

Economics of Innovation and New Technology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/gein20>

Patents as quality signals? The implications for financing constraints on R&D

Hanna Hottenrott^{abc}, Bronwyn H. Hall^{def} & Dirk Czarnitzki^{bcg}

^a Düsseldorf Institute for Competition Economics (DICE), Düsseldorf, Germany

^b Center for R&D Monitoring (ECOOM) at KU Leuven, Leuven, Belgium

^c Centre for European Economic Research (ZEW), Mannheim, Germany

^d Department of Economics, University of California, Berkeley, USA and NBER, Cambridge, USA

^e Maastricht University, Maastricht, The Netherlands

^f National Institute of Economic and Social Research, London, UK

^g Department of Managerial Economics, Strategy and Innovation, KU Leuven, Leuven, Belgium

Published online: 01 Sep 2015.



CrossMark

[Click for updates](#)

To cite this article: Hanna Hottenrott, Bronwyn H. Hall & Dirk Czarnitzki (2015): Patents as quality signals? The implications for financing constraints on R&D, *Economics of Innovation and New Technology*, DOI: [10.1080/10438599.2015.1076200](https://doi.org/10.1080/10438599.2015.1076200)

To link to this article: <http://dx.doi.org/10.1080/10438599.2015.1076200>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or

howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Patents as quality signals? The implications for financing constraints on R&D

Hanna Hottenrott^{a,b,c}, Bronwyn H. Hall^{d,e,f} and Dirk Czarnitzki^{b,c,g}

^aDüsseldorf Institute for Competition Economics (DICE), Düsseldorf, Germany; ^bCenter for R&D Monitoring (ECONOM) at KU Leuven, Leuven, Belgium; ^cCentre for European Economic Research (ZEW), Mannheim, Germany; ^dDepartment of Economics, University of California, Berkeley, USA and NBER, Cambridge, USA; ^eMaastricht University, Maastricht, The Netherlands; ^fNational Institute of Economic and Social Research, London, UK; ^gDepartment of Managerial Economics, Strategy and Innovation, KU Leuven, Leuven, Belgium

ABSTRACT

Information about the success of a new technology is usually held asymmetrically between the research and development (R&D)-performing firm and potential lenders and investors. This raises the cost of capital for financing R&D externally, resulting in financing constraints on R&D, especially for firms with limited internal resources. Previous literature provided evidence for start-up firms on the role of patents as signals to investors, in particular to Venture Capitalists. This study adds to previous insights by studying the effects of firms' patenting activity on the degree of financing constraints on R&D for a panel of established firms. The results show that patents do indeed attenuate financing constraints for small firms where information asymmetries may be particularly high and collateral value is low. Larger firms are not only less subject to financing constraints, but also do not seem to benefit from a patent quality signal.

ARTICLE HISTORY

Received 15 February 2014
Accepted 3 February 2015

KEYWORDS

patents; quality signal;
research and development;
financial constraints;
innovation policy

JEL CLASSIFICATION

O31; O32; O38

1. Introduction

A view widely held by economists and entrepreneurs is that investments in research and development (R&D) are discouraged by imperfections in capital markets. The main reason is that information about the success of a new technology is usually held asymmetrically between the R&D performer and potential lenders and investors, making it difficult for these outsiders to judge the R&D-performing firms' quality (Arrow 1962). This raises the cost of external capital and makes it in some cases impossible to obtain financing for projects that would have a positive expected net present value if normal interest rates or the cost of internal funds (if available) were used to estimate value. In the light of this phenomenon, an increasing number of academic studies have attempted to understand, identify, and explain the occurrence of financing constraints for R&D and innovation.¹

Drawing on the concept of job market signals (Spence 1973), several studies have suggested that patents provide signals to external investors that mitigate such financing constraints. As lenders may be able to derive probabilities for the success of R&D-active firms across certain industries, but usually have difficulties assessing the value of R&D activities of individual firms, the role of quality signals thus lies in their potential to reduce information asymmetries by providing a 'sorting mechanism'. Signals thus help outsiders to derive expectations about the quality of the firm that cannot be directly observed, such as R&D success. Due to the inherent characteristics of the R&D process, when evaluating R&D-intensive firms, external lenders and investors therefore usually have to rely on observable firm characteristics which are presumably correlated with characteristics directly related to the R&D

project(s) and their success, which are not easily observable. Long (2002) was among the first to argue that patents are an effective instrument for reducing information asymmetries between the patenting firm and outside investors. Patents have properties that may make them ideal candidates as proxies for the quality assessment of R&D-active firms: they are costly to obtain, easily observable and verifiable by outsiders. If lenders believe that patents correlate with other, less easily observable firm characteristics which are not necessarily directly related to the inventions, patent applications or grants may function as signals for otherwise unobservable or difficult-to-measure attributes, such as knowledge capital or the productivity of R&D spending. Moreover, the patenting process may help to reveal information about technological discoveries and their potential value that otherwise would be more difficult to convey to lenders and investors. The ability to convey information credibly to outsiders at relatively low cost may therefore be a highly valuable certification function of patents (Arora, Fosfuri, and Gambardella 2001; Long 2002).

Previous research that has studied the signaling value of patents has focused mainly on start-up firms in high-tech industries. This literature usually finds a positive relationship between patents and Venture Capital (VC) financing (e.g. MacMillan, Siegel, and Subbanarasimha 1985; Baum and Silverman 2004; Mann and Sager 2007; Haeussler, Harhoff, and Mueller 2009; Conti, Thursby, and Rothaermel 2013; Hsu and Ziedonis 2013). While the evidence for patents as a quality signal for attracting VC financing concludes that they do indeed function that way, the evidence for the impact of patents on obtaining later stage financing, such as for the success of initial public offerings (IPOs), is rather mixed (Deeds, DeCarolis, and Coombs 1997; Stuart, Hoang, and Hybels 1999; Heeley, Matusik, and Jain 2007).

This paper contributes to the existing literature by providing panel data evidence for a large sample of established, R&D-active firms. To our knowledge, it is the first to look at established firms rather than start-ups. Recent research stressed that not only firms' age (young firms are usually also small), but also size among older firms matters for access to financing (Czarnitzki and Hottenrott 2011a; Fort et al. 2013). The following analysis will therefore study the certification effect of patents taking size heterogeneity among the firms into account. Moreover, it is among the first papers to study the relationship using patents filed at the EPO rather than the US Patent and Trademark Office. We further employ a methodology that allows studying financing constraints in the market for bank finance as bank loans constitute the major external financing source for firms in most European countries.

More precisely, the study adds to previous research on the topic by investigating a large sample of R&D-active firms from the Flemish part of the Organisation for Economic Co-operation and Development (OECD) R&D survey in a broad range of industries comprising both small and large firms. We estimate panel data models for the period 2000–2009 that allow us to control for unobserved firm-specific effects. However, due to the unbalanced nature of the panel and the fact that the dependent variable is censored at zero, we are unable to estimate fully dynamic panel data models.

The results show that patents indeed attenuate financing constraints. This holds for the patent stock of the firms as well as for recently filed patents. As patents may be particularly useful in reducing information asymmetries between firms and lenders when information asymmetries are large and when alternative ways of achieving credibility are limited, we expect small firms to benefit more from patent signals than larger ones. In line with these expectations, we find the effects to hold only for small firms with less than 50 employees. Larger firms are not only less subject to financing constraints in the first place, but also do not seem to benefit from a patent quality signal. We do not find any corresponding effect for young firms versus old firms, but this may be due to the fact that our sample includes only established young firms (those older than five years old) and not start-ups.

This article proceeds as follows. Section 2 outlines the motivation for this research and briefly summarizes related research. Section 3 sets out the conceptual framework of our analysis and Section 4 describes the data. The econometric set-up, our model specifications and the results are described in Section 5. Section 6 concludes.

2. Capital market imperfections and the signaling value of patents

2.1. *The role of internal finance for R&D*

Generally, a firm is considered to be financially constrained if it cannot carry out its R&D activities at desired scale and scope due to a lack of financing availability or a very high cost of financing. Unlike most investment in tangible goods, R&D projects are characterized by high and usually firm-specific investments, on the one hand, and low collateral value, on the other hand. Before willing to grant a loan, banks usually require some degree of collateral value. Especially small, R&D-active firms may fail to provide sufficient collateral value to lenders that would back potential loans. Additionally, information asymmetries between the R&D-active firm and lenders adversely affect financing conditions. Information asymmetries may be particularly severe in case of small firms for which credibly conveying information regarding their technological capabilities and overall creditworthiness is hard. As argued by Berger and Udell (1998), 'unlike large firms, small firms do not enter into contracts that are publicly visible or widely reported in the press – contracts with their labor force, their suppliers, and their customers are generally kept private'. Moreover, small firms usually do not issue traded securities that are continuously priced in public markets and often do not have audited financial statements that are available to providers of outside finance.

Consequently, it is relatively more expensive for lenders to collect information on small firms, who usually apply for loans of relatively small amounts, where cost is measured by screening costs per borrowed or invested Euro. Likewise, small firms face a relatively high cost of providing information to lenders as doing so requires scarce human, financial and time resources. As a result, small firms may have larger difficulties to credibly convey their quality to outsiders than larger firms.

If instead of detailed assessment, lenders consider average project quality in the market to assess a firm's R&D quality, this may result in a 'lemon's premium' for above-average projects increasing financing costs even for the most promising firms (Leland and Pyle 1977). Constrained firms therefore (have to) rely to a larger extent on internal resources when financing their R&D than firms that mainly invest in capital goods (Hall 1992; Himmelberg and Peterson 1994; Harhoff 1998; Bougheas, Görg, and Strobl 2003; Levitas and McFadyen 2009; Czarnitzki and Hottenrott 2011a). This fact constrains R&D projects for firms whose internal financial sources are limited and whose innovation potential is high (Czarnitzki and Hottenrott 2011b; Brown, Martinsson, and Petersen 2012; Hottenrott and Peters 2012). Not surprisingly, earlier empirical evidence supported the view that small firms in particular encounter difficulties financing R&D leading to delayed, canceled or postponed projects (Carpenter and Petersen 2002; Schneider and Veugelers 2010; Czarnitzki and Hottenrott 2011a).² In line with these previous insights, we thus hypothesize that

Hypothesis 1: Small R&D-active firms are more likely to be financially constrained in their R&D investment than larger R&D-active firms. Thus, small firms' R&D investment should be more sensitive to internal liquidity than that of larger firms.

2.2. *The role of patents*

If firms seek access to external financing while engaged in complex R&D projects that require a high degree of specialized skills to understand the technological details, lenders and investors usually have to rely on observable firm characteristics which are presumably correlated with properties that are not easily observable such as those directly related to the firms' R&D project(s). Because it can be costly and difficult for potential lenders to assess the value and thus the creditworthiness of a firm, quality signals may be used to reduce cost and effort devoted to quality assessment of the firms. Signals may provide a 'sorting mechanism' based on an easily observable attribute that allows deriving expectations about qualities of the firm that are not immediately observable.

Long (2002) argued that patents are effective for reducing information asymmetries between the patenting firm and outside investors. She distinguished 'the simple view of intellectual property

rights' that regards patents as an exchange of information for compensation in the form of protection, from a broader view that considers patents also as a tool to credibly convey information about the underlying innovation. The argument is based on the fact that patents have properties that may make them good and readily available proxies for the quality assessment of R&D-active firms. First, patents are costly to obtain (administrative and attorneys' fees in addition to the R&D that is often needed to come up with a patentable invention),³ and are easily observable and verifiable for outsiders. Myers and Majluf (1984) stressed the importance of supplying a 'verifiable detail' to convey information. Patents are publicly available documents that minimize information costs for potential lenders and investors and since penalties for intentionally misrepresenting information in a patent application are severe, outsiders know that the information contained in a patent has some credibility (Long 2002).

Second, if lenders assume that patents correlate with difficult-to-measure firm characteristics that are not necessarily directly related to the firms' patented inventions, patents may still be a useful signal. For instance, patents provide information about the firms' ability to perform valuable research as patents measure the outcome of past R&D and thus 'advertise' the firms' innovative capabilities. For an invention to be patentable, it must be new, industrially applicable and involve an inventive step. These requirements and the fact that patent applications need to be approved by the patent office through a certification process suggest that possessing a patent is the result of successful previous R&D, hence signaling the general R&D competencies of the firm (Stuart, Hoang, and Hybels 1999).⁴ Henderson and Cockburn (1994), for example, used patent counts to measure the research competencies of firms in the pharmaceutical industry and Harhoff (2009) argues that patents may signal the quality of the firms' R&D staff and its ability to handle intellectual property rights.

Moreover, market value studies typically find that both R&D expenditures and patent stocks correlate positively with firms' market value, and that patent stocks add information on the value of firms' knowledge assets beyond R&D stocks (Hall 2000; Hall, Jaffe, and Trajtenberg 2005; Czarnitzki, Hall, and Oriani 2006). Thus, lenders may use patent counts to extrapolate the future value of the firm. In addition, firms owning a patent experience a larger growth rate and higher productivity than firms not owning a patent and this relationship has been shown to be stronger for small patentees in the UK (Helmets and Rogers 2011; Hall et al. 2013).

Levitas and McFadyen (2009) note that patents raise the prospects of future cash flows and as patents protect firms – at least to some extent – against competition, they may be expected to earn higher profit margins in the future. Moreover, since patents facilitate the licensing of technology, patents may signal additional returns to the patented technologies (e.g. Kulatilaka and Lihui 2006).

Almost more important than the profitability of the firm for lenders is the survival of the firm. The high risk of bankruptcy is one reason why small and young firms face difficulties in raising external financing. Cockburn and Wagner (2007) show that possessing patents is positively correlated with the survival of the firm and Mann and Sager (2007) also find a positive relationship between patenting activity and several success measures one among which is survival.

From the perspective of the firm, a reluctance to disclose innovation-related information to outsiders because of fear of imitation by competitors may exist (Bhattacharya and Ritter 1983; Anton and Yao 2002), so that one would expect rational firms to seek patent protection only if the expected returns from the patent outweigh the costs of disclosing the information. If patents, however, have some signaling value, firms may be willing to disclose the information on their inventions in patent applications not only in exchange for being able to exclude others from using the information in certain ways, but also in order to reduce informational asymmetries between themselves and outsiders. Being aware of such a signaling value, firms may apply for patents to signal information about themselves and their R&D that would be more expensive or even impossible, or less credible when revealed in other contexts. This may explain why firms (and especially small and young companies) patent even when the need to exclude others is not important because of high cost of imitation. Moreover, because of the comparatively higher burden of obtaining a patent for small firms, it provides an even stronger patent signal to external parties. Finally, patents may also signal some salvage

value that will be available if the firm goes bankrupt. However, it can be argued that the true collateral value is very difficult to assess and that therefore the signal stems more from the fact that patents make research output 'as tangible as it gets'.

Based on these arguments, we hypothesize that patents have some signaling value that helps the firm to obtain finance:

Hypothesis 2: Firms' past patenting activities alleviate financing constraints.

We will measure the presence of these constraints via the sensitivity of firms' R&D investment to the availability of internal funds. Additionally, the previous considerations lead us to hypothesize that small firms benefit more from the existence of patent signals than larger firms. Thus, we further hypothesize the following:

Hypothesis 3: Firms' past patenting activities are more important for alleviating financing constraints for small firms' than for larger firms.

A crucial feature of a patent is that it signals hidden attributes of the firm that lenders assume will increase the value of the firm or may make it likely that the firm will repay its debt, even if the value gain is not directly related to the patent. For example, having a patent may constitute a competitive advantage through being a first-mover in the industry (Bessen and Maskin 2009). According to Long (2002), this might explain why industries in which competitive advantage in product markets is often derived from being a first mover, such as semiconductors and information technology (IT), are also among the industries in which patenting is most active (Hall and Ziedonis 2001). Furthermore, it might explain why small firms, which usually face greater informational asymmetries in capital markets than large firms, tend to patent relatively more intensely (in comparison to their R&D) than large firms, even though they may enforce their patents less (Mansfield 1986; Griliches, Pakes, and Hall 1987).⁵

Importantly, Lemley (2000) argues that venture capitalists use patent applications as evidence that the company is well managed, is at a certain stage in development, and has defined and carved out a market niche, rather than attributing a certain value to the patent itself. Similarly, patents may simply indicate the firm's confidence in its research which may not be necessarily related to the relevance of the technology for future inventions. Thus, if patents constitute a quality signal, we expect that

Hypothesis 4: The signaling value of a patent application is related to its existence, but not related to the covered technology's ex-post value.

2.3. Empirical evidence

Since the work of MacMillan, Siegel, and Subbanarasimha (1985), patents have been recognized as a relevant selection criterion for VC investors. A considerable number of studies have since supported the hypothesis of a positive relationship between the patent stock of high-tech start-ups and the amount of VC funding received.

Hall and Ziedonis (2001) interview executives in the US semiconductor industry and find that they consider patent rights to be of significant importance in attracting VC funding. Similarly, Baum and Silverman (2004) show a positive relationship between patent applications at the US Patent Office and VC financing. However, they conclude that the importance of patents in this regard varies across industries. Mann and Sager (2007) analyze the relationship between patenting of software start-up firms and the progress of those firms through the VC cycle. They find significant and robust positive correlations between patenting and the number of financing rounds, total investment, as well as the receipt of late-stage financing. Interestingly, they observe that the effect of patents depends less on the size of the patent portfolio than on the firm's receipt of at least one patent.

Hsu and Ziedonis (2013) argue that patents can increase the perception about the value of start-ups and that new entrepreneurial firms benefit most in early stages of financing when technological uncertainty is high and alternative means for conveying quality to outsiders are lacking. In particular, they find that venture-backed semiconductor start-ups with a higher patent application stock than others are more likely to attract initial funding from a prominent venture capitalist. For start-ups by founders without prior success in securing initial funds from prominent VCs, patents are even more influential. Moreover, they find patents to induce steeper valuation adjustments in earlier rounds of VC financing.

Using a sample of German and British biotechnology companies, Haeussler, Harhoff, and Mueller (2009) find that VC funding happens earlier when patent applications are present. Levitas and McFadyen (2009) suggest that patents signal the firms' invention and innovation competencies and facilitate access to external financing, as they observe that patent owning firms seem to rely less on accumulating large cash holdings to fund their (future) R&D projects. Most recently, Conti, Thursby, and Rothaermel (2013) examine a sample of start-up firms in the Georgia Institute of Technology new firm incubator and find that those with patents obtain more external financing; the authors conclude that patents serve as a signal for venture capitalists. Hoenen et al. (2014), however, find for US-based biotechnology firms that patent applications are positively associated with first-round, but not with second-round VC financing. Conti, Thursby, and Thursby (2013) concluded that patents serve to attract new investors and are intended for that purpose by Israeli start-up firms. This signal, however, is only effective for venture capitalists, but not for private investors. On the contrary, Hoenig and Henkel (2014) argue that VCs rely on research alliances as indicators of technological quality, rather than on patents, which influence VC decisions in their primary role as property rights.

While previous research usually finds a positive relationship between patents and VC financing, evidence for later stage financing is rather ambiguous. Examining the IPO performance of biotechnology start-ups, Deeds, DeCarolis, and Coombs (1997) find no effects of patents on the amounts raised in an IPO and conclude that patents may only be 'noisy' signals that do not really affect the expectations of public investors. Stuart, Hoang, and Hybels (1999) observe that biotechnology start-ups advertise their patent filings when aiming at IPOs although these authors also find that patents have minimal effect on market value of new biotechnology listings. Likewise, Heeley, Matusik, and Jain (2007) find contradictory results concluding that patents can serve as signaling devices in sectors such as biopharmaceuticals and chemicals, while they find no such evidence for IT firms.

The motivation for the following study is thus based on two aspects that have not been addressed by previous research. First, this study is the first to use panel data evidence for a large sample of established, R&D-active firms. Recent research on financing constraints for R&D reported evidence for such constraints not only for young, start-up firms, but also for more established firms (Czarnitzki and Hottenrott 2011a, 2011b; Czarnitzki, Hottenrott, and Thorwarth 2011; Hottenrott and Peters 2012; Lahr and Mina 2013; Mina, Lahr, and Hughes 2013). However, no study examines the role of patents for mitigating financing constraints for these firms. Second, the following study is among the first to look at this question using patents filed at the EPO.

3. Conceptual framework

Following on the seminal work of Fazzari, Hubbard, and Petersen (1988), many econometric studies have approached the detection of financing constraints by comparing different groups of firms in terms of their investments' sensitivity to internal financing. While this approach was initially applied for any type of investment, later studies have adopted the methodology analogously to investment in R&D (e.g. Hall 1992; Himmelberg and Peterson 1994). For the group of supposedly unconstrained firms, R&D spending should not be as sensitive to the availability of internal funds as the R&D of constrained firms, as the former group is able to raise financing externally. Recent

research further stressed the importance of R&D smoothing through cash holdings, especially for firms that are most likely to face financing frictions (Brown and Peterson 2011; Brown, Martinsson, and Petersen 2012). In line with this methodology, we use a standard empirical model of R&D investment sensitivity to internal liquidity and examine how the estimates of this model vary across firms of different sizes. We measure internal liquidity by the firms' working capital including cash holdings. To explore the role of firm size, we distinguish between large and small firms where 'small' is defined using the European Commission definition, namely that the firm has fewer than 50 employees, and estimate separate equations for small and large firms' investment to identify differences in the reliance of firms on internal funds, on the one hand, and difference in the effects of firms patenting activity on access to external financing, on the other. We expect a positive relationship between firms' liquidity and the firms' expenditures in R&D and we expect this relationship to be stronger for the small firms, as suggested by hypothesis (1).

If patents serve as a quality signal, the firms' stocks of patents (or the number of pre-period patent applications) should reduce the firms' reliance on internal funds for their R&D investments. Harhoff (2009) argues that patents do not necessarily have to be granted yet in order to work as a signal as even patent applications reveal information and require money and time. Hence, we use patent applications rather than granted patents in the subsequent analysis. We expect that the interaction term between patent applications and internal funding is negative, (partially) offsetting the positive effect of internal liquidity.

4. Data

The following analysis uses a unique database that we constructed based on several sources: the Flemish R&D survey, the OECD/EPO patent citations database, and the Bureau van Dijk BEL-FIRST database. The proposed analysis requires non-anonymized firm-level data including variables such as R&D collected over a long period of time as well as financial information for small firms that are not subject to strict publication rules for accounting data. Although such data are available for other countries, it is usually not possible for external researchers to access these data in the non-anonymized form that allows search by company names in a patent database. For the present paper, we had such data available and we were able to link firms and patents at the firm level using text-field string matching based on firms' names and addresses.

Information on firms' R&D-related activities comes from the Flemish part of the OECD R&D survey. This survey is harmonized across OECD countries and is conducted every second year in order to compose the OECD Main Science and Technology Indicators. The sampling population from which the survey sample is drawn targets all R&D-active companies in Flanders. Our analysis is based on repeated cross-sections that form an unbalanced panel from five consecutive waves of the R&D survey covering the period from 2000 to 2009. Each wave provides information at the firm level for two consecutive years. The definition of R&D used in the survey is based on the definition of the OECD Frascati Manual ([1993] 2002) which frames the methodology for collecting and using statistics about R&D in OECD countries.

Patent information comes from a database issued by the EPO, the 'OECD/EPO patent citations database' (Webb et al. 2005). This database covers all patents applied for at the EPO since its foundation in 1978 as well as all patents applied for under the Patent Cooperation Treaty (PCT) in which the EPO is designated, the so-called 'Euro-PCT applications'. Additionally, information from the Belgian patent office was used to include information about patents filed in Belgium only. Patent data are available as a time series from 1978 until the end of 2011.

The accounting and balance sheet data for our firms stem from the BELFIRST database provided by Bureau van Dijk. BELFIRST is a comprehensive database that contains information on about 1.2 million active and non-active Belgian companies. Approximately half of the companies have financial account information; the remainders are generally individuals (sole traders).

Our sample comprises firms that invested at least once in R&D during the panel period and are observed at least twice during that time. We require two years of data since we estimate simple panel data models that control for unobserved heterogeneity. On average, we observe each firm about four times in our panel. After eliminating data with missing values in the variables of interest and requiring the firms to be observed at least twice during the sample period, our final unbalanced panel consists of 4309 unique firm-year observations referring to 1135 different firms active in a broad range of industries. Table A1 in the [appendix](#) provides details on the distribution of firms across industries.

4.1. Variables

Firms' R&D expenditures (more precisely, firms' R&D intensity measured as the ratio of R&D spending to tangible capital) serve as the dependent variable in the following analysis (*R&D*). We derive indicators for the firms' capital structure from balance sheet information.⁶ The firms' stock of working capital serves as a measure of operating liquidity. As suggested by Hall and Krainer (1995), using working capital instead of cash flow as a measure of firms' liquidity is preferable, because it is a better indicator of the funds available for investment.⁷ Although working capital is affected by cash flow, working capital is a more precise liquidity indicator when it comes to investment decisions as it also includes not only cash but also values that can relatively easily be converted into cash; in short, it is a stock rather than a flow. Working capital (*WCAP*) is defined as net short-term assets, that is, the difference between current assets and current liabilities of a firm. In this study, we use a somewhat stricter measure that is to a high degree comparable across firms in our sample and not biased by accounting options, computing working capital *WCAP* as cash + inventories + accounts receivable–accounts payable.⁸ Other short-term assets (other current assets, prepaid expenses, and deferred charges) and short-term liabilities (other short-term debt and other creditors) are not included. The higher the working capital, the more secure is a firm's liquidity and accordingly its financial flexibility. This variable can take positive or negative values. Positive working capital means that short-term liabilities are covered by current assets, whereas negative working capital indicates that a firm's current assets are not sufficient to cover its current liabilities.

As an indicator of the state of the firm's balance sheet and its access to the credit market, we use the ratio of long-term debt (consisting of all non-current liabilities payable later than one year) to tangible assets of the firm.⁹ For this variable, we use a two-period lag as debt is measured at the end of the year $t-2$, so that its visibility to potential lenders is effective in $t-1$. We calculate the firms' debt-to-tangible assets ratios (*DEBTRATIO*) rather than debt-to-equity ratios, as the former type is more meaningful in reflecting the firms' liabilities relative to the firms' collateral value. Thus, as common in the literature, we scale the dependent variable as well as *WCAP* and *DEBT* by firm assets (see e.g. Fazzari, Hubbard, and Petersen 1988; Fazzari and Petersen 1993; Harhoff 1998). We use tangible assets (*K*) from the firm accounts, which excludes intangible assets, financial assets, and current assets.

Our measure of the key variable, patenting activity, is computed as the stock of patent applications made by the firm. We compute this quantity for each firm and year as a perpetual inventory of past and present patent applications of the firm with a constant depreciation rate (δ) of 15%, as is common practice in the literature (see Griliches and Mairesse 1984):

$$\text{PATSTOCK}_{i,t} = (1 - \delta)\text{PATSTOCK}_{i,t-1} + \text{PATAPPS}_{i,t}. \quad (1)$$

We also control for the size of the firms' tangible assets, measured as the log of those assets. Larger firms may be able to realize economies of scale and scope when doing R&D activities, which may affect their R&D intensity either positively or negatively. This result was originally pointed out by Fisher and Temin (1973), who show that a finding that R&D intensity increases with firm size is neither necessary nor sufficient to show that the productivity of R&D increases with firm size or the size of the R&D program. Therefore, we have no prior expectation about the sign of this coefficient.

Because R&D investment may also depend on the life cycle of the firm, and younger firms are often observed to invest relatively more in R&D than older firms, we control for age-related effects by including the log of age, $\ln(AGE)$. Additionally, the dummy variable $GROUP$ is included to take into account that firms that are part of an enterprise group may conduct more R&D since firms associated with a group can benefit from intra-firm knowledge spillovers as well as from R&D funding through intra-group sources. A set of yearly time dummies is included to account for overall business cycle effects and 16 sector dummies on the basis of the European standard industry classification (NACE Bel rev2) are included to capture differences in technological opportunities that determine R&D investment. To avoid simultaneity bias due to feedback effects from the dependent variable to current explanatory variables, we use lagged values of all time-varying independent variables (with the exception of AGE).

4.2. Descriptive statistics

Table 1 presents the descriptive statistics for these variables for the full sample as well as for the groups of small and larger firms separately. We define small firms as those whose employment averages less than 50 during the sample period, which is essentially the definition used by the European Commission. Out of a total of 4390 firm-year observations, 44% refer to small firms.

Average R&D to tangible assets ratio in the full sample is 0.88 corresponding to annual R&D spending of about 3 million euros on average. Median spending is much lower, however, at about 132 thousand euros (not reported). Almost 20% of firms have at least one patent in the sample period. The

Table 1. Descriptive statistics (main variables).

Variable	Units	Mean	Std. Dev.	Min	Max
<i>Full sample (4390 obs. on 1147 firms)</i>					
$R\&D_{i,t}/K_{i,t}$	Ratio	0.88	3.88	0	128.57
$PATSTOCK_{t-1}$	Count	1.09	8.06	0	231.2
$PATAPPS_{t-1}$	Count	0.60	4.52	0	132
$CITSTOCK_{t-1}$	Count	9.72	181.72	0	5667.5
$WCAP_{i,t-1}/K_{i,t-1}$	Ratio	4.87	9.40	-0.91	112.26
$DEBT_{i,t-2}/K_{i,t-1}$	Ratio	1.34	3.27	0	38.76
$K_{i,t-1}$	Million €	17.96	99.26	0.001	2253.24
$EMP_{i,t}$	Headcount	255.70	693.01	1	11,575
$AGE_{i,t}$	Years	28.79	19.82	5	138
$GROUP_i$	Dummy	0.57	0.50	0	1
<i>Large firms (2428 obs. on 567 firms)</i>					
$R\&D_{i,t}/K_{i,t}$	Ratio	0.50	1.81	0	27.81
$PATSTOCK_{t-1}$	Count	1.89	10.77	0	231.2
$PATAPPS_{t-1}$	Count	1.04	6.04	0	132
$CITSTOCK_{t-1}$	Count	1.34	3.27	0	38.76
$WCAP_{i,t-1}/K_{i,t-1}$	Ratio	17.49	244.09	-0.82	5667.5
$DEBT_{i,t-2}/K_{i,t-1}$	Ratio	1.59	3.79	0	38.76
$K_{i,t-1}$	Million €	31.72	131.86	0.02	2253.24
$EMP_{i,t}$	Headcount	443.93	888.29	13	11,575
$AGE_{i,t}$	Years	33.00	22.19	5	138
$GROUP_i$	Dummy	0.76	0.43	0	1
<i>Small firms (1962 obs. on 580 firms)</i>					
$R\&D_{i,t}/K_{i,t}$	Ratio	1.36	5.41	0	128.57
$PATSTOCK_{t-1}$	Count	0.11	0.51	0	7.4
$PATAPPS_{t-1}$	Count	0.06	0.34	0	5
$CITSTOCK_{t-1}$	Count	0.10	1.29	0	36
$WCAP_{i,t-1}/K_{i,t-1}$	Ratio	5.60	10.59	-0.91	111.5
$DEBT_{i,t-2}/K_{i,t-1}$	Ratio	1.04	2.44	0	38.13
$K_{i,t-1}$	Million €	0.94	2.27	1	49.63
$EMP_{i,t}$	Headcount	22.77	14.00	1	85
$AGE_{i,t}$	Years	23.58	14.85	6	106
$GROUP_i$	Dummy	0.33	0.47	0	1

average patent stock is 1.09 and firms file on average 0.6 patents per year. In the group of patent-active firms, that is, firms with at least one patent application, the average number is 2.9 patents per year (not reported). The firms' long-term debt is around 22 million euros on average resulting in a mean debt to tangible assets ratio of 1.34; the median is much lower at a ratio of 0.52. The working capital to tangible assets ratio is 4.87 and firms' employment averages 256 (median 64). The mean firm age is close to 29 years and 57% of the firms are part of an enterprise group.

When splitting our sample into small and larger firms, we see interesting differences in the main variables between these two groups. Small firms have significantly (at 1% level) higher R&D expenditures to tangible assets ratios, smaller patent stock and fewer patent applications in a given year. Small firms' patents receive significantly fewer citations, reflected in smaller citations stocks. Moreover, these firms are younger, more often independent ventures and have lower debt ratios (*DEBT/K*), on average. The amount of working capital is also significantly lower for the subsample of small firms as one would expect, but the mean of the working capital to tangible assets ratio is larger for the group of small firms.

In terms of their basic characteristics, we believe that the firms in the sample are representative of Flemish R&D performers. We base this assertion on two facts: (1) the sampling methodology is that used by government statistical agents to collect data for various R&D reports, both Eurostat and OECD. (2) Key statistics of the sample, such as the patentee share of 20%, are well in line with numbers for Europe in general. On average, 19% of European manufacturing firms with innovation activity filed at least one patent. The share varies between 15% in countries such as Italy and Denmark, 18% in the Netherlands, 24% in Germany and 27% in France (European Communities/Eurostat 2004, p. 60). Furthermore, the firm-size distribution is similar to the one of other European countries such as Germany, Austria, France and the UK where the large majority of firms employs less than 250 employees and the median firm size ranges between 40 and 50 employees (Rubini et al. 2012).

5. Econometric analysis

In the following econometric analysis, we estimate censored panel regression models, as not all of our firms in the sample perform R&D in each year, which results in a left censoring of the dependent variable. Small firms especially may conduct R&D only on an irregular basis. Indeed, in our sample, the number of censored observations is larger in the group of firms with fewer than 50 employees. Thus, we estimate random-effects Tobit models that can be written as

$$y_{it} = \max(0, x_{it}\beta + c_i + u_{it}), \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T \quad (2)$$

$$u_{it}|x_i, c_i \sim N(0, \sigma_u^2),$$

where y denotes the dependent variable, x the set of regressors, c a firm-specific time-constant effect, and u the usual random error term. The parameters to be estimated are denoted by the vector β .

The first specification of the model to be estimated assumes that there is no correlation between c and x (see Wooldridge 2002, 540–541, for further technical details). Note that it is not appropriate to estimate a fixed-effects Tobit model, as the maximum likelihood estimator of this model is not consistent (see e.g. Cameron and Trivedi 2005). As the uncorrelatedness assumption between x and c can easily be challenged, we relax this assumption by adding 'within' means of each of the time-varying covariates to the set of regressors to proxy 'quasi-fixed effects', following Wooldridge (2002). Thus, if $c_i = \psi + \bar{x}_i\xi + a_i$ we can write

$$y_{it} = \max(0, \psi + x_{it}\beta + \bar{x}_i\xi + a_i + u_{it}), \quad (3)$$

with $u_{it}|x_i, a_i \sim N(0, \sigma_u^2)$ and $a_i \sim N(0, \sigma_a^2)$.

The appropriateness of the Wooldridge model, that is, that the assumption of uncorrelatedness between the firm-specific effect and the regressors is not valid, will be tested by the joint significance of the x -variables' 'within' means.

The basic model for R&D investment is specified as:¹⁰

$$\frac{R\&D_{it}^*}{K_{it}} = \beta_0 + \beta_1 \ln(\text{PATSTOCK}_{i,t-1}) + \beta_2 \frac{\text{WCAP}_{i,t-1}}{K_{i,t-1}} + \beta_3 \frac{\text{WCAP}_{i,t-1}}{K_{i,t-1}} \times \ln(\text{PATSTOCK}_{i,t-1}) \\ + \beta_4 \frac{\text{DEBT}_{i,t-2}}{K_{i,t-1}} + \sum_{h=5}^8 \beta_h Z_{ihk} + \gamma_i + \delta_t + c_i + u_{it},$$

where Z_{ik} corresponds to the set of firm-level control variables including *SIZE* in terms of tangible assets, *AGE* and *GROUP*. γ_i and δ_t denote the 16 two-digit industry and the 10-year dummies, respectively. The model for the observable *R&D/K* ratio is the following:

$$\frac{R\&D_{it}}{K_{it}} = \begin{cases} \frac{R\&D_{it}^*}{K_{it}} & \text{if } x_{it}\beta + c_i + u_{it} > 0 \\ 0 & \text{otherwise.} \end{cases} \quad (5)$$

We include an interaction term of the working capital ratio and the patent indicator to measure the impact of patenting activity on the firms' sensitivity in R&D investment to the availability of internal liquidity as captured by working capital. The patent indicator $\text{PATSTOCK}_{i,t-1}$ measures the firms discounted patent stock as described above at period $t-1$. We use the natural log of one plus $\text{PATSTOCK}_{i,t-1}$ in estimation to because of the skewness of the patent distribution (and to avoid missing values when the stock is zero). One may also include an indicator that captures recent patenting activity, that is, a dummy for new patent applications (*PATDUMMY*) that takes the value one if the firms filed for at least one patent in $t-1$.

One problem that arises when estimating R&D investment equations is the potential simultaneity between R&D and the variables such as leverage and size used to predict it. We have tried to mitigate this problem by using lags of all our predictor variables, but given the intertemporal nature of firm strategies, especially those associated with R&D behavior, this is not a complete solution. It might have been desirable to estimate dynamic panel data models since theoretical investment models are typically based on the firm's inter-temporal optimization problem conditional on the current level of (R&D) capital stock (see Mulkay, Hall, and Mairesse 2001; Brown and Peterson 2011; Brown, Martinsson, and Petersen 2012). However, application of the methods used by these authors would require four consecutive observations per firm in order to conduct meaningful panel regressions. Our panel dataset is not only unbalanced but has also gaps in the time-series structure because firms did not necessarily respond to the surveys in adjacent years. Therefore, we found it impossible to estimate dynamic models, given the sparseness of the data.

In addition, due to the unbalanced nature of our panel data, we could not follow the familiar panel data approach of using lagged values of the regressors as instrumental variables, as we would lose a large share of the observations. In addition, the validity of such instruments would be questionable, as many variables show high persistency over time. Thus, instruments external to the current model would be required. Unfortunately, it is very difficult to think about appropriate instrumental variables in the present context even conceptually, and the availability of appropriate data constitutes another hurdle for implementing appropriate IV regressions.

5.1. Estimation results

The results of the random-effects panel model are presented on the left-hand side in Table 2 and the results for the model that allows for correlated effects by including the within sample means of the time variant firm characteristics are presented on the right panel. Table 2 shows the results of the specification with the *PATSTOCK* variable as outlined above. The first and fourth columns present the results for the full sample, columns two and five show the results for small firms, and columns three and six for larger firms.

Table 2. Estimation results from Tobit regressions on R&D intensity (R&D over tangible assets) on lagged patent stock.

Variable	Random-Effects Panel Model			Wooldridge Estimator		
	Full sample	EMPL < 50	EMPL > 50	Full sample	EMPL < 50	EMPL > 50
$\ln(\text{PATSTOCK})_{t-1}$	0.785*** (0.156)	1.689*** (0.610)	0.409*** (0.071)	0.574** (0.203)	1.353* (0.740)	0.243*** (0.086)
$\text{WCAP}_{t-1}/K_{t-1}$	0.111*** (0.009)	0.159*** (0.016)	0.008 (0.006)	0.115*** (0.010)	0.175*** (0.019)	-0.001 (0.007)
$(\text{WCAP}_{t-1}/K_{t-1}) * \ln(\text{PATSTOCK})_{t-1}$	-0.051*** (0.010)	-0.105*** (0.023)	0.001 (0.005)	-0.052*** (0.010)	-0.105*** (0.023)	0.003 (0.005)
$\text{DEBT}_{t-2}/K_{t-1}$	0.042** (0.021)	0.104* (0.054)	0.045*** (0.010)	0.043* (0.023)	0.085 (0.062)	0.045*** (0.011)
$\ln(K_{t-1})$	-0.368*** (0.062)	-0.581*** (0.152)	-0.265*** (0.044)	-0.216 (0.125)	0.013 (0.248)	-0.422*** (0.071)
$\ln(\text{AGE}_t)$	-0.120 (0.181)	-0.365 (0.371)	0.029 (0.111)	-0.096 (0.182)	-0.289 (0.373)	0.007 (0.111)
GROUP _t	0.295* (0.168)	0.695** (0.334)	0.006 (0.099)	0.312* (0.170)	0.661** (0.337)	-0.016 (0.099)
Joint sign. of time dummies $\chi^2(9)$	23.0***	22.1***	13.2	23.9***	25.1***	14.2
Joint sign. of ind. dummies $\chi^2(15)$	102.2***	55.6***	68.0***	96.2***	49.7***	66.4***
Joint sign. of within means $\chi^2(4)$	-	-	-	5.8	11.3**	18.0***
Log-Likelihood	-10,118.7	-5093.6	-3717.3	-10,115.8	-5088.0	-3708.4
ρ (s.e.)	0.633 (0.015)	0.564 (0.025)	0.733 (0.017)	0.633 (0.015)	0.566 (0.024)	0.733 (0.016)
# observations	4390	1962	2428	4390	1962	2428
# censored observations	666	305	361	666	305	361

Notes: Standard errors are in parentheses. *** (**, *) indicate a significance level of 1% (5%, 10%). All models include an intercept (not shown). Coefficients of variables' within means in Wooldridge model are omitted from the table. The value of ρ indicates the share of the total variance which is due to the cross-sectional variation.

First, it should be noted that the tests of whether x and c are uncorrelated are rejected for the regressions for both subsamples (tests on joint significance on within means). Thus, we prefer the Wooldridge generalization of the random-effects model over the 'traditional' random-effects model. In the following, we therefore limit our discussion to these results.

As can be seen in Table 2, we observe a significant positive coefficient on lagged working capital intensity for the full sample. The sample split models, however, indicate that this effect is mainly driven by small firms. In line with previous literature identifying financing constraints by investments' sensitivity to internal liquidity, we may interpret the different size in the coefficients between small and large firms as an indication that smaller firms are more dependent on internal means for financing their R&D (supporting Hypothesis 1).

The patent stock itself is related positively and significantly to R&D spending in all model specifications. Our main attention is directed at the interaction effect between the firms' past patent activity and the firm's liquidity. As can be gathered from Table 2, the sign of the coefficient of the interaction term $(\text{WCAP}_{t-1} / K_{t-1}) * \ln(\text{PATSTOCK}_{t-1})$ is negative and significant, but only in the sample of small firms. Its negative sign suggests that the firm's patent stock helps to reduce the dependence on working capital (supporting Hypotheses 2 and 3). This 'mitigation' effect is robust to the inclusion of controls for correlated fixed effects. In terms of the magnitude of the mitigation effect, we see that the interaction coefficient of -0.105 when compared to the working capital coefficient of 0.175 corresponds to about two-thirds of the initial effect. In other words, the larger a small firm's patent stock, the lower its dependency on internal liquidity when investing in R&D. In terms of marginal effects, we also find that the patent stock has a significant economic impact on investment. Consider a small firm that does not hold any patents and has otherwise average firm characteristics including an average value of WCAP/K . Now suppose it is hit by a shock in liquidity such that its value of WCAP/K is reduced by one standard deviation. Consequently, its R&D investment to tangible assets ratio is expected to decline by about 48%, other things equal. If, however, the same liquidity shock hits a small firm that patents at the average value of the patent stock distribution in the sample, its

investment to assets ratio would only reduce by 23%. Thus, the significant coefficient estimates of the liquidity, the patent stock and their interaction, also translate into economically significant results.

These insights are robust to the altering the specification by using a dummy variable for recent patenting activity only.¹¹ Thus, in general, small firms depend highly on their internal resources, but having patent applications alleviates the constraint, on average. Thus, whatever attributes of the firms' patents are assumed to correlate with, the signal seems to be positive. In line with previous studies, we find that liquidity is less associated with R&D in larger firms. In addition, although the past patent stock is strongly associated with current R&D intensity, patents have no impact on the small liquidity coefficient, suggesting that there is no signaling role of patents for large firms.

We further tested for which thresholds in the firm size distribution these results hold. For that purpose, we interacted size with the three variables working capital, patent stock, and their interaction. The result are shown in Figure 1. Using a loglinear interaction, all the three coefficients become insignificant at about 100 employees and approach zero as firm size reaches 1000 employees. We also tried a splitting the sample at 100 employees instead of 50, and found that the results were similar but slightly weaker.¹²

To test whether the effects differ between sectors, we ran the models on different industry subgroups. When we distinguish Information and Communication Technology (ICT) (518 obs.) from non-ICT sectors, we find positive and significant working capital coefficients and significant negative interaction effects in both groups. Interestingly, the working capital coefficient is much larger in the ICT group. When we distinguish manufacturing from services, we find that manufacturing drives the results, which is not surprising, given the relative importance of patents in that sector. Dividing the sample further is really not feasible, given the limited number of observations with positive patenting.

The control variables show the expected signs. Among the larger firms, more physical capital-intensive firms invest less in R&D, while group membership is positively associated with R&D for small firms. Not surprisingly, industry is a strong predictor of R&D spending. Interestingly, for the subsample of small firms, we further find evidence for a sensitivity of R&D to business cycle movements as captured by the year dummies, while larger firms' R&D spending seems less sensitive to fluctuations in the business cycle.

5.2. Patent signal or patent value?

The previous results suggest that patents affect the firms' dependence on internal funds for conducting R&D for small firms. If this effect were due to a signaling value of patents, then we would expect

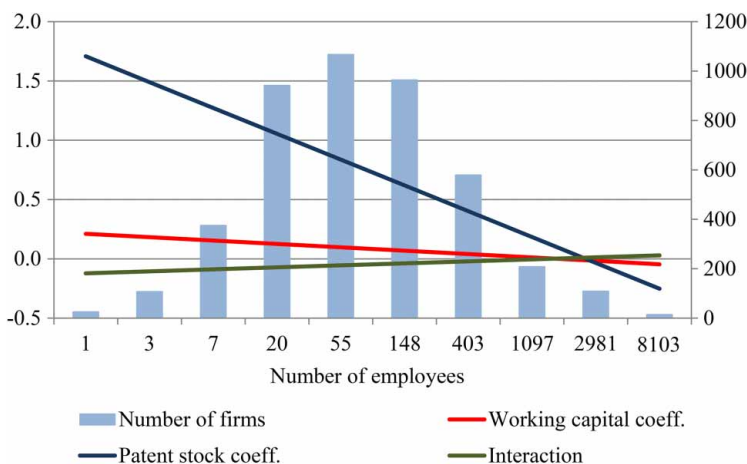


Figure 1. Coefficients as a function of average firm employment.

the effect to be related to the patent application and not necessarily to the ex-post value of the patented technology. In other words, the effect should stem from the patent application independently of whether or not the technology turned out to be highly valuable in the end. For the purpose of testing this, we use the forward citations to the patent applied for in $t-1$ by the firm. As shown in previous research, the value distribution of patented inventions is subject to considerable uncertainty early in the patent life and ultimately highly skewed. Using a number of measures (renewal rates, citations, surveys, etc.), researchers have found that only a few patents turn out to be of high economic value, while the remainder are worth almost nothing (Pakes 1985; Schankerman and Pakes 1986; Harhoff et al. 1999; Deng 2007). Thus, one does not expect patents to alleviate financing constraints unless patents signal something more, for example, overall technological competencies, than simply the expected rents from appropriating returns on R&D via IP protection. This would make the patent right itself valuable, independently of the value of the underlying technology. Hall, Jaffe, and Trajtenberg (2005) suggest using forward patent citations (references to the patent in subsequent patent applications) as a patent value indicator. The more citations a firm's patents receive, the more influential are these patents for follow-on technology developments, and consequently the higher is the assumed economic value of the patents. Research on the appropriateness of forward citations as value indicator found citations to correlate positively and significantly with patents' economic value reported in surveys (Harhoff et al. 1999; Jaffe, Trajtenberg, and Fogarty 2000; Gambardella, Harhoff, and Verspagen 2008).

In the sample of small firms, we observe only very few patenting firms that receive citations to their patents at all (18 firms, corresponding to slightly less than one-third of the small firms who patent). In other words, the reported signaling effect is unlikely to be due to the ex-post value of the underlying invention, as proxied by the average number of forwards citations to the patent in a five year-window after the patent was filed.

Among larger firms, about 12% (or half of the patenting firms) receive citations to their patents. On average, these firms received eight citations to their patents in the sample period. This number is, of course, downward biased by the number of non-patenting firms in our sample. Among the firms with at least one patent, the overall number of citations is 27 with a maximum of 4554 total citations. More meaningful is the average number of citations per patent that firms receive, on average. In the subsample of large firms, this number is 0.47, with a maximum of 255 citations per patent. It should be noted that we consider patent profiles at the level of the firms which implies that we aggregate citations over all the patents the firm applied for in a given year and then divide by patents

The citations per patent variable has a very skewed distribution, as expected. Table 3 shows the distribution of the citation stock-patent stock ratio (lagged) for our sample:

Given the skewness of the citation distribution, we therefore experimented with a number of specifications of the citations variable: the lagged cite stock-patent stock ratio (in levels and logs), the previous year's citation/patent ratio (in levels and logs), and a simple dummy for the 242 observations with a nonzero citation stock. The citations stock (*CITSTOCK*) is calculated in the same fashion as the patent stock. The results are presented in Table 4, for the whole sample of firms. The coefficients of *WCAP/K* and the signs and significance levels of the control variables are comparable to the previous specification. Neither the citations term nor its interaction with working capital is ever significant, singly or jointly, supporting Hypothesis 4.¹³

Table 3. Citation distribution.

$CITSTOCK_{t-1}/PATSTOCK_{t-1}$	Number of observations
None	4148
0-1	75
1-2	47
2-5	48
5-10	35
More than 10	37

Table 4. Estimation results from Tobit regressions with Wooldridge correction on R&D over tangible assets with citations.

Variable	Form of citation variable ($CITATIONS_{t-1}$)				
	$\ln(CITSTOCK/PATSTOCK)$	$CITSTOCK/PATSTOCK$	$\ln(\text{average citations per patent})$	$\text{average citations per patent}$	$\text{dummy (non-zero CITSTOCK)}$
$PATSTOCK_{t-1}$	0.491** (0.209)	0.780*** (0.156)	0.598*** (0.199)	0.588*** (0.199)	0.616*** (0.203)
$WCAP_{t-1}/K_{t-1}$	0.116*** (0.010)	0.111*** (0.009)	0.115*** (0.010)	0.115 (0.010)	0.115*** (0.010)
$(WCAP_{t-1}/K_{t-1})$	-0.032* (0.017)	-0.051*** (0.010)	-0.054*** (0.011)	-0.052*** (0.011)	-0.055*** (0.011)
* $PATSTOCK_{t-1}$					
$CITATIONS_{t-1}$	-0.169 (0.125)	0.000 (0.019)	-0.155 (0.192)	-0.003 (0.021)	-0.398 (0.389)
$(WCAP_{t-1}/K_{t-1})$	0.029 (0.018)	0.002 (0.007)	0.031 (0.037)	0.003 (0.010)	0.063 (0.065)
* $CITATIONS_{t-1}$					
$DEBT_{t-2}/K_{t-1}$	0.044* (0.023)	0.042** (0.021)	0.044* (0.023)	0.044* (0.023)	0.044* (0.023)
$\ln(K_{t-1})$	-0.218* (0.125)	-0.368*** (0.062)	-0.218* (0.125)	-0.216* (0.125)	-0.224* (0.125)
$\ln(AGE_{t-1})$	-0.093 (0.182)	-0.118 (0.181)	-0.097 (0.183)	-0.095 (0.183)	-0.092 (0.182)
GROUP	0.319* (0.170)	0.296* (0.168)	0.315* (0.170)	0.311* (0.170)	0.319* (0.169)
Joint test for citation variables $\chi^2(2)$	3.1	0.1	0.9	0.1	1.3
Joint sign. of time dummies $\chi^2(9)$	24.1***	23.9***	24.0***	23.9***	23.6***
Joint sign. of ind. dummies $\chi^2(15)$	95.7***	96.2***	96.1***	95.9***	96.4***
Joint sign. of within means $\chi^2(4)$	5.9	5.7	6.0	5.8	9.5*
Log-Likelihood	-10,114.2	-10,115.8	-10,115.3	-10,115.8	-10,115.3
ρ (s.e)	0.632 (0.015)	0.633 (0.015)	0.632 (0.015)	0.633 (0.015)	0.631 (0.015)
# observations	4390	4390	4390	4390	4390
# censored observations	666	666	666	666	666

Notes: Standard errors are in parentheses. *** (**, *) indicate a significance level of 1% (5%, 10%). All models include an intercept (not shown). Coefficients of variables' within means in Wooldridge model are omitted from the table. The value of ρ indicates the share of the total variance which is due to the cross-sectional variation.

The irrelevance of the ex-post patent quality points to the conclusion that the signaling value of a patent is irrespective of the actual value of the patented technology for small firms and controlling for patent quality does not compromise the result for larger firms.¹⁴ We caution that this conclusion may be somewhat weaker than the conclusion that patents matter for financing, for two reasons: (1) citations may be a relatively weak indicator of value, especially citations based on EPO data, which are fewer in number; and (2) these citations have been collected over a relatively short horizon.

6. Conclusion

Previous literature has suggested that patents may serve as a signal to lenders and investors easing access to external financing in addition to their original function of protecting an invention from imitation. The current study was motivated by a gap in the literature on the role of patents as quality signals for established R&D-active firms. The role of patents as quality signals for these firms, unlike for start-up firms and entrepreneurial ventures, has received little systematic treatment so far. The focus on a European economy allowed a study of the certification effects for bank loans, as they constitute the most important source of external funding for most SMEs in Europe.

In line with previous research, the results showed that small firms are more likely to rely on internal liquidity to fund their R&D activities as a result of limited access to external financing. Moreover, the

results showed that patenting activity may help small firms to attract external financing more easily compared to non-patenting firms. Hence, their R&D spending relies to a lesser extent on available internal funds. We also found that the mitigating effect of patent applications is not due to the actual ex-post value of the patented technology, and we therefore conclude that patents do have some signaling effect beyond the fact that they proxy for the underlying technological and economic value of the patented invention. An alternative and related interpretation of our findings is that the private value of the invention is so uncertain at the time of application that capital markets and financial institutions are unable to distinguish among the various patents held by small firms, although they do evaluate the mere existence of a patent application positively.

Our findings add to previous research that suggested that patents play a particularly valuable signaling role in the start-up phase of a firm by finding patents to be important for small firms to attract external financing even if they are already established. The results thus stress that firms' size may not only determine the likelihood that firms face financing constraints for R&D, but also whether patent helps firms to signal technology competencies. As about half of the firms in our sample qualify as being small, the significance of the findings for technological advances at the level of the Flemish economy is clear. If small firms slow down growth in order to adapt their growth to the rates that can be maintained with its available financial means, as a consequence, growth of such firms is constrained by internal finance postponing technological advances and forgoing some technological opportunities. For many small technology firms, the signaling value of patents may thus be valuable adding to the protection function of patents.

In light of the relatively high share of small and medium-sized firms in many European regions, these insights are interesting beyond the region of Flanders. Testing the generalizability of the results to other regions or countries, however, would require conducting a comparable study on internationally harmonized data. Such an approach is feasible, but requires researchers who have access to non-anonymized data on firm-level R&D and other firm characteristics, country by country. We would certainly expect to find similar results on other European countries whose economies and financial markets resemble Belgium's.

Long (2002) argues that investors give high importance to patent counts when looking at established firms. In contrast, when looking at less established firms, investors investigate the quality as well as the quantity of the patents. This may have affected our findings, as the present study explicitly studied established firms. So it might be, that if we had considered young firms in our sample, patent quality would have mattered more. This distinction should be addressed in more detail in future research. Moreover, as individual patents can convey information about a particular invention, 'patent portfolios can provide information about the lines of research a firm is conducting and how quickly the research is proceeding' (Long 2002). Future research may therefore benefit from a more detailed assessment of the firms' patent portfolios in order to disentangle the portfolio effect from the signal value of the individual patent.

Future research would also benefit from studying in much greater detail how the signal varies between different external investors and also whether it matters for attracting public R&D funding. Previous research suggested that public funding agencies may act like private investors in the sense that they favor less uncertain projects that are more likely to result in marketable products sooner.

Finally, we cannot rule out that our findings are subject to some degree of simultaneity bias. Therefore, it would be useful to find exogenous shocks to financing in order to identify the parameters of the R&D investment equation with fewer endogeneity concerns.

Despite these limitations, this study contributes to the literature on patent signals in several ways. First, studying a sample of firms in Europe, this study is the first to investigate signaling value of European patent application. Second, while previous evidence is mainly found for early-stage financing such as VC in selected industries, in this paper we explicitly focused on more established firms for which the financing constraints argument cannot be explained by a liability of newness. Third, we find that the patent signaling effect does not seem to arise in larger firms and, fourth, that the

effect on external financing tends to be driven by the mere presence of patents rather than observable ex post indicators of the value of those inventions. It would be highly desirable for future work to investigate the replicability of these results in other economies.

Acknowledgements

The authors thank Thorsten Doherr for help with retrieving the patent data and participants at the CONCORDi 2013 (Seville, Spain), the DRUID conference 2014 (Copenhagen, Denmark), the IIOC 2014 (Chicago, USA), and the EARIE conference 2014 (Milan, Italy) for helpful comments. This revision has benefitted greatly from comments by Rosemarie Ziedonis and two anonymous referees. Hottenrott appreciated research funding from the Flemish Science Foundation (FWO).

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. See Hubbard (1998), Hall and Lerner (2010) and Czarnitzki and Hottenrott (2010) for surveys of the literature.
2. One might think that this lack of access to debt would lead to firms issuing equity. However, small firms may be particularly reluctant to issue equity, even if this excludes them from certain projects. In Belgium, as in many other European countries, raising equity for financing investment projects generally appears to be disfavored and only relatively few firms are listed at stock exchanges. Particularly small, family-owned firms view issuing of new equity as not particularly desirable, as it dilutes their ownership position. For example, Deloof and Jegers (1999) point out that there were no public issues of a straight bond by a Belgian company between 1990 and 1995. Borrowing from banks is the most common form of raising funds for investment besides internal sources such as intra-group loans (see e.g. Deloof 1998).
3. Note that inventions do not always require systematic R&D upfront.
4. The threshold for patentability in the USA is considered by some observers to be low, especially in IT-related sectors (Jaffe and Lerner 2004), which casts doubts on the signaling value of patents. The threshold is considered to be higher in Europe (Van Pottelsberghe de la Potterie 2011). In addition, Haeussler, Harhoff, and Mueller (2009) argue that European patents are approximately 5–10 times more expensive than US patents. However, this is a controversial area, and there exist dissenters (Christie et al. 2013). Hall, Thoma, and Torrisi (2007) find that the valuation of US and EPO patents in US and European firms is fairly similar.
5. This argument applies to small producing firms. There is other evidence that small non-producing firms that specialize in acquiring patents litigate more than other firms, at least in the USA. See Lanjouw and Schankerman (2004), *inter alia*.
6. These accounts follow the Belgian GAAP on an annual basis.
7. The appropriateness of cash flow as an indicator for financial liquidity and the interpretation of the sensitivity of R&D investment to changes in cash flow has been criticized in the literature (Fazzari and Petersen 1993; Hao and Jaffe 1993; Kaplan and Zingales 1997, 2000). Especially for large firms, cash flow levels may be determined by accounting practice as well as by dividend policies (Jensen and Meckling 1976; Jensen 1986).
8. Accounts receivable and accounts payable are termed Trade Debtors and Trade Creditors in the data source. Inventories are called Stocks.
9. We also experimented with a debt measure based on a firm's total liabilities (current plus non-current liabilities), but the results were quite similar, so we do not display them in the paper.
10. Although the model contains a time-invariant firm-specific effect, we also include the time-invariant regressors *GROUP* and the industry dummies, as the firm-specific effect is treated as a random component in the estimation.
11. Detailed results are available from the authors upon request. The $\chi^2(3)$ for coefficient equality across small and large firms is 82.6 for patent applications and 75.1 for the patenting dummy.
12. For a sample split of young versus old firms, where young is defined as age less than or equal to 20 years (results are similar for a cut at 25 years), we find that both sub-groups are sensitive to financing constraints and that this sensitivity is mitigated by patents. Similarly, testing young/small versus old/small, we find again very similar patterns in both groups. These results point to the conclusion that not their age that constrains firms in our sample, but rather their size. It should be noted, however, that our sample contains firms that are at least active for five years, that is, are not truly nascent firms. The results in the paper also show that the variable age itself is never statistically significant in predicting R&D intensity in the presence of the other variables.

13. We also experimented with using a series of dummies for different levels of average citations per patent, as in Hall, Jaffe, and Trajtenberg (2005), but without success.
14. Note that the number of citations is always truncated. Moreover, in our case, observations in the years later than 2008 have a shorter citation window than five years. We tested the sensitivity of our results to dropping these observations and found that the coefficients' magnitude and significance is hardly affected.

References

- Anton, J., and D. Yao. 2002. "The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting." *Review of Economic Studies* 69 (3): 513–531.
- Arora, A., A. Fosfuri, and A. Gambardella. 2001. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. Cambridge, MA: MIT Press.
- Arrow, K. J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity*, edited by R. Nelson, 609–626. Princeton, NJ: Princeton University Press.
- Baum, J. A., and B. S. Silverman. 2004. "Picking Winners or Building Them? Alliance, Intellectual, and Human Capital as Selection Criteria in Venture Financing and Performance of Biotechnology Startups." *Journal of Business Venturing* 19 (3): 411–436.
- Berger, A., and G. Udell. 1998. "The Economies of Small Business Finance: The Roles of Private Equity and Debt Markets in the Financial Growth Cycle." *Journal of Banking and Finance* 22 (6–8): 613–673.
- Bessen, J., and E. Maskin. 2009. "Sequential Innovation, Patents, and Imitation." *RAND Journal of Economics* 40 (4): 611–635.
- Bhattacharya, S., and J. Ritter. 1983. "Innovation and Communication: Signaling with Partial Disclosure." *The Review of Economic Studies* 50 (2): 331–346.
- Bougheas, S., H. Görg, and E. Strobl. 2003. "Is R&D Financially Constrained? Theory and Evidence from Irish Manufacturing." *Review of Industrial Organization* 22 (2): 159–174.
- Brown, J. R., G. Martinsson, and B. C. Petersen. 2012. "Do Financing Constraints Matter for R&D?" *European Economic Review* 56: 1512–1529.
- Brown, J. R., and B. C. Petersen. 2011. "Cash Holdings and R&D Smoothing." *Journal of Corporate Finance* 17: 694–709.
- Cameron, A. C., and P. K. Trivedi. 2005. *Microeconometrics: Methods and Applications*. New York, NY: Cambridge University Press.
- Carpenter, R., and B. C. Petersen. 2002. "Capital Market Imperfections, High-Tech Investment, and New Equity Financing." *The Economic Journal* 112: F54–F72.
- Christie, A., C. Dent, J. Liddicoat, and A. Lim. 2013. "What Difference Does Patent Examination Make?: An Analysis of the Effect of Examination in the USPTO, the EPO and APO." Paper presented at the TILEC Workshop on Innovation and the Patent System, June 20–21.
- Cockburn, I., and S. Wagner. 2007. *Patents and the Survival of Internet-Related IPOs*, NBER Working Paper No. 13146.
- Conti, A., M. C. Thursby, and F. T. Rothaermel. 2013. "Show Me the Right Stuff: Signals for High Tech Startups." *Journal of Economics & Management Strategy* 20 (2): 341–364.
- Conti, A., M. C. Thursby, and J. Thursby. 2013. "Patents as Signals for Startup Financing." *The Journal of Industrial Economics* 61 (3): 592–622.
- Czarnitzki, D., B. H. Hall, and R. Oriani. 2006. "The Market Valuation of Knowledge Assets in US and European Firms." In *The Management of Intellectual Property*, edited by D. Bosworth and E. Webster, 111–131. Cheltenham: Edward Elgar.
- Czarnitzki, D., and H. Hottenrott. 2010. "Financing Constraints for Industrial Innovation: What do we Know?" *Review of Business and Economics* 55 (3): 346–362.
- Czarnitzki, D., and H. Hottenrott. 2011a. "R&D Investment and Financing Constraints of Small and Medium-Sized Firms." *Small Business Economics* 36 (1): 65–83.
- Czarnitzki, D., and H. Hottenrott. 2011b. "Financial Constraints: Routine versus Cutting Edge R&D Investment." *Journal of Economics and Management Strategy* 20 (1): 121–157.
- Czarnitzki, D., H. Hottenrott, and S. Thorwarth. 2011. "Industrial Research versus Development Investment: The Implications of Financial Constraints." *Cambridge Journal of Economics* 35 (3): 527–544.
- Deeds, D., D. DeCarolis, and J. Coombs. 1997. "The Impact of Firm Specific Capabilities on the Amount of Capital raise in an Initial Public Offering: Evidence From the Biotechnology Industry." *Journal of Business Venturing* 12: 31–46.
- Deloof, M. 1998. "Internal Capital Markets, Bank Borrowing, and Financing Constraints: Evidence from Belgian Firms." *Journal of Business Finance and Accounting* 25 (7&8): 945–968.
- Deloof, M., and M. Jegers. 1999. "Trade Credit, Corporate Groups, and the Financing of Belgian Firms." *Journal of Business Finance and Accounting* 26 (7&8): 945–966.
- Deng, Y. 2007. "Private Value of European Patents." *European Economic Review* 51: 1785–1812.
- European Communities/Eurostat. 2004. "Innovation in Europe Results for the EU, Iceland and Norway." In *Panorama of the European Union*, European Commission, Theme 9 Science and Technology, Brussels.

- Fazzari, S., R. Hubbard, and B. C. Petersen. 1988. "Financing Constraints and Corporate Investment." *Brookings Papers on Economic Activity* 1: 141–206.
- Fazzari, S. M., and B. C. Petersen. 1993. "Working Capital and Fixed Investments: New Evidence on Financing Constraints." *The RAND Journal of Economics* 24 (3): 328–342.
- Fisher, F. M., and P. Temin. 1973. "Returns to Scale in Research and Development: What Does the Schumpeterian Hypothesis Imply?" *Journal of Political Economy* 81 (1): 56–70.
- Fort, T. C., J. Haltiwanger, R. S. Jarmin, and J. Miranda. 2013. "How Firms Respond to Business Cycles: The Role of Firm Age and Firm Size." *IMF Economic Review* 61 (3): 520–559.
- Gambardella, A., D. Harhoff, and B. Verspagen. 2008. "The Value of European Patents." *European Management Review* 5: 69–84.
- Griliches, Z., and J. Mairesse. 1984. "Productivity and R&D at the Firm Level." In *R&D, Patents, and Productivity*, edited by Z. Griliches, 339–374. Chicago: University of Chicago Press.
- Griliches, Z., A. Pakes, and B. H. Hall. 1987. "The Value of Patents as Indicators of Inventive Activity." In *Economic Policy and Technological Performance*, edited by P. Dasgupta and P. Stoneman, 97–124. Cambridge: Cambridge University Press.
- Haeussler, C., D. Harhoff, and E. Mueller. 2009. *To Be Financed or Not – The Role of Patents for Venture Capital Financing*, ZEW Discussion Paper No. 09–003.
- Hall, B. H. 1992. *Research and Development at the Firm Level: Does the Source of Financing Matter?* Cambridge, MA: NBER Working Paper No. 4096.
- Hall, B. H. 2000. "Innovation and Market Value." In *Productivity, Innovation and Economic Performance*, edited by R. Barrell, G. Mason, and M. O'Mahoney, 177–198. Cambridge: Cambridge University Press.
- Hall, B. H., C. Helmers, M. Rogers, and V. Sena. 2013. "The Importance (or not) of Patents to UK Firms." *Oxford Economic Papers* 65 (3): 603–629.
- Hall, B. H., A. B. Jaffe, and M. Trajtenberg. 2005. "Market Value and Patent Citations." *RAND Journal of Economics* 36: 16–38.
- Hall, B. H., and H. Krainiker. 1995. *The Role of Working Capital in the Investment Process*, unpublished manuscript, Berkeley.
- Hall, B. H., and J. Lerner. 2010. "The Financing of R&D and Innovation." In *Handbook of the Economics of Innovation*, edited by B. Hall and N. Rosenberg, 609–639. North Holland: Elsevier, Version August 2009.
- Hall, B. H., and R. H. Ziedonis. 2001. "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979–1995." *RAND Journal of Economics* 32 (1): 101–128.
- Hall, B. H., G. Thoma, and S. Torrisi. 2007. *The Market Value of Patents and R&D: Evidence from European Firms*. Cambridge, MA: NBER Working Paper No. 13428.
- Hao, K. Y., and A. B. Jaffe. 1993. "Effect of Liquidity on Firms' R&D Spending." *Economics of Innovation and New Technology* 2 (4): 275–282.
- Harhoff, D. 1998. "Are There Financing Constraints for R&D and Investment in German Manufacturing Firms?" *Annales d'Economie et de Statistique* 49/50: 421–456.
- Harhoff, D. 2009. "The Role of Patents and Licenses in Securing External Finance for Innovation." *European Investment Bank (EIB) Papers* 14 (2): 75–97.
- Harhoff, D., F. Narin, F. M. Scherer, and K. Vopel. 1999. "Citation Frequency and the Value of Patented Innovation." *Review of Economics and Statistics* 81 (3): 511–515.
- Heeley, M. B., S. F. Matusik, and N. Jain. 2007. "Innovation, Appropriability, and the Underpricing of Initial Public Offerings." *Academy of Management Journal* 50 (1): 209–225.
- Helmers, C., and M. Rogers. 2011. "Does Patenting Help High-Tech Start-ups?" *Research Policy* 40 (7): 1016–1027.
- Henderson, R., and I. Cockburn. 1994. "Measuring Competence? Exploring Firm Effects in Pharmaceutical Research." *Strategic Management Journal* 15 (S1): 63–84.
- Himmelberg, C., and B. Peterson. 1994. "R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries." *The Review of Economics and Statistics* 76: 38–51.
- Hoenen, S., C. Kolympiris, W. Schoenmakers, and N. Kalaitzandonakes. 2014. "The Diminishing Signaling Value of Patents between Early Rounds of Venture Capital Financing." *Research Policy* 43 (6): 956–989.
- Hoening, D., and J. Henke. 2014. "Quality Signals? The Role of Patents, Alliances, and Team Experience in Venture Capital Financing." *Research Policy* 44: 1049–1064.
- Hottenrott, H., and B. Peters. 2012. "Innovative Capability and Financing Constraints for Innovation: More Money, More Innovation?" *Review of Economics and Statistics* 94 (4): 1126–1142.
- Hsu, D., and R. Ziedonis. 2013. "Resources as Dual Sources of Advantage: Implications for Valuing Entrepreneurial-Firm Patents." *Strategic Management Journal* 34: 761–781.
- Hubbard, R. 1998. "Capital-Market Imperfections and Investment." *Journal of Economic Literature* 36: 193–225.
- Jaffe, A., and J. Lerner. 2004. *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress and What to Do About It*. Princeton: Princeton University Press.
- Jaffe, A. B., M. Trajtenberg, and M. Fogarty. 2000. "Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors." *American Economic Review* 90 (2): 215–218.
- Jensen, M. 1986. "Agency Cost of Free Cash Flow, Corporate Finance, and Takeovers." *American Economic Review* 76: 323–339.

- Jensen, M., and W. Meckling. 1976. "The Theory of the Firm: Managerial Behavior, Agency Cost, and Ownership Structure." *Journal of Financial Economics* 3: 305–360.
- Kaplan, S., and L. Zingales. 1997. "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics* 112 (1): 169–215.
- Kaplan, S., and L. Zingales. 2000. "Investment-Cash Flow Sensitivities are not Valid Measures of Financing Constraints." *The Quarterly Journal of Economics* 115 (2): 707–712.
- Kulatilaka, N., and L. Lihui. 2006. "Impact of Licensing on Investment and Financing of Technology Development." *Management Science* 52 (12): 1824–1837.
- Lahr, H., and A. Mina. 2013. "Dynamic Financial Constraints and Innovation: Evidence from the UK Innovation Surveys," European Conference on Corporate R&D and Innovation CONCORDi-2013 Conference Paper, Seville (Spain).
- Lanjouw, J. O., and M. Schankerman. 2004. "Protecting Intellectual Property Rights: Are Small Firms Handicapped?" *Journal of Law and Economics* 47: 45–74.
- Leland, H., and D. Pyle. 1977. "Informational Asymmetries, Financial Structure, and Financial Intermediation." *Journal of Finance* 32: 371–387.
- Lemley, M. A. 2000. "Reconceiving Patents in the Age of Venture Capital." *Journal of Small and Emerging Business Law* 4: 137–148.
- Levitas, E., and M. A. McFadyen. 2009. "Managing Liquidity in Research-Intensive Firms: Signaling and Cash Flow Effects of Patents and Alliance Activities." *Strategic Management Journal* 30 (6): 659–678.
- Long, C. 2002. "Patent Signals." *University of Chicago Law Review* 69 (2): 625–679.
- MacMillan, I. C., R. Siegel, and P. N. Subbanarasimha. 1985. "Criteria Used by Venture Capitalists to Evaluate New Venture Proposals." *Journal of Business Venturing* 1 (1): 119–128.
- Mann, R. J., and T. W. Sager. 2007. "Patents, Venture Capital, and Software Start-ups." *Research Policy* 36 (2): 193–208.
- Mansfield, E. 1986. "Patents and Innovation: An Empirical Study." *Management Science* 32 (2): 173–181.
- Mina, A., H. Lahr, and A. Hughes. 2013. "The Demand and Supply of External Finance for Innovative Firms." *Industrial and Corporate Change* 22 (4): 869–901.
- Mulkey, B., B. H. Hall, and J. Mairesse. 2001. "Investment and R&D in France and in the United States." In *Investing Today for the World of Tomorrow*, edited by Herrman, Heinz, and Rolf Strauch, 229–273. Cambridge, MA: Springer Verlag.
- Myers, S., and N. Majluf. 1984. "Corporate Financing and Investment Decisions When Firms Have Information That Investors Do Not." *Journal of Financial Economics* 13: 187–221.
- OECD. [1993] 2002. *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*. Luxembourg: OECD.
- Pakes, A. 1985. "On Patents, R&D, and the Stock Market Rate of Return." *Journal of Political Economy* 93 (21): 390–408.
- Rubini, L., K. Desmet, F. Piguillem, and A. Crespo. 2012. *Breaking Down the Barriers to Firm Growth in Europe: the Fourth EFIGE Policy Report*, Bruegel Blueprint Series, Volume XVIII, Brussels.
- Schankerman, M., and A. Pakes. 1986. "Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period." *The Economic Journal* 96: 1052–1076.
- Schneider, C., and R. Veugelers. 2010. "On Young Innovative Companies: Why They Matter and How (not) to Policy Support Them." *Industrial and Corporate Change* 19 (4): 969–1007.
- Spence, M. 1973. "Job Market Signaling." *The Quarterly Journal of Economics* 87 (3): 355–374.
- Stuart, T. E., H. Hoang, and R. Hybels. 1999. "Interorganizational Endorsements and the Performance of Entrepreneurial Ventures." *Administrative Science Quarterly* 44 (2): 315–349.
- Van Pottelsberghe de la Potterie, B. 2011. "The Quality Factor in Patent Systems." *Industrial and Corporate Change* 20 (6): 1755–1793.
- Webb, C., H. Dernis, D. Harhoff, and K. Hoisl. 2005. *Analyzing European and International Patent Citations: A Set of EPO Database Building Blocks*. STI Working Paper 2005/9, OECD.
- Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Appendix

Table A1: Industry classifications

Industry	NACE rev. 2	Description	Firms	Observations	%
1	10, 11, 12	Food and tobacco	107	394	8.97
2	13, 14, 15	Textiles, clothing and leather	79	302	6.88
3	16, 31	Wood and furniture	42	137	3.12
4	17, 18	Paper	19	99	2.26
5	19, 20	Chemicals	85	357	8.13
6	21	Pharmaceuticals	19	81	1.85
7	22	Rubber and plastic	60	225	5.13
8	24, 25, 33	Metal	94	389	8.86
9	27, 28	Machines and equipment	148	606	13.80
10	26	ICT	58	245	5.58
11	29, 30	Transport	30	123	2.80
12	41	Building and construction	33	110	2.51
13	1, 5, 23, 37, 35, 32	Miscellaneous manufacturing	76	340	7.74
14	45, 46, 47, 49, 55, 58	Commerce and transport	94	335	7.63
15	59, 64, 68, 69, 71–79	Other services	124	374	8.52
16	61, 62	Software development and communication	79	273	6.22
			1147	4390	100.00

Table A2: Variable description

Label	Unit	Description	Source
R&D	Million €	Annual R&D expenditure	OECD R&D survey Flanders provided by ECOOM (K.U. Leuven)
PATSTOCK	Count	Discounted sum of patent application since first observed patent	EPO
PATAPPS	Count	Sum of patent applications in a given year	EPO
CITSTOCK	Count	Discounted sum of patent citations since first observed patent	EPO
CITATIONS	Count	Sum of citations to patents in first observed patent	EPO
WCAP	Million €	Book value cash + inventories + accounts receivable – accounts payable	Bureau van Dijk BEL-FIRST database
DEBT	Million €	Book value of liabilities	Bureau van Dijk BEL-FIRST
K	Million €	Book value of tangible assets	Bureau van Dijk BEL-FIRST
EMP	Headcount	Number of dependent employees in a given year	Bureau van Dijk BEL-FIRST and OECD R&D survey
AGE	Years	Survey year minus founding year	Bureau van Dijk BEL-FIRST and OECD R&D survey
GROUP	[0,1]	Survey question on group structure	OECD R&D survey Flanders

Notes: Year and industry dummies not presented. Year refers to the reference year of the corresponding survey and the industry definition stems from the survey and has been cross-checked with the BEL-FIRST Database. It refers to the company's main activity.