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

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ABSTRACT

In the presence of asymmetric information, economic agents need to communicate their quality to investors and other parties. While much of the literature focuses exclusively on signaling, we develop a conceptual framework that extends this view with elements of the literature on certification. We derive and test empirically several hypotheses using a sample of British and German companies that seek venture capital (VC). We find that patent applications – as signals from ventures – are positively related to VC-financing. Moreover, applications trigger institutionalized processes at the patent office, which can generate valuable technological and commercial information via search reports, citations and opposition procedures and thus affect VC-financing. Our results highlight the role of signaling, but additional information about venture quality is generated via an institutionalized certification process.

Keywords: signaling, certification, liabilities of newness, venture capital, patent system, biotechnology

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

Debating Points

1) 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 (Connelly et al. 2011). We consider certification theory to offer important complementary insights in order to explain company strategies and organizational behavior. As such we proclaim that signaling and certification theory should be used in tandem.

2) A large strand of literature has investigated the traditional view of patents as an asset or means of protection. So far, scholars have overlooked that patents can serve as signals which "may be more valuable to the rights holder than the substance of the rights" (Long 2002; 625). In this paper, we shed light on how the informational value of patents is generated, which role third-party certifiers play, and which particular forms of information are important at a particular stage of the financing decision.

3) Patents are typically seen as a barrier to entry. However, patents may reduce information asymmetries between financiers and founders, and they may therefore 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.

INTRODUCTION

The quality of intangible assets, such as know-how, business concepts, teams 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 this form of finance is among the most important ones 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; Cohen and Dean, 2005; 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 (Lemley, 2000; Mann and Sager, 2007; Heeley, Matusik, and Jain, 2007; Hsu and Ziedonis, 2011). However, the relationship between patents and venture capital financing (VC-financing) has turned out to be a complex one. A fully convincing theoretical foundation of the function of patents has not been developed as yet. In our paper, we seek to contribute such a conceptual foundation by combining elements of the literature on signaling and of that on certification. In addition, we test empirically hypotheses derived from this framework. So far, the literature in this field has mainly relied on signaling theory (Spence, 1973) as its conceptual foundation. While we acknowledge that signaling theory provides an interesting starting point for any theoretical discussion, we view an exclusive focus on it as limited. We suggest complementing this perspective with the theory of certification. The

two bodies of literature are related, but emphasize very distinct economic and managerial mechanisms which we explore and juxtapose in this paper.

Signaling theory following the seminal work by Spence (1973) emphasizes self-selection. Parties that have high (marginal) costs of undertaking the action which constitutes the signal will not purchase the signal. In a separating equilibrium, only the high-quality group of agents would acquire the signal and thus reveal their type. In the classical model of signaling, the process of generating the signal is an automatic one. All decisions reside with the party seeking the signal. Our main objection to the use of signaling as the main theory for this field is that it assigns a passive role to institutions (Montiel, Husted, and Chrisman, 2012). This leads to an unrealistic and theoretically uncompelling view, which neglects the fact that institutions might generate new (certified) information in a complex process of interaction between the participating parties. Applied to our field of study, we note that the communication of startups with the patent office, the gradual emergence of salient information and the interaction with other players in the system are all aspects which are neglected in the pure signaling view. Thus, the signaling model in its simple form has a mechanistic quality to it.

The certification literature (see, e.g., Biglaiser, 1993; Lizzeri, 1999; Stahl and Strausz, 2011) takes a different view and assigns an active role to institutions and intermediaries. In this perspective, a certifying agent is either hired by the seller of a good seeking to convince a buyer of its quality, or by the buyer of the good who seeks to determine the quality of the good (inspection). Positive or negative information generated by the certifier impacts the purchaser's decision. The decision to engage a certifier may be subject to self-selection phenomena, thus encompassing aspects of signaling. Applying this idea to our context, the startup submits a patent filing to the patent office in order to have the quality of the invention certified. Certification theory emphasizes the active contribution of the certifying organization. This organization

engages in costly activities that help to separate 'the wheat from the chaff'. Quite naturally, the structure of a certifying organization and the way in which it runs its processes will matter for the outcomes.

We are not the only and not the first scholars to view the dominant and sole use of signaling theory critically. Some researchers have recently emphasized that transferring the key aspects of signaling theory to strategic management and organizational contexts has been difficult (Connelly *et al.*, 2011). We build on this view and emphasize that institutionalized certifiers, as well as the certification process itself, might be important sources of valuable and credible information. The acquisition of a costly signal, which is the key aspect of signaling theory, may only be one, and possibly a minor, part of the overall communication and information aggregation process. In our view, the signal is important and may generate information of value to investors. More importantly, the signal may initiate a process of certification. Subsequent to the original signal, the institutionalized certifier will generate – possibly with the help of third parties – credible information which can be positive as well as negative for the company seeking financing.

To highlight and explore this view, we undertake a detailed analysis of the certification process established at patent offices. Patent offices are primarily known for granting a time-limited exclusion right to the patent holder. Long (2002, 625) points out that most scholars have overlooked the informational function of patents, which 'may be more valuable to the rights holder than the substance of the rights'. 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). But it has remained unclear in this literature how the informational value of patents is generated and how it unfolds over time. The process of certification through patent offices has so far been neglected and deserves attention.

We do not view the certification process as a substitute of signaling in Spence's sense; instead, we consider it a potentially important complement. To demonstrate its contribution, we undertake an empirical study of the timing of VC-financing for biotechnology startups in Germany and the United Kingdom. Our theoretical discussion suggests that once companies reach a quality threshold (e.g., in the development of their invention), they can signal their quality by filing patent applications. If signaling theory in its original form holds, VCs should observe the actions of the patent applicant and draw conclusions from these actions. Explanatory power should therefore reside with the filing of applications. The contrarian view would emphasize the value of information being generated by the patent office in its capacity as a certifying agency. Over time, the patent office sends out communication pertaining to the quality of the patent. Moreover, if competitors oppose a patent grant, they may become indirectly engaged in the certification process. If information of this type affects VC-financing in a major way, the certification interpretation appears relevant for our understanding of how information asymmetries are reduced over time.

In our study, we utilize a unique survey dataset of 190 VC-seeking German and British biotechnology companies to test our theoretical reasoning empirically. 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 use predominantly 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 analyze these data using hazard-rate models with time-varying covariates. Our results suggest that the information generated in the certification 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.[1] Both our estimates and the qualitative results support our assumption that signaling and certification explain the role of patents in startup financing in a complementary manner. Patent applications *per se* significantly impact VC-financing. But subsequent information generated by the patent system also contributes to explaining VC-financing events. 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 in this vein.

The remainder of this paper is structured as follows: we first develop conceptual links between the literature on signaling and that on certification, which need to be more thoroughly connected. We then introduce how the patent system generates information and develop our hypotheses. In the next section we describe the methodology and data we used to test these hypotheses. We discuss our empirical results in the following section, while in the final section we conclude with a discussion on the implications and limitations of our study.

THEORY AND HYPOTHESES

A. Signaling Theory and the Certification Literature

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

[1] The idea of the pin factory approach is to complement empirical evidence with insights provided, for example, by conducting additional interviews or by visiting the manufacturing site and observing individuals. The 'pin factory' idea goes back to Adam Smith's observations during his visit at a pin factory, which helped him to explain the division of labor.

too costly for low-quality actors to pursue; conversely, for high quality actors, it yields returns that are greater than the costs of the signal. 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 (Connelly *et al.*, 2011). 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 (a) the ability to interpret signals may vary among actors (Connelly *et al.*, 2011), (b) agreement on a specific action that serves as a signal is hard to achieve (Holm, 1995) and (c) signal quality might be diluted, as strong signals are imitated over time by low quality actors. Heil and Robertson (1991) argue that the latter effect may result in a 'signaling war'. Hence, while individuals and companies would clearly benefit from widely accepted and observable coordination mechanisms, it requires considerable efforts and possibly external interventions to have specific actions or forms of information being accepted as a signal and being sustained over time as an economic signal (Holm, 1995; Greif, 2005). Recently, Montiel *et al.* (2012) have argued that the current literature 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 ignored 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 ignores subsequent mechanisms or institutional processes. These may be

set in motion by the signal and tend to generate valuable information over time. In contrast, most studies on certification assign to an intermediary the task of actively reducing information asymmetry and thus improving the level of quality-related information (Albano and Lizzeri, 2001). Building on Akerlof's (1970) 'lemons market', Viscusi (1978) was among the first to formally demonstrate that there exist gains from trade if an external certifier is able to reduce information asymmetries. Subsequent studies went on to provide rationales for the existence of such intermediaries (e.g., Biglaiser, 1993; Biglaiser and Friedman, 1994; Lizzeri, 1999). Leading examples are credit-rating agencies (Boot, Milbourn and Schmeits, 2006; Sufi, 2009), investment banks (Beatty and Ritter, 1986), venture capitalists (Megginson and Weiss, 1991), environmental rating agencies (Chatterji and Toffel, 2010) and agencies that certify management practices (Terlaak, 2007; Montiel *et al.*, 2012). So far, the literature on signaling has not been thoroughly connected to that on certification. Most previous works have focused either on signaling (e.g., Hsu and Ziedonis, 2011) or on certification (e.g., Sufi, 2009; Terlaak, 2007). The few studies that have drawn on both bodies of literature tend to argue that informed agents that initiate costly certification generate a credible signal (e.g., Balachander, 2001; King, Lenox, and Terlaak, 2005). Going beyond these arguments, our study emphasizes the dynamic accumulation of information over time, which may include 'good' and 'bad' news. We show that the information generated in the course of the certification process has considerable impact on the timing of VC investments.

The objective of our paper is to provide an integrated view of signaling *and* of certification. We argue that this joint perspective will allow us to pinpoint various mechanisms which contribute to a reduction of information asymmetries. We also emphasize that signals in the spirit of Spence (1973) may be *per se* informative but may also set in motion a certification process in the course of which institutionalized certifiers will provide more detailed information about quality. Signals

may be conducive to systematic design considerations, e.g., influencing prerequisites for sending the signal. But design and management considerations will also matter for certification processes whose importance has been neglected so far.[2]

B. 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, forthcoming) for a survey. Long (2002) notes that scholars may have overlooked that patents can serve as signals. 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). Nevertheless, these studies do not examine how the informational value of patents is generated, which role third-party certifiers play, and which particular forms of information are important at a particular stage of the financing decision.

A number of scholars have 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 discrete industries where the link between the patent and profit appropriation is transparent, patent information decreases information asymmetries. But in (complex) technologies where the link is less clear, patent information might even increase information asymmetries. In our study, we show that the patenting process itself contributes to the certification of quality and generates valuable technological and commercial information. In a recent study, Hsu and Ziedonis (2011) 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

[2] Both views may have different implications for the asset value of a patent. In signaling theory, the asset value of the patent could be negligible, but the signal would still be informative as long as a separating equilibrium between different types of startups is achieved. That is not the case for certification – the object of this process is to show that the patent right will have high asset value.

information asymmetry is more pronounced, and for companies which lack alternative means of signaling quality to investors. 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. 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.[3] In comparison to these papers, our contribution contains a much more detailed assessment of the information flow generated by the patent office.

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. On the whole, previous literature fails to take the role of the patent system as a certifier into account; it also neglects the timing, type and source of information that is produced through the patenting process.

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. Therefore, we focus on the initial private-equity financing event. At this 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

[3] While Baum and Silverman (2004) do not comment on this aspect, the use of USPTO data limits the study to applications that were ultimately granted, since publication occurs only at grant. Conversely, our EPO data allow us to trace unsuccessful applications as well as successful ones which became granted patent rights.

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. Petty and Gruber (2011), for example, provide evidence that the time-constraints of VCs can be so severe at times that they have to reject deals that they would have otherwise pursued because they lack the time to come to a detailed assessment. Hence, timely and credible information on the quality of ventures is of high importance for the investment decision.

C. Sources of Information within the Patent System

The entrepreneur as initiator of the patenting process

By filing a patent application, an entrepreneur provides a signal that the startup has matured sufficiently to invest in the protection of the technology it has been seeking to develop for commercialization. Patent applications correspond with Spence's definition of signals (1973, 2002), as the filing of a patent application requires considerable resources, but is less costly for high-quality companies than for low-quality companies. The preparation of patent applications requires effort and time, since applicants have to follow strict guidelines and to 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. Moreover, applicants are required to disclose publicly their invention (Long, 2002; Hsu and Ziedonis, 2011) and thus lose the option of using secrecy as a protection mechanism.

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 institutional setup at the US Patent and Trademark Office (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. Hence, submitting an application of low quality could create major reputational problems for the startup. In addition, most information generated by the EPO is publicly available. 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 certification 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. A product that is proprietary or can otherwise be protected is an important selection criterion for VCs (MacMillan, 1985). In addition, patents may facilitate the licensing of technology (e.g., Gans, Hsu, and Stern, 2008), giving the venture an additional source of revenue. Moreover, patents enable VCs to recover some salvage value from failing companies (Hall and Harhoff, forthcoming). 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 very skewed distribution, with most patents being of little value. Hence, the patent application *per se* may be of limited value for assessing the quality of inventions and, more importantly, the commercial potential of a company's innovative activity (Heeley *et al.*, 2007). A clearer picture may emerge, once further (certified) information provided by the patent examination process is considered in more detail. With the patent application, the entrepreneur sets in motion a certification 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 improve the quality of certification. 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

Figure 1 shows the average timing of events in the patent examination process of the EPO, illustrating the flow of information that is initiated with the patent application (t=0). Typically, an application will be first filed at a national patent office and then within the priority year be transferred to the EPO.

While patent applications may provide a first indicator of the technological progress of a company, the information is technical and often only accessible to individuals with considerable expertise (Heeley *et al*., 2007). However, the patent system also provides important information about the technical and commercial potential of the underlying technology. Moreover, 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. 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 are unrelated to the quality of the underlying invention and 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. 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.[4] 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 react favorably to unanticipated grant decisions if they have not made a financing decision prior to this event:

Hypothesis 4: Startups with granted patents receive VC-financing faster.

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

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

venture. VCs can make use of this information in order to decide to invest in a startup. Taking all arguments into account, we expect that:

Hypothesis 5: Startups with highly cited patents and with patents cited by large technology followers receive VC-financing faster.

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. In contrast to citations which are mostly determined by the examiner and therefore costless for the filing company, engaging in an opposition procedure is costly. We therefore 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 expect that this market related information is very informative for VCs and thus hypothesize:

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

Relative importance of information generated by the patent system versus evaluation by VCs

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. As explained in the theoretical framework, the patent system provides detailed information about the technology of the potential portfolio company. We therefore expect that patent information is relevant to funding decisions:

> *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.*

In order to strengthen our claim that the patent system generates genuinely new information, which then impacts VC decision-making, we explore whether this information might be anticipated by the VC at the time of application. 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 on the filing date. We would then see the following hypothesis confirmed:

> *Hypothesis 8: VCs anticipate information on the quality of a patent application at the time that application is filed.*

This hypothesis can be tested rigorously in a dataset with time-series information. In order to do so, we define 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

hypothesis test. If the variable based on the official publication dates turns out to be statistically dominant, then we will reject hypothesis H8, and our confidence in H7 should be strengthened.

DATA AND SAMPLE

Data and sample description

Our objective is to distinguish empirically between information generated through the acquisition of a signal and information generated in and after the process of patent examination. To that end, we study the role of patents for the dynamics of VC-financing in the German and British biotechnology industry. Our database for this study combines information from a company survey with detailed information from patent offices. The company survey was conducted among German and British biotechnology companies in 2006. 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.[5]

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

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 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,[6] which left us with a relatively homogenous sample of companies. 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.[7]

Our final database consists of a combination of primary data from a survey and secondary data from patent databases. Given our research question, one of our challenges was to control for company information in order to identify patent-related effects on VC-financing. While detailed information on company characteristics is often accessible only via a survey, it is well known that self-reported survey data might suffer from biases introduced through, for example, ex-post

[6] Companies might not be in need of VC, 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. Companies that have received a large amount of money, e.g., from 'business angels', are another example. 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. A comparison between firms in the excluded group and firms in our sample is instructive. The VC-seeking firms pursue more radical technologies, apply for more patents at the founding stage, and consider patents to be more important to protect their product or technologies. In addition, these firms put stronger emphasis on fast growth than their non VC-seeking counterparts. In order to realize a strategy of fast growth, it is important that these startups receive funding fast. This notion corresponds with the finding that the presence of VC-financing reduces the time it takes a company to bring a product to the market (Hellmann and Puri, 2000).

[7] 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. The Online Appendix 1 presents the dataset and shows the results for the effect of patents on the likelihood of obtaining VC for companies that are still in the market as well as for companies that failed. This calculation attests that the effects of patent applications are robust in both samples.

rationalization and overconfidence. Nonetheless, we are confident that by combining primary and secondary data, the reliability of our results is actually enhanced.

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 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. 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 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. 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 certification process of 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 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 patents* 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

[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).

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

ANALYSIS AND RESULTS

Descriptive statistics

In Figure 2 we explore the differences between VC-financed and non VC-financed companies. For all quarters after founding, VC-financed companies have a higher average number of patent applications. However, it is interesting to note that the differences in the first 1.5 years after founding are quite small. 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. Once this longer period is considered, 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.

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

[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.

accommodate time-varying covariates, we split the complete time period into quarter-year spells. The hazard of obtaining VC-financing is defined as the probability of obtaining VC-financing in the current period, given that no VC-financing has been received up to the previous period. Our main interest is to investigate how patent-related variables influence this hazard. The Cox proportional hazard model accommodates the influence of covariates by multiplying the baseline hazard by a function of observables. The hazard function itself is estimated non-parametrically and can take any form. Companies that have not received VC-financing by the time of the survey are treated as right-censored. Tied failure times are dealt with according to the 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.

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 system in its role as certifier. 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. Hence, our findings support H2 and H3.

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.

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

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.

At this point, we have not yet considered the possible impact of anticipated quality information. In other words, VCs may have sufficient information at the time of patent filing already such as to anticipate future disclosures of information in search reports, citations, and oppositions. Column (4) provides a test of H8, which addresses the extent to which information generated by the patent system is not anticipated by the VC. Here, we modify the timing of the two aggregate variables by artificially attaching the information to the filing date of the respective patents. We then include both the modified and the original variables in the specification. If information is fully anticipated at the time of the filing, then our artificial variable should perform better in statistical terms than the variable timed to the official disclosure date. In this 'horse race' specification, 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).[11] These results allow us to reject H8, as the actual information disclosure is more closely aligned 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.[12]

[11] 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)

[12] 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).

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. Since high risk at the founding stage has been self-assessed by our respondents, this variable might be prone to overconfidence and ex-post rationalization.[13] 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]

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. As an alternative to our 'horse race' specification, we employed the method suggested by Abbring and van den Berg (2003), which was recently applied by Gans *et al.* (2008). To

[13] In unreported regressions, we find that our patent variables were robust in terms of sign and significance to the exclusion of *high risk startup*.

[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. In order to test for differences between the two countries, we included an interaction between EPO application stock with *German company* and find an insignificant coefficient.

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.

We also estimated specifications with the existence of a foundational patent as a further control variable.[16] A foundational patent is precedes the founding of the company. For example, if the founder – prior to founding the firm – has filed a patent while working at a university, then the patent may have been assigned to the university (for *spin-out science*). Similarly, a foundational patent might also be assigned to the previous employer of the founder (for *spin-out company*) or to the founder himself (for *independently founded*). While our controls for company type (e.g., *spin-out science*) may catch part of the effect of foundational patents, an omitted variable bias could be present nonetheless. We therefore included an additional variable *foundational patent* which was coded one when respondents indicated in our survey that at the date of founding there had been at least one foundational patent, and zero otherwise. We find that *foundational patent*

[15] The average lag is about 1.7 years.
[16] These results are available from the authors upon request.

shows a negative, but insignificant coefficient. Our patent variables remain robust to the inclusion of this additional control variable.[17]

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.

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'.

[17] The insignificance of the variable *foundational patent* could indicate that the protected invention is a highly science-driven one. In such a case, it is likely that VCs will start to consider the company an investment target only after further development of the technology has taken place.

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.

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, they 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 standardised 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.

IMPLICATIONS AND CONCLUSION

Implications for Research

Our paper makes several contributions. First, we extend a growing body of literature on entrepreneurial resource allocation by showing that information generated in the patent system facilitates access to external finance and thus helps companies to overcome the liabilities of newness. While recent research has shown that investors pay attention to patent portfolios in their valuation decision (Hsu and Ziedonis, 2011; Mann and Sager, 2007; Lerner, 1994), we show that information generated by the patenting process affects the financing decision, even

long before the first patent is granted. In addition, whereas Heeley *et al.* (2007) show that patent information is able to reduce information asymmetries only in industries where the link between patent and value appropriation is clear, we complement their study and provide support for the idea that the patenting process at the patent office is able to generate technological and commercial information that goes far beyond the patent application document. Second, we extend both the literature on signaling and that on certification by demonstrating their complementarity. In doing so, we seek to clarify the limitations of applying signaling theory to organizational contexts and offer compelling arguments on how certification theory can help to compensate some of the weaknesses of signaling theory. While signaling theory is mainly focused on the sender of the signal (Spence, 1973), valuable and credible information might be primarily produced through an institutionalized certification process. While the signal sender sets a certification process in motion, a well-designed institutionalized certification process (a) is able to generate valuable information by an active certifier, (b) helps elucidate how third parties build and react to the original signal and (c) produces quality-related information over time. Thus, the signaling literature neglects important aspects of the certification process. Our study takes these into account and demonstrates that the positive as well as negative news generated in the course of the patenting process are reflected in 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 is especially valuable to resource providers such as investors, because it relates to the commercial potential as opposed to the technological potential of inventions.

Third, we contribute to the literature on the optimal design of institutions by demonstrating that the patent system generates useful information for the financing decisions of VCs. So far, while most literature emphasize the role of the patent system as an institution granting a time-limited

exclusion right, very few studies highlight its role as information provider. Indeed, our results show that the patent system is a valuable source of information for the financing decisions of VCs. Our interviews confirm that VCs invest in the exploitation of information generated by the patent system by trying to stay informed about available patent documents and hiring external experts to evaluate the patent portfolios of potential investments.

Finally, we also contribute to the literature on the economic effects of the patent system. In its role as institutionalized certifier, the patent office fulfils a pro-competitive role. Typically, patents are 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 phenomenon is more complex: by facilitating the entry of VC-financed startups, patents also fulfill a pro-competitive role. Whereas some scholars (e.g., Hall and Ziedonis, 2001) have argued that patents support the resource acquisition of startups, the specific pieces of information on which investor decisions are based have not been addressed so far.

Practical Implications

Besides extending the scientific literature, our results have important practical implications for entrepreneurs, investors, and public policy. When entrepreneurs weigh the costs and benefits of applying for a patent, they should be aware that the combination of the signaling aspect of the patent application and the certification aspect of the patent office may help their companies to overcome the liability of newness (Stinchcombe, 1965). Companies often need to determine the optimal time for submitting a patent application. 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, to reduce the time to financing further it is also important that the applications are of high quality and generate good news from the patent office. In addition, managers need to be aware that the patenting process can also reveal negative news about the technology of the company. The 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 have implications also for investors who can make use of patents in order to learn about a startup's technology. VCs can make use of information from the patent system to improve their investment decisions. 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 act as a certifier of the quality of inventions. The EPO generates information in the course of examination and triggers the provision of third-party information. Good news from the patent system is associated with faster acquisition of VC; the reverse applies in the case of bad news. Patents may thus reduce information asymmetries between financiers and founders and may positively influence the market entry of startups. This finding indicates that the patent system has an important economic role that is not fully reflected in the current debate on the 'optimal' patent system. Moreover, our findings lead to an important design question: how can the information-generating function of the patent system be supported? 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.

Limitations and Future Research

Various caveats need to be taken into account when considering our results. 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 one industry. It would be interesting to know whether the effects shown here, and in particular the certification role of the patent office, are also present in industries other than biotechnology. Previous literature suggests that the role of patents in securing financing is industry-specific. In discrete technologies – such as chemicals, pharmaceuticals and biotechnology – patent protection plays a very important role (Cohen *et al.*, 2000). It must be left to future research to what extent the ability of the patent process to certify and generate additional information differs industry-specifically.

A second issue concerns potential omitted variable bias. Previous research has shown that the characteristics of founder teams, such as variation in background or social networks (Eisenhardt and Schoonhoven, 1990; Shane and Stuart, 2002) and affiliations with prominent third parties (e.g., Stuart *et al.*, 1999; Hsu, 2006), are related to better performance. Ideally, we would like to control for these quality attributes in our analysis, since it is possible that they are correlated with patenting. Unfortunately, our survey data does not include the necessary information.

Finally, the patenting process at the EPO differs from the process at the USPTO. Specifically, the EPO generates more information because *all* patent applications are published 18 months after priority, references are qualified according to whether they are detrimental for novelty (X and Y references) and the opposition process provides early information regarding patent validity (Graham and Harhoff, 2009). 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.

Despite these limitations, we are confident that our study points to important complementarities between signaling and certification and casts new light on the role of patents in the financing of startups.

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FIGURES AND TABLES

Figure 1: Timing of Patent-related Information at the European Patent Office (EPO)

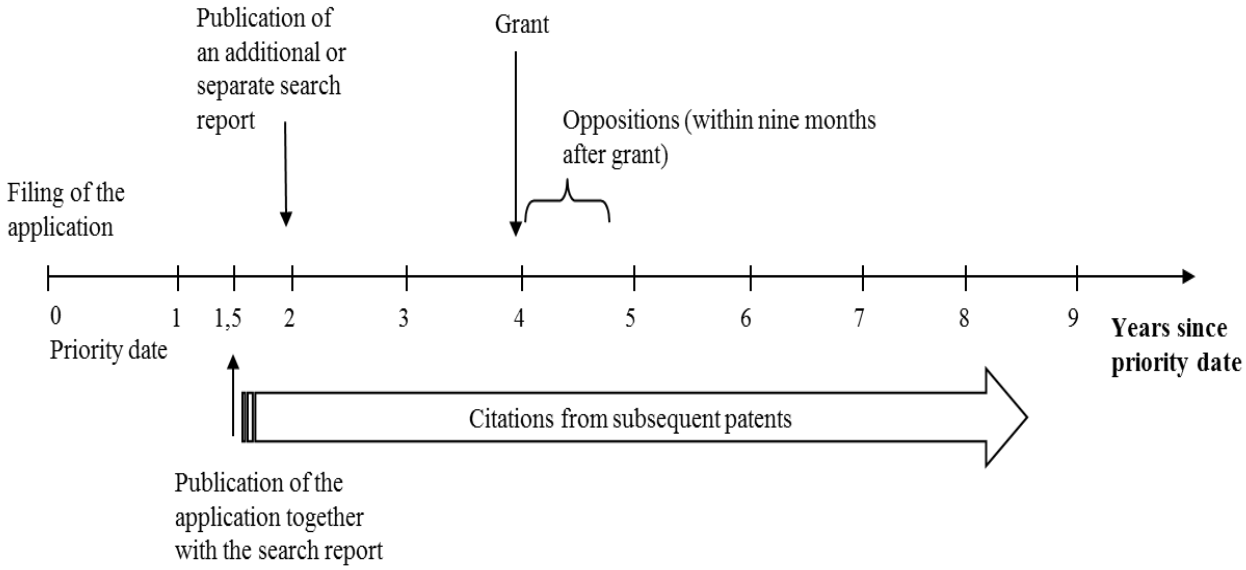

Figure 2: Quarterly Patent Applications by Company Type

Table 1: Descriptive Statistics of Time-Variant Patent Variables

	VC-financed firms			Non VC-financed firms			Diff. mean
Variable	Obs	Mean	St.Dev.	Obs	Mean	St.Dev.	p-value
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. * 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. Firms that are VC-financed received VC-financing within the first 16 quarters after being founded.

Table 2: Descriptive Statistics of Time-Invariant Control Variables

	VC-financed firms			Non VC-financed firms			Diff. mean
Variable	Obs	Mean	St. Dev.	Obs	Mean	St. Dev.	p-value
technological capabilities	87	2.16	1.31	103	1.69	1.04	0.006
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%.

Online Appendix

Appendix 1. Robustness Check: Selection

We compiled an additional dataset 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 focusing 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 were not counted as closures if their legal entity had not been 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 was established from the information on ownership structure in the dataset. In our sample, 112 companies received VC financing; 37 of these are already out of business. Of the VC-financed companies, 61% had applied for at least one patent at the time of financing. Companies that have filed applications had applied for 4.3 patents on average (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 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 dataset are not distorted by selection bias.

Table A1: Hazard Models – Alternative Data Source

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

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