The Market Value of Blocking Patent Citations

Abstract

There is a growing literature that aims at assessing the private value of knowledge assets and patents. It has been shown that patents and their quality as measured by citations received by future patents contribute significantly to the market value of firms beyond their R&D stocks. This paper goes one step further and distinguishes between different types of forward citations patents can receive at the European Patent Office. While a patent can be cited as non-infringing state of the art, it can also be cited because it threatens the novelty of patent applications ("blocking citations"). Empirical results from a market value model for a sample of large, R&D-intensive U.S., European and Japanese firms show that patents frequently cited as blocking references have a higher economic value for their owners than patents cited for non-blocking reasons. This finding adds to the patent value literature by showing that different types of patent citations carry different information on the economic value of patents. The result further suggests that the total number of forward citations can be an imprecise measure of patent value.

Keywords: Market Value, Patents, Citations, Patent Value

JEL-Classification: O31, O34, O38

1 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 examining whether certain types of citations correlate more strongly with patent value than others. If there is evidence for value differences with regard to different citation types, 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 blocking patent citations are 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).

We test the assertion that blocking citations correlate more highly with the economic value of patents than other citations by adding a measure for "blocking citations" 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. Besides examining the impact of "blocking" patent citations on the market value of firms, this paper has several other new features compared to existing market value studies. First, while most market value studies focus on U.S. or U.K. firms, in combination with national patent data (see the survey by Czarnitzki et al., 2006), we use a sample of multinational firms, i.e. the top R&D spending U.S., European and Japanese firms in three R&D intensive industries, and benchmark the value of triadic patents, i.e.

[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).

patents that are jointly filed at the U.S., European and Japanese patent offices. Triadic patents reflect a selected group of inventions of which the owner expects most profits as she is willing to incur the relatively high patent filing and patent maintenance costs at all three patent offices (Guellec and van Pottelsberghe de la Potterie, 2008). Second, we use panel data methods to control for unobserved firm-specific fixed effects which is not common in this strand of literature.[2] Third, our data set features a characteristic that has not been considered in prior market value studies. Large firms are often involved in M&As over time. However, scholars so far only consolidated data on patents at a single point in time of the period under review without tracing the annual changes due to M&As or spin-outs. Our patent data is consolidated annually, taking into account annual changes in corporate group structures.

The remainder of the paper is organized as follows. The next section contains an overview of the literature on the valuation of firms' knowledge assets and patents. Section 3 describes the market value methodology. Section 4 presents the data set, explains variables definitions and contains descriptive statistics. Section 5 shows the empirical results, and the last section concludes and discusses the implications of our findings.

2 Literature Overview

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

[2] Notable exceptions are Blundell et al. (1999), Bloom and van Reenen (2002) and Toivanen et al. (2002).

Mohnen, 1996). As, however, returns to innovation 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, current profits or productivity effects are generally very 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.[3] 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-

[3] 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.

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),[4] 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[5], that forward citations only explain 1.4 percent 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 percent) of the variance in patent value.

3 Estimating the Market Value of Blocking Patent Citations

Following Griliches (1981) a market value approach is applied to assess the private value of firms' knowledge assets, including patents that receive blocking patent 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 estimate the economic value of knowledge assets of firms (Hall et al., 2000; Czarnitzki et al., 2006).

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[4] There is also evidence that forward patent citations correlate positively with patents' social value (Trajtenberg, 1990).
[5] See Giuri et al. (2007) for a description of the PATVAL inventor survey and some first descriptive results.

Following most existing studies we assume a market value equation, 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*:

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

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

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

(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.

We use different variables to capture the knowledge assets *K* of a firm. First, we use the stock of firm's R&D expenses. As R&D activities are highly uncertain activities, we use besides R&D expenses, also the stock of patent applications 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) we use the stock of forward citations, i.e. citations patents receive by later filed patent applications, as a measure for the importance of patents, following Hall et al. (2005).

As a last measure for the knowledge assets of firms we use a measure of the stock of blocking patent citations to test whether blocking citations correlate more strongly with market value than other types of patent citations. Since blocking citations are measured by “X” and “Y” type of citations (see data section), the blocking citation stock variable is labelled as XYCIT in the specification below. The specification of the market value equation has a cascading structure in order to avoid identification issues due to potentially high correlations of different knowledge variables (see Hall et al., 2005). This results in the following specification:

$$ln\,Q_{it} = ln\,q_t + ln\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CIT_{it}}{PAT_{it}} + \gamma_4 \frac{XYCIT_{it}}{CIT_{it}}\right) + \varepsilon_{it} \qquad (3)$$

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.

4 Data and Variables

4.1 Sample

Our sample consists of 151 publicly traded European[6], U.S. and Japanese manufacturing companies who have their main economic activity in one of the following three industries: Chemicals & Pharmaceuticals (including Biotechnology), Electronics & IT Hardware, and Engineering and General Machinery. We have chosen these industries as the propensity to patent inventions is relatively large (Arundel and Kabla, 1998), making patents a good indicator of the output of R&D activities in these industries. The sample firms are the largest R&D spenders in their sector and country of origin according to the '2004 EU Industrial R&D Investment Scoreboard'. The scoreboard lists the top 500 corporate investors in R&D whose headquarters are located in the EU, and the top 500 companies whose headquarters are located outside the EU (mainly the U.S. and Japan), based on corporate R&D investments. The sample consists of 63 pharmaceutical and chemicals firms, 60 in electronics and IT hardware and 28 firms active in engineering and general machinery. Regarding the distribution of firms across countries, 52 firms are U.S. based, 60 are Japanese and 39 firms are Europe based.

We collected financial, R&D and patent data at the corporate level for building a firm-level panel database (1995-2000). Market value, total assets and R&D expenditures (all expressed in $U.S.) are obtained from Datastream and Worldscope financial databases. Patent data is gathered from the OECD/EPO patent citation database (Webb et al., 2005). This database contains information on all patent applications filed at the European Patent Office (EPO) and the World Intellectual

[6] European companies are located in Belgium, Switzerland, Denmark, Finland, France, Germany, the Netherlands, Sweden, and the U.K.

Property Organization (WIPO), under the Patent Co-Operation Treaty (PCT), from the introduction of EPO in 1978 until September 2006 (2nd edition database). The patent database also provides for these patents a list of patent publications in other national or regional patent office's pertaining to the same patent (equivalent patents). This information is used to calculate firm-level patent stocks on triadic patents. Further, patent equivalents are taken into consideration by the construction of the patent citation measures.

To construct patent indicators at the consolidated level, we collected patents by the sample firms as well as their majority-owned subsidiaries. For this purpose, yearly lists of companies' subsidiaries included in corporate annual reports, yearly 10-K reports filed with the SEC in the U.S., and, for Japanese firms, information on foreign subsidiaries published by Toyo Keizai in the yearly 'Directories of Japanese Overseas Investments', are used. This consolidation exercise has been conducted annually to take into account changes in the group structure of firms, due to M&As, green-field investments and spin-offs. The patent stock of an acquired firm is considered to be part of the patent stock of an acquiring firm from the acquisition year onwards. The annual consolidation exercise constitutes a methodological improvement over existing market value studies where scholars consolidated data only in a single point in time. Due to missing data, our final sample is an unbalanced panel of 876 observations for 151 firms.

4.2 Variables

Our dependent variable is Tobin's Q, the ratio of the market value of the firm to the replacement (book) value of its physical assets. Market value is defined as the sum of market capitalization (share price times the number of outstanding shares at the end of the year), preferred stock, minority interests, and total debt minus cash. The book value is the sum of net property, plant and equipment, current assets, long term receivables, investments in unconsolidated subsidiaries and other investments.

R&D stocks are calculated for each firm (and year) as a perpetual inventory of past and present annual R&D expenditures of the firm with a constant depreciation rate (δ) of 15 percent, as is common practice in the literature (see Griliches and Mairesse, 1984). We use the following formula for the R&D stock of a firm *i* in year *t*:

$$R\&D\,stock_{it} = \left(1-\delta\right) R\&D\,stock_{it-1} + R\&D_{it}\,. \tag{4}$$

The initial value of the R&D stock is calculated, for each firm, at the first year of available R&D data as:

$$R\,\&\,D\,stock_{i0} = R\,\&\,D_{i0} \,/\left(\delta + g\right). \tag{5}$$

An annual growth rate (g) of 8.7 percent is used.[7] Annual R&D expenditures and the firms' total assets are deflated using GDP deflators.

Patent stocks are constructed using the same formula as for R&D stocks and the same depreciation rate (δ) of 15 percent. They are based on the complete listing of firms' triadic patents. Triadic patents are patents that are simultaneously filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), and the Japanese Patent Office (JPO). Triadic patents are collected from the OECD/EPO patent citation database (Webb et al., 2005) by identifying, for each firm and consolidation year, all EPO patent applications since 1978, the foundation year of the EPO, and only keeping those patents that are also filed (i.e. have equivalent patents) at the USPTO and the JPO. Since we have complete annual

[7] This is the average R&D growth rate in our sample. Similar results are obtained when we use a growth rate of 8 percent, which is used in other market value studies (e.g. Hall and Oriani, 2006; Hall et al., 2007).

listings of the triadic patents of the sample firms, starting in 1978, no initial values for the patent (and citation) stock variables are calculated. Patent stocks are computed based on triadic patents in order to have comparable indicators for firms from different home countries (Europe, Japan and US). Patenting may namely be characterized by a home bias as firms may be more likely to apply for patents at the patent office of their home country rather than at other patent offices (Dernis and Khan, 2004).

Patent citation stocks are constructed based on the citations received by the firms' patents during a fixed time window of five years after the patent's priority date, following earlier work (e.g. Hall et al., 2007), using the same formula as for R&D and patent stocks. Citations are restricted to citing patents with a search report prepared by EPO examiners (direct EPO filings and PCT filings at EPO) because these reports allow distinguishing between different types of citations to prior art. Patent equivalents of these filings at national patent offices are taken into account in the calculation of the citation counts. If patent equivalents would be ignored, the number of forward citations that a patent receives would be underestimated (see Harhoff et al., 2005; Webb et al., 2005). Other than at the 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 percent 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*[8], which define a certain quality standard for patent examination and ensure equal treatment of all EPO patent applications. The

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

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. While prior art can be cited as documents defining the non-infringing state of the art in a technology field, two types of citations restrict the patentability of the patent application, namely citation types X and Y. 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).[9] We label X and Y-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

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[9] *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.

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.

In this study, we use the number of *forward* blocking citations that firms' patents receive as indicator of the extent to which these patents may hinder the granting of other firms' patents (Grimpe and Hussinger, 2008). These patents can hinder technology competition and are expected to contribute more to the market value of the firms by which they are owned than patents with receive non-blocking forward patent citations. The X and Y forward citations are used to build the blocking citation stock variable, which is based on equation (4), using a depreciation rate (δ) of 15 percent. In addition, we use two industry dummies, ten country dummies and five year dummies in all the market value specifications. As a robustness check we control for firm-level fixed effects.

4.3 Descriptive Statistics

Table 1 shows descriptive statistics for our sample. The sample firms are large and R&D intensive with total assets, R&D stocks, and triadic patent stocks equal to respectively $U.S. 9,771 million, $U.S. 603 million and 303 triadic patents, on average. The Tobin's Q values have a mean value of 2.02, well above unity. Firms' patents receive, on average, more than 1 citation (1.47), reflecting the, on average, high economic value of triadic patents. About 42 percent of the patent citations received by the sample firms' patents can be labelled as "blocking", as measured by their classification as X or Y references.

Insert table 1 about here

Table 2 shows the correlation coefficients. The cascading specification of the variables keeps the correlations between the regressors at a reasonable level.

Insert table 2 about here

5 Market Value Estimations

Table 3 reports the results for the estimation of the market value equation. We estimate equation (3) by nonlinear least squares. We start with a model that includes R&D over assets only and then sequentially add patents, citations and blocking citations. Year, country and industry dummies are included in all specifications. The results are largely in line with Hall et al. (2005). The R&D, patent and citation variables are positively and significantly related to Tobin's Q (Models I, II and III). In our augmented model IV, our variable of main interest, the blocking citation ratio, is added. The estimated coefficient for this variable shows a positive sign and is statistically significant at the 5 percent level, all else constant. This result shows that the market value of firms is higher when firms' patents receive forward citations that are "blocking" in nature.

To get an indication of the economic magnitude of the estimated effects, we calculated semi-elasticities of Tobin's Q with regard to each of the main variables. Table 3 reports average values of the semi-elasticities and standard errors across all sample observations. Three major observations are apparent. First, as we move from Model I to Model IV, the semi-elasticities of R&D, patent and citation variables decrease as further variables are added. Second, the semi-elasticities for the patent and citation variables are significantly higher for our sample than those reported in other studies (e.g. Hall et al., 2005, for a sample of U.S. firms, or Hall et al., 2007, for a sample of European firms). This may be explained by the fact that we use stocks of triadic patents and focus on the largest R&D actors in the world in our sample. Third, the largest effect for a unit change of a regressor is found for the blocking citations (ratio) variable. A unit change, i.e. a change in the blocking citation ratio from 0 to 1, increases the market value by 89 percent. A more realistic change in the blocking citation ratio of one standard deviation (=11 percent points) yields a higher market value of about 10 percent.

Insert table 3 about here

To control for unobserved firm-specific effects, we re-estimate the models using a panel data estimator which employs pre-sample information for the dependent variable (Czarnitzki and Dhaene, 2011). The estimator is based on a count data fixed effect estimation approach proposed by Blundell et al. (1995). It has the advantage that it does not rely on the assumption of strict exogeneity of the regressors. Czarnitzki and Dhaene (2011) show that the pre-sample fixed effects approach is consistent and efficient for both linear and non-linear least squares regressions.[10] Technically, this estimator models fixed effects as the average value of the dependent variable in the pre-sample period, which is included in the model as an additional regressor.

Table 4 reports the regression results and average semi-elasticities of the models including firm-level fixed effects. It is apparent that a large part of the firms' market value is explained by unobserved firm-specific effects. The estimated coefficients and semi-elasticities are much smaller if firm-specific effects are taken into account. Nevertheless, the results are largely in line with the pooled cross-sectional estimations. Again, the blocking citation ratio shows a strong positive

[10] Czarnitzki and Dhaene (2011) have applied this method to the data used in Hall et al. (2005) and have shown that their original regression results hold if pre-sample fixed effects are taken into account.

impact on market value with a semi-elasticity of 110 percent, on average. The most remarkable difference compared to Table 3 is that the R&D stock over assets turns insignificant for most model specifications once fixed effects are taken into account. This may be explained by the fact that R&D changes only slowly over time and is therefore highly correlated with the firm specific fixed effect (Hall et al., 2005).

Insert table 4 about here

As an additional robustness check we repeated the pooled cross-sectional and fixed effect regressions of Models III and IV, but excluded self-citations from the two citation-based variables. Self-citations are defined as citations to patents that are owned by the same parent firm, or one of its consolidated subsidiaries, as the cited patent. On average, 28 percent of the patent citations received by the firms are self-citations (see Table1). It is important that our results hold in this setting since the rationale for the high economic value of patents with blocking citations is that these patents have to potential to hinder the granting of patents on related technologies of other firms. The results of these regressions are reported in Table 5, and confirm the earlier finding that the blocking citation ratio has a strong positive impact on the market value of firms. The estimated effect of the blocking citation ratio variables in Table 5 is higher than in the comparable models that include self-citations (cf. Tables 3 and 4), supporting our rationale that patents with blocking forward citations derive their value by blocking “other firms”.

Insert table 5 about here

6 Conclusions

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). This paper contributes to this stream of the literature.

We add to this literature in that we 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) are distinguished from patents cited as non-infringing state of the art in a technology field. The research hypothesis of the paper is 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.

The research hypothesis is examined by introducing a measure for "blocking citations" to the market value equation that is used by Hall et al. (2005). Market value estimations are performed on a panel dataset (1995-2000) of 151 publicly traded European, U.S. and Japanese R&D intensive firms from three manufacturing industries. Firm-level patent variables are calculated based on annually consolidated patent data, and we include firm-level fixed effects in the analyses. The identification of “blocking” patent citations is done by using a feature of the European patent system, the search report, where patents are classified according to their relevance for the patent application in question. Citations that are classified as “X” or “Y” references are labeled as blocking citations.

Our findings show that the market value of firms is larger when they possess a patent stock which receives more “blocking” patent citations. The estimated effect of the blocking citation ratio on the market value of firms is very large, with an average semi-elasticity above 100 percent. This result adds to the literature on the measurement of the economic value of patents (e.g. Harhoff et al., 1999; Hall et al., 2005; Gittelman, 2008) by showing that there are differences in the informational value of patent citations on the economic value of patents depending on the citation type. The observation that a substantial part of the value assigned to forward citations stems from one category of patent citations (“blocking citations”), suggests that total forward citations may be an imprecise measure of the economic value of patents.

In this paper, we used firm-level data and the market value approach to investigate the value of patents receiving blocking citations. An interesting track for future research concerns the validation of our results in an analysis on data at the level of individual patents. Data on the economic value of individual patents could be collected from surveys of patent inventors (such as the PATVAL surveys for EPO patents), or by undertaking surveys of patent applicants (firms and universities) on the value of their patent portfolios. Another suggestion for future research is to examine whether there are differences across technologies and industries in the importance of blocking patent citations. It may be that blocking citations are more important for patents in discrete than in complex technologies. In discrete technologies, individual patents may have the potential to create monopolies in a technology space allowing firms to extract rents, while in complex technologies, the ability to extract rents may come less from monopolies of individual patents, but rather from the size of firms' patent portfolios.

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Tables

Table 1: Descriptive statistics (876 obs.)

	mean	std. dev.
Tobin's Q	2.03	2.14
assets	9770.99	13541.76
R&D stock	603.29	947.89
R&D stock/ assets	0.30	0.20
triadic patent stock	302.83	584.20
triadic patent stock/ R&D stock	0.13	0.13
triadic citation stock	447.11	833.37
triadic citation stock/triadic patent stock	1.47	0.57
triadic XY citation stock	181.35	331.64
triadic XY citation stock/triadic citation stock	0.42	0.11
triadic self-citation stock	133.70	284.95
triadic citation stock excl. self-citations	313.41	579.05
triadic XY citation stock excl. self-citations	131.34	237.21
triadic XY citation stock excl. self-citations/ triadic citation stock excl. self-citations	0.42	0.11

Table 2: Correlation matrix (876 obs.)

	1	2	3	4	5	6
1 log of Tobin's Q						
2 R&D/assets	0.37 ***					
3 patents/R&D	-0.02	-0.20 ***				
4 citations/patents	0.38 ***	0.41 ***	-0.08 **			
5 XY citations/citations	0.35 ***	0.38 ***	-0.09 ***	0.47 ***		
6 citations/patents[A]	0.30 ***	0.40 ***	-0.23 ***	0.88 ***	0.45 ***	
7 XYcitations/citations[A]	0.37 ***	0.40 ***	-0.04	0.47 ***	0.94 ***	0.44 ***

[A] Variables are calculated without self-citations. Note that these variables are used in the estimations as alternatives to the citation variables that include self-citations.

Table 3: Market value estimates

	I	II	III	IV
		dependent variable: log of Tobin's Q		
	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]
constant	0.60***	0.49***	0.04	-0.33
	(0.08)	(0.09)	(0.17)	(0.26)
R&D/assets	0.70***	0.90***	0.72**	0.72
	(0.21)	(0.26)	(0.35)	(0.51)
patents/ R&D		0.72***	0.95***	1.20**
		(0.21)	(0.32)	(0.50)
citations/ patents			0.44***	0.37*
			(0.16)	(0.22)
XY citations/ citations				2.55**
				(1.01)
N	876	876	876	876
adjusted R^2	0.40	0.41	0.42	0.44
			Semi-elasticities	
	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]
R&D/assets	0.58***	0.67***	0.37**	0.25
	(0.15)	(0.16)	(0.16)	(0.16)
patents/ R&D		0.54***	0.49***	0.42***
		(0.14)	(0.14)	(0.14)
citations/ patents			0.23***	0.13**
			(0.06)	(0.06)
XY citations/ citations				0.89***
				(0.20)

[A] Robust standard errors
[B] Standard errors are obtained by the delta method.
The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.
*,**,*** indicate 10, 5 and 1percent significance levels.

Table 4: Market value estimates controlling for unobserved heterogeneity

	I	II	III	IV
	dependent variable: log of Tobin's Q			
	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]
constant	0.33***	0.27***	-0.02	-0.43***
	(0.07)	(0.07)	(0.12)	(0.16)
R&D/assets	0.20	0.27*	0.10	-0.21
	(0.14)	(0.16)	(0.20)	(0.29)
patents/ R&D		0.41***	0.47**	0.59**
		(0.15)	(0.18)	(0.27)
citations/ patents			0.25**	0.15
			(0.10)	(0.13)
XY citations/ citations				2.41***
				(0.59)
pre-sample mean (log Tobin's Q)	0.62***	0.61***	0.59***	0.60***
	(0.05)	(0.05)	(0.05)	(0.05)
N	876	876	876	876
adjusted R^2	0.53	0.53	0.54	0.56
	Semi-elasticities			
	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]
R&D/assets	0.19	0.24*	0.07	-0.10
	(0.13)	(0.13)	(0.14)	(0.13)
patents/ R&D		0.36***	0.33***	0.27**
		(0.12)	(0.12)	(0.11)
citations/ patents			0.17***	0.07
			(0.05)	(0.05)
XY citations/ citations				1.10***
				(0.18)

[A] Robust standard errors
[B] Standard errors are obtained by the delta method.
The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.
*,**,*** indicate 10, 5 and 1percent significance levels.

Table 5: Market value estimates excluding self-citations

	I	II	III	IV
	dependent variable: log of Tobin's Q			
	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]	coefficient (s.e.)[A]
constant	0.25*	-0.16	0.16	-0.27**
	(0.15)	(0.21)	(0.11)	(0.14)
R&D/assets	0.90***	0.83*	0.23	-0.10
	(0.32)	(0.46)	(0.18)	(0.26)
patents/ R&D	1.01***	0.98**	0.50***	0.40*
	(0.30)	(0.42)	(0.17)	(0.23)
citations/ patents	0.27*	0.08	0.11	-0.05
	(0.14)	(0.19)	(0.09)	(0.12)
XY citations/ citations		2.72***		2.38***
		(0.79)		(0.45)
pre-sample mean (log Tobin's Q)			0.60***	0.61***
			(0.05)	(0.05)
N	876	876	876	876
adjusted R^2	0.41	0.43	0.53	0.56
	Semi-elasticities			
	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]	semi-elasticity (s.e.)[B]
R&D/assets	0.55***	0.33**	0.19	-0.05
	(0.16)	(0.16)	(0.14)	(0.13)
patents/ R&D	0.61***	0.39***	0.40***	0.21*
	(0.14)	(0.13)	(0.12)	(0.11)
citations/ patents	0.16**	0.03	0.09	-0.03
	(0.07)	(0.07)	(0.07)	(0.07)
XY citations/ citations		1.07***		1.23***
		(0.18)		(0.16)

[A] Robust standard errors
[B] Standard errors are obtained by the delta method.
The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.
*,**,*** indicate 10, 5 and 1percent significance levels.