communicate'. Signaling theory is based on the assumption that an effective signal is too costly for low-quality actors to pursue. In an equilibrium separating high- from low-quality actors, the signal allows outsiders to distinguish among different types of actors. In the context of new ventures seeking VC financing, effective signals would allow investors to distinguish accurately between new ventures in terms of quality and potential return on investment.

While empirical research on signaling has gained momentum in the past years, applying signaling theory as developed by Spence (1973) to real-world contexts has not been without difficulties. In particular, scholars in the field of strategic management and organization have noted that transferring signaling theory to the context of companies is challenging, since the ability to interpret signals may vary among actors (Connelly *et al.*, 2011) and agreement on a specific action that serves as a signal is hard to achieve (Holm, 1995). Recently, Montiel *et al.* (2012) have argued that the current literature typically does not take into account the institutional context and design through which signals are being diffused. By simply assuming that regulatory institutions work effectively, the literature has so far understated the need for appropriate institutional design.

Following this line of reasoning, we add the observation that the limitations of signaling theory become even more apparent when a specific action – which can be a signal – starts an institutional process. Signaling theory restricts its attention to the initial action or impulse and the sender of the signal, but may not give sufficient attention to subsequent mechanisms or institutional processes. These may be set in motion by the signal and tend to generate valuable information over time. In this paper, we outline a more comprehensive framework which takes both the initial signal and subsequent information generating processes into account. A signal is a helpful mechanism when the quality of an actor or project is not directly observable (Stuart et al., 1999). We argue that individuals form expectations based on a signal, but may still be under considerable uncertainty. But, as receivers gather more information about an issue, and this information might be triggered by the signal, they derive tighter estimates (Benoit and Dubra, 2011). Hence, the subsequent information results in an update of information and also tends to reduce uncertainty.[1] Bayes' Rule is frequently used to describe how individuals update their expectations or beliefs under uncertainty. Related research by behavioral economists has mainly investigated if and in which contexts individuals update their expectations according to Bayes' Rule (Rabin and Schrag, 1999; Charness and Levin, 2005; Charness et al., 2007) and which type of information triggers updating (Eil and Rao, 2011; Chambers and Healy, 2012). Our approach is to link the signaling theory with an updating process. This allows us to build a framework which is in line with various real life situations in which a signal is coupled with an information

[1] Note, if new information is inconsistent with the initially formed expectations or if information arriving over time is contradictory, the degree of uncertainty might rise again.

generating process initiated by the signal. Hence, our study emphasizes the dynamic accumulation of information over time, which may include ‘good’ and ‘bad’ news.

2.2 The Impact of Patents on VC financing Decisions

In our paper, we focus on information generated through the patenting process. A large strand of literature has investigated the traditional view of patents as an asset (see Hall and Harhoff, 2012). Long (2002) notes that the signaling function of patents has been overlooked in much of the earlier literature. Patents may indicate to outsiders 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).

A number of scholars have recently investigated the signaling role of patents for investors. Heeley *et al.* (2007) study the role of patents in IPO underpricing and argue that the role of patents in the reduction of information asymmetries is highly context-dependent. In a recent study, Hsu and Ziedonis (2013) report that patents have a positive effect on investors’ estimates of company value for a sample of VC-financed semiconductor startups. They find stronger effects for early funding rounds, where information asymmetry is more pronounced, and for companies which lack alternative means of signaling quality to investors. Furthermore, Conti et al. (2013) suggest a model including the preferences of external investors and show that this effects the founders’ investment in patents as signals. They outline that VCs take patent signals into account while angel investors do not.

Mann and Sager (2007) investigate correlations between the availability of patents and performance indicators. Without taking the timing of events into account, they generally find positive correlations. Baum and Silverman (2004) examine some of the selection criteria used by VCs and subsequent company performance and find a positive association between patent applications at the USPTO and pre-IPO financing. The effect of patent grants is also positive, but considerably smaller than that of patent applications. In comparison to these papers, our contribution contains a more detailed assessment of the information flow generated by the patent office and of its impact on a startup's first VC financing.

The existing literature has largely focused on companies with VC financing and on subsequent performance measures such as IPO or company profitability. Evidence on whether patents play a role in the initial selection decision of VCs is still scarce (for an exception see Cockburn and MacGarvie, 2009), and there is no empirical evidence as to which information from the patent system is taken into account. We aim to fill this gap and provide a detailed study on the role of the patent system as information provider; in doing so, we take the timing, type and source of information that is produced in the course of the patenting process into account.

We consider these aspects to be potentially important and in need of detailed analysis. Given that first-round financing is the starting point of the relationship between VCs and startups, it is of some importance to gain more insight into determinants of VC financing at this stage. At this particular point, VCs need to make their investment decisions under considerable uncertainty. Technology startups are typically hard to evaluate when they seek to obtain external financing for the first time. They do not have a track record that is indicative of their growth potential, they are often years away from first revenues, their assets are mostly intangible and they are plagued by a high failure rate. Moreover, VCs are often under considerable time pressure to make investment decisions. Information generated by patent filings and in the subsequent patenting process may therefore have considerable impact.

2.3 Sources of Information within the Patent System

The entrepreneur as initiator of the patenting process

By filing a patent application, an entrepreneur informs that the startup has matured sufficiently to invest in the protection of the technology it is developing for commercialization. We build on

Spence’s definition of a (productive) signal (1973, 1974, 2002) and argue that patent applications provide a mechanism to sort companies and, thus, are related to the presence of a separating equilibrium (Long, 2002; Hsu and Ziedonis, 2013; Conti et al., 2011). The criteria of patenting require an invention to be novel, inventive and capable of industrial application. The preparation of patent applications requires effort and time, since applicants have to follow strict guidelines and describe technical information in detail. In addition, patenting is quite costly as applicants have to cover fees, translation costs, as well as the fees of patent lawyers. We follow Conti et al. (2011) in arguing that the effort and cost involved in showing that an invention is in line with the patenting criteria, are a decreasing function of the quality of the underlying technology. Hence, the filing of a patent informs outsiders that an invention has been sufficiently developed to be described in a patent application. This conceptualization is similar to the educational model by Spence whereby the “employer reads the educational signal and predicts productivity with it.” (Spence 1974, 297).

Our empirical tests use data on patent applications at the EPO. This choice entails several important advantages for our empirical investigation. First, obtaining patent protection in Europe via the EPO is considerably more costly than at the USPTO (de Rassenfosse and van Pottelsberghe, 2007). Second, contrary to the USPTO, patent filings at the EPO involve a strong *ex ante* commitment by the patent applicant. There are no provisional patents at the EPO which can be easily amended later. Moreover, the possibility of filing continuations is more limited at the EPO than at the USPTO. Thus, the initial EPO filing commits the applicant more strongly than it would at the USPTO. This is important as it makes the signaling story more compelling: the applicant will only submit a filing once a minimum quality standard for the invention is reached. Third, at the EPO the examiner has greater decision-making authority than at the USPTO and may ultimately stop the examination process with a rejection of the application.

Fourth, by using data from the EPO we are able to observe unsuccessful applications that were never granted. Using USPTO data would not allow us to do that for longer periods. Finally, third parties can intervene and improve the quality of information to a greater extent than at other patent offices, thus contributing to the process of information aggregation (Graham and Harhoff, 2009). Hence, EPO data provide a particularly suitable institutional setting in which we can test our hypotheses

Patents not only reveal information, but are also attractive assets from the VC's perspective, since they allow the venture to exclude rivals from using the underlying product or technology. In addition, patents may facilitate the licensing of technology (e.g., Gans, Hsu, and Stern, 2008; Haeussler, 2011), giving the venture an additional source of revenue. Moreover, patents enable VCs to recover some salvage value from failing companies (Hall and Harhoff, 2012). 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. Our most basic hypothesis therefore postulates a relationship between the filing of a patent application and VC investment:

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

This hypothesis serves as the starting point of our evaluation. However, empirical evidence supporting this hypothesis is subject to various caveats. Harhoff *et al.* (1999), among others, have shown that patent value has a highly skewed distribution, with very few patents being highly valuable. Hence, the patent application *per se* may be of limited value for identifying particularly promising investment targets from a VC's perspective. A clearer picture may emerge, once further information provided by the patent examination process is considered in more detail. With the patent application, the entrepreneur sets in motion an institutionalized process at the patent office. The process itself provides a rich source of technological and commercial information, but also includes the assessment of various third parties which are called to intervene and allow investors to update their expectation about a company's prospects. In the following sections we will take a closer look at these sources of information, which have been neglected in the existing literature.

The patent office as information provider

While the filing of patent applications may provide a first indicator of the technological progress of a company, the information contained in patent filings is technical and often only accessible to individuals with considerable expertise (Heeley *et al*., 2007). However, the patent office may act as an independent and objective evaluator of the patent's quality. Information by the patent system is guided by official procedures and in this respect more objective and credible than the information provided by the entrepreneur. If VCs want to take 'official' information into account, they can use the information contained in the patent office's search reports, in which examiners include their view of the underlying prior art. Such search reports are made publicly available quite early on in the patenting process, typically 18 months after a patent has been filed for the first time. The assessment contained in the search report will affect the likelihood of a patent being granted and the scope of the patent, if it is granted. It may therefore affect the financing decision. Hence, we propose:

> *Hypothesis 2: The more favorable the evaluation of the startup's patents in the search reports, the shorter the time to receiving VC financing.*

Usually the search report is published together with the patent application 18 months after the priority date of the patent filing. However, in some cases there is a delay in the publication of the search report, which prolongs the period of uncertainty concerning the potential scope of the patent right. Delays in search reports occur for purely administrative reasons and are unrelated to the quality of the underlying invention. They mostly occur if the patent office experiences a shortage of examiners in a given technology field. We treat these delays as exogenous sources of variation in our data which can be used to identify the impact of information flows on VC financing. Unanticipated publication of a supplementary search report may occur as well; this report then contains additional prior art discovered in the course of examination and thus reduces the scope of the patent. Both types of events may be interpreted as a prolongation or even an increase in uncertainty, which is likely to reduce the attractiveness of a startup for a potential investor. This leads us to our third hypothesis:

> *Hypothesis 3: Delays in the publication of search reports and publication of additional search reports cause uncertainty and thus increase the time to receiving VC financing.*

Whereas the search report is available quite early, the final decision at the EPO to grant the patent is made about three to four years after the application has been filed. Clearly, a granted patent will be of higher value to a startup (and thus to a VC) than a mere patent application, as the grant offers higher certainty concerning the scope and strength of patent protection. However, if the VC has inspected the patent application and the search report and has come to a positive assessment with sufficient confidence, then the grant event may not include surprising information. To summarize, we expect that VCs will – on average - react favorably to grant decisions:

> *Hypothesis 4: The patent office's decision to grant a patent positively affects the likelihood of VC financing.*

Technology followers as an information source

The patenting process not only reveals the quality assessment by the patent office but also elicits valuable third-party information on the quality of a technology and on its commercial potential. Early information about the commercial value of a technology is of utmost importance for an investor in startups. While patent office examiners as insiders are highly qualified to judge the technical novelty and inventive step, technology followers and competing companies are most qualified to reveal information about the commercial value of a patented invention.

In our setting, technology followers, whom we identify via patent citations, build their inventions on the basis of a venture's patented technology. The presence of technology followers may provide indirect information about the attractiveness and potential of a patented invention. Previous literature has shown that the number of citations received is positively related to the economic and technological importance of patents (e.g., Jaffe, Trajtenberg, and Hall, 2005). Moreover, a large follower might even be considered to be an attractive licensing partner for the venture. VCs can make use of this information in order to decide to invest in a startup. Hence we expect that:

> *Hypothesis 5: Startups with highly cited patents and with patents cited by large technology followers receive VC financing faster than startups without such patents.*

The patent system also generates information on a patent's potential value through the opposition mechanism. In the first nine months after the grant of a patent, any third party can file an opposition at the EPO. Because engaging in an opposition procedure is costly, we expect that a technology has high commercial value, if a third party engages in opposition (Harhoff and Reitzig, 2004). However, an opposition also indicates that the patent faces a threat of revocation. 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). Overall, we conjecture that the aspect of value discovery in the opposition proceeding may be considerably more important than the threat of revocation. We come to this conclusion as it is well known that market-related information on the commercial potential of a venture is rarely available, though such information is highly relevant for investors. An opposition filed by a competitor thus informs the VC about commercial prospects and contributes to an updating of the expected value of the company and a reduction of uncertainty.[2] Second, proponents of the updating literature have shown that individuals react to a positive update of information stronger than to negative information (Eil and Rao, 2011; Camerer and Lovallo, 1999). This suggests that the positive impact of an opposition outweighs the negative impact.

Thus, we hypothesize:

Hypothesis 6: Startups whose patents are being opposed in post-grant reviews receive VC financing faster.

The patenting process generates detailed information about the technology of the potential portfolio company. This information can be of a positive or negative nature. We end our hypothesis development with a summary hypothesis of how we expect information generated in the course of the patenting process to be relevant to funding decisions:

[2] Consider the following stylized calculation. Let V be the value expectation at the outset if no opposition occurs. Let $V+\Delta V$ be the updated value expectation once opposition has occurred. But this value will only be captured in those cases in which the opposition is rejected or an amendment of the patent does not dilute its value. Denote this probability as p. Then, if $p\,(V+\Delta V) > V$, opposition has a positive impact on the investor's assessment of the patent. Clearly, it is an empirical question how often this condition will hold. But prior research on the value of patents (Harhoff et al. 2003, 1358) indicates that patents that have not be revoked in opposition are on average 11.2 times more valuable than comparable patents which never experienced opposition. As long as $p>1/11.2$, the above condition would hold. This simple calculation would thus lead us to argue that the positive effect of opposition should by far outweigh the negative impact on the VC's assessment.

Hypothesis 7: If the patent system reveals positive information regarding the patents of a startup, the time to receiving VC financing decreases. Conversely, if it discloses negative information, the respective time increases.

3 Data and Sample

3.1 Data and Sample Description

We study the role of information generated in the course of patenting for VC financing in the German and British biotechnology industry. Our database combines information from a 2006 company survey of German and British biotechnology companies with detailed information from patent offices. The relevant population comprises all companies active in the bio-pharmaceutical sector according to the OECD definition (OECD, 2005). We identified the population for our analysis using several industry sources (e.g., Bio Commerce, Dechema, Biocom, and regional databases like erbi and Bio-M) and internet resources. Companies not founded in one of the two countries, subsidiaries of foreign companies and companies offering solely services or supplying products without conducting research were excluded. The companies we identified were validated against our selection criteria with the help of biologists and biotechnologists. We ended up with a well-defined population of 346 German and 343 British core biotechnology companies that were at least one year old. We performed face-to-face interviews with 162 German and 118 British companies from this population using a preformatted and intensively tested questionnaire.[3]

The objective of the current analysis is to shed light on how information generated during the patenting process influences VC financing. Therefore, we excluded companies that – according

[3] The response rate in our survey was unusually high (47% for Germany, 34% for the UK). Nonetheless, we cannot fully control for selection effects.

to our survey responses – were not interested in VC financing, either because they did not want to give up control of the company or were not in need of VC financing.[4] Moreover, we only included 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. Of these, 87 received VC financing by the end of our sampling period, while 103 did not. For these 190 companies we compiled data on all patents filed at the EPO. We used information from an EPO patent database and from EPO search reports in order to operationalize the variables that measure the emergence of information which VCs have access to.[5]

3.2 Measures

Dependent variable

The dependent variable in our analysis is the time of first VC financing. The variable is measured on a quarterly basis. The last time period observed in the data is the second quarter of 2005. Data are right-censored if the company has not obtained VC financing by the date of the survey.

Independent variables

The main variables of interest in the regression specification contain patent-related information. All patent-related variables are measured on a quarterly basis. We use the variable *EPO application stock* to investigate the influence of the cumulative number of patent applications

[4] Companies might not be in need of VC, e.g., 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. Start-ups could also focus on business angels as investors in early stages of their development. While we excluded from our sample companies that did not intend to raise VC, the sample does include those companies that tried to obtain VC, but were not successful. Since we do not have information about the exact date when entrepreneurs decided to apply for VC, we cover the whole history of the venture in our analysis.

[5] Sample selection bias may pose a problem with relation to 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 may have severely affected our results, we compiled a second dataset with all German biotechnology companies founded since 1991. We observed companies that had gone out of business and companies still in business. Our results show that patent applications speed up the time to VC financing for companies that are still in the market as well as for companies that failed. This calculation attests that the effects of patent applications are robust in both samples. The results are available upon request from the authors.

filed at the EPO. This variable is time-variant, i.e., it measures the size of the application stock as it could be observed in each quarter. For the empirical analysis we use the natural logarithm of the stock variable, assuming that additional patent applications would have a decreasing marginal effect on the hazard rate (Hall, Thoma, and Torrisi, 2009). We increase the stock by one before calculating the logarithm in order not to lose observations for companies without patent applications.

The search reports published by the EPO provide the earliest official information about the quality of an application. The prior art references in the search report are allocated to one of several categories. An X-type reference means that a claim about a certain aspect of the invention cannot be considered novel or inventive, and that the claim may thus not deserve patent protection. A Y-type reference is also detrimental to the novelty requirement, but only calls a claim into question if it is combined with another Y reference. We compute the variable *share high proportion X/Y references* as the share of patent applications that receive a proportion of X and Y references, which is in the highest decile of all applications held by the companies included in our analysis. A Y reference is given half the weight of an X reference in our composite measure.[6] Applications with a high share of X and Y references can be considered to have low novelty or inventive step. Harhoff and Wagner (2009) show that such applications are particularly likely to be refused or withdrawn at the EPO.

Patent applications at the EPO are published 18 months after the priority date in a so-called A1 publication. The A1 document typically contains a search report. However, due to delays and backlogs at the patent office, the search report may not have been completed – in this case, the publication is made in an A2 document. The search report is then published later separately as a

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[6] Our computation of this variable builds on the fact that X-referenced documents question the inventive step of important features or incorporate already claimed features of the patent under investigation if taken alone, while Y-references documents question the inventive steps claimed in the patent document when combined with one or more documents (see EPO examination guides lines part B chapter X). We chose the upper decile of patents and classified these as particularly risky from an investor's point of view.

separate A3 document. Whether publication occurs with (A1) or without search report (A2) is not known *ex ante*, nor is the publication date of the A3 document. The publication of an A2 document therefore indicates a prolongation of the period during which external parties have no access to the patent office's assessment of novelty and inventive step of the application. Moreover, the EPO may decide at any time to issue an additional (supplementary) search report, the A4 document, if further prior art becomes available. Typically, A4 documents contain negative news, since the previously published search results were incomplete. The timing of an A4 document is not tied to any schedule, either. The publication of either A2 or A4 documents is therefore likely to be interpreted as negative news. During our sampling period, first publications were A1 documents in 64.4%, and A2 documents in 35.6% of all cases. Supplementary reports (A4) were issued in 10.5% of all cases.[7] The variable *separate search reports/application stock* gives the time-variant share of patent applications that are subject either to unexpected delays in the publication of the search report (A2) or to the presence of supplementary search reports (A4).

A further step in the process pursued by the patent office is the grant decision (which is published at the EPO as the B1 document). The variable *share granted EPO applications* is the share of patent applications that have already been granted at the time of the respective quarter.

As a measure of the quality of a company's patent portfolio, we use the variable *share highly cited patents*. For the patents held by the companies included in our analysis we calculate the distribution of patent citations received within the first four years after publication (this occurs 18 months after priority). A patent application is counted as highly cited from the quarter onwards in which its citations reach the highest decile of this distribution (which corresponds to three citations). We count citations in the quarter in which the search report of the citing patent was published. Thus, the information used for the calculation of this variable is derived from

[7] Supplementary search reports pertain in 72% of all cases to A1 documents and in 28% of all cases to A2 documents.

publicly available information. We exclude self-citations to focus our measure on the impact of a company's patent on subsequent technological developments outside the focal company. The variable *share highly cited patent* is calculated as the number of highly cited applications divided by the total number of applications. This variable should indicate whether a company has potentially valuable applications, i.e., applications that are of special interest to VCs. As a further measure of quality and commercial potential, we use the variable *cited by large technology follower*, which is a dummy equal to one if at least one application of the focal company has been cited by a large company. A company is defined as large if it generates at least 15 citations to the applications of our sample companies. With this definition we cover the most active 5.0% of the citing companies. *Share opposed patents* measures 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.

To come to a more parsimonious specification, we aggregate the information generated during and after the examination process into *positive news* and *negative news*. We calculate these aggregate measures by summing the standardized values of the underlying variables. *Positive news* is composed of *share highly cited patents, cited by large technology follower* and *share opposed patents*; *negative news* is composed of *share high proportion X/Y references* and *separate search reports/application stock*.

Control variables

The regressions also contain controls for company characteristics. All company characteristics are defined with reference to the time of founding. *Technological capabilities* are proxies for the skill set of the employees. The variable depicts 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. This may include up to nine methods. *High risk startup* measures the self-reported risk at founding that the company would fail to bring its technology to the market.[8] The variable *CEO industry experience* is included to account for the experience of entrepreneurs. Previous research has shown that experienced entrepreneurs are more likely to be able to secure financial resources and go IPO (Gompers *et al.*, 2010). In a related study, Hsu and Ziedonis (2011) show that patents are less relevant to entrepreneurs with IPO experience who seek funding from a prominent VC investor. Our variable *CEO industry experience* is coded 1 when the founder CEO has worked in biotechnology or in the pharmaceutical industry in a leading position, and 0 when the founder has not accumulated industry experience before founding the focal company.

At the macroeconomic level, the regressions include a control for the supply conditions in the market for VC financing (*early stage financings*). The early stage financings are comprised of seed and startup financings. The data for Germany were taken from the annual statistical publication of the German Private Equity and Venture Capital Association 'BVK Statistik' (BVK, 2007); the data for the UK were 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 annual early stage financings over the sample period 1990–2005 is 401 for Germany and 307 for the UK.

Finally, the binary variable *therapeutics* is equal to one if at least one of the core areas of a company is in therapeutics. Other industries are diagnostics, vaccines or platform technologies. *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 reference group consists of independently founded companies. We also included controls for the founding period. We differentiate the periods 1990–1995, 1996–1999,

[8] Companies had been asked in our survey to rate this risk on a five-point Likert scale from (1) no risk to (5) very high risk. The dummy *high risk startup* is equal to one if the company has given a rating of high risk (4) or very high risk (5).

2000–2002, and 2003–2005. *German company* is a dummy indicating that the company is based in Germany as opposed to the UK.

4 Analysis and Results

4.1 Descriptive Statistics

In Figures 1 and 2 we explore the differences between VC-financed and non VC-financed companies. While Figure 1 does not account for the timing of VC financing, Figure 2 includes only patent applications for VC-financed companies before they receive VC funding. Figure 1 shows that VC-financed companies have a higher average number of patent applications per quarter than non VC-financed companies. Part of the difference can be due to the additional VC funds to support R&D. When excluding post-financing information in Figure 2, we find that VC-financed companies have slightly more patent applications than non VC-financed companies in the first six years after founding, thereafter the differences become more pronounced. The descriptive statistics in Table 1 are calculated for the first 16 quarters (4 years) after founding and show pronounced differences between the patenting activities of VC-financed and non VC-financed companies. Please note that this table does not account for the timing in terms of pre and post VC financing, this is accounted for in the multivariate hazard model. The share of observations with at least one patent application is higher for VC-financed than for non VC-financed companies (46% vs. 39%). Furthermore, VC-financed companies have a larger application stock. There are also differences in the characteristics of the patent portfolios. Companies that receive VC financing have portfolios of applications with a lower incidence of the share of X- and Y-type references and with a lower incidence of separate search reports. The share of granted patents is higher for VC-financed companies but the difference is only marginally significant. Again, applications of VC-financed companies have a higher probability of being highly cited, being cited by a large company and receiving an opposition. When aggregating the information from the patent office, we find that VC-financed companies receive *positive news* more often and *negative news* less often than non VC-financed companies.[9] Further differences in company characteristics are displayed in Table 2. Companies that receive VC financing have capabilities in more technical areas and are less likely to be a high-risk startup than startups that do not receive VC financing. Their CEOs are more likely to have gained industry experience before founding but the difference is not significant. Neither the type of founding nor whether the company is situated in Germany or the UK has a significant relationship with VC financing. However, companies founded during or shortly before the boom period of VC financing (1996–1999) have a higher probability of obtaining VC financing, as have companies that are active in the field of therapeutics.

4.2 Multivariate 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. 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. Tied failure times are dealt with according to the

[9] For the standardization of positive and negative news we used all observations in our dataset. Table 1 includes only the first 16 quarters after founding. This explains why the mean of negative news is positive for both VC-financed and non VC-financed companies.

Breslow method. In our data, we observed 190 companies for a total of 3001 quarterly observations. Of these, 87 companies received VC during our observation period, while the dependent variable is right-censored for 103 companies.

4.3 Main Results

Our hazard rate results are shown in Table 3 and shed light on whether patent information impacts the time to receiving VC financing. Our estimation strategy is as follows: we present estimates from Cox proportional hazard models in which we include our time-varying patenting variables, as well as our control variables. In column (1) we introduce only one patenting-related variable – the logarithm of the application stock. This is the only component of information that is generated by the startup so it has a pure signaling function. All other patent variables are generated by either the patent office or by rival companies. Consistent with H1, which serves as our base hypothesis, the application stock has a positive significant effect on the hazard. Thus, once companies apply for patent protection, they receive VC financing faster.

In column (2) we add another six time-varying variables, which represent the information generated by the patent office and third parties. The first two variables are generated by the patent examiner: a high share of negative 'marks' in the search report and the occurrence of belated search reports. The results suggest that concerns about novelty and/or inventive step matter for the timing of VC finance. The variables *share high proportion X/Y references* and *separate search reports/appl. stock* indicate a lower degree of novelty and/or inventive step. In line with H2 and H3, we find that VC financing will be delayed if the search reports contain a high number of negative references and if they are delayed.

As an additional variable we include the share of granted patents. We find that, although the share of granted patents is positively related to VC financing, the coefficient is not significant so there is no statistical support for H4.[10]

We do not find a positive and significant coefficient for *share highly cited patent* either; nevertheless, citations by large technology followers appear to speed up the time to receiving VC financing. Thus, the evidence for hypothesis H5 is mixed. It might be that the rich information provided by the search report reduces the surprise factor of the variable that captures the number of citations. Another reason might be that VCs focus on citations by large technology followers because these indicate relatively important commercial opportunities for licensing.

Lastly, the variable *share opposed patents* has a significant hazard ratio that is larger than one. In support of H6, a company receives VC financing significantly faster if a relatively high share of patents is opposed by third 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.

In column (3), we aggregate the (standardized) variables into our construct of *positive news* and *negative news*. The aggregation indeed allows us to identify significant effects for positive and as well as for negative information, providing support for H7.[11] This specification summarizes the main result of our analysis: the initial patent application as well as the information generated by the ensuing process at the patent office constitutes valuable information for the funding decisions of VCs.

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[10] If we only include the application stock and the share of granted applications as patent-related variables, the grant variable still remains insignificant.

[11] We also tested for country differences by interacting EPO application stock, positive news and negative news with a country dummy (German company). The coefficients of interaction terms were not significant. In addition, we interacted our patent variables with a dummy for therapeutics companies for which patenting might be particularly relevant (Haagen et al., 2011). Again, the interaction effects were not significant.

It is not clear a priori whether VCs need to rely at all on information generated by the patent system or if they can evaluate the technology of startups more cheaply on their own. Because entrepreneurs may be reluctant to disclose details of their invention to VCs before they have filed a patent application, we assume that VCs get full insight into the potential of a particular technology from the time of the filing. The question now arises whether VCs are able to evaluate fully the technology at the time of the patent application or whether they make use of the information which is generated by the patent system.

If quality-related information were indeed fully anticipated at the time that the patent application is filed, then the timing of VC financing should be related to information that is effectively already available at the filing date. We can rigorously test for this possibility in our dataset since it contains time-series information. In order to do so, we define modified variants of "good news" and "bad news" in which we time the variables describing the information from search reports and other events to the date of application rather than to the actual event date. This is equivalent to assuming that the information revealed publicly is already available to VCs at the time of filing. Including both variables (timed separately on the date of disclosure and on the filing date) allows us to conduct a 'horse race' test. If information is fully anticipated at the time of the filing, then our modified variable should perform better in statistical terms than the variable timed to the official disclosure date.

Colum (4) provides the results of our test. The variables capturing the anticipated information are neither individually nor jointly significant (Chi^2=2.17 (df=2), p=0.34), while the two variables capturing the actual timing of information retain their significance (Chi^2=13.13 (df=2), p<0.01).[12] These results allow us to conclude that VCs rely on information as it is generated through the whole patenting process, as the actual information disclosure is more closely aligned

[12] We further tested for significant differences between the hazard ratios of the revealed and anticipated information for both good news and bad news and found that the differences are highly significantly different (Chi^2=10.59 (2df), p<0.01).

with the VC financing events than the information structure constructed for our thought experiment. We readily admit that this is not a full substitute for an experimental design; nor does it rule out all possibilities of spurious effects. Nevertheless, this result clearly underlines the earlier insight that information generated during the patenting process is impacting VC financing and that this information is not anticipated fully at the time of patent filing.[13]

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 estimates in column (3). Companies with a larger set of *technological capabilities* receive VC financing faster. The variable *high risk startup* leads to a considerable reduction of the hazard of VC financing. Companies characterized by particularly high risks are less likely to be financed than other startups. The variable *CEO industry experience* suggests that companies founded by a CEO with industry experience access VC financing faster than companies whose CEOs had not gained industry experience before founding the company. Our control for the supply side conditions in the VC market, *early stage financings*, has the expected positive influence but is not statistically significant in all models. 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, therapeutics, and location in Germany are individually and jointly insignificant (e.g., for specification 1 in Table 3: Chi^2=4.97 (df=7), p=0.66).[14]

4.4 Robustness Checks and Auxiliary Analyses

As already noted, the presence of unobserved heterogeneity in the technology of the startups can lead to a spurious correlation between patent information and the time to receiving VC financing.

[13] In a further 'horse race' specification, we included the disaggregated news variables and found that, again, the variables that capture the exact timing of information are significant (Chi^2=13.84 (6 df), p=0.03), while the variables that capture the anticipated information are not significantly related to VC-financing (Chi^2=4.38 (6 df), p=0.63).

[14] Only the coefficient *founded '90–'95* shows significance on the 10% level for model 2. We also experimented with interaction terms of *EPO application stock* with *years to market entry*. We expected a positive coefficient since the patent signal could be stronger in environments with higher uncertainty, but find no significant difference.

As an alternative to our 'horse race' specification, we employed the method suggested by Abbring and van den Berg (2003), which was applied by Gans *et al.* (2008). To control for unobserved heterogeneity, we included the average time lag between the publication date of the search report and the application date as a regressor in the hazard function.[15] A long time lag between the application and the publication of the search report prolongs the initial period of uncertainty. Our number of observations was reduced to 1,266 as we could only include observations for which there is at least one patent application with an associated search report in the current or preceding calendar quarters. Column (5) in table 3 shows that the odds ratio of the variable *average lag between application and publication of search report* is close to one and insignificant, suggesting that unobserved heterogeneity is not a problem in this study. In addition, when we include the lag variable, we find that the size of the other hazard rates remains almost unchanged. Furthermore, the hazard rates of positive and negative news remain significant. For comparison, column (6) in Table 3 contains the specification with the restricted number of observations but without the lag-variable.

In order to test the proportionality assumption implied by the Cox model, we included interactions of our time-varying covariates with time. We chose to use log (time), which is the most common functional form. No time interaction with a time-varying covariate shows up significantly in our models, which indicates that the proportionality assumption of the Cox model is not violated.

In Table A1 in the appendix we further investigate the relative importance of early versus late applications and the speed with which VCs react to patent-related information. Column (1) shows a specification in which the logarithmic functional form for the application stock has been replaced with a linear functional form. The likelihood ratio test as quality indicator for the overall specification indicates a better fit for the logarithmic form. The Chi^2 (12df) test statistic is

[15] The average lag is about 1.7 years.

42.71 for the logarithmic specification (see Table 3, column (1)) and only 42.36 for the linear specification. This suggests that additional applications tend to have a decreasing marginal influence. Thus, earlier patents are more relevant for the VC investment decision compared to later patents.

We also investigate whether the influence of patent-related information decays over time. In column (2) we add a dummy variable that indicates whether an additional application was filed in the current quarter. A hazard ratio of larger than one for this variable indicates that current filings speed up the time to VC financing to a larger extent than implied alone by the application stock. In column (3) we include an additional dummy variable indicating not the current quarter but the quarter *after* the additional application has been filed. The variable is still significant but to a lower degree and with a smaller hazard ratio than the dummy with the current timing. Further, column (4) adds a dummy indicating two quarters after an additional application has been filed. The insignificance of this variable shows that VCs react quite fast upon new information from patent filings.

5 Interview Evidence

We conducted five in-depth interviews with VCs from Germany and the United Kingdom to complement our analysis in the ‘pin factory’ tradition (Borenstein *et al.*, 1998). We were interested in getting the views of different types of VCs and selected our interview partners accordingly. We interviewed investment managers of early stage VCs, late stage VCs and of a corporate VC. The aim of these interviews was to gain insights into the importance of patent information for the financing decision and detailed information on the patent due diligence. To that end, we constructed a guide that had open-ended questions. Typically, the interviews lasted from 1 to 1.5 hours and were transcribed. We also collected relevant documents from the VCs about the due diligence. Finally, the interviewer discussed her impressions with the VCs to ensure alignment between interviewer and interviewee.

The first insight we gained from our interview partners is that *both* the protection and the information function of patents and the patent system are of great importance to VCs. One of the interviewees stressed 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 negotiations with the VC.

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). Our interview partners suggested that patent documents offer information on the technology in a condensed and standardized format, which helps in the process of due diligence. Nevertheless, patent applications are often quite technical and formal and therefore difficult for VCs to read. To overcome this hurdle, VCs use highly specialized technical experts and patent lawyers to evaluate the patents. Consequently, 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 (e.g., search reports) very carefully, although the differences among VCs seem to be considerable. One of our interviewees gave us a list of 35 criteria on which hired technology experts in the field of biotechnology that the company focused on should base their evaluation of the patent portfolio. Another interviewee said that the respective company had no standardized patent due diligence. When we asked interviewees about the relevance of information contained in the search report, the responses were greatly heterogeneous. Whereas one VC appeared to be very interested in the information from the search report ‘to see what the examiner thinks, to learn who [else] is also working in this area and how the prior art limits the possibilities of the company under consideration’, another VC of similar size and with similar investment focus rarely made use of search reports. The interviewed CVC investor pointed out that the final report of a technology expert hired to evaluate the patent portfolio of a company is explicitly asked to include all relevant prior art from the search report. 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 to the evaluation process, while the appraisal of a single patent is less meaningful. With regard to patent oppositions, our interviews revealed that an opposition informs the VC that a third party is interested in the technology, which signals 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 startup is severely endangered by the opposition.

To sum up, the interview evidence shows that (1) entrepreneurs are aware of the positive signaling aspect of patent applications and (2) even though the further processing of information generated by the patenting process incurs certain costs, VCs do make use of this detailed information.

6 Implications and Conclusion

6.1 Implications for Research

Our paper seeks to make several contributions. First, we extend a growing body of literature on entrepreneurial resource allocation by showing that information generated in the patenting process facilitates access to external finance and thus helps companies to overcome the liabilities of newness. Moreover, while recent research has shown that investors pay attention to patent portfolios in their valuation decision (Hsu and Ziedonis, 2013; Mann and Sager, 2007), we show that information generated in the course of the patenting process affects the financing decision dynamically, even long before a first patent is granted.

Second, the types and sources of information which we focus on in this paper (search reports, unexpected delays in communication by the PTO, opposition) have not been considered in prior literature. Our study demonstrates that the positive as well as negative news generated in the patenting process impact VC decision-making. Moreover, the patenting process also entails the discovery and dissemination of information generated by third parties (technology followers and competitors). This information should be especially valuable to resource providers such as investors, because it relates to the commercial potential as opposed to the technological relevance of inventions.

Third, our results portray the patent office in a new role – rather than merely creating a time-limited exclusion right at some point, the patent office affects VC decision-making by providing – over an extended time period – information related to the quality of a company’s patents. Very few studies highlight the patent office’s role as information provider. Our interviews confirm that VCs invest in the exploitation of this information by trying to stay informed about available patent documents and by hiring external experts to evaluate the patent portfolios of potential investment targets in the light of information released by the patent office.

Finally, our results should give researchers reason to reconsider the welfare economics of the patent system. Patents are usually seen as a barrier to entry in a given sector. For instance, studies show that with increasing patenting, entry rates of startups in the software sector are reduced (Cockburn and MacGarvie, 2011). Furthermore, Cockburn and MacGarvie (2009) report that companies operating in markets with denser patent thickets experience a delay in receiving their first funding from external investors. Our results, however, suggest that the welfare impact of patenting is more complex: by facilitating the entry of VC-financed startups, patents also fulfill a pro-competitive role. This finding is in line with earlier studies providing support for the idea that patent protection under a strong appropriability regime allows new entrants to partner in the market for ideas and successfully profit from their invention (e.g., Teece, 1986; Gans and Stern, 2002; Hall and Ziedonis 2003; Haeussler, 2011).

6.2 Practical Implications

Besides extending the scientific literature, our results have practical implications for entrepreneurs, investors, and public policy. When entrepreneurs weigh the costs and benefits of applying for a patent, they consider various tradeoffs. For example, refining the application prior to filing may yield a broader patent scope and better protection, but delaying the filing may raise the danger of being pre-empted by rivals. We find that the mere existence of patent applications reduces the time to receiving VC financing, presumably because an application reflects progress in the development of a technology. However, in order to reduce the time to financing further it is also important that the application generates good news at and from the patent office. These dynamic aspects of information provision need to be taken into account in addition to the standard considerations of protection and reputation when drafting the patent and deciding about the filing strategy.

Our results also have implications for investors who can make use of patent-related information in order to learn about a startup’s technology. VCs may improve their investment decisions by taking various forms of information generated in the course of the patenting process into account more systematically. Some VCs may profit from making further investments in their capability to analyze patent related information.

With respect to public policy, we show that the current design of the EPO allows this patent office to generate information reflecting the quality of inventions and to trigger the provision of third-party information, e.g. via opposition. Good news from the patent system is associated with faster acquisition of VC; the reverse applies in the case of bad news. Our findings lead to an important design question: how can the information-generating function of the patent system be supported and optimized? While we have shown that disclosure of patent information may facilitate the financing of ventures, further research may lead to improvements in the informational value of patent office information and disclosures.

6.3 Limitations and Future Research

Various caveats need to be taken into account when considering our results, but these may also become starting points for new studies. First, there is the question of external validity. This study investigated the importance of information generated by the patent system for obtaining VC financing in biotechnology. As in other discrete technologies such as chemicals and pharmaceuticals (Cohen *et al.*, 2000), patent protection plays a very important role in this sector and is unusually strong when compared to mechanical or electrical engineering. Hence, our insights may not be applicable to other sectors. It must be left to future research to determine to what extent the patenting process generates useful information in these sectors.

Second, the patenting process at the EPO differs from the process at the USPTO. Historically, the EPO has generated more information because *all* patent applications have been published 18 months after priority – typically with a search report. References are qualified according to whether they are detrimental for patentability (X and Y references) and the opposition process provides early information regarding patent validity (Graham and Harhoff, 2009). Although the

USPTO has recently adopted an 18-month publication regime, there are still differences in the content of information available to outside observers. A study comparing the impact of information generated through the patenting process at the USPTO and the EPO respectively could reveal interesting insights into institutional differences.

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Figures and Tables

Figure 1: Quarterly Patent Applications
– Including pre- and post-financing patents for VC-financed companies –

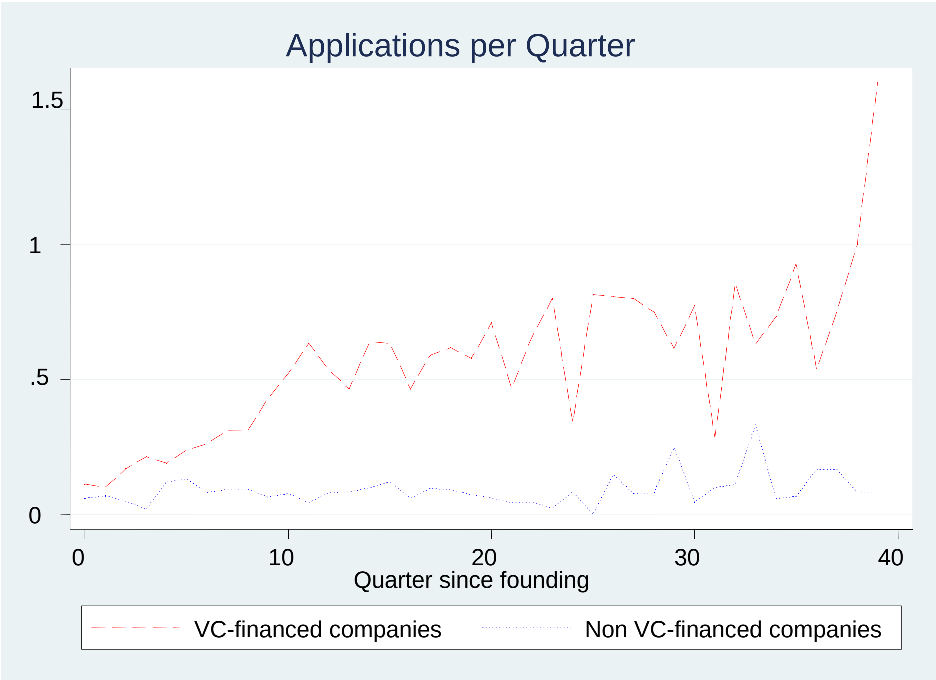

Figure 2: Quarterly Patent Applications
– Including only patents pre-financing for the VC-financed companies –

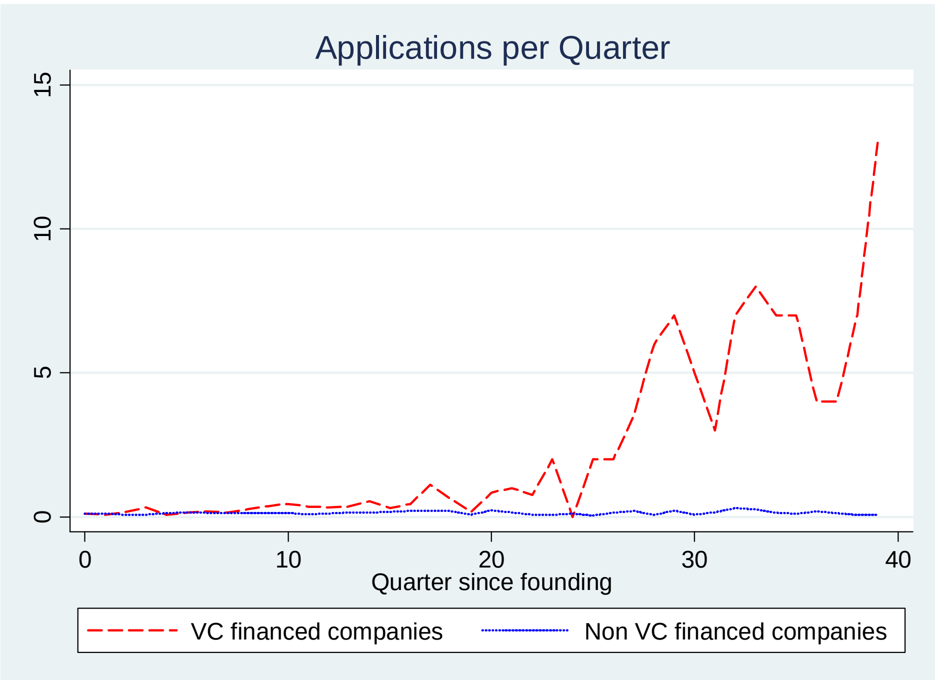

Table 1: Descriptive Statistics of Time-Variant Variables

Variable	VC-financed companies Obs	Mean	St.Dev.	Non VC-financed companies Obs	Mean	St.Dev.	Diff. mean p-value
EPO application (0/1)	1258	0.46	-	1748	0.39	-	0.00
*EPO application stock**	864	5.27	6.98	696	3.42	3.37	0.00
*share high proportion X/Y references**	864	0.03	0.09	696	0.06	0.16	0.00
*separate search reports/appl. stock**	864	0.11	0. 20	696	0.20	0.32	0.00
*share granted EPO applications**	864	0.05	0.16	696	0.04	0.13	0.10
*share highly cited patents (excl. self-cites)**	864	0.003	0.014	696	0.001	0.017	0.00
cited by large technology follower (0/1)	864	0.21	-	696	0.16	-	0.01
*share opposed patents**	864	0.008	0.052	696	0.001	0.009	0.00
*positive news**	864	0.50	3.49	696	-0.13	1.73	0.00
*negative news**	864	0.07	1.37	696	0.76	2.34	0.00

Note: The statistics refer to the first 16 quarters after founding. Companies that are VC-financed received VC financing within the first 16 quarters after being founded. Information for VC-financed ventures also include the quarters after financing was received. * 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

Variable	VC-financed companies Obs	Mean	St. Dev.	Non VC-financed companies Obs	Mean	St. Dev.	Diff. mean p-value
technological capabilities	87	2.16	1.31	103	1.69	1.04	0.006
high risk startup (0/1)	87	0.06	-	103	0.21	-	0.000
CEO industry experience	87	0.47	-	103	0.36	-	0.118
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
therapeutics (0/1)	87	0.64	-	103	0.47	-	0.014
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
German company (0/1)	87	0.63	-	103	0.59	-	0.574

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)
ln EPO application stock	1.454***	1.564***	1.632***	1.496**	1.416	1.430
	(0.181)	(0.245)	(0.231)	(0.246)	(0.332)	(0.337)
share high proportion X/Y references		0.938*				
(scaled by 100)		(0.032)				
separate search reports/appl. Stock		0.979**				
(scaled by 100)		(0.009)				
share granted EPO applications		1.115				
		(0.995)				
share highly cited patents		0.992				
(scaled by 100)		(0.041)				
cited by large technology follower (0/1)		2.258**				
		(0.900)				
share opposed patents		1.091**				
(scaled by 100)		(0.043)				
positive news			1.157***	1.148***	1.126**	1.127**
			(0.054)	(0.061)	(0.058)	(0.058)
negative news			0.579***	0.572***	0.591***	0.598***
			(0.103)	(0.102)	(0.110)	(0.111)
anticipated positive news				1.057		
				(0.084)		
anticipated negative news				1.094		
				(0.075)		
average lag between application					1.000	
and publication of search report					(0.000533)	
technological capabilities	1.193**	1.200**	1.221**	1.209**	1.156	1.133
	(0.104)	(0.109)	(0.108)	(0.108)	(0.155)	(0.150)
high risk startup	0.420*	0.406*	0.400*	0.412*	0.925	0.996
	(0.200)	(0.195)	(0.191)	(0.199)	(0.531)	(0.569)
CEO industry experience	1.656**	1.817**	1.794**	1.805**	1.408	1.552
	(0.417)	(0.473)	(0.464)	(0.470)	(0.560)	(0.597)
early stage financings	1.120**	1.097	1.096	1.096	1.084	1.092
(scaled by 1/100)	(0.062)	(0.063)	(0.062)	(0.062)	(0.085)	(0.085)
Observations	3,001	3,001	3,001	3,001	1,266	1,266
Chi-squared	42.71	64.72	62.17	64.15	25.14	24.28
log likelihood	-402.3	-391.3	-392.6	-391.6	-170.1	-170.6

Note: Standard errors in parentheses. Hazard ratios shown. 190 firms, 87 exits from the risk set for columns (1) to (4); 98 firms, 49 exits from the risk set for columns (5) and (6). All specifications contain dummies for spin-out science, spin-out company, therapeutics, founded ’90–’95, founded ’96–’99, founded ’03–’05, German company.
* significant at 10%; ** significant at 5%; *** significant at 1% (two-sided tests).

Appendix

Table A1: Cox-Hazard Models – Analysis of Functional Form and Timing

Variable	(1)	(2)	(3)	(4)
EPO application stock	1.041**			
	(0.018)			
ln EPO application stock		1.288*	1.148	1.204
		(0.178)	(0.180)	(0.196)
additional application in the current quarter		2.098**	2.126**	2.093**
		(0.628)	(0.645)	(0.634)
additional application in the current quarter (t+1)			1.799*	1.787*
			(0.587)	(0.579)
additional application in the current quarter (t+2)				0.623
				(0.313)
technological capabilities	1.225**	1.199**	1.210**	1.202**
	(0.106)	(0.105)	(0.106)	(0.106)
high risk startup	0.375**	0.411*	0.410*	0.413*
	(0.177)	(0.195)	(0.195)	(0.197)
CEO industry experience	1.714**	1.702**	1.688**	1.677**
	(0.429)	(0.429)	(0.426)	(0.424)
early stage financings	1.118**	1.118**	1.116**	1.118**
(scaled by 1/100)	(0.062)	(0.0615)	(0.0613)	(0.0616)
Observations	3,001	3,001	3,001	3,001
Chi-squared	42.36	48.30	51.34	52.32
log likelihood	-402.5	-399.5	-398.0	-397.5

Note: Standard errors in parentheses. Hazard ratios shown. 190 firms, 87 exits from the risk set. All specifications contain dummies for spin-out science, spin-out company, therapeutics, founded ’90–’95, founded ’96–’99, founded ’03–’05, German company.
* significant at 10%; ** significant at 5%; *** significant at 1%.