Fraunhofer ISI Discussion Papers *Innovation Systems and Policy Analysis* No. 28

ISSN 1612-1430

Karlsruhe, February 2011

Patents and the financial performance of firms – An analysis based on stock market data

Peter Neuhäusler[1]
Rainer Frietsch[1]
Torben Schubert[1,2]
Knut Blind[2,3,4]

[1]Fraunhofer Institute for Systems and Innovation Research ISI

[2]Faculty of Economics and Management at the Berlin University of Technology

[3]Fraunhofer Institute for Open Communication Systems FOKUS

[4]Rotterdam School of Management of the Erasmus University

Contents Page

Tables and Figures

Abstract

The following article systematically analyzes the question of how the results of R&D and its protection – or so to say, the technology base of a firm – can influence its market value and profits. Based on theoretical arguments it is hypothesized that large and highly valuable patent portfolios of firms have significant effects on their competitiveness in the long run.

For the empirical testing a panel dataset including 479 firms from 1990 to 2007 based on the DTI-Scoreboard is used, which contains data on R&D expenditures, market capitalization, turnover etc. and structural information like firm-size and industry sector. To this database the relevant information on patenting behavior and financial performance are added, so effects of firm characteristics can be calculated.

To assess the value of a firm's patent portfolio, different value measures like the number of received patent citations, opposed patents, number of inventors etc. are being applied. The results suggest that at least at the firm level, especially forward citations and family size positively influence market value. Concerning the Return on Investment, especially oppositions and family size show positive effects. This leads to the conclusion that securing international markets has a positive effect on the value of the firm in the home market.

1 Introduction

The value and competitive advantage of firms is depending on a large number of different factors, such as business strategy, knowledge resources, or market position. Increasing importance is also paid to innovative capacity, because it allows firms to constantly renew their products and adapt their production techniques to new developments not only in a technological sense but also to new market situations. Innovation therefore becomes a self-sustained competition parameter (compare Schubert 2010). Furthermore, it is often argued, that increased innovative capability leads to competitive advantage, because firms, especially at the beginning of the product cycle, face other market participants in a technology (or quality) rather than a price competition (Kleinknecht/Oostendorp 2002; Legler/Krawczyk 2006; Maskus/Penubarti 1995; Utterback/Abernathy 1975).[1]

Broadly speaking, innovative capability is the ability to successfully complete innovative processes, i.e. implement respectively commercialize new or improved products, services and technologies, where the major innovation incentive are increased future profit prospects. The successful completion of the innovation process alone, however, is not a sufficient condition to obtain the expected benefits from innovation. A firm has also to be able to appropriate these benefits, implying that it prevents its competitors from imitation. Thus, effectively protecting innovations (be they product or process changes) requires firms to set up effective protection mechanisms, where formal intellectual property rights, in particular patents, are among the most important instruments.

Following this argumentation, it is obvious that besides systematic generation and systematization of knowledge, the active protection of the developed intellectual property is also decisive for increasing and securing competitive advantage.

The following analysis tries to shed light on the question of how far the results of R&D and the protection of outputs can influence the market value of a firm. To approximate the protected outputs and the technology base of a firm, we will use patent applications. Patents are one of the most important innovation indicators to assess technological competitiveness on the micro and the macro level as they are among the most important visible artefacts of R&D processes (Freeman 1982; Frietsch/Schmoch 2006; Grupp 1997; Grupp 1998). To assess and differentiate between the values of patent portfolios, several of their characteristics – such as the average number of patent for-

1 This usually changes during the product life cycle. In later phases, when technologies mature, the technology competition shifts regularly to a price competition, driving some firms out of the market.

ward citations, family size or number of inventors - are employed, which are believed to explain part of the difference in financial performance measures of firms in the sample.

The novelty of this paper lies in several aspects. First, different outcome values of firm performance will be compared. Not only the stock-market-related data is taken into account, but also the profit-based measure Return on Investment (ROI). This goes beyond studies that have been performed up to now, since it allows separating effects of the patenting portfolio on expectations of financial markets about future profitability from that on current returns that is reflected by the income statement. Second, a broad set of patent indicators is used, where, although several of them have been used at the national level or at the level of individual patents (see for example Frietsch et al. 2010; Harhoff et al. 2003), evidence at the firm level is still absent. Third, the study builds on an international panel dataset of large R&D-conducting firms, where earlier studies have mainly relied on cross-section data or on small and selective panels, often comprising data only on specific sectors or nations. Thus, what follows here is much more general than earlier studies in terms of financial performance, analyzed patent indicators, and dataset.

The remainder of this paper is organized as follows. In Section 2, we will give a short account of the literature. Section 3 presents some more theory and derives the main hypotheses. In Section 4 we describe the data and methods. Section 5 presents the empirical results and Section 6 concludes.

2 Literature Review – Technology base and economic performance

The idea that the long-term development of market shares is not only driven by price but also by technology competition, finds its theoretical foundation in the "product cycle model" or "technology gap model", which is usually used to explain differences in international trade. The product cycle model was first proposed by Posner (1961) and Vernon (1966; 1979) and further elaborated by Krugman (1979), as well as Dosi and Soete (1983; 1991). In essence, the product cycle model assumes a dynamic change of production technology and different ability to exploit new technologies between different entities. Furthermore, it assumes the presence of an imitation lag, i.e. it will take time and costs for a follower to absorb superior technology and apply it for manufacturing processes. Under these conditions, new or advanced products integrating superior technologies will form oligopolistic markets, at least temporarily, before the followers catch up. Therefore, firms developing new products integrating superior technology will dominate the markets for these products, not only resulting in high market shares but also allowing them to (at least temporarily) reap above-normal profits as a result of market power. This argumentation is also empirically supported. Some empirical evidence for example comes from a study by Hendricks and Singhal (1997) who showed, that delaying the introduction of new products decreases the market value of the firm. Significant penalties for firms seem to exist for not introducing new products on time.

Therefore, innovation should drive the long-term competitive advantage of firms, which eventually should be mirrored also in the financial performance measures. Patents as one of the most important visible artefacts should thus be positively related to financial performance.

Although there is a broad literature on patents as a measure of the national/regional technology base or the value of individual patents, especially, at the level of individual companies, evidence of an association between patent characteristics and financial performance is not overwhelmingly large.

Several other studies take the stock market value of firms as an aggregated measure of economic value or other financial performance indicators at the firm level. They examine how these value measures are predicted by various patent indicators including the number of patents, forward citations and others. Notable studies are for example Griliches (1981), who found a significant relationship between firm market value and what he calls its 'intangible' capital, proxied by past R&D expenditures and the number of patents, based on data for large U.S. firms. Narin and Noma (1987) found correlations in the range of 0.6 to 0.9 between an increase in a company's profit and sales and citation frequency as well as concentration of patents in only a few patent classes. The results of Deng et al. (1999) indicate that the number of patents, forward citations and closeness of R&D to basic research are associated with future firm performance. By analyzing a sample of 50 business firms within the German mechanical engineering industry, Ernst (1995) revealed that the number of international patent applications, the rate of valid patents and highly cited patents are positively related to economic performance. In a sample of German machine tool manufacturing firms, he could also show that national patent applications lead to sales increases with a time lag of two to three years after priority filing (Ernst 2001). Bosworth and Rogers (2001) analyzed the value of large Australian firms. Their findings suggest that R&D and patent activity are positively and significantly associated with market value as measured by Tobin's q. Hagedoorn and Cloodt (2003) found a composite indicator consisting of R&D inputs, patent counts, patent citations and new product announcements to be related with firm performance. Lanjouw and Schankerman (2004) used an index of patent quality and could show that research productivity at the firm level is negatively related to the patent quality index but exerts a positive influence on the stock market valuation of patented innovations held by firms. Also, the stock of patents within a firm is known to be positively associated with sales revenue from new products (Nerkar/Roberts 2004). Hall, Jaffe and Trajtenberg (2005) used patents and citations from 1963 to 1999 and found firm market value positively related to the ratios of R&D to assets stocks, patents to R&D, and citations to patents. In a firm dataset from the US pharmaceutical and semiconductor industries Lee (2008) estimated a Tobin's q equation on the R&D intensity, patent yield of firms, and citations to patents. Interestingly, he found that information on patent citations received long after a patent is granted bears significant information about the market value of innovating firms. In more recent studies, Chen and Chang (2010b) found that the relative patent position[2] and patent citations of firms were positively associated with corporate market value in the pharmaceutical industry. Additionally, they found an inversed u-shaped relationship between patent citations and corporate market value. Using the method of artificial neural networks, they discovered an optimal value for patent citations (2010a). Furthermore, in an analysis of a sample of German manufacturing firms Czarnitzki and Kraft (2010) found that the patent stock of a company has a strong and robust effect on profitability. Levitas and Chi (2010) used a real options approach to analyze the effect of patent intensity and capital investment in technology on firm's opportunities to create value through future investment. In a sample of 161 US based biotechnology firms, they found mixed results with regard to the rela-

---

2 The relative patent position is a measure proposed by Ernst (1998), which compares the patent counts of a company to its most active competitor in terms of patent counts.

tionship between patenting and firm value and therefore argued that such investment primarily creates value by offering future technology options. Finally, Hall and MacGarvie (2010) in an analysis of firms in the ICT sector found slightly higher market values for firms holding software patents compared to those firms with no software patents.

Building on this literature, the aim of this study is to show how the patent portfolio influences the economic value of a firm in total. The proposed analyses go beyond older studies by accounting for different kinds of financial performance, by accounting for patent characteristics not analyzed before and by employing a large scale panel dataset.[3]

3 A significant implication of an association between patenting measures and firm performance would be that the more patents reflect the economic results of R&D activities, the more meaningful they become as an outcome indicator of R&D activities (Ernst 1995; Griliches 1990), which is even more important, given that patenting information especially for firms is more easily accessible than information on R&D activities.

3 Theory & Hypotheses

In the following we will first discuss the different indicators of firms' financial performance. Then we will review important patent indicators. Based on both discussions we will derive our working hypotheses.

3.1 Assets, profitability, and their relation to market capitalization

A variety of different stock-market-based indicators have been used to assess the value of firms. In this analysis we intend to use the Tobin's q and the Return on Investment. As will appear in the empirical section, the analyzed patent indicators may exhibit different kinds of relationships. In order to interpret these differences properly, we will here define the Tobin's q and the Return on Investment formally. This will allow us to highlight the different perspectives taken by these two indicators.

Most notable is the use of stock market data for at least two reasons. Firstly, stock market data are easily available. Secondly, if stock markets are arbitrage free and traders are rational, we would expect that the market capitalization of a firm equals the flow of all discounted future profits plus the selling value of all remaining assets. In simpler words, the market value of a firm should resemble its value when seen as an investment object.

More formally let assume that a firm is infinitely lived and there is no uncertainty. Let r be the discount rate (consisting of an appropriate interest rate and possibly time preference), π be profits before interest and tax, V the market capitalization of a firm, R the selling value of the firm and A be tangible assets. The following relationship is expected to hold for any firm i:

$$\frac{V_{0i}}{A_{0i}} = \sum_{t=0}^{T} \frac{\pi_{ti}}{A_{0i}} \frac{1}{(1+r_{ti})^{t}} + \frac{R_{Ti}}{A_{0i}} \frac{1}{(1+r_{Ti})^{T}} \qquad (1)$$

where the left-hand side is the ratio of market capitalization to the book value of a firm. This measure is also called Tobin's q (Brainard/Tobin 1968; Griliches 1981; Hall et al. 2005; Narin et al. 2004; Nguyen/Schüßler 2010; Tobin 1969).[4]

[4] The popularity of this indicator has also to do with its nice interpretation. A value greater than unity means that the firm is worth more than the sum of its tangible assets. A value less than one, on the contrary, implies that the firm value is below the book value of the tangible assets. Because of this, Tobin’s q is often taken as a measure of under- or over-valuation.

At the same time, abstracting from the returns, the value of a firm can also be defined in terms of its assets. Following the q-model (Griliches 1981), we assume that the value a firm depends on the stock of tangible assets A and knowledge assets K. More precisely, the following structure is assumed:

$$V_{0i} = \lambda_{0i}(A_{0i} + \gamma K_{0i})^{\sigma} \tag{2}$$

where λ_i is a firm-specific multiplier that captures, for example, market characteristics or other kinds of firm specifics including not yet controlled resources, while σ measures the returns to scale and γ is the shadow-value of knowledge assets. Dividing (2) by A yields:

$$V_{0i} / A_{0i} = \lambda_{0i}(1 + \gamma K_{0i} / A_{0i})^{\sigma} \tag{3}$$

We note that the term on the right-hand side is actually once again Tobin's q.[5]

Taking together equation (1) and (3), it becomes obvious that Tobin's q is actually both determined by the value of the assets and by the future discounted profits of a firm, where this equivalence forms the theoretical justification for treating the Tobin's q both as a measure of asset and investment value of a firm.

Indeed under the model assumptions of perfect predictability of all future returns, tobin's q is theoretically very appealing because it defines a nice way of incorporating all information on the expected performance of the company. However, we should note that future profit rates are unlikely to be predictable and often we may even be unable to specify a sensible distribution. Thus, observed market capitalization and Tobin's q are frequently very noisy measures of future profitability and are more likely to reflect herd instinct, speculative bubbles, or general market expectations (so to say, the state of mind of the shareholders).

Therefore, we intend to use also a measure of contemporaneous profitability. In particular, we use the Return on Investment, which is defined as profits before interest and tax divided by total assets:

$$ROI_{0i} = \pi_{0i} / A_{0i} \tag{4}$$

---

5 Note that from (3) it is possible to derive an econometric model that can be estimated by NLLS. However, the non-linearity implied by (3) is nothing structural and only reflects a model choice with respect to the functional form. Since implementing the NLLS procedure for panel data would prevent us from dealing with more important topics related to panel data driven endogeneity, we take equation (3) rather as a theoretical inspiration and a general guideline than to overemphasize the actual functional form.

Comparing (1) and (4) actually reveals that Tobin's q and the Return on Investment are indeed closely related. The former takes into account all future profit flows, while the latter focuses only on the present day profits.

Using these two measures is theoretically very appealing, because in our context it allows us to differentiate the influence of patent portfolio characteristics both on market expectations (resembled by Tobin's q) and on the income statement, that is, the realized present day profits. As we will see, this distinction also reveals that some of the contradictions prevailing in the literature can in fact be reconciled, because patent indicators will be found to have effects that vary with the employed measure of financial performance.

3.2 Patent Characteristics

The most important indicator for the output of invention/innovation processes within firms are patent counts or patent stocks. However, since patents can differ both in economic and technological value, simple patent counts give a distorted impression of a firm's technological basis. Therefore, many other indicators have been proposed to correct for quality or value of patents (compare for example Frietsch et al. 2010). The most important indicators, both with respect to quantity and quality, will be reviewed in the following. For the sake of simplicity, all of patent characteristics that could indicate patent value, will be referred to as value indicators in the remainder of this paper, although the article aims to find out which of these indicators are applicable for the evaluation of a company's patent portfolio.

3.2.1 Patent applications

Despite quality considerations, it is still reasonable to assume that the number of patent applications positively affects firm performance. Large patent portfolios not only indicate stronger efforts in R&D activities and therefore a higher innovative output. Large patent portfolios are also strategically useful, for example, to block competitors (Blind et al. 2006). Additionally, larger patent portfolios increase the chance for licensing agreements or trade with other firms and can also be used to prevent smaller potential competitors from entering relevant markets. Furthermore, patent output can be seen as a positive signal to the market. Taken together, this leads to our first hypothesis:

H1: A larger patent output leads to an increase in market value and profits.

3.2.2 Citation-based measures

3.2.2.1 Forward Citations

Probably the most common and widely used indicator to indicate the value of a patent is patent forward citations (Narin/Noma 1987; Trajtenberg 1990). It is assumed that the number of forward citations (citations a patent receives) measures the degree to which a patent contributes to further developing advanced technology, thus this can be seen as an indicator of technological significance (Albert et al. 1991; Blind et al. 2009; Carpenter et al. 1981).[6]

H2a: A larger average number of forward citations per patent has a positive effect on firm performance in terms of market value and ROI.

Yet, several studies show, that patent citations are a very noisy signal of patent value (Alcacer et al. 2009; Alcacer/Gittelman 2006; Hall/Ziedonis 2001). For this reason, additional measures of patent value are taken into account in the following the analysis.

3.2.2.2 Backward Citations

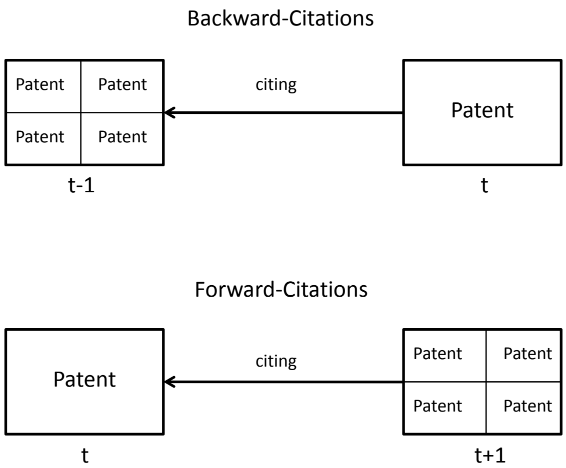
Backward citations (citations a patent makes) refer to previous patents and are mostly used as an indicator of technological breadth or background of an application and can give hints on the scope of a patent. However, the logic of backward citations is ambiguous (Frietsch et al. 2010). On the one hand, backward citations reflect a patent's scope, as a patent examiner may include more references if the scope of the patent is large. On the other hand, Harhoff (2003) offered the argumentation that a higher number of backward citations could cause the content of the patent to be more restricted, which could therefore limit its possible value. However, in his analyses he found a positive influence of backward citations on patent value. Therefore, the following hypothesis can be derived:

H2b: A larger average number of backward citations per patent has a positive effect on firms' financial performance measures.

---

6 As a specific feature of the EPO, patent citations are categorized into different types. First of all, there are citations which are particularly relevant regarding the assessment of the novelty or the inventiveness of the application (invention) examined. These can be called the "relevant" citations with the codes X or Y. We assumed, that X or Y citations could exert a different influence on firm performance measures compared to using forward citations in total. The analysis of correlations, however, revealed that X and Y citations are highly correlated with forward citations in total. Therefore, X and Y citations were left out in the following analyses for reasons of multicollinearity.

Figure 1: Taxonomy of patent citations



Source: own compilation

3.2.3 Granted Patents

Another patent characteristic that could serve as an indicator of patent value is granted patents. The interpretation of this indicator is very straightforward, as it can be assumed, that the value of a patent is determined by the granting process per se. A granted patent can be seen as more valuable than a non-granted patent as it has met the criteria of novelty, technological height and commercial applicability.

H2c: A larger share of granted patent leads to an increase in market value and profit of firms.

The alternative to a grant decision are a withdrawal by the applicant or a refusal. The refusal should clearly be a negative event, because refused patents do not even meet the regular conditions for being granted. A withdrawal, however, can indicate different things. Of course, it may only be an anticipation of a future refusal (compare for example Harhoff/Wagner 2009). Then, it would likewise be interpreted as a negative sign. On the contrary, withdrawn patents can also have had a strategic (e.g. blocking value) during their lifetime. Furthermore, a withdrawal decision can reflect the successful product portfolio management of a firm.

H2d: i) The share of refused patents should have a negative effect on firm performance. ii) The influence of the share of withdrawn patents is ambiguous.

3.2.4 Opposed Patents

In addition, opposition or litigation history has been well established as an indicator of patent value (Harhoff et al. 2003; Harhoff/Reitzig 2004; van der Drift 1989). At the EPO, any third party may file an opposition against a granted patent within a period of nine months after grant. This counts only to a limited extent for the USA, where patents are more frequently litigated in court. Therefore, in the US litigation fees have been used as an indicator (Lanjouw/Schankermann 1998).

The explanation for the use of oppositions as a patent value indicator is twofold. Opposing a patent is subject to significant additional costs, for which companies should only be willing to pay if they see a market for one of their inventions which is to be covered by the contested patent. In addition, an appeal against a patent means that at least two parties conduct research for exactly the same piece of technology. Therefore, the cost and risks associated with the dispute signal the existence of a market for the patented invention (Van Zeebroeck 2009). In practice, however, opposition is a rare event, as for example only about eight to nine percent of all EPO patents are challenged (Harhoff/Reitzig 2004).

H2e: With a larger share of opposed patents firm financial performance increases.

3.2.5 Family size

Another important patent characteristic which could potentially indicate a patent's value is family size. Family size is determined by the number of countries or patent offices, at which a patent has been applied (Putnam 1996; Schmoch et al. 1988). For each of these countries, however, application and maintenance fees have to be paid to the respective offices. Therefore, an application for a patent in a foreign country means that the applicant tries to secure that market to sell his invention and is prepared to bear additional costs. In this sense, it is assumed that a patentee only files a patent abroad, if he expects a corresponding profit with the sale of the protected technology. Put simply, a large patent family means greater market coverage which is associated with preliminary costs.

H2f: With increasing average family size, financial performance increases.

3.2.6 Number of inventors

Lastly, the average number of inventors per patent is included as an indicator in the analysis. This measure is based on the assumption that a patent stemming from research by several inventors should be of greater value than a patent, which was developed by a single inventor (Schmoch et al. 1988). The basic argument is that inventions can be regarded as a combination of existing ideas. The broader the set of underlying ideas, the more valuable the patent or the invention (Guellec/van Pottelsberghe de la Potterie 2000).

H2g: With a higher average number of inventors, market value and profit increase.

4 Data and Methods

4.1 Data and Sample

For the empirical analysis, a panel dataset including 479 firms from 1990 to 2007 based on the DTI-Scoreboard[7] was constructed that contains firm-specific data on, amongst other R&D expenditures, market capitalization and turnover. The basis year for the construction of the dataset is 2001 where in total 500 companies were listed in the DTI-Scoreboard. Data on preceding and following years were added to this dataset. If any of the 500 companies had not been listed in the years before or after 2001, the respective observations were treated as missing. Fortunately, each year's scoreboard provides information on the R&D expenditures for the previous four years, so at least some information could be added to fill the gaps. Since some observation variables are still missing in some time periods, the panel is unbalanced.

In case of mergers and acquisitions between companies listed in the DTI-Scoreboard, which could be identified over the years, all data for the respective firms were added up. Using this method, the firms were treated as if they were merged from the beginning of the observation period.[8] This approach was chosen to preserve comparability over time, as no separation of information is possible after the merger.[9] Mergers and acquisitions where not all concerned units were listed in the scoreboard had to be left uncontrolled. In any case, since the DTI-Scoreboard already contains the most important R&D performers, enterprises not listed should be smaller, and distortions should be limited.

The relevant information on patenting behavior and financial indicators were added to this database. The relevant patent data were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 81 patent authorities worldwide. The annual sum of patent applications filed by each company at the European Patent Office (EPO) in total and differen-

---

7 The DTI-Scoreboard is provided annually by the British Department for Innovation, Universities & Skills (DIUS) and the Department for Business, Enterprise & Regulatory Reform (BERR). For the year 2008, it lists the Top 1400 international companies according to their R&D expenditures by industry (the number of companies is smaller in preceding years). In addition to the R&D expenditures, further firm-specific values, like sales and the number of employees, are shown. http://www.innovation.gov.uk/rd_scoreboard/

8 For details of this method of dataset construction, see Frietsch (2006).

9 Clearly, this treats merged companies as being the sum of its parts, which may be problematic, if mergers and acquisitions caused for example synergy effects. Still, we think that this is the most suitable approach.

tiated by 35 high-technology fields (Legler/Frietsch 2007) was calculated. We restricted the analyses to EPO data, to be able to focus on a consistent and homogeneous patent system. The companies were identified via keyword searches, where the keywords also included the names of the companies' subsidiaries, which were held by the parent company with a direct share of at least 25% to keep the patent data comparable with the financial data from the companies' balance sheets. Information on the names of the relevant subsidiaries by company was added from the LexisNexis (http://www.lexisnexis.com) and Creditreform Amadeus (http://www.creditreform.com) databases. Furthermore, patent value indicators – like patent forward citations, family size, patent oppositions etc. – were added to the database. PCT citations were included if the EPO search report makes reference to the PCT document. All patent data reported are dated by their priorities, i.e. the year of world-wide first filing.

The financial data for the companies – like total assets or returns before interest and tax – that are needed to calculate the firm's financial performance indicators were added from Standard & Poor's COMPUSTAT Global and COMPUSTAT North America databases. All monetary measures were converted to British pounds (GBP) based on a yearly averaged exchange rate which was taken from COMPUSTAT Global Currency database. Tobin's q is only available from the year 2000 onwards, which is why the following models on ROI are also calculated with the restricted dataset.

4.2 Indicators for the value of a patent portfolio

Before proceeding, we will shortly present the patent indicators from the PATSTAT database and the other explanatory variables. Following the discussion in chapter 3.2, these indicators are as follows.

Table 1: Indicators for the value of a patent portfolio

Number of EPO applications (in thousands)	A count of a company's issued patents year. The number of patents is the outcome of a company's R&D activity.
Patent stock of a company	A sum of the company's issued patents in the last five years, depreciated by 15% each year. This accounts for the fact that knowledge is cumulative. Therefore, it can be assumed that patent stock could exert some additional influence on firm market value.
Granted patents as a share of patent applications (lagged 5 years)	Granted patents divided by patent applications lagged by five years. The lag is based on the assumption that on average the grant of a patent at the EPO takes about five years (Frietsch et al. 2010).
Withdrawn patents as a share of patent applications	The sum of withdrawn patents of a company by year, divided by total patent applications.

Refused patents as a share of patent applications	The sum of refused patents of a company by year, divided by total patent applications.
Opposed patents as a share of patent applications	The sum of opposed patents by company and year divided by total applications.
Average number of forward citations	The number of forward citations in a four year time window divided by the number of applications with forward citations (also in a 4 year time window). With this time window it is assured that all patents have the same amount of time to be cited. Not using a time window would lead to higher citation counts for older patents, as they had a longer time period to be cited, which would cause a systematic bias.
Average number of backward citations	The number of backward citations of a company's patents divided by the number of applications with backward citations.
Average family size	The average number of distinct patent offices a company's patents were filed at.
Average number of inventors	The average number of inventors that are named on the company's patent applications.

In addition to the independent variables, some control variables are included in the model. First of all, the number of employees per company (in thousands) is added to control for size effects. Additionally, the share of sales by employee and R&D expenditures as a share of total sales are added, which are used as proxies to measure how efficiently firms generate sales and how well a firm converts results of R&D processes into revenues.

To account for the firm's productivity in general, the share of sales (in million GBP) by employee is calculated. To control for increased monetary input into the innovation process, the share of R&D expenditures (in million GBP) divided by sales (in million GBP) is calculated which can also be seen as a proxy of how well a firm converts results of R&D processes into revenues. Additionally, the number of employees (in thousands) is included into the model to take differences in firm size into account.

Table 2: Overview of the variables and summary statistics

Variable	Abbrev.	Mean	Std. Dev.	Min	Max	# Obs.	# firms
Tobin's q	Tobin's q	1.30	1.31	0.00	9.87	3223	446
ROI	ROI	0.08	0.09	-0.76	0.50	7635	462
# employees (in k)	emp	45.85	62.49	0.00	484.00	6392	456
R&D (in m)/Sales (in m)	rd_sales	0.07	0.08	0.00	0.99	5342	479
Sales (in m)/Employees	sales_emp	0.19	0.13	0.00	0.98	4423	443
# EPO applications (in k)	npat	0.09	0.20	0.00	3.08	7185	453
Patent Stock (5years) (in k)	patstock	0.39	0.76	0.00	10.74	4769	417
Grants/Applications (lagged 5 years)	grant_share	0.59	0.26	0.00	1.00	5225	452
Withdrawals/Applications	withd_share	0.21	0.21	0.00	1.00	7142	453
Refusals/Applications	refd_share	0.02	0.06	0.00	1.00	7142	453
Oppositions/Applications	opp_share	0.03	0.07	0.00	1.00	7142	453
Avg # FW-Citations	avg_nr_fw_cit	3.69	2.80	1.00	72.00	6525	452
Avg # BW-Citations	avg_nr_bw_cit	6.67	4.26	1.00	198.00	7148	453
Avg Family Size	famsize	6.18	2.90	2.00	31.89	7158	453
Avg # Inventors	invtcnt	2.87	1.11	0.00	24.03	7185	453

4.3 Estimation Methods

Since the data used for the analysis is a firm-level panel, the econometric specifications have to take account of the typical peculiarities of panel data. In particular, consider the following panel-data model

$$y_{it} = x_{it}\beta + c_i + u_{it} \qquad i = 1,...,n \qquad t = 1,...T \tag{1}$$

where y_{it} is the explained variable of unit i in period t, x_{it} is a vector of explanatory variables, β is a coefficient vector c_i is a firm-specific effect and u_{it} idiosyncratic errors.

Model (1) can be consistently estimated by pooled OLS or a random effects estimator, if we have i) $\mathrm{E}(c_i \mid x_i) = \mathrm{E}(c_i) = 0$ and i) $\mathrm{E}(u_{it} \mid x_i, c_i) = 0 \quad t = 1,...,T$. The first assumption is typically referred to as the random effects assumption, while the second is the assumption of strict exogeneity.

If any one of these fails, neither pooled OLS nor random effects estimation provides consistent estimation of the model (1), because the composite error term $v_{it} \equiv c_i + u_{it}$ is correlated with the explanatory variable, leading to endogeneity.

Looking at the economic meaning of the two assumptions reveals that fixed effects imply that although firm-specific effects are allowed to be existent, their value does not affect firms' choices about the explanatory variables. In our context, this for example rules out that unobserved firm differences for example with respect to innovative capacity or profitability may influence the decisions of the firm with respect to patenting activities. This is already clearly restrictive und not very convincing from an economic point of view. Strict exogeneity implies that random shocks in one period to not affect the explanatory variables (e.g. the firm's decisions about input) in any other period. It therefore rules out that for example a shock to return on investment induces changes to behavior in later periods. Also this is unlikely to hold with rational actors that will usually adjust their choices after shocks. Thus, there are no strong grounds in assuming strict exogeneity.

Fortunately, there are methods to deal with the failure of both assumptions. If the random effects assumption is not guaranteed to hold, it is common practice to use estimation techniques that eliminate the time constant firm-specific effect, either by first differencing or by time-demeaning. The latter is called the fixed-effects estimator, which is consistent, if assumption i) fails. However, it still requires strict exogeneity.

Failure of the latter is, although equally problematic, unfortunately not commonly discussed in empirical applications. However, it is possible to replace strict exogeneity, which is unlikely to hold, with an assumption called sequential exogeneity. This should usually hold in economic contexts with rational actors (Keane/Runkle 1992). To see why, note that sequential exogeneity requires shocks only to be uncorrelated with the explanatory variables of earlier periods, where it allows arbitrary correlation between random shocks and the explanatory variables in later periods. More formally, instead of assuming $\mathrm{E}(u_{it} \mid x_i, c_i) = 0 \quad t = 1,...,T$, sequential exogeneity only requires that $\mathrm{E}(u_{it} \mid x_{it}, ...x_{i1}, c_i) = 0 \quad t = 1,...,T$. Under this assumption there are several straightforward IV estimation techniques that eliminate the fixed effect by first differencing and use lagged explanatory variables as instruments for the endogenous explanatory variables (Wooldridge 2002, Ch. 11).

In this case we have used the first to lags, i.e. we instrumented x_{it} with (x_{it-1}, x_{it-2}). We further have run tests both on the random effects assumption and on strict exogeneity. Both tests indicated that both assumptions might be violated in our models.

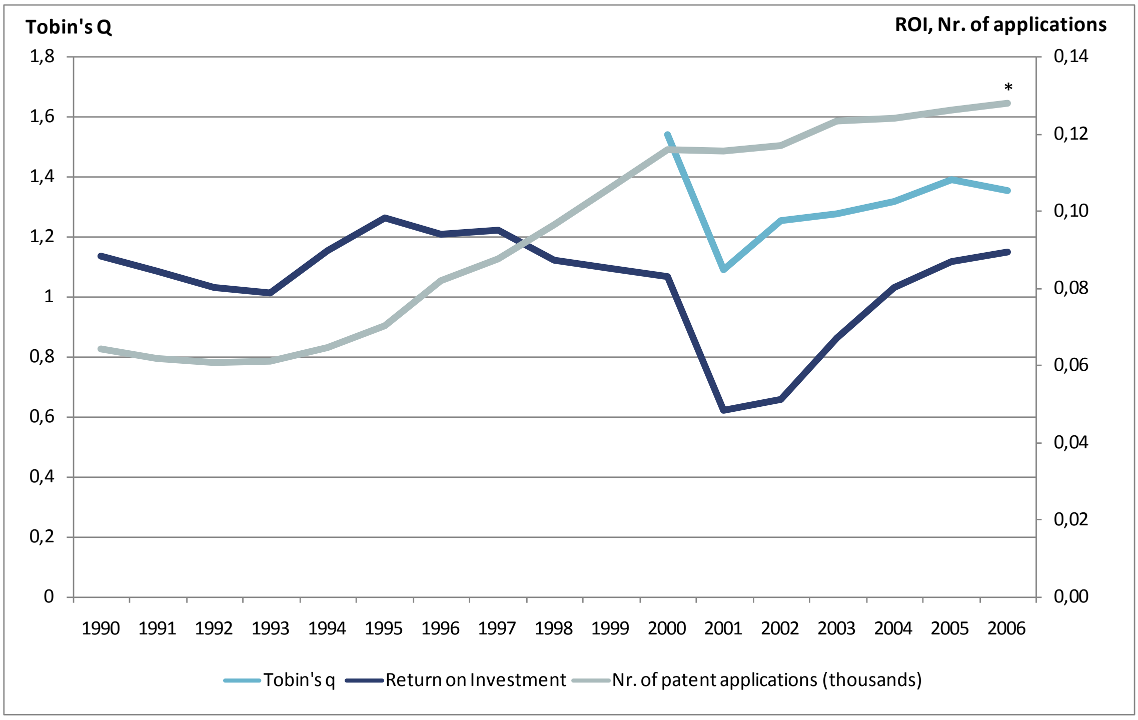
5 Results

5.1 Descriptive Results

In Figure 2, Tobin's q, Return on Investment and total patent applications at the EPO averaged for the companies in the dataset are plotted. As can be seen from the picture, patent applications rose dramatically, especially in the 1990s. This is a general phenomenon that can be observed throughout most OECD countries during that time and is commonly referred to as the patent upsurge (Blind et al. 2006).

Comparing the co-evolution of the patent counts and the financial performance measures ROI and Tobin's q in any case reveals that the financial measures are highly correlated, which should be expected in light of the theoretical discussion about the ROI and Tobin's q in Section 3.1. The correlation of the financial performance measures and the patent counts, on the contrary, although obviously present, is much less profound. This might indicate that using simple patent counts as a measure of the technology base of a firm, may be too noisy. It might therefore call for the incorporation of additional patent indicators, like citations.

Figure 2: Average Tobin's q, Return on Investment and total patent applications at the EPO, 1990-2006



* Tobin's q value for 2008 estimated, data for Tobin's q only available from the year 2000 onwards

This argument is corroborated by taking a look at the bivariate associations between the variables. This again reveals that the mere number of patent applications does not seem to have an effect on the firm performance measures. A much larger influence can be found for the value indicators, especially family size, which asserts an influence on both Tobin's q and ROI. The average number of forward citations only seems to affect market value in a positive way, but does not seem to have any influence on ROI.

Table 3: Pairwise correlations for the firm performance measures and the patent value indicators

	Tobin's q	**ROI**	**emp**	**rd_sales**	**sales_emp**	**npat**	**patstock**	**grant_share**	**withd_share**	**refd_share**	**opp_share**	**avg_nr_fw_cit**	**avg_nr_bw_cit**	**famsize**
ROI	0.45													
	(0.00)													
emp	-0.19	-0.07												
	(0.00)	(0.00)												
rd_sales	0.32	-0.12	-0.24											
	(0.00)	(0.00)	(0.00)											
sales_emp	0.15	0.09	-0.09	-0.06										
	(0.00)	(0.00)	(0.00)	(0.00)										
npat	0.01	-0.02	0.47	0.02	0.01									
	(-0.69)	(-0.08)	(0.00)	(-0.14)	(-0.48)									
patstock	0.00	-0.01	0.47	0.02	0.06	0.92								
	(-0.92)	(-0.55)	(0.00)	(-0.15)	(-0.00)	(0.00)								
grant_share	-0.13	-0.02	0.10	-0.20	-0.05	0.04	-0.04							
	(0.00)	(-0.26)	(0.00)	(0.00)	(-0.00)	(-0.02)	(-0.01)							
withd_share	0.01	0.02	-0.05	0.05	-0.04	-0.01	-0.05	0.16						
	(-0.57)	(-0.13)	(0.00)	(0.00)	(-0.01)	(-0.34)	(0.00)	(0.00)						
refd_share	0.07	0.01	0.00	0.02	-0.07	-0.02	0.00	0.09	0.05					
	(0.00)	(-0.69)	(-0.81)	(-0.16)	(0.00)	(-0.16)	(-0.78)	(0.00)	(0.00)					
opp_share	-0.05	0.02	0.02	-0.13	-0.01	-0.05	-0.05	0.17	-0.05	0.03				
	(-0.01)	(-0.12)	(-0.12)	(0.00)	(-0.72)	(0.00)	(0.00)	(0.00)	(0.00)	(-0.03)				
avg_nr_fw_cit	0.17	0.08	-0.08	0.14	0.04	-0.03	-0.06	0.18	0.18	0.07	0.14			
	(0.00)	(0.00)	(0.00)	(0.00)	(-0.02)	(-0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
avg_nr_bw_cit	-0.07	-0.01	-0.03	-0.13	0.03	-0.03	-0.07	0.19	-0.01	-0.03	0.11	0.24		
	(0.00)	(-0.39)	(-0.02)	(0.00)	(-0.04)	(-0.01)	(0.00)	(0.00)	(-0.50)	(-0.01)	(0.00)	(0.00)		
famsize	0.25	0.15	-0.07	0.09	0.07	-0.03	-0.07	0.16	0.03	0.04	0.18	0.37	0.25	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(-0.01)	(0.00)	(0.00)	(-0.01)	(0.00)	(0.00)	(0.00)	(0.00)	
invtcnt	0.11	-0.01	-0.05	0.12	0.21	0.01	-0.01	-0.04	-0.01	-0.02	-0.02	0.12	0.10	0.18
	(0.00)	(-0.31)	(0.00)	(0.00)	(0.00)	(-0.45)	(-0.50)	(-0.00)	(-0.45)	(-0.07)	(-0.19)	(0.00)	(0.00)	(0.00)

p-values in brackets

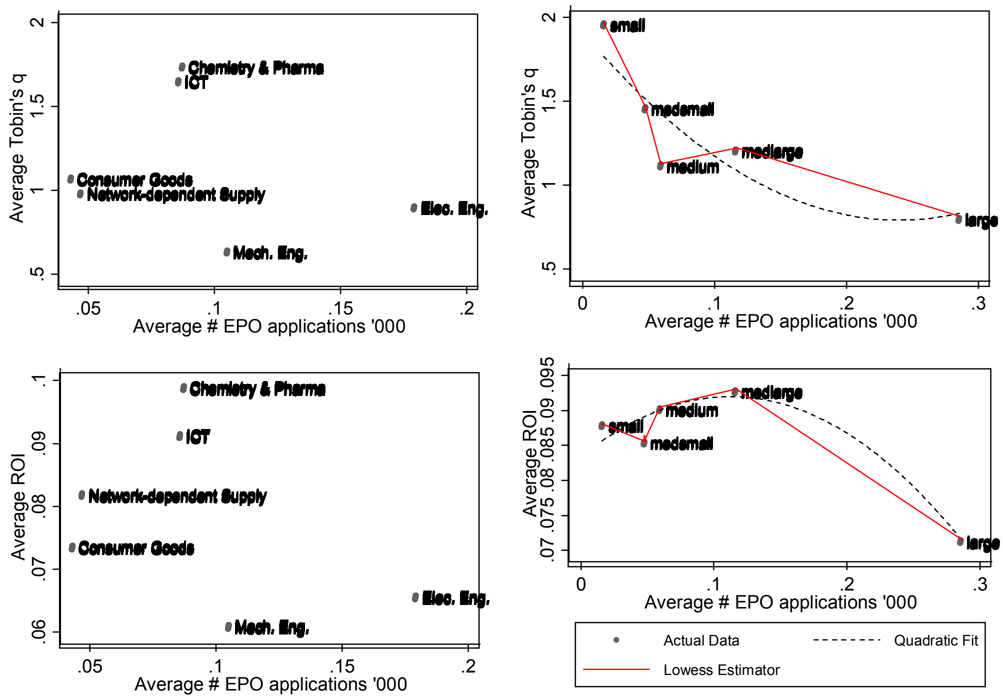
Significance Level: ***p<0.01, **p<0.05, *p<0.1

The average number of backward citations, on the other hand, is negatively associated with both measures, which means, that at least at the level of patent portfolios, a larger number of backward citations restricts the contents of a patent and therefore restricts its possible value. Also the average number of inventors seems to exert a rather high influence on both firm performance measures. Furthermore, the table shows that the patent stock measure for the firms is highly correlated with the number of EPO patent applications per year, which is why the patent stock variable is dropped for the following analyses.

For the sake of completeness, we will also hint at the importance of industry differences: figure 3 plots Tobin's q and ROI by the number of patent applications by industries and size averaged over all available years. One can observe large inter-industry differences on the association between patent applications and both firm performance measures. For the firms in the sample the electrical engineering sector is most actively patented but does not score very high on market value or ROI. A similar effect can be found for the mechanical engineering sector. The highest values on the firm performance measures are reached by the chemistry and pharmaceutical sector as well as Information and Communication Technologies (ICT). Consumer goods and network dependent supply, as expected, both show rather low numbers of patent applications but score medium on Tobin's q and ROI. This can be explained by the fact, that non research-intensive sectors are not that strongly dependent on technology, which is why several additional mechanisms affect market value. Concerning firm size, a negative effect of patent applications on market value can be observed. With increasing number of employees the number of patent applications rises but market value decreases. For ROI this effect only counts for very large companies, which is why an inverse u-shaped distribution can be found. Going down to the company level a surprising result can be observed. At least at first sight, there seems to be no association between the number of patent applications per company and firm performance.

In any case, since sector differences are not of the core of the study, they will not be analyzed further in the next section. We should note that using the estimators proposed in Section 5.2 eliminate the sector differences anyhow, making them both irrelevant for our analysis.

Figure 3: Average Tobin's q and ROI by average number of patent applications (all available years) over industries and size



5.2 Multivariate Results

Turning to the multivariate analyses, Table 4 shows the output of the fixed effects panel regression models on Tobin's q and ROI.[10]

Starting with the general characteristics of the firm we can see from the table that there seems to be no effect of R&D productivity (R&D expenditures per sales) on market value as measured by. An explanation might be that R&D expenditures are an input into the innovation process and may only be a very noisy indicator of the actual technology base, which should be much more related to the output measures of innovation (i.e. patents). With respect to ROI R&D has a negative effect, which can be explained

10 We should note that industry-specific effects are absent from the model, because they drop out by using the fixed effects estimator. This does not mean that they remain uncontrolled, rather they simply cannot be identified.

by the fact that R&D expenditures are at least partly instantaneous costs[11] reducing profits, for example for the payment of R&D personnel.

A positive coefficient can be found for the sales indicator, meaning that sales per employee significantly influence market value. The effect is clearly to be expected, because higher labor productivity should increase the returns for the share-holder both in the short and the long run.

Furthermore, a negative effect of firm size on market value can be found, which could already be observed in the bivariate results, which implies that, holding all other factors constant, an increase in the number of employees leads to a decline in market value. It may indicate a distaste of the financial market for firms that become increasingly large. However, this seems to be more an effect on the stock markets alone, because no relationship can be observed with respect to the Return on investment. On the contrary, the sales indicator has a positive effect on ROI.

---

11 This does not hold for R&D investments, which become costs via depreciations only in later periods.

Table 4: Results of the fixed-effects panel regression model

	Tobin's q			ROI		
	Coef.		**S.E.**	**Coef.**		**S.E.**
Firm-efficiency measures						
R&D (in m)/Sales (in m)	0.033		0.863	-0.535	***	0.093
Sales (in m)/#emp	2.928	***	1.059	0.150	***	0.057
Number of patents						
#EPO applications (in k)	-0.135		0.275	0.005		0.012
Patent characteristics						
grant share (lagged 5years)	0.182		0.116	-0.002		0.009
withd_share	0.402	*	0.213	0.005		0.018
refd_share	1.278		1.334	0.055		0.077
opposed share	-1.091	**	0.481	0.107	***	0.035
avg # fw cit	0.069	***	0.022	-0.001		0.002
avg # bw cit	0.002		0.007	0.000		0.001
family size	0.104	***	0.025	0.005	***	0.002
avg # inventors	-0.078	**	0.036	-0.001		0.002
Size						
# employees (in k)	-0.006	**	0.003	0.000		0.000
Constant	0.350		0.363	0.055	**	0.022
Time-Dummies	YES			YES		
Number of companies	388			383		
Observations³	2,281			1,952		
R^2 within	0.172			0.270		
F	9.31	***		12.65	***	

Significance Level: ***p<0.01, **p<0.05, *p<0.1, ³ the difference in the number of observations can be explained by the fact that we use an unbalanced panel, in which data for some observations in the respective years could be missing

Turning to the patent indicators, no significant effect can be found for the mere number of patent applications on firm market value, which, possibly indicating that the simple size of the patent portfolio is only an incomplete measure of the technology base, corroborates the bivariate results. The value indicators, on the other hand, influence market value strongly. In particular, this is true for the family size, which affects both Tobin's q and ROI. In fact, this is something to be expected, because the family size is a rough measure of potential market size for the patented invention. The larger the family, the larger is also the market. Furthermore, since it is costly to uphold patents at several patent offices because of renewal fees, the family size should indeed measure an economically substantial value.

The number of forward citations is positively related to the Tobin's q but not to ROI. This may be interpreted in several ways. On the one hand, it may indicate that market expectations may diverge from actual financial performance of a firm in terms of contemporaneous profits. On the other hand, it may also mean that the market perceives signals about the technology base that have not yet become relevant for actual profits, even though they may become so in the future.

A negative effect can be found for the average number of inventors for the Tobin's q but not for the ROI. Thus, unlike what was hypothesized in H2g, the argument that many inventors reflect a broad knowledge pool seems to be unimportant with respect to contemporaneous profits, while respect to Tobin's q, the markets may even fear that too many cooks spoil the broth. This is also backed by the assumption that many inventors reflect large possibly spatially and organizationally distributed teams, inducing market fears about additional transaction costs.

In line with H2dii, the share of withdrawn seems to affect Tobin's q positively. Thus, instead of seeing withdrawals as anticipations of refusals, it should be realized that financial markets regard withdrawals as positive events. Once again we should note that even a withdrawn patent may have had considerable strategic value during the lifetime. Thus, markets seem to value also a strategic decision to withdraw, when upholding is not necessary. Another explanation could be that withdrawn patents measure the effectiveness of the firm in creating a valuable patent portfolio, which also implies withdrawing patents that are not promising for the future development of the firm. On the contrary, the hypothesized negative relationship between refusal and financial performance (H2di) cannot be observed.

A very interesting effect is connected to the share of oppositions, which influences market value negatively, but is significantly positive for the ROI. Comparable results can be found in Häussler et al. (2009), where obviously it is true that the markets observe an opposition is a potential thread. However, taking into consideration that the costs of raising an opposition are only taken with respect to inventions that are valuable enough to justify the efforts, the actual profits actually are positively correlated to this event. A similar result has already been found by Allison et al. (2004). In a dynamic perspective, this does not necessarily mean that markets react inefficiently. It rather indicates a difference in perspectives. While oppositions might be positively correlated to contemporaneous profits (because they indicate valuable inventions), they may also imply bad news for future profits, which may be endangered. This indeed suggests a dual role of oppositions as a value indicator. At the very least, it implies that the information contained in them is contingent on the measure of financial performance, implying that H2e is only confirmed for the ROI but rejected for Tobin's q.

Concerning the explanatory power of the models, we find quite a high R^2 of 0.172 for the model on Tobin's q and an even higher R^2 of 0.270 for the model on the ROI.[12] Leaving out the control variables leads to a decline of 0.067 in the Tobin's q model and of 0.150 in the ROI model, which still gives some evidence on a distinct predicting power of the patent indicators taken alone.

Anyhow, a statistically significant F-test on strict exogeneity (F=4.21***) revealed that the abovementioned model may be plagued by estimation problems. Therefore, the same model was calculated again as an instrumental-variables two-stage least squares regression model, which only needs sequential exogeneity (see Section 4.2).

In fact, this model yields similar results to previous one. Controlling for endogeneity, the effect of sales per employee on market value becomes insignificant. The same counts for the number of inventors. However, a significantly positive effect can be found for our proxy for R&D productivity, at least in the model on Tobin's q. Additionally, a small but significant negative effect for backward citations can be found. So at least at the firm level, backward citations rather seem to restrict a patents value than they indicate a technological breadth, which the original idea of Harhoff et al. (2003).

It is interesting to see, that in this model the number of patent applications has a small but significant effect on the Return on Investment, which means that size of a patent portfolio at least has some (even if weak) predicting power. Additionally, a significant but very small size effect can be found.[13]

With respect to explanatory power we find an R^2 of 0.091 for the model on Tobin's q and an R^2 of 0.159 for the model on the ROI. This should, however, not be interpreted as a drop in predicting power, since we have to bear in mind that in the instrumental variables regression model R^2 does not reflect a split into explained and unexplained variance as in a simple OLS-regression and is therefore hard to interpret.

Summing up the above mentioned results of the regressions, we find results that contradict the hypothesized the relationship for the positive effect of backward citations (H2b), which are negative for both ROI and Tobin's q in the second model. Further-

---

12 The low R^2 for the Tobin's q model as compared to the ROI model could be explained by the fact, that general market fluctuation are not taken into account. Yet, this is not of particular interest for the study but can be seen as a subject for further research.

13 As can be seen from the bivariate analyses, there seems to be an inversed u-shaped relation between firm size and ROI. Including a quadratic size effect could shed some more light on this interrelation. But this is not of particular interest for this study.

more, number inventors show a negative relation to Tobin's q in the first model, tendentially implying a rejection of H2g.

We find contradictory ambiguous results for the oppositions, which are positive on ROI but negative on Tobin's q in model one. Thus H2e would be accepted for the latter but rejected for the former indicator.

Due to a lack of statistical significance in all models, we would neither confirm nor reject H2c (positive influence of share of granted patents) and H2di (negative influence of share of refused patents).

With respect to H2dii (unknown effect of withdrawal shares) the results indicate that there is a stable positive effect on Tobin's q, implying that withdrawals should not be understood as anticipated refusals.

With respect to several indicators we can confirm our results. In particular, this is true for family size which is positive for both indicators in the first and for Tobin's q in the second model, leading us to accept H2f. Furthermore, a relatively stable relationship is found for forward citations and Tobin's q, implying an acceptance of H2a. Furthermore, there is a slight positive effect of patent counts on the Return on investment in the second model, leading us to accept H1, even though the evidence is admittedly weak.

Table 5: Results of the instrumental-variables regression model

	Tobin's q			ROI		
	Coef.		**S.E.**	**Coef.**		**S.E.**
Firm-efficiency measures						
R&D (in m)/Sales (in m)	5.076	**	2.274	-0.819	***	0.175
Sales (in m)/#emp	1.442		1.447	-0.035		0.108
Number of patents						
#EPO applications (in k)	0.681		0.525	0.076	*	0.041
Patent characteristics						
grant share (lagged 5years)	0.038		0.194	0.011		0.015
withd_share	0.877	***	0.303	0.005		0.024
refd_share	0.767		1.224	0.023		0.095
opposed share	-0.720		0.761	-0.046		0.059
avg # fw cit	0.092	***	0.022	-0.002		0.002
avg # bw cit	-0.039	***	0.013	-0.002	**	0.001
family size	0.116	***	0.026	0.001		0.002
avg # inventors	-0.013		0.052	-0.007	*	0.004
Size						
# employees (in k)	-0.020	**	0.010	-0.002	**	0.001
Constant	0.066	**	0.031	0.002		0.002
Time-Dummies	YES			YES		
Number of companies	331			331		
Observations	1,636			1,649		
R^2 within	0.091			0.159		
Wald Chi²	230.0	***		236.3	***	

Significance Level: ***p<0.01, **p<0.05, *p<0.1. Note that in the instrumental variables regression model R^2 can be below 0 and above 1, which has to be considered for the interpretation.

6 Summary and conclusion

The main aim of the current study was to shed light on the question of how far the technology base of a firm can influence its financial performance in terms of market value and profits.

For the analysis, a large international firm database was created that contains information on financial performance, R&D expenditures, patenting behavior and indicators for the value of the companies' patents.

To sum up the results of the multivariate models, the mere number of patent applications does not seem to be a very good predictor of firm performance, although a significantly positive but small effect can be found on Return on Investment. For the value indicators, forward citations and family size seem to be most promising indicators of patent value at the micro level of the firm, although the results for forward citations do not hold for Return on Investment. Some interesting results come up for the share of withdrawn patents as well as for the share of opposed patents. Especially, the contradictory resulty of opposed patents for Tobin's q and ROI hint at conceptual differences between these indicators of financial performance. We should always make ourselves aware that the ROI is measure of contemporaneous profits, while Tobin's q is a measure of expectations about future profits. Bearing that in mind, it is even economically sensible that oppositions have contradictory effect, depending on the measure. We regard this also as a reunification of the contradictions that have been made in Häussler et al. (2009) and Allison et al. (2004). Eventually, we would argue that both are right, arguing for a reconciliation. However, it depends on the measure of financial performance.

Some potential for further research remains. In particular, it could be shown that inter-industry differences exist for the association between patenting and firm performance, which were not of particular interest here. The same holds for country differences in the number of patent applications at the EPO, which could be particularly important for family size, since firms from countries with large home markets tend to have smaller family sizes.

References

Albert, M.B./Avery, D./Narin, F./McAllister, P. (1991): Direct validation of citation counts as indicators of industrially important patents, *Research Policy,* 20 (3), 251-259.

Alcacer, J./Gittelman, M. (2006): Patent citations as a measure of knowledge flows: The influence of examiner citations, *Review of Economics and Statistics,* 88, 774-779.

Alcacer, J./Gittelman, M./Sampat, B. (2009): Applicant and examiner citations in U.S. patents: An overview and analysis, *Research Policy,* 38, 415-427.

Allison, J.R./Lemley, M.A./Moore, K.A./Trunkey, R.D. (2004): Valuable Patents, *Georgetown Law Journal,* 92, 435-479.

Blind, K./Cremers, K./Mueller, E. (2009): The Influence of Strategic Patenting on Companies' Patent Portfolios, *Research Policy,* 38, 428-436.

Blind, K./Edler, J./Frietsch, R./Schmoch, U. (2006): Motives to patent: Empirical evidence from Germany, *Research Policy,* 35, 655-672.

Bosworth, D./Rogers, M. (2001): Market value, R&D and intellectual property: An empirical analysis of large Australian firms, *The Economic Record,* 77, 323-337.

Brainard, W./Tobin, J. (1968): Pitfalls in financial model-building, *American Economic Review,* 58, 99-122.

Carpenter, M.P./Narin, F./Woolf, P. (1981): Citation rates to technologically important patents, *World Patent Information,* 3, 160-163.

Chen, Y./Chang, K. (2010a): Exploring the nonlinear effects of patent citations, patent share and relative patent position on market value in the US pharmaceutical industry, *Technology Analyses & Strategic Management,* 22, 153-169.

Chen, Y./Chang, K. (2010b): The relationship between a firm's patent quality and its market value - The case of US pharmaceutical industry, *Technological Forecasting and Social Change,* 77, 20-33.

Czarnitzki, D./Kraft, K. (2010): On the profitability of innovative assets, *Applied Economics,* 42, 1941-1953.

Deng, Z./Lev, B./Narin, F. (1999): Science and technology as predictors of stock performance, *Financial Analysts Journal,* 55 (3), 20-32.

Dosi, G./Soete, L. (1983): Technology Gaps and Cost-Based Adjustment: Some Explorations on the Determinants of International Competitiveness, *Metroeconomica,* 35, 197-222.

Dosi, G./Soete, L. (1991): Technical Change and International Trade. In: Dosi, G./Freeman, C./Nelson, R./Silverberg, G./Soete, L. (eds.): *Technical Change and Economic Theory*. London: Pinter Publishers, 401-431.

Ernst, H. (1995): Patenting strategies in the German mechanical engineering industry and their relationship to firm performance, *Technovation,* 15, 225-240.

Ernst, H. (1998): Patent Portfolios for Strategic R&D Planning, *Journal of Engineering and Technology Management,* 15, 279-308.

Ernst, H. (2001): Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level, *Research Policy,* 30, 143-157.

Freeman, C. (1982): *The Economics of Industrial Innovation*. London: Pinter Publishers.

Frietsch, R. (2006): Micro data for macro effects. In: Hingley, P./Nicolas, M. (eds.): *Forecasting Innovations. Methods for Predicting Numbers of Patent Filings*. Berlin: Springer, 125-158.

Frietsch, R./Schmoch, U. (2006): Technological Structures and Performance Reflected by Patent Indicators. In: Schmoch, U./Rammer, C./Legler, H. (eds.): *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*. Dordrecht: Springer.

Frietsch, R./Schmoch, U./van Looy, B./Walsh, J.P./Devroede, R./Du Plessis, M./Jung, T./Meng, Y./Neuhäusler, P./Peeters, B./Schubert, T. (2010): *The Value and Indicator Function of Patents*, Studien zum deutschen Innovationssystem, Nr. 15/2010: Expertenkommission Forschung und Innovation (EFI).

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

Griliches, Z. (1990): Patent statistics as economic indicators: a survey, *Journal of Economic Literature,* 18, 1661-1707.

Grupp, H. (1997): *Messung und Erklärung des Technischen Wandels - Grundzüge einer empirischen Innovationsökonomik*: Berlin, Springer-Verlag.

Grupp, H. (1998): *Foundations of the Economics of Innovation - Theory, Measurement and Practice*. Cheltenham: Edward Elger.

Guellec, D./van Pottelsberghe de la Potterie, B. (2000): Applications, grants and the value of patents, *Economic Letters,* 69, 109-114.

Hagedoorn, J./Cloodt, M. (2003): Measuring innovative performance: is there an advantage in using multiple indicators?, *Research Policy,* 32 (8), 1365-1379.

Hall, B.H./Jaffe, A./Trajtenberg, M. (2005): Market value and patent citations, *The Rand Journal of Economics,* 36 (1), 16-38.

Hall, B.H./MacGarvie, M. (2010): The private value of software patents, *Research Policy,* 39, 994-1009.

Hall, B.H./Ziedonis, R.H. (2001): The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry 1979-1995, *Rand Journal of Economics,* 36 (1), 101-128.

Harhoff, D./Reitzig, M. (2004): Determinants of opposition against EPO patent grants - the case of biotechnology and pharmaceuticals, *International Journal of Industrial Organization,* 22 (4), 443-480.

Harhoff, D./Scherer, F.M./Vopel, K. (2003): Citations, Family Size, Opposition and the Value of Patent Rights, *Research Policy,* 32, 1343-1363.

Harhoff, D./Wagner, S. (2009): The duration of Patent Examination at the European Patent Office, *Management Science,* 55, 1969-1984.

Häussler, K./Harhoff, D./Schirge, M. (2009): Stock Market Reactions to Oppositions in Biotechnology and Pharmaceuticals: EPO Conference – Patent Statistics for Decision-Makers 2009, Vienna, October 2009.

Hendricks, K.B./Singhal, V.R. (1997): Delays in new product introductions and the market value of the firm: The consequences of being late to the market, *Management Science,* 43, 422-436.

Keane, M.P./Runkle, D.E. (1992): On the Estimation of Panel-Data Models with Serial Correlation When Instruments Are Not Strictly Exogenous, *Journal of Business & Economic Statistics,* 10, 1-9.

Kleinknecht, A./Oostendorp, R. (2002): R&D and Export Performance: Taking Account of Simultaneity. In: Kleinknecht, A./Mohnen, P. (eds.): *Innovation and Firm Performance*. New York, 310-320.

Krugman, P. (1979): A Model of Innovation, Technology Transfer, and the World Distribution of Income, *Journal of Political Economy,* 87, 253-266.

Lanjouw, J.O./Schankermann, M. (1998): Stylized Facts of Patent Litigation: Value, Scope and Ownership .

Lanjouw, J.O./Schankermann, M. (2004): Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators, *The Economic Journal,* 114, 441-465.

Lee, S.J. (2008): Measure of R&D Success and Market Value of a Firm, Seitz, J. (ed.), 7th Wuhan International Conference on E-Business, May 31 - June 01, 2008.

Legler, H./Frietsch, R. (2007): Neuabgrenzung der Wissenswirtschaft - forschungsintensive Industrien und wissensintensive Dienstleistungen (NIW/ISI-Listen 2006) (= Studien zum deutschen Innovationssystem No. 22-2007). Hannover, Karlsruhe: NIW, Fraunhofer ISI.

Legler, H./Krawczyk, O. (2006): The Global Distribution of R&D Activities. In: Schmoch, U./Rammer, C./Legler, H. (eds.): *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*. Dordrecht: Springer, 31-45.

Levitas, E./Chi, T. (2010): A look at the value creation effects of patenting and capital investment through a real options lens: the moderating role of uncertainty, *Strategic Entrepreneurship Journal,* 4, 212-233.

Maskus, K.E./Penubarti, M. (1995): How trade-related are intellectual property rights?, *Journal of International Economics,* 39, 227-248.

Narin, F./Breitzman, A./Thomas, P. (2004): Using Patent Citation Indicators to Manage a Stock Portfolio. In: Moed, H.F./Glänzel, W./Schmoch, U. (eds.): *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems*. Netherlands: Kluwer Academic Publishers, 553-568.

Narin, F./Noma, E. (1987): Patents as indicators of corporate technological strength, *Research Policy,* 16, 143-155.

Nerkar, A./Roberts, P.W. (2004): Technological and product-market experience and the success of new product introductions in the phamaceutical industry, *Strategic Management Journal,* 25 (8-9), 779-799.

Nguyen, T./Schüßler, A. (2010): Aktienbewertung auf der Grundlage fundamentaler Daten - Darstellung ausgewählter Kennzahlen, *WiSt – Wirtschaftswissenschaftliches Studium,* 39, 121-127.

Posner, M.V. (1961): International Trade and Technical Change, *Oxford Economic Papers,* 13, 323-341.

Putnam, J. (1996): *The value of international patent rights*. Yale: Yale University.

Schmoch, U./Grupp, H./Mannsbart, W./Schwitalla, B. (1988): *Technikprognosen mit Patentindikatoren*. Köln: TÜV Rheinland.

Schubert, T. (2010): Marketing and Organisational Innovations in Entrepreneurial Innovation Processes and their Relation to Market Structure and Firm Characteristics, *Review of Industrial Organization,* 32, 189-212.

Tobin, J. (1969): A general equilibrium approach to monetary theory, *Journal of Money Credit and Banking,* 1, 15-29.

Trajtenberg, M. (1990): A penny for your quotes: patent citations and the value of innovation, *Rand Journal of Economics,* 21, 172-187.

Utterback, J.M./Abernathy, W.J. (1975): A dynamic model of process and product innovation, *Omega,* 3, 639-655.

van der Drift, J. (1989): Statistics of European patents on legal status and granting data, *World Patent Information,* 11, 243-249.

Van Zeebroeck, N. (2009): The puzzle of patent value indicators (= CEB Working Paper No. 07/023).

Vernon, R. (1966): International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics,* 80, 190-207.

Vernon, R. (1979): The Product Cycle Hypothesis in a New International Environment, *Oxford Bulletin of Economics & Statistics,* 41, 255-267.

Wooldridge, J.M. (2002): *Introductory Econometrics - A modern approach*: South-Western Educational Publishing, 2nd edition.