The Market Value of Blocking Patents

Dirk Czarnitzki [a,b,c,d], Katrin Hussinger [e,a,c] and Bart Leten [a]

[a] *K.U. Leuven, Dept. of Managerial Economics, Strategy and Innovation (Belgium)*

[b] *Center for R&D Monitoring (ECOOM) at K.U. Leuven (Belgium)*

[c] *Centre for European Economic Research (ZEW), Mannheim (Germany)*

[d] *Centre for Industrial Economics, University of Copenhagen (Denmark)*

[e] *Maastricht University, Dept. of Organization and Strategy (The Netherlands)*

March 2010

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 measured by citations they receive by future patents (forward citations) contribute significantly to the market value of firms beyond their knowledge 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 state of the art, it can also be cited because it threatens the novelty of new patent applications. Those patents have the power to block other patent applications from being granted. Empirical results from a market value equation for 151 large R&D spending U.S., European and Japanese firms show that patents with blocking power are more valuable than other patents. This finding adds to the patent value literature by showing that there is heterogeneity regarding the informational value of patent citations and that mainly blocking patent citations are good predictors of the economic value of patents.

Keywords: Patent value; market value, patents

JEL-Classification: O31, O38

1 Introduction

Investment in research and development (R&D) is often considered as one of the most important strategic decisions to be taken by a firm. Compared to investment in tangible assets, R&D features several different characteristics, for instance, a) due to its intangible nature the outcome of the investment is more difficult to appropriate by the firm due to positive externalities (Arrow, 1962), b) the investment is basically not reversible and thus sunk, as most of an R&D expense goes into wages of R&D personnel (see Czarnitzki and Toole, 2009, for a discussion of the reversibility option), c) the expected return from R&D investments are highly uncertain. The latter reason generated several streams of research where scholars attempted to estimate both the private and social return to R&D (e.g. Hall, 1996).

As returns to innovation rarely occur during the period in which the investment in innovation occur, and in fact, may be spread over the number of years following such investment, measure like current profits or productivity effects are generally very partial and incomplete indicators of the returns to innovation (Czarnitzki et al., 2006). For this reason, scholars often employed the so-called market value approach which is based on a seminal contribution by Griliches (1981).[1] 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 R&D measures. Typically scholars have measured the knowledge stock of firms by the (depreciated) sum of prior

[1] This strand of literature is surveyed in Hall (2000) and Czarnitzki et al. (2006).

R&D investments and/or counts of their patent stock, sometimes weighted by the number of forward patent citations received by patents in the patent stock (e.g. Hall et al., 2005).

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, scholars typically use 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 inventor a temporary monopoly and eases appropriation of the returns obtained from the initial investment. Recently, Hall et al. (2005) introduce patent citation measures to the market value approach. In the past it has been found that the value distribution of patents is highly skewed and that most patents have zero value (Trajtenberg, 1990; Harhoff et al., 1999; Gambardella et al., 2008). Thus, an estimated average effect of patent stocks can be misleading in valuing knowledge assets of a firm. Hall et al. (2005) therefore use forward citations as an additional value correlate. Forward citations are references to the patent in question that are made in future patent

[2] See Czarnitzki and Kraft (2004) for a supplemental method of forward looking evaluation. They suggested relating measures of innovation to firms' credit ratings, which are also forward-looking. The advantage of this method is that credit ratings are available for most firms in an economy, while market value indicators are only available for stock market-traded companies on well-functioning stock markets.

applications. The more citations a firm's patent portfolio receives, the higher is its assumed value. While the addition of patent citations is certainly a significant contribution towards improved patent value measures, a recent study shows that the variance of patent values is very poorly explained by the number of patent forward citations. Gambardella et al. (2008) show, based on patent value information from the PATVAL survey[3], that the four major patent value indicators in recent literature (patent forward citations, backward references, patent claims and designated countries) explain only 2.7% of the variance in patent value.

In this paper, we add to the literature on the economic value of patents by making use of unique information in the European patent system. At the European Patent Office (EPO), patent examiners classify each patent reference according to their relevance for the patent application in question (Webb et al., 2005, Harhoff et al., 2005). Among others, patent references are marked as X and Y references if they challenge the novelty or inventive step of the patent under examination. X references challenge a new patent application individually, and Y references refer to prior art that, in combination with other documents, questions the patentability of the new invention (Harhoff et al., 2005; Criscuolo and Verspagen, 2008). Firm patents that frequently appear as X or Y references in future patent filings are supposingly more valuable than other patented inventions as X/Y references can threaten the patentability of inventions of rivals and (partly) block their R&D activities (Grimpe and Hussinger, 2008a,b; Guellec et al., 2009). This forces rival firms to negotiate a licensing contract (Grimpe and Hussinger, 2009) or to invent

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

around these ‘blocking’ patents (Ziedonis, 2004) and search for alternative patentable inventions in different parts of the technology landscape. Licensing is however costly and alternative technologies are often less effective (Granstrand, 1999), which grants the owners of blocking patents an important competitive advantage. Firms with blocking patents enjoy legal protection of their technology against unwanted usage by third parties which allows them to safeguard their current profit streams. This paper investigates the impact of such blocking patents on firms’ market value.

Besides examining the market value of ‘blocking’ patents, this paper has several new features compared to existing market value studies. First, while most market value studies are based on samples of U.S. or U.K. firms, in combination with national patent data (Czarnitzki et al., 2006), we use a sample of multinational companies, i.e. top R&D spending U.S., European and Japanese firms in three R&D intensive industries. In order to avoid a country bias we benchmark the value of triadic patents, i.e. patents that are jointly filed at the U.S., European and Japanese patent offices. As it is known that most patents generate no value for the patent owners (Harhoff et al., 1999), triadic patents are 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 in all three patent office’s (Guellec and van Pottelsberghe de la Potterie, 2008). Second, we use panel data methods to control for unobserved firm heterogeneity which is not common in this strand of literature. One reason for that is that most panel data methods require that the right-hand variables are strictly exogenous. Within a market value framework, strict exogeneity would however be an inconsiderate assumption (Hall et al., 2005). We employ a new estimator to control for firm specific fixed effects, which is consistent and efficient without assuming strict exogeneity (Czarnitzki and Dhaene, 2009). Third, our data features a detail that has not been considered in any other market value study beforehand. Large firms are often involved in mergers and acquisitions (M&A) over time. However, scholars so far only consolidated their data on R&D and patents at a single point in time of the period under review without tracing annual changes due to M&A activity or sell-offs over time. Our data is consolidated annually, and takes all mergers and de-mergers into account.

The remainder of the paper is organized as follows: the next section describes the method for estimating the private value of knowledge assets. Section 3 presents the database, provides variables definitions and descriptive statistics. Section 4 shows the empirical results and the last section concludes and discusses the implications of our findings.

2 Estimating the Economic Impact of Blocking Patents

Following Griliches (1981), a market value approach is applied to assess the private value of patents with a blocking potential. The market value approach draws from the hedonic price model in viewing firms as bundles of their assets and capabilities, from plants and equipment to intangible assets such as brand names, good will and knowledge. The firms' assets and capabilities are difficult to be disentangled and 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 this approach to evaluate the economic value of knowledge assets (see Hall et al., 2000, and Czarnitzki et al., 2006, for surveys of the market value literature on firm-level R&D activities).

Following most existing studies we assume a linear market value equation assuming that the 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 constant returns to scale (σ=1) equation (1) can be rewritten as:

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

The left hand side of the equation is the log of Tobin's q, defined as the ratio of market value to the replacement cost of the firm's physical assets. γ_t is the marginal or shadow value of the ratio of knowledge capital to physical assets at time *t*. 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* presents the intercept of the model, which is the average log of Tobin's q for the sample firms.

We use different variables to capture the knowledge assets *K* of a firm. First, we use the stock of firm's research and development (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 projects. In order to take the skewness of the patent value distribution into account (Trajtenberg, 1990; Harhoff et al., 1999; 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. Forward patent citations have been found to correlate positively with various indicators of patent and firm value (Trajtenberg, 1990; Harhoff et al., 1999; Hall et al., 2005) and have become a well established measure for the “importance”, “quality” or the “significance” of a patented inventions in the literature on technological change (e.g. Henderson et al., 1998; Hall et al., 2001; Trajtenberg, 2001). As a last measure for the knowledge assets of firms we use a measure for blocking patent citations to account, and explicitly test, for the heterogeneity of forward patent citations. 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:

$$\log q_{it} = \log q + \log\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CITES_{it}}{PAT_{it}} + \gamma_4 \frac{blocking\ CITES_{it}}{CITES_{it}} \right) \quad (3)$$

The following section introduces the dataset and described the variables.

3 Data and Variables Definitions

3.1 Sample

Our sample consists of 151 publicly traded European, U.S. and Japanese manufacturing companies who have their main economic activity in one of the following three industries: Chemicals & Pharmaceuticals, Electronics & IT Hardware, Non-Electrical Machinery. We limit our sample to these three industries as patent propensities are relatively high in these sectors (Arundel and Kabla, 1998), making patent data appropriate indicators of technological activities. The sample firms are high R&D spenders in their sectors 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 U.S. & Japan), based on corporate R&D investments.[4]

We collected accounting (balance sheet), market and patent data at the consolidated corporate level over a period of 6 years (1995-2000) for the sample firms. Due to missing data for some firms and years, this resulted in an unbalanced panel dataset of 876 observations for 151 firms. Data on the market value (Tobin's Q) and R&D expenditures of firms are obtained from Thomson Financial's Datastream database and corporate annual reports. Patent indicators (patent and citation stocks) are constructed from the OECD/EPO patent citation database (Webb et al., 2005). The (second edition of) this database contains information on all patent applications filed at the European Patent Office (EPO) and the World Intellectual Property Organization (WIPO), under the Patent Co-Operation Treaty (PCT), from the introduction of EPO in 1978 until September 2006. The patent database also provides a list of equivalent patents at other national or regional patent offices protecting the same technology. This information is taken into account for the calculation of the firm-level triadic patent stocks and our patent citation based measures.

Because company names in patent databases are not unified and patents may be applied for under names of subsidiaries or divisions of a parent firm, we linked patent and firm data at the consolidated corporate level. We searched for patents applied under the

---

[4] The sample consists of 63 pharmaceutical and chemicals firms, 60 in Electronics and IT hardware and 28 firms active in Non-Electrical Machinery. Regarding the distribution of firms across countries, 52 firms are U.S. based, 60 are Japanese and the remaining 39 firms are European firms.

name(s) of the parent firm as well as under the names of their majority-owned subsidiaries. For this purpose, we used yearly lists of companies' subsidiaries constructed from 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'. The annual consolidation (1995-2000) takes into account annual changes in the group structure of firms due to mergers, acquisitions, 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. Hence, variations in firm-level patent stocks over time in our data reflect both changes in the size and efficiency of internal R&D investments and changes in corporate group structures. In that sense, the patent stocks in this study differ from stocks in most other market value studies who assume stable ownership structures over time. The consolidation exercise proved to be a time-consuming task as the sample firms are leading R&D actors in their industries which typically have long lists of subsidiaries and a considerable number of annual changes in the corporate structure. In total 2,168 different patent applicants name variants have been linked to 151 firms over the period 1995-2000.

3.2 Variables

Our dependent variable is Tobin's q for the firm, the ratio of the market value of the firm to the replacement (book) value of the physical assets. Firms' 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 computed as a perpetual inventory of past and present annual R&D expenditures with a constant depreciation rate (δ) of 15 percent, as described in detail by Griliches and Mairesse (1984) and Hall (1990). We use the following formula for the R&D stock of a firm in year *t*:

$$R\&D\ stock_t = R\&D_t + (1-\delta)R\&D\ stock_{t-1} \quad (4)$$

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

$$R\&D\ stock_0 = R\&D_0/(\delta + g) \quad (5)$$

In line with prior work (e.g. Hall and Oriani, 2006, Hall et al., 2007) an annual growth rate (g) of 8.7 percent is used.[5] Equation (5) assumes that firm R&D expenditures have been growing at a constant annual rate (g) prior to the first R&D observation year. Note that the R&D expenditure and the firms' total assets are deflated using GDP deflators.

Patent stocks are constructed in the same way as R&D stocks, applying the same declining balance formula (4) (depreciation rate of 15%) based on patent applications. For the calculation of the patent application stocks the complete listing of EPO patents is available since the foundation of EPO in 1978. Our sample starts in 1995, so the effect of missing initial conditions (patents prior to 1978) should be very small in the calculation of the patent stocks. Patent stocks are computed based on triadic patents in order to have

[5] While Hall and Oriani (2006) and Hall et al. (2007) use 8 percent as growth rate, we chose 8.7 percent because this is the average R&D growth rate in our sample. The results are not sensitive to this choice.

comparable indicators for firms in different home countries (Europe, Japan and U.S.). Triadic patents protect inventions that are patented at all three major patent offices, the EPO, the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO). Patenting is typically characterized by a home bias as firms are more likely to apply for patents at the patent office of their home country (Dernis and Khan, 2004). To deal with this bias in patenting, triadic patent stocks are used in this study.[6]

Patent citation stocks as a measure of patent quality are constructed based on forward citations to the triadic patents of firms. The number of forward citations to any patent is truncated in time because only citations received until the last year of the available patent data (2006 for this study) are observed. The truncation problem is addressed by counting forward citations over a fixed five year window between the priority dates of citing and cited patents. Citation counts are restricted to citing patents with a search report prepared by EPO examiners (EPO filings and PCT filings at EPO). This is a necessary restriction because we rely on information in the EPO search reports to identify which firm patents exert a blocking potential to other patents. Forward citation counts are calculated using citations to all patent equivalents of EPO and PCT patents. Citation stocks are calculated based on equation (4) using a 15 percent depreciation rate.

The information in the EPO search report allows distinguishing different types of patent references. For each EPO patent application a patent examiner prepares a so-called search report that lists all important documents which are considered as prior art. Based

---

[6] A significant share of the sample firms' patents are filed as triadic patents, which is commonly the case for large R&D spending firms (Dernis et al., 2001). As we only have listings of EPO and triadic patents for our sample firms, we could only calculate "the share of national patents that are triadic" for the European sample firms. About 54 percent of the EPO patents of the European firms are also triadic patents.

on the search report a decision is made as to whether a patent application is novel enough to be granted. An interesting feature of the EPO search reports is that references to prior art are classified according to their importance for the patent filing in question. Prior art which threatens the novelty requirement of the patent application in question is thus made visible. In the search report, references made for individual claims in the patent application are marked with an “X” if the invention cannot be considered to be novel or cannot be considered to involve an inventive step when the referenced document alone is taken into consideration. References are marked with a “Y” if the invention cannot be considered to involve an inventive step when the referenced document is combined with one or more other documents of the same category, such a combination being obvious to a person skilled in the art (Harhoff et al., 2005). A patent can still be granted (although this is less likely) if it has many references classified with X or Y. This can, for example be the case for patent applications with many claims. X and Y references may only pertain to particular claims and the remaining claims can be strong enough to get a (modified) patent application with fewer patent claims granted. Citations in categories X and Y are defined as ‘blocking’ citations. It has been shown empirically that patents cited as X/Y references have the power to block new patent applications (Guellec et al., 2009) and that they have a distinctive value in the market for corporate control (Grimpe and Hussinger, 2008a,b). We compute blocking citation stocks of the firms. Again, the stock is calculated based on equation (4) using a 15 percent depreciation rate. Our regression equations also include a set of control variables which may have a direct impact on firms’ market value: industry dummies, country dummies and year dummies.

3.3 Descriptive Statistics

Table 1 shows some descriptive statistics. It is clear that the firms in the sample are large and R&D intensive. On average, our firms' totals assets account for 9771 M$ and their R&D stocks for 603 M$, which leads to an average R&D intensity of 0.30. Also, the Tobin's q values are fairly high. With a mean value of 2.02 the Tobin's q values are well above unity. Focusing on the patent stock variables shows again the high engagement of the sample firms in R&D activities. The average sample firm has a triadic patent application stock of 303. The citation stock relative to the patent stock is 1.47, indicating that patent applications get on average more than one citation, reflecting the, on average, high quality and value of triadic patent documents. Focusing on the blocking potential of the firms' patent stocks as measured by X and Y forward patent citations, it is shown that 42% of the patent citations received can be labelled as blocking citations. Table 1 further shows the distribution of observations over time, sectors and countries.

Insert Table 1 about here

----

4 Market Value Estimations

Table 2 reports the regression results of estimating the market value equation (6) by nonlinear least squares, including year dummies, country and industry fixed effects.

$$\log q_{it} = \log q + \log(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CITES_{it}}{PAT_{it}} + \gamma_4 \frac{blocking\ CITES_{it}}{CITES_{it}}) + u_{it} \quad (6)$$

We estimate four different specifications. Starting with a basic model that only includes the ratio between the R&D stock and total assets as indicator of firms' knowledge capital, we add patents, citations and blocking citations step-wise to the market value equation. The results show a positive and significant effect of the ratio between R&D and total assets on Tobin's q. The size of the coefficient is in line with previous studies (Czarnitzki et al., 2006). Previous research has shown that there is considerable variance with regard to the impact of R&D on firms' market value depending on the home country of firms. In particular, there is a high effect of R&D for U.K. firms (Toivanen et al., 2002) whereas the effect for Italian firms is small, and U.S. firms score in between (Hall and Oriani, 2006). Our sample of European, U.S. and Japanese firms yields estimated coefficients for the R&D/assets ratio of 0.7 to 0.9, which falls in the range of the coefficients reported by Hall and Oriani (2006) for a sample of U.S. and European firms (0 to 1.9).

In all specifications, estimations for patents over R&D are positive and significant. This shows that the patent application stock contributes to the market value of the sample firms on top of the R&D stock that has generated the patents. The magnitude of the coefficient (0.7) is significantly higher than the coefficients obtained by Hall et al. (2005; 2007) for U.S. data (approximately 0.03) and European data (approximately 0.3). These studies rely on national patents (U.S. and European patents respectively). The estimations presented in this paper are the use triadic patents and suggest that triadic patents are, on average, more valuable than EPO and USPTO patents.

Citations reveal an additional premium over the patent stock. The citation variable is positive and significant in all specifications, confirming that forward patent citations are an indicator of patent quality. The last column of Table 2 shows the results for the market value equation in which the ratio between the blocking and total citations stock is added to the equation. The positive and significant coefficient of this variable suggests that patent citations that block patents are perceived as the most valuable type of patent citations by the market.

To get an indication of the size of the estimated effects, semi-elasticities for the knowledge asset variables that are included in the regressions are reported in Table 2. Reported values are average values of the semi-elasticities for all sample observations. Standard errors of the semi-elasticities are obtained using the delta method. An increase of one point in the R&D intensity of a firm (i.e. in the ratio R&D/Assets) leads to an increase in the market value of the firm in the range of 25 to 67 percent. Further, one extra triadic patent per million dollars of R&D increase the market value by about 40-50 percent and one additional citation per patent boosts market value of firms by about 13-23 percent. The semi-elasticities for the patent and citation variables are significantly higher in our study than in the study of Hall et al (2005) for USPTO patents of U.S. firms. Again, this may be explained by the fact that we use stocks of triadic patents and focus on the largest R&D actors within our industries. Most notably, the semi-elasticity for the ratio between blocking and total patent citations is considerably high. An increase of one point in the ratio blocking over total patent citations, i.e. if a firm without any blocking patents would suddenly own blocking patents only, increases the market value of the sample firms by 89 percent.

Insert Table 2 about here

The pooled cross-sectional estimations presented in Table 2 have the disadvantage that they do not account for the impact of unobserved firm fixed effects. It is rather uncommon in the market value literature to apply panel data methods to control for firm fixed effects [7]. A problem with panel techniques is, as Hall et al. (2005) argue, that the right-hand side variables cannot be considered as strictly exogenous, an assumption required by most panel data methods. In this paper, we employ a new panel data estimator which uses pre-sample information for the dependent variable to control for unobserved firm specific effects. The estimator is based on a count data fixed effect estimation approach proposed by van Reenen et al. (2007). It has the advantage that it does not rely on the assumption of strict exogeneity of the regressors. Czarnitzki and Dhaene (2009) show that the pre-sample fixed effects approach is also consistent and efficient if the dependent variable is not a count. Equation (7) is the market value equation in which the pre-sample mean of the dependent variable (v_i) is added to the specification.

$$\log Q_{it} = \log q + \log(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CITES_{it}}{PAT_{it}} + \gamma_4 \frac{blocking\ CITES_{it}}{CITES_{it}}) + v_i + u_{it} \qquad (7)$$

Table 3 reports the regression results of estimating the market value equation (7) by nonlinear least squares, also including year, country and industry dummies as controls. Adding pre-sample information on the dependent variable considerably increases the explanatory power (adjusted R^2) of the market value model from 44 to 56 percent. The

---

[7] The few exceptions are Blundell et al. (1999), Bloom and van Reenen (2002) and Toivanen et al. (2002).

sign and significance of most estimated coefficients in Table 3 are in line with the coefficients obtained for the pooled cross-sectional model in Table 2. The most remarkable difference is that the R&D stock over assets turns insignificant for most model specifications if 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 firm specific fixed effect (Hall et al., 2005). The coefficients for patents over R&D and citations over patents are positive and (mostly) significant, but smaller than those reported in Table2. The premium for blocking citations stock remains positive and significant and is comparable in magnitude to the results reported in Table 2. In addition, the semi-elasticities presented in Table 3 show that the inclusion of fixed effects does not change our previous results.

Insert Table 3 about here

We check the robustness of our results by calculating citation measures without self-citations. Regression results without self-citations are reported in Table 4. Table 4 presents specification III and IV using both pooled cross-sectional and panel data techniques (pre-sample means). We see little difference in the estimated coefficients of the variables with regard to size and significance. This is in line with previous results for the market value of patents for U.S. (Hall et al., 2005) and European firms (Hall et al., 2007).

Insert Table 4 about here

----

5 Conclusions & Discussion

Innovation is considered to be a major cause of economic growth and welfare of countries (Schumpeter, 1934; Solow, 1957; Griliches, 1979). A necessary condition for private innovative activity to take place is that innovation has a positive impact on firm profits. This has stimulated researchers in accessing the value of firms' R&D investments (e.g. Hall et al., 2005) and innovation strategies (e.g. Ceccagnoli, 2009). This paper contributes to this stream of the literature. Making use of a unique feature of the European patent system, we investigate differences in the value of patented inventions by investigating the role of 'blocking' patent citations. At the European Patent Office (EPO), patent examiners classify patent citations according to their relevance for the patent application in question. Patent references are marked as X or Y references if they, alone or in combination with other documents, challenge the novelty or inventive step of the patent under examination (Webb et al., 2005; Harhoff et al., 2005; Criscuolo and Verspagen, 2008). These references are referred to as 'blocking' references in this paper as they can threaten the patentability of inventions of rival firms and (partially) block their R&D activities (Grimpe and Hussinger, 2008a,b; Guellec et al., 2009). Blocking patents can enable their owners to better protect their markets, and are therefore expected to be of high value. The aim of the paper is an investigation behind the economic value of blocking patents.

Our empirical analysis follows the market value approach of Griliches (1981) in which the market value of firms is regressed on a set of indicators of their knowledge stocks, including the share of blocking patent citations to firm patents. Our paper makes several methodological contributions to the market value literature. First, we employ a new panel data method based on pre-sample information to control for unobserved firm fixed effects. Second, our patent stock variables are based on annually consolidated data and calculated based on triadic patents (i.e. patents filed simultaneously at the European, U.S. and Japanese patent offices). Third, our sample firms have their home countries in different European countries, Japan and the U.S., whereas most prior studies focus on firm samples from the U.K. and U.S. only.

The results show that firms owning a high share of blocking patents (relative to all patent citations received by firm patents) have a superior market value. This suggests that patents which receive a higher number of blocking citations have a higher economic value to firms than other patented inventions. Our finding adds to the literature on patent value (e.g. Trajtenberg, 1990; Harhoff, 1999; Hall et al., 2005; Gambardella et al., 2008) by showing that there are differences in the informational value of patent citations on the economic value of patents, and that mainly 'blocking' patent citations (X and Y citations) are a good predictor of the value of patents.

The finding that a substantial part of the value assigned to forward citations stems from a specific type of forward citations, namely those with a blocking potential, suggests that the use of pooled forward citations as a measure of patent quality can lead to an overestimation of the patent value. Recently, Alcacer and Gittelman (2006) have raised similar concerns regarding examiner-given versus applicant-given citations for

USPTO patents, arguing that examiner-given citations inflate citation measures. Rather than looking at the source of citations (examiner or applicant given), we investigate the role of patent citations in the grating process of other patents. Our study indicates that it is important to make a distinction between citations that are made to question the novelty of patents (blocking citations) and citations that are simply (non-infringing) prior art references.

References

Alcacer, J. and M. Gittelman (2006). Patent Citations as a Measure of Knowledge Flows: The Influence of Examiner Citations. *Review of Economics and Statistics* 88(4): 774-779.

Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. in: R.R. Nelson (ed.): *The Rate and Direction of Inventive Activity*. Princeton, NJ: Princeton University Press: 609-25.

Arundel, A. and Kabla, I. (1998). What percentage of innovations are patented? Empirical estimates from European firms. *Research Policy*, 27, 127-141.

Bloom, N. and J. Van Reenen (2002). Patents, Real Options and Firm Performance. *Economic Journal* 112(3), 97-116.

Blundell, R., R. Griffith and J. Van Reenen (1999). Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms. *Review of Economic Studies* 66, 529-554.

Ceccagnoli, M. (2009). Appropriability, Preemption and Firm Performance. *Strategic Management Journal* 30:81-98.

Criscuolo, P. and Verspagen B.(2008). Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. *Research Policy*, 37, 1892-1908.

Czarnitzki, D. and G. Dhaene (2009). Efficient Fixed Effects Estimation Using Pre-Sample Means, mimeo, KU Leuven.

Czarnitzki, D., B.H. Hall and R. Oriani (2006). The Market Valuation of Knowledge Assets in US and European Firms. in: D. Bosworth and E. Webster (eds.): *The Management of Intellectual Property*, Cheltenham Glos: 111-131.

Czarnitzki, D. and K. Kraft (2004). Innovation Indicators and Corporate Credit Ratings: Evidence from German Firms. *Economics Letters* 82(3): 377-384.

Czarnitzki, D. and A.A. Toole (2009). Patent Protection, Market Uncertainty, and R&D Investment. Review of Economics and Statistics, *forthcoming*.

Dernis, H., Guellec, D., B. van Pottelsberghe de la Potterie (2001). Using Patent Counts for Cross-Country Comparisons of Technology Output. *STI Review* 27: 129–146.

Dernis, H. and M. Khan (2004). *Triadic Patent Families Methodology*. OECD Science, Technology and Industry Working Papers 2004/2, OECD Publishing.

Gambardella, A., D. Harhoff and B. Verspagen (2008). The Value of European Patents. *European Management Review* 5: 69-84.

Giuri, P., M. Mariani, S. Brusoni, G. Crespi, D. Francoz, A. Gambardella, W. Garcia-Fontes, A. Geuna, R. Gonzales, D. Harhoff, K. Hoisl, C. Lebas, A. Luzzi, L. Magazzini, L. Nesta, O. Nomaler, N. Palomeras, P. Patel, M. Romanelli and B. Verspagen (2007). Inventors and Invention Processes in Europe: Results from the PatVal-EU Survey. *Research Policy* 36: 1107–1127.

Granstrand, O. (1999). *The Economics and Management of Intellectual Property*. Edward Elgar, Cheltemham, UK.

Grimpe, C. and K. Hussinger (2008a). *Building and Blocking: The Two Faces of Technology Acquisitions*. ZEW Discussion Paper No. 08-069, Mannheim.

Grimpe, C. and K. Hussinger (2008b). Pre-empting Technology Competition through Firm Acquisitions. *Economics Letters* 100: 189-191.

Grimpe, C. and K. Hussinger (2009), *Inventions under Siege? The Impact of Technology Competition on Licensing*, ZEW Discussion Paper No. 09-039, Mannheim.

Griliches, Z. (1981). Market Value, R&D and Patents. *Economics Letters* 7: 183-187.

Griliches, Z., and J. Mairesse (1984). Productivity and R&D at the Firm Level. in Z. Griliches (ed.): *R&D, Patents and Productivity*: 339-74. Chicago, University of Chicago Press.

Griliches, Z. (1995). R&D and productivity: Econometric results and measurement issues. In Stoneman, P. (ed.). *Handbook of the Economics of Innovation and Technological Change*. Oxford, Blackwell, pp. 52-89.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics*, 10, 92-116.

Guellec, D. and van Pottelsberghe de la Potterie, B. (2008). *The Economics of the European Patent System*, Oxford University Press.

Guellec, D., C. Martinez and M.P. Zuniga (2009). More Exclusion than Invention: Blocking Patents at Work. *mimeo*. OECD, Paris.

Hall, B. H. (1990). The Manufacturing Sector Master File: 1959-1987, *NBER Working Paper*. Cambridge, MA.

Hall, B.H. (1996). The prívate and societal returns to research and development. In: *Technology, R&D and the Economy*. Smith B. and Barfield C. (Eds). Brookings Institution, Washington DC, 140-183.

Hall, B.H. (2000). Innovation and Market Value. in R. Barrell, G. Mason and M. O'Mahoney (eds.): *Productivity, Innovation and Economic Performance*. Cambridge: Cambridge University Press.

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., Link, A.N., J.T. Scott (2001). Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program. *Journal of Technology Transfer* 26: 87-98.

Hall, B.H. and R. Oriani (2006). Does the Market Value R&D Investment by European Firms? Evidence from a Panel of Manufacturing Firms in France, Germany, and Italy, *International Journal of Industrial Organization* 5: 971-993.

Hall, B.H., G. Thoma and S. Torrisi (2007). *The Market Value of Patents and R&D: Evidence from European Firms*. NBER Working Paper 13426.

Harhoff, D., K. Hoisl and C. Webb (2005). European Patent Citations: How to Count and how to Interpret them, *mimeo*, Munich.

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.

Henderson R., A. Jaffe and M. Trajtenberg (1998). Universities as a Source of Commercial Technology. *Review of Economics and Statistics* 80(1): 119-127.

Mairesse, J. and Mohnen, P. (1996). R&D-productivity growth: What have we learned from econometric studies? *Proceedings of the EUNETIC Conference on Evolutionari Economics of Technological Change: Assessment of results and new frontiers.* Strassbourgh, October 1994, pp. 817-888.

Schumpeter, J. (1934). *Business cycles: a theoretical, historical and statistical analysis of the capitalist process*. New York, McGraw-Hill.

Solow, R. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics*, 39, 312-320.

Toivanen, O., P. Stoneman and D. Bosworth (2002). Innovation and Market Value of UK Firms, 1989-1995. *Oxford Bulletin of Economics and Statistics* 64: 39-61.

Trajtenberg, M. (1990). A Penny for Your Quotes: Patent Citations and the Value of Innovations. *RAND Journal of Economics* 21(1): 172-187.

Trajtenberg, M. (2001). Innovation in Israel 1968-97: A Comparative Analysis Using Patent Data. *Research Policy* 30: 363-389.

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.

Ziedonis, R.H. (2004). Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. *Management Science*, 50(6), 804-820.

Tables

Table 1: Descriptive statistics

	mean	st. dev.	min	max
		# 876		
Tobin's q	2.03	2.14	0.22	16.60
log(Tobin's q)	0.37	0.76	-1.53	2.81
assets	9770.99	13541.76	40.03	90908.60
R&D stock	603.29	947.89	8.43	5564.48
R&D stock/ assets	0.30	0.20	0.02	1.72
triadic patent stock	302.83	584.20	0.00	4689.90
triadic patent stock/ R&D stock	0.13	0.13	0.00	0.09
triadic citation stock	447.11	833.37	0.00	5568.96
triadic citation stock/triadic patent stock	1.47	0.57	0.00	4.09
triadic XY citation stock	181.35	331.64	0.00	2215.45
triadic XY citation stock/triadic citation stock	0.42	0.11	0.00	0.84
triadic self-citation stock	133.70	284.95	0.00	2032.21
triadic citation stock excl. self-citations	313.41	579.05	0.00	3765.15
triadic XY citation stock excl. self-citations	131.34	237.21	0.00	1608.77
triadic XY citation stock excl. self-citations/ triadic citation stock excl. self-citations	0.42	0.11	0.00	0.78
Year 1995	0.16	0.37	0.00	1.00
Year 1996	0.16	0.37	0.00	1.00
Year 1997	0.17	0.37	0.00	1.00
Year 1998	0.17	0.37	0.00	1.00
Year 1999	0.17	0.37	0.00	1.00
Year 2000	0.17	0.38	0.00	1.00
Electronics & IT Hardware	0.39	0.49	0.00	1.00
Non-Electrical Machinery	0.18	0.39	0.00	1.00
Chemistry & Pharmaceuticals	0.43	0.49	0.00	1.00
Belgium	0.01	0.12	0.00	1.00
Switzerland	0.01	0.10	0.00	1.00
Denmark	0.01	0.12	0.00	1.00
Finland	0.03	0.16	0.00	1.00
France	0.03	0.18	0.00	1.00
Germany	0.05	0.22	0.00	1.00
Japan	0.40	0.49	0.00	1.00
Netherlands	0.03	0.18	0.00	1.00
Sweden	0.02	0.14	0.00	1.00
United Kingdom	0.04	0.20	0.00	1.00
United States	0.35	0.48	0.00	1.00

Table 2: 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		.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
ll	-768.62	-762.58	-748.51	-736.50
adjusted R^2	0.40	0.41	0.42	0.44
			Semi-elasticities	
	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)
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

The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.

Table 3: 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	0.62***	0.61***	0.59***	0.60***
	(0.05)	(0.05)	(0.05)	(0.05)
N	876	876	876	876
ll	-661.55	-658.40	-649.21	-629.56
adjusted R^2	0.53	0.53	0.54	0.56
	Semi-elasticities			
	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)
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

The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.

Appendix

Table 4: Robustness check: 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			0.60***	0.61***
			(0.05)	(0.05)
N	876	876	876	876
ll	-758.42	-741.23	-656.91	-632.82
adjusted R^2	0.41	0.43	0.53	0.56
	Semi-elasticities			
	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)	semi-elasticity (s.e.)
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

The regressions contain 10 country dummies, 2 industry dummies and 5 year dummies.