Improving Citation-Based Patent Value Measures

Dirk Czarnitzki [1,2,3], Katrin Hussinger [4,1,3] and Bart Leten [5,1]
[1] K.U. Leuven, Dept. of Managerial Economics, Strategy and Innovation (Belgium)
[2] Centre for R&D Monitoring (ECOOM) at K.U. Leuven (Belgium)
[3] Centre for European Economic Research (ZEW), Mannheim (Germany)
[4] Maastricht University, Dept. of Organization and Strategy (The Netherlands)
[5] Vlerick Leuven Gent Management School (Belgium)
(*k.hussinger@maastrichtuniversity.nl*)

Abstract - **A growing literature aims at determining the private value of patents. It has been shown that patents and the citations they receive by future patent applications contribute significantly to the private value of firms beyond their R&D stocks. But it has also been shown that citations can explain very little of the variance of the patent value distribution. This paper suggests that citation-based patent value measures can be improved by taking the reason for which patents are cited into account. Such information is available at the European Patent Office.**

Keywords - **Patents, Citations, Patent Value**

I. INTRODUCTION

Patent-based measures are the most frequently used indicators in empirical research on innovation and technological change. The first studies employing patent data used patent counts as indicators of innovation output (Scherer, 1965; Schmookler, 1966; Griliches, 1984). Patented inventions differ however widely in their technological and economic 'value' or 'importance' (Schankerman and Pakes, 1986; Albert et al., 1991; Harhoff et al., 1999). In response, patent forward citations have been put forward as a measure for the technological and economic value of patents (Trajtenberg, 1990; Hall et al., 2005). While forward patent citations are found to correlate positively and significantly with patents' economic value reported in surveys (Harhoff et al., 1999; Gambardella et al., 2008) as well as with firms' market value (Hall et al., 2005), forward citations appear to explain only very little of the actual variance in patent value. Studies by Gambardella et al. (2008) and Bessen (2008) show that forward citations explain no more than five percent of the actual variation in the value of European and US patents.

A possible reason why forward citations explain little of the variance in patent value may be that citations to prior art are made for different reasons. The aim of this study is to exploit heterogeneity in patent citation types by analyzing whether certain types of citations correlate more strongly with patent value than others. It is argued that different citation types reflect value differences. This means that patent citation-based value indicators could be improved by taking into account different citation types. Information on citation types is available for patents that are examined at the European Patent Office (EPO). At the EPO, patent examiners classify patent citations in different categories according to their relevance for the patent application in question (Harhoff et al., 2005; Webb et al., 2005; Criscuolo and Verspagen, 2008). Patent references that challenge the novelty or inventive step of the patent under examination ("blocking citations") can be distinguished from references that define the state of the art in a technology field but are not prejudicing novelty or the inventive step.[1]

We suggest that some types of citations are more highly correlated with the patent value than others. For instance, blocking patent citations are likely to be more highly correlated with the economic value of cited patents than other types of citations. Blocking citations indicate that the cited patent threatens the granting of other patent applications (Michel and Bettels, 2001; Harhoff et al., 2005), which may provide the owner of the cited patent with an important competitive advantage as the cited patent may keep competitors off markets or technologies that are important to the owner of the cited patent by legally depriving competitors from obtaining own patents on related inventions (Guellec et al., 2008). On the other hand, there are patents receiving many citations as non-infringing state of the art. Such patents trigger future patent applications and have been shown to be of higher technological importance that document cited as infringing prior art (Guellec et al., 2008). We expect that these patents would also generate a higher value for their owners but for a different reason.

The assertion that different types of citations correlate more or less highly with the economic value of patents than other citations can be tested by adding measures for different citation types to the market value equation that is used by Hall et al. (2005) and checking whether this variable allows for a better assessment of the value of patents. The remainder of the paper suggests a testing strategy. The next section contains an overview of the literature on the valuation of firms' knowledge assets and patents. Section 3 describes the patent application procedure at the European Patent Office (EPO). Section 4 outlines the market value framework and section 5 concludes.

[1] Another type of patent citation heterogeneity stems from the source of citations, i.e. examiner versus applicant given citations (Alcacer and Gittelman, 2006; Hedge and Sampat, 2009).

II.PATENT VALUE STUDIES

A broad set of studies has examined the value of firms' knowledge assets and patents, employing different methodologies. One strand of the literature focuses on the estimation of production functions to study the returns to R&D at the firm and sector level (for reviews of this literature see Griliches, 1995, and Mairesse and Mohnen, 1996). Returns to innovation, however, rarely occur during the period in which the investment in innovation occurs, and in fact, may be spread over the number of years following such an investment. This renders current profits or productivity effects partial and incomplete indicators of the returns to innovation (see the surveys by Hall, 2000, and Czarnitzki et al., 2006). For this reason, other scholars employed the so-called market value approach, which is based on a seminal contribution by Griliches (1981), to estimate returns to innovation. The market value framework employs the stock market value as an indicator of the sum of expected future profits of the firm which is then related to its book value and, in addition, to several measures of firms' R&D activities. Typically scholars have measured the knowledge stock of firms by the (depreciated) sum of prior R&D investments and/or their patent stock (e.g. Bloom and van Reenen, 2002).

Although the market value method is intrinsically limited in scope, because it can be used only for public firms that are traded on a well-functioning financial market, using this method avoids timing problems of R&D costs and revenues, and is capable of forward-looking evaluation, something that studies analyzing profitability or productivity during a given period of time are not able to do.[2] Furthermore, the market value method is useful for calibrating various innovation measures, in the sense that one can measure their economic impact and possibly enabling one to validate these measures for use elsewhere as proxies for innovation value. The latter argument motivates our study.

As stated above, most scholars used the R&D stock as measure for knowledge capital and supplemented it with patent stocks that may generate a premium as patent-protected knowledge grants the owner a temporary monopoly and eases appropriation of the returns obtained from the initial R&D investment. While R&D stocks reflect firms' inputs, or investments, in R&D, patent stocks measure the output, or "success", of the R&D investments. The typical finding of prior market value studies is that both R&D and patent stock variables correlate positively with firms' market value, and that patent stocks add information on the value of firms' knowledge assets above and beyond R&D stocks (Hall, 2000, Czarnitzki et al., 2006).

While patent-based measures have the advantage that they are easily available from patent offices, cover long time series and a broad range of technologies (with software as partial exception in some patent systems, Hall et al., 2007), their usefulness as output indicator of R&D activities is seriously affected by the fact that patented inventions differ widely in their technological and economic value or "importance". The value distribution of patents is highly skewed. A few patents are very valuable, but many are worth almost nothing (Pakes, 1985; Schankerman and Pakes, 1986; Harhoff et al., 1999; Deng, 2007). Thus, the estimation of an average effect of patent stocks may be misleading in valuing the knowledge assets of a firm. Hall et al. (2005) therefore suggest using forward patent citations as a patent value indicator in the market value equation. Forward citations are references to patents made by future patent applications. The more citations a firm's patents receive, the more influential its patents are for future technology development, and the higher is the assumed economic value of a firm's patent stock. While forward patent citations are found to correlate positively and significantly with patents' economic value reported in surveys (Harhoff et al., 1999; Jaffe et al., 2000; Gambardella et al., 2008) as well as with firms' market value (Hall et al., 2005),[3] forward citations appear to explain only very little of the actual variance in patent value. Gambardella et al. (2008) show, based on patent value information from an inventor survey[4], that forward citations only explain 1.4% of the variation in the economic value of European patents as reported by their inventors. Using patent renewal data to estimate the value of a set of patents filed at the United States Patent and Trademark Office (USPTO), Bessen (2008) similarly finds that patent citations explain only a very small portion (less than 6%) of the variance in patent value. We propose that the fact that patents are cited for different reasons can be taken into account in order to improve patent value estimates.

III. DIFFERENT PATENT CITATION TYPES AT THE EUROPEAN PATENT OFFICE

The European Patent Office (EPO) was established in 1977 after the ratification of the European Patent Convention (EPC). It's task is to grant legal protection for invention on behalf of all contracting states. Legal protection can be granted for inventions that fulfill three criteria: 1) novelty, 2) inventive step and 3) industrial applicability according to article 52(1) of the EPC. Novelty is defined as not being state of the art. The state of the art is defined as "everything made available to the public by means of written or oral description, by use, or in any other way, before the date of filing at the European patent application" (EPC, articles 54(2)). The inventive step requires that an invention is not obvious to a person skilled in the art (EPC, article 56).

[2] See Czarnitzki and Kraft (2004) for an alternative method of forward looking evaluation. They suggested relating measures of innovation to firms' credit ratings, which are also forward-looking.

[3] There is also evidence that forward patent citations correlate positively with patents' social value (Trajtenberg, 1990).

[4] See Giuri et al. (2007) for a description of the PATVAL inventor survey and some first descriptive results.

Once a patent application is filed at the EPO, the search divisions carry out a patentability search. The aim of this search is to judge the appropriateness of the scope of the legal protection as requested by the patent application. The patent grant decision is based on the outcome of this search for prior art. Note that other than at the United States Patent and Trade Mark Office (USPTO) the patent applicant at the EPO is not subject to the "duty of candor" and does not have to report relevant prior art in the patent application. In consequence, about 90% of all patent citations in EPO patents are added by the patent examiner (Criscuolo and Verspagen, 2008).

The search for prior art taken out by the patent examiner follows *The Guidelines for Examination in the European Patent Office*[5], which define a certain quality standard for patent examination and ensure equal treatment of all EPO patent applications. The examination guidelines explicitly require examiners to be objective and selective when defining the documents referred to as prior art. For most of the cases one to two documents are sufficient to determine the scope of the patent application in question (Michel and Bettels, 2001). This parsimonious and objective approach ensures that the references are a relevant subsample of the actual state of the art rather than an overview on the subject-matter of the invention (Harhoff and Reitzig, 2004, Harhoff et al., 2005). The result of the patent examiners' search for prior art is summarized in the so-called patent search report.

The Guidelines for Examination in the European Patent Office require that the references to prior art are classified according to their relevance for the patent application in question. Prior art can be cited as documents defining the non-infringing state of the art in a technology field (A-type references). Citations can also be made to restrict the patentability of the patent application, namely citation types X, Y and E. X-type citations are documents showing essential features of the invention under investigation or at least questioning the inventive step of these features *if taken alone*. Y-type citations question the inventive steps claimed in the invention being examined, *when combined with one or more documents* (Harhoff et al., 2005; Criscuolo and Verspagen, 2008). [6] E-type citations are conflicting documents that are published on or after the filing date of the patent application in question. We label X, Y and E-type citations as blocking citations in line with prior research (e.g. Guellec et al., 2008). Prior research has shown that patents which receive *backward* blocking citations have a lower probability to get granted (Guellec et al., 2008) and a higher probability to face opposition after granting since they are "weak" patents (Harhoff and Reitzig, 2004; Czarnitzki et al., 2009). Note that a patent application can still be granted if it receives backward blocking citations (although this is less likely). This can, for instance, be the case for patent applications with many claims. Blocking citations may only pertain to single claims and the remaining claims can be strong enough to get a modified patent application granted. Table I shows the full citations classification of the EPO.

In this paper, we argue that different citations types can be used to get a better understanding of the patent value. While A-type citations are likely to suggest patents of high technological relevance that trigger future patents without restricting their novelty, X, Y, E-cites might have a high importance in technology markets as they can block related patent applications.

TABLE I
DIFFERENT CITATION TYPES AT THE EPO

X	particularly relevant documents when taken alone (implies: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step)
Y	particularly relevant if combined with another document of the same category
A	documents defining the general state of the art
O	documents referring to non-written disclosure
P	intermediate documents (documents published between the date of filing and the priority date)
T	documents relating to theory or principle underlying the invention (documents which were published after the filing date and are not in conflict with the application, but were cited for a better understanding of the invention)
E	potentially conflicting patent documents, published on or after the filing date of the underlying invention
D	document already cited in the application

Source: Webb et al.(2005)

III. SUGGESTESD METHODOLOGY

Following Griliches (1981) a market value approach can be applied to assess the private value of firms' knowledge assets, including patents that receive different types of citations. The market value approach draws on the hedonic price model in viewing firms as bundles of assets and capabilities, from plants and equipment to intangible assets such as brand names, good will and knowledge. It is difficult to disentangle firms' assets and capabilities since they are priced simultaneously on the market. The market value approach assumes that financial markets assign a valuation to the firm's assets bundle that is equal to the present discounted value of their future cash flows. A number of recent empirical studies used the market value approach to

[5] See http://www.epo.org/patents/law/legal-texts/guidelines.html.

[6] *The Guidelines for Examination in the European Patent Office* present two examples for references to be marked with a "Y" (see Chapter X, paragraph 9.1.2). First, the combination of patents and scientific documents which typically cover rather basic technological advances that need to be combined with applied technologies to be novelty challenging (Della Malva and Hussinger, 2010) are Y-type citations. Second, patent families that threaten the novelty of patent applications are cited as Ys.

estimate the economic value of knowledge assets of firms (Hall et al., 2000; Czarnitzki et al., 2006).

Following most existing studies the following market value equation can be assumed, relying on the assumption that a firm's assets enter additively. This leads to the following equation, with A representing the physical assets and K the knowledge assets of firm i at time t:

$$V_{it}(A_{it}, K_{it}) = q(A_{it} + \gamma K_{it})^{\sigma} \quad (1)$$

Under the assumption of constant returns to scale ($\sigma = 1$) equation (1) can be rewritten in logarithmic form as:

$$\log Q_{it} = \log \frac{V_{it}}{A_{it}} = \log q + \log\left(1 + \gamma \frac{K_{it}}{A_{it}}\right) \quad (2)$$

The left hand side of the equation is the log of Tobin's Q, defined as the ratio of the market value to the replacement cost of the firm's physical assets. The marginal or shadow value of the ratio of knowledge capital to physical assets is represented by γ. It captures the expectations of the investors over the effect of the knowledge capital relative to physical assets on the discounted future profits of the firm. Log q is the intercept of the model.

Prior studies used different variables to capture the knowledge assets K of a firm. First, the stock of firm's R&D expenses is often used as a measure for firms' investment into R&D. As R&D activities are highly uncertain activities, the stock of patent applications is typically used as a measure for successfully finished R&D activities. Since previous literature has shown that the distribution of patent value is highly skew (Pakes, 1985; Schankerman and Pakes, 1986; Harhoff et al., 1999; Deng, 2007; Gambardella et al., 2008) the stock of forward citations, i.e. citations patents receive by later filed patent applications, has been introduced into the market value literature as a measure for the importance of patents (Hall et al., 2005).

We suggest that within this framework different forward citation types that patent receives at the EPO can be distinguished. For instance, the stock of blocking patent citations can be used to test whether blocking citations (X, Y and E-type citations) correlate more strongly with market value than other types of patent citations. Similarly, the stock of non-infringing building patents can be added to the market value equation in order to test whether these patent with a potentially superior technological content have a higher impact on the market value than other patent citations. This results in the following empirical specification:

$$lnQ_{it} = lnq_i + \ln\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CIT_{it}}{PAT_{it}} + \gamma_4 \frac{XYECIT_{it}}{CIT_{it}} + \gamma_5 \frac{ACIT_{it}}{CIT_{it}}\right) + u_{it} \quad (3)$$

The coefficients in this cascading specification have to be interpreted as a premium or a discount on the former variable (Hall et al., 2005). For example, if the R&D stock over assets has a positive impact, a positive estimated coefficient of the patent stock over the R&D stock would reflect a premium of successfully finished R&D projects (as visible in patents) on top of the positive evaluation of the firms' R&D input. Regarding our variable of main interest, the share of blocking citations, the estimated coefficient γ_4 is expected to be positive, showing a value-premium for the share of citations that are "blocking" on top of the value of the total number of received patent citations. Similarly, the estimated coefficient γ_5 is expected to be positive, showing a value-premium for the share of citations that are classified as non-infringing state of the art in a technology field.

VI. CONCLUSION

Innovation is considered to be a major cause of economic growth and welfare. A necessary condition for private innovative activity to take place is that innovation increases the profits of those performing R&D activities. This has stimulated researchers to assess the value of firms' R&D activities, patents, patent citations as a patent value correlate (e.g. Hall et al., 2005) and innovation strategies (e.g. Ceccagnoli, 2009). We add to this literature in that we suggest to investigate differences in the value of patented inventions as visible in the purpose for which they are cited by later patent applications. Making use of the citation classification available at the EPO, patents cited in later patent applications because they challenge their novelty or inventive step (blocking citations) can be distinguished from patents cited as non-infringing state of the art in a technology field. We suggest that patents that frequently appear as blocking references in future patent filings (of other firms) are more valuable to their owners than patented inventions which receive mainly non-blocking citations. Blocking citations indicate that the cited patent threatens the granting of other patents, which may provide the owner of the cited patent with an important competitive advantage as the cited patent may keep competitors off markets and technologies, by legally depriving competitors from obtaining patents on related inventions or by narrowing the scope of their patents. Blocking references can refer to single patent claims so that a patent application can still be granted if the respective claim is removed or modified. Similarly, patents that often appear as non-infringing state of the art are suggested to have a higher value than the average. Patents receiving many cites as state of the art are presumably patents that make a very valuable technological contribution so that they trigger many follow-up inventions.

The hypotheses of whether different citation types correlate to a different extent with the private value

of patents can be investigated using the market value approach.

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