RICAFE 2

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# Innovation and the Performance of Technology Firms -

## - Evidence from Initial Public Offerings in Germany

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# Innovation and the Performance of Technology Firms

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**Abstract**

In this study we investigate the patenting behavior and long-run performance of German firms that went public (IPOs) on the "Neuer Markt" during the period from 1997 to 2002. The main objective of the empirical analysis is to examine whether IPOs with patents outperformed those firms with no patented technology. The technology is measured by both the patent stock and patent indicators. The impact of patents on performance is analyzed with buy-and-hold-abnormal returns (BHAR), the three-factor Fama-French asset pricing model as well as cross-sectional-regressions. In the regression analysis we include specific patent variables such as the number of International Patent Classifications (IPC), family size, the number of backward- and forward citations, and the frequency of cited articles. The empirical evidence suggests that innovation, patents, and intellectual capital are important factors that have a positive impact on the success, valuation, and the long-run performance of start-up technology firms.

*Keywords: Innovation, Patents, Initial Public Offerings, Long-run Performance*

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## 1. Introduction

Innovation as measured by research and development (R&D) and patents as well as by intangibles and intellectual capital should have a significant impact on the success, value, and long-run performance of technology firms. Although the positive effect of innovation on value creation is intuitively appealing, it is much more difficult to provide empirical evidence that an increase in innovation will lead to a higher firm value or that firms with more innovation will outperform firms with less innovation in the long-run. One of the difficulties is to find adequate measures for innovation on the one hand and for firm performance on the other hand. Possible innovation variables that are observable are patents and patent indicators. Stock prices are usually a good proxy for capturing the market value of firms and the valuation effects of events and specific factors. With respect to the impact of technology and growth opportunities, we would expect that the valuation effects are more pronounced for young start-up firms and especially for firms that raised new equity by going public. Hence, it is important and challenging to provide empirical evidence on the success and superior long-run financial performance of firms that focus on innovation. The primary objective of the empirical analysis is to examine whether firms that filed for patents outperformed those firms with no patented technology.

The firms for which we investigate the patenting behavior and performance in this study are all German firms that went public on the "Neuer Markt" in Germany during the period from 1997 to 2002. Because the "Neuer Markt" was created by the Deutsche Börse as a special market segment for high-technology firms, these initial public offerings (IPOs) are an interesting sample for analyzing the effects of technology or innovation on firm performance. Moreover, patents are usually considered a good measure for technical innovations. This research extends the existing literature in several ways. First, patents and patent indicators are considered separately and simultaneously for measuring the long-run performance. Second, the firms included are all from the German high-tech stock market segment "Neuer Markt", which attracted a large number of start-up firms over a short period of time. This market was characterized by extreme swings in valuation and market performance. Overall, this study provides empirical evidence on the impact of patent counts and patent value indicators on the long-run performance of German IPOs.

In the empirical analysis we proceed as follows. In the first part we test the hypothesis that the long-run performance of IPOs is related to the number of filed patents. This relationship is analyzed by employing various methodologies. First, we calculate buy-and-hold-abnormal returns (BHAR) for the first two years after going public. Second, we control for the size-and growth-effect by estimating the abnormal returns with the Fama-French three-factor asset pricing model. Third, we employ cross sectional regressions by including additional variables that may explain the abnormal returns while controlling for specific factors. For this we use, on the one hand, various firm specific variables such as size and market-to-book ratios at the time of the going public and, on the other hand, patent indicators as patent specific variables such as the number of IPC classes (International Patent Classification), the family size, the number of backward- and forward citations, and the frequency of cited articles. The results of our empirical analysis support the hypothesis that innovation as measured by the number of patents has a positive impact on firm valuation. In particular we find significant evidence that IPOs with patents generate a superior short- and long-run performance at the Neuer Markt. Because these performance differences diminish over time, there may be some overvaluation of growth opportunities for firms with patents during the first year after going public. These results are even more pronounced when we separate between hot and cold issue markets. Legal and tax considerations may have an impact as well.

The rest of the paper is organized as follows. In the next section we review the literature with respect to the importance of intellectual capital for firm performance. In section 3 the stock market data as well as the patent data are described and the methodology is briefly explained in section 4. The empirical results are presented in section 5. Section 6 concludes this study.

## 2. Review of the Literature

There exists a vast amount of literature related to measures of innovation on the one hand and innovation and firm performance on the other hand. Innovation measures usually include R&D, patent counts and patent value indicators. Performance measures usually range from productivity and accounting numbers to stock market performance. In this section we review the relevant literature for a variety of innovation measures as well as for innovation and performance.

### 2.1 Measuring Innovation

When measuring the impact that innovations have on firm value, one difficulty is to find an accurate measure for the firm's innovation potential as well as for the quality of the innovations. Because the base for the firm's intangible assets are usually the expenditures for research and development (R&D), this is often used as independent variable.

#### 2.1.1 R&D as an Innovation Measure

When R&D-expenditures are used as a proxy for innovation, there are usually some inherent shortcomings. First of all, it is not clear whether the amount of R&D-expenditure has a direct impact on firm value. In addition, Grabowski (1994) points out that the failure rate is extremely high in that only 30% of all R&D-projects generate a positive net present value. Consequently, the use of R&D expenditures as an innovation measure does not allow for differentiating between successful and failed projects. In a comparison of the stock market reaction of successful and unsuccessful R&D projects, Shortridge (2004) finds that these results could be biased because only successful projects result in a positive capital market reaction. So the findings that R&D is a value driver could be misleading. More importantly, R&D expenditures are not fully disclosed in the traditional German accounting reports (HGB). To cope with this dilemma, the rules and regulations of the "Neuer Markt" introduced higher listing requirements in Germany. These IPOs had to publish their financial statements by following either IAS/IFRS or US GAAP. However, a large number of firms did not fulfill these requirements appropriately (Glaum and Street, 2003) resulting in some problems with respect to the completeness and the bias of the R&D database. Nevertheless, Ramb and Reitzig (2005) investigate the relevance of accounting rules for IPOs at the Neuer Markt. They find empirical evidence that the impact of R&D expenditures on the market value of the firm is higher when the firms reported under the traditional German accounting standards (HGB) compared to US GAAP or IAS. This finding is quite surprising because reporting R&D expenditures under HGB are voluntary and intellectual capital has to be reported only when it is acquired externally. In our sample 92 firms reported R&D expenditure in the year of the going public and 112 firms in the year after going public. In our own study for IPOs of the Neuer Markt we do not find any differences in performance due to a variation in R&D intensity, where R&D intensity is measured as the ratio of reported R&D expenses to total assets.

### 2.1.2 Patents as an Innovation Measure

As an alternative to R&D, patents have been used as an innovation measure. Pakes and Griliches (1984) suggest that patents should result in both profits and new R&D expenditures. They consider patents as one knowledge output in the knowledge production function, whereas R&D expenses are used as an input. Valuation effects are measured by using the market value of the firm. Firms that apply for a patent have to pay for the application, for the granting procedure as well as for the annual renewal. Because especially the cost for international patents can be high, Licht and Zoz (1998) conclude that only valuable ideas are worth to be patented. Consequently, the number and quality of a firm's patents should be in general a better measure for the innovative activity of a firm than R&D expenditures. Most importantly, the patent database appears to be of higher quality than the R&D database. Moreover, patents are publicly available and most patent offices publish the application date, the publication date, and the patent code independently of the status of the patent. A patent can be either pending, which means that the assignee already applied for the patent but the patent is not yet granted ("application later on") or the patent is already granted ("patent later on"). Given these arguments, a vast amount of studies follows these approaches and uses patents as an innovation indicator and value driver when analyzing the long-run performance.

The use of patents, however, creates new obstacles, because patent counts could be to imprecise as a measure. Moreover, there is no accepted methodology or common approach for patent valuation. In fact, valuing technology requires very specific knowledge and skills. Moreover, the valuation of a patent is challenging due to the skewed value distribution of patents. When valuing patents by using renewal data, Schankerman and Pakes (1985) find evidence of a highly skewed distribution as well as of an inverse relationship between the number of applied patents in one year and the quality of the patents in this period. Furthermore, they find that the year of application and the characteristics of the analyzed firm are important factors. Scherer (1998) supports the results of a skewed distribution by analyzing the value distributions of royalties, new ventures that are dependent on patents, and renewal fees. Harhoff et al. (1999) and Scherer and Harhoff (2000) use survey data to estimate the value distribution and find not only strong evidence that the data is log-normally distributed but also that the patent age and citations are important factors for patent valuation. Silverberg and Verspagen (2004) sup-

port these results by using different European and US Patent Office data. So far most of the empirical studies find that the value distribution of patents is highly skewed. This is not surprising but makes the patent valuation more difficult. A solution to this problem could be the use of patent value indicators as a proxy for the patents value.

### 2.1.3 The Valuation of Patents

There is number of indicators that have been used to measure the value of patents. Especially forward-citations seem to contain important information about the private and social value of patents (Hall et al., 2000, 2005, Harhoff et al., 1999, Harhoff et al., 2003, Reitzig, 2002, 2003, Trajtenberg, 2002). Bloom and Van Reenen (2002), for example, use forward citations and include time lags and find evidence that especially time lags enhance the explanatory power. Furthermore, the results by Bloom and Van Reenen (2002) suggest that the capital market reacts immediately to new patent information while productivity increases with a time lag. As an alternative measure Lerner (1994) employs the number of IPC-classes as a proxy for patent breadth. Putnam (1996) and Dernis and Khan (2004) highlight the relevance of patent families and triadic patents whereas Ramb and Reitzig (2004) use the family size as an indicator for patent value. Lanjouw and Schankerman (2004) apply family indicators and weighted patent counts. A few studies extend the indicators by creating indices or ratios. Trajtenberg et al. (2002) introduces new measures for the importance and the breadth of a patent. These indicators are based on different citation measures as well as on the field of technology relative to IPC classes. Attalah and Rodriguez (2003) create chains of citations in that they include the quality of the citing patents. A measurement of originality is introduced by Orlando (2005) by calculating the ratio of forward citations to the sum of backward and forward citations. In contrast, Austin (1993) employs an event study methodology and investigates the valuation effects of granted patents on the firm as well as on rival firms. For valuating these patents the study distinguishes whether or not the patents were published in the Wall Street Journal. Austin also controls for the patent breadth and demonstrates that oftentimes only a few patents have high values. However, not all studies find a direct relationship between one innovation indicator and firm performance. Consequently, Lanjouw and Schankerman (2004) consider multiple patent indicators. Moreover, Hirschey and Richardson (2001, 2004) as well as Deng et al. (1999) employ the patent indicators of the CHI research which are calcu-

lated by using citations and segment data. They find evidence that the value relevance of the indicators depends on the growth opportunities of the firms.

Overall, most studies support the notion that patent counts have a positive effect on firm performance and several studies support the importance of the citation indicators. Such common indicators for measuring patent breadth and inventive importance of the patent are IPC classes, family size, backward and forward citations as well as cited articles. Later on we will employ these variables as innovation measures in our own empirical study.

### 2.2 Innovation and Performance

In the previous research on innovation a number of different measures and methodologies have been employed to analyze the performance of innovative firms. In several studies research and development (R&D) expenditures and patent data are used as innovation proxies. The objective of these studies is to test the hypothesis that innovative firms are able to outperform the market in the long-run. In order to explore the impact of innovation (R&D) on firm value, several studies use either individual stock returns or other market data such as Tobins'q, market-to-book value, and market capitalization as dependent variable. In one of the first studies Griliches (1981) utilizes Tobin's q as the measure of success. He finds empirical evidence that innovation positively impacts the market value of firms. Several other studies such as Cockburn and Griliches (1988), Hirschey and Richardson (2001), Bosworth and Rogers (2001), Lanjouw and Schankerman (2004) and Hall and Orani (2004) extend this research and add to the empirical evidence by employing the market-to-book value or similar variables instead of Tobin's q. All these studies support the idea that innovation has a positive impact on firm performance.

A different approach is employed by Chung et al. (2005) who analyze the premium that investors are willing to pay for firms that employ intangible assets. For this they separate the offering price at the time of the IPO into two components. One part measures the traditional value of tangible assets and the other the value of intangible assets. A high proportion of intangible assets is used as an indicator that the firm has a high growth potential and that this growth option of the firm is the justification for the higher value. The empirical findings support these ideas in that more innovative firms as meas-

ured by its intellectual capital have both, a higher offering price as well as a higher underpricing or larger initial returns at the time of the IPO. Nevertheless, these high innovative firms also reveal negative BHAR after two years, which is in accordance with the usual negative long-run performance of IPOs. However, the underperformance of these innovative IPOs is smaller than that of other IPOs. Thus, innovation appears to have a positive impact on the valuation and the relative performance of firms that went public.

Another approach for analyzing the long-run-performance of innovative firms is to investigate the abnormal returns that are generated by asset pricing models. Guo et al. (2005) find evidence that R&D-intensity is positively related to both the underpricing and the long-run performance. They suggest that due to the additional risk of high R&D the valuation of high R&D firms should be lower and the expected return higher compared to low R&D firms. They conclude that in general the investor's optimism should be lower for R&D firms which results first in a higher underpricing but subsequently in a positive long-run performance. They use the alpha (intercept) from the Fama-French model as abnormal return measure and find support for their hypothesis. These findings are in accordance with Eberhardt et al. (2004) who report a long-run outperformance when firms increase their R&D-expenditures. Other studies expand the model structure to multi-factor asset pricing models by including additional R&D and patent variables. For example, Al-Horani et al. (2003) and Chauvin and Hirschey (1993) are able to improve the explanatory power of the three-factor Fama-French model by including an additional R&D factor. Hirschey and Richardson (2004) and Deng et al. (1999) include weighted patent counts in the market model. In one of the first studies including continental Europe, Hall and Orani (2004) find evidence for different valuations effects of R&D-expenditures and intellectual capital stock in continental European compared to Anglo-Saxon countries. When controlling for the ownership structure of the company, the results confirm previous findings. There are also some studies for German firms that investigate the relationship between knowledge stock, as measured by R&D-expenditures or patents, and firm performance as measured by productivity increases or market performance. Ernst (1996, 1999) analyzes the German machine building sector and finds a positive impact of patent counts and patent quality indicators on productivity. He also finds evidence for a productivity effect of patent filings when he incorporates lag-structures in a panel analysis. The study by

Ramb and Reitzig (2004) analyzes the relevance of information that is contained in accounting and patent data. They find that there is a stronger positive relationship between the number of filed patents and the residual market value of the firm than between accounting information about R&D and intangibles and firm value. Booth et al. (2005) take a different research direction and offer interesting insights into the importance of the financial system. In a study of 10 countries they find empirical evidence that technology and innovations are more rapidly priced in a financial market oriented system compared to a bank oriented financial system. This is interesting for our own research because the opening of the Neuer Markt was one initiative to complement the traditional bank oriented system in Germany to a more capital market oriented approach.

## 3. Data

The data that is required for the empirical analysis is stock price data for the initial public offerings and the market index at the Neuer Markt in Germany as well as patents counts and patent value indicators for these IPOs. These two data sets are explained in the next two sections.

### 3.1. Initial Public Offerings at the Neuer Markt

Historically, the German capital market was small relative to the size of the economy and did not offer great opportunities for start-up firms to raise additional equity by going public. The traditional financing alternative in this bank based financial system was bank loans. In the late 1970s and the beginning of the 1980s, less than 10 firms went public each year. Over the period from 1983 to 1997 the annual number of new listings was between 9 and 33 (Bessler and Thies, 2006). Given the size and the focus of the German economy on innovation and technology, this was still a very small number. With the bull market of the 1990 and the technology boom in the late 1990s, IPOs suddenly became tremendously popular and an important financing source for start-up technology firms in Europe and especially in Germany. The stock market performance as measured by the “NEMAX All-share” index as well as the number of all initial public offerings for the period from 1997 to 2003 is presented in Figure 1. In 1997, the year of the opening of the Neuer Markt, 12 (11) firms went public and in 1998 there were 41 (39) IPOs. In the following two years this number increased to 131 (112) in 1999 and to 133 (114) in 2000. The numbers in parentheses indicate the IPOs of German firms. This

distinction between German and foreign IPOs is important because we concentrate on German firms in the empirical analysis. Obviously, 1999 and the first three months of 2000 were a great environment for issuing equity at very favorable terms. This period can clearly be labeled as a hot issue market (Bessler and Kurth, 2005).[1] Due to the substantial decline in the stock prices since March 2000, the IPO activity slowed down dramatically. In 2001 only 11 (11) firms and in 2002 merely 1 (1) firm went public. This latter period is clearly a cold issue market. In 2003, there was no IPO and the "Neuer Markt" as a market segment was finally closed.[2] During the period from 1997 to 2003 there were 329 firms that went public of which 288 were German firms. All information about the IPO date and size are from the "Deutsche Börse AG". Stock prices are from Reuters.

*[Insert Figure 1 about here]*

The Neuer Markt is a perfect example of the valuation problems of start-up technology firms that usually exist at the time of IPO but also of the market timing abilities of firms. As presented in Figure 1, the "NEMAX Allshare" index rose from about 500 index points in March 1997 to 8,583 in March 2000 which is an increase by about 1,600% within three years. This "window of opportunity" in a hot issue market was exploited by many firms that went public either in 1999 or at the beginning of 2000. Within that period more than 80% of all German initial public offerings on the Neuer Markt occurred. Subsequently, the index declined from its peak of 8,583 in March 2000 to a level of 353 on October 8, 2002, which was a dramatic decline of 96%. Consequently, the Deutsche Börse closed the "Neuer Markt" segment in 2003 in response to this decline, but also due to several company scandals and legal problems

Thus, the attempt to overcome the traditional bank based financial system in Germany by creating a new stock market segment for innovative growth firms was clearly not a long term success. Nevertheless, the hot issue market of 1998, 1999 and the beginning of 2000 and the cold issue market thereafter was unique for the German stock market. Especially for high-tech firms the first period pro-

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[1] For the sake of simplify we consider the IPOs that went pubic during the years 1997 until 1999 as the hot-issue IPOs and the IPOs that went public from 2000 until 2002 as the cold-issue IPOs, later on. A more detailed analysis did not change the results.

[2] The need for a stock market segement for start-up firms is clearly supported by the fact that Deutsche Börse opened a new market segment called "Entry Standard" in October 2005.

vided a great "window of opportunity" to issue new equity at relatively high prices. Thus, this market environment offers a great opportunity to investigate the valuation effects and long-run performance of high-tech firms in extreme bull and bear markets. An interesting question is whether the initial public offerings of technology firms were favorably valued compared to the other firms with less or even no technology. Thus, the important question is whether innovation is positively valued in the stock market resulting in higher firm value. Due to the difficulty of correctly valuing R&D and patents it is also possible that the growth potential stemming from technology was overvalued in the up-market and undervalued in the down-market. Moreover, it is interesting to compare the valuation effects for high-tech and low-tech firms in a down market, especially whether firms with high intellectual capital were better protected from a rapid decrease in value.

### 3.2 Patent Data

The data source for patents and patent value indicators is the "Derwent Innovation Index" from Thomson Financial. We include all patent applications (6,255) filed by the 288 German IPOs that went public during the period from 1997 until 2002. The patent data starts 1980 and has to end in 2003 due to the publication time lag of 18 months imposed by the regulation of the patent offices. The "Derwent Innovation Index" consists of the "Derwent World Patent Index" and the "Derwent Citation Index". The citation index allows searching for the forward citations for each patent. The "Derwent Innovation Index" includes the patent data from 40 patent offices (Derwent, 2003). There are about 20 million patents listed in the index. The data goes back to 1963. For the purpose of this study, we use the following patent information. The patent count is identified by the patents and applications of the firm. The patents are counted by their patent number, which is used as an identifier. Furthermore, the patent number reveals the country for which the patent protection was applied for. In addition to the national patents there are European patents (EP) filed with the European patent office and global applications filed with the World Intellectual Property Organization (WO). The patent count for each firm equals the number of patents applied for by the specific firm and includes also all patents by wholly owned subsidiaries as listed in "Hoppenstedt Aktienführer". The database contains backward and forward citations as well as cited articles, which we use as indicators for the overall patent value. Furthermore, breadth of a patent is an important measure for patent quality. For patent breadth the

family size and patent scope is used. We also include the size of the family which is approximated by the number of patents belonging to a family. Another indicator for patent breadth is the number of IPC classes in which the invention is protected by patents.

In order to create a link between patent data and firm performance, the application as well as the publication date is included in the data base. An analysis of the data suggests that for the firms in the sample the patent propensity increased over the last decades. This result is in accordance with previous findings of Kortum and Lerner (1999), Greif and Schmiedl (2002), and Hall (2004). In 1980 firms filed on average for less than one patent per year. This figure increased to an average of 4 applications per year in 2001 (Figure 2). In 2002 the rate decreased. The subsequent decrease in 2003 is related to the publication lag that is due to the regulation of the patent offices. On average this lag is 2 years for our sample. In Germany the publication lag for applications is 18 months and the publication lag for granted patents is 3 years.[3]

*[Insert Figure 2 about here]*

In our sample of the 288 German firms that went public during the period from 1997 to 2002 90 firms have patents. These 90 IPOs filed 6,255 applications which include all documents published by the patent offices. In this study we do not differentiate between the statuses of the patents, e.g. application and granted. In another study, we find evidence that the results are similar when only granted patents are considered. We exclude foreign IPOs due to a different patenting behavior and specific patent rights in other countries. Of all the patents 30% are applied for with the German patent office, 18.5% with the European patent office, 16% with the US-patent office, and 13% with the WIPO.[4] If we include only the earliest patent in a patent family as the priority patent, 72% of all patents are filed with the German patent office and 17% with the US Patent Office (Table 1)[5]. During the period of

3 This time lag is incorporated into the patent system because the assignee has to publish his invention when he decides to apply for a patent. The publication lag gives the assignee the opportunity to keep his invention secret for a longer time period and enables the patent office to examine the formalities of the patent application.

4 7% and 2% of the patens are applied for with the Japanese and the Korean patent office, respectively. The other 6% are patents that have been filed with 25 different offices.

5 There are 7% of the priority registrations with the European patents office, 1% with the WIPO and 1% in Japan. The other 2% of the registrations are with 10 different patent offices.

three years before and three years after the IPO, 86 firms filed applications with a patent office. In sum these were 4,448 applications.

*[Insert Table 1 about here]*

## 4. Methodology

In this study we employ various methodologies to test empirically whether the firms with more innovation as measured by the number of patents and patent indicators outperformed the market index. In addition, and most importantly, we investigate whether they significantly outperformed the group of IPOs without patents. Moreover, we test for the difference in performance during hot and cold issue market periods. The long-run performance is measured by using buy-and-hold abnormal returns (BHAR). In order to adjust for some common valuation factors such as book-to-market and firm size we also employ the three-factor model of Fama and French (1993). Finally we investigate the relationship between firm innovation and performance with cross sectional regressions by including various patent value indicators. Moreover, we include the patent quality in our analysis as approximated by the patent value indicators described above. All approaches are briefly outlined below.

### 4.1 Buy-and-Hold Abnormal Returns

The long-run performance of an IPO is measured by holding period returns (BHR) which are calculated for a single stock i for time period T as follows:

(1) $$BHR_{i,T} = \left[\prod_{t=1}^{T}\left(1 + R_{i,t}\right)\right] - 1$$

where $R_{i,t}$ is the return of stock i at time t, and T is the time period for which the BHR is determined. For an equally-weighted portfolio of stocks the return is calculated as:

(2) $$dBHR_{P,T} = \frac{1}{N}\sum_{i=1}^{N} BHR_{i,T}$$

where $dBHR_{P,T}$ is the average BHR of the portfolio, N is the number of stocks in the portfolio, and T is the time period for which the BHR is calculated. To calculate “Buy-and-Hold-Abnormal-Returns” (“BHAR”) the return of the benchmark is subtracted from the IPO return.

$$(3) \qquad BHAR = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\prod_{t=1}^{T}(1+R_{i,t})\right)-\left(\prod_{t=1}^{T}(1+R_{M,t})\right)\right]$$

The advantage of this method is that the terminal values of the two strategies, i.e. investing in an IPO or investing in the benchmark, are directly comparable. Thus, BHAR compare real investment strategies over a defined period. The "NEMAX Allshare" index is used as a benchmark. This market weighted performance index includes all companies that are listed at the "Neuer Markt". The firms are separated into two major sub-groups: firms with patents and firms without patents.

We use various methodologies to test for the statistical significance of our empirical findings. Because abnormal returns are highly skewed, both parametric (Anova and t-test) and non-parametric tests (Mann-Whitney U-test / Wilcoxon, Kruskal-Wallis test) are employed. To analyze whether the BHAR is significantly different from zero we employ a skewness-adjusted t-test as documented in Lyon et al. (1999). Furthermore, we compare the BHAR of four different sub-groups: 1) IPOs with patents, 2) IPOs with no patents at all, 3) IPOs with more than the median number of patents and 4) IPOs with less than the median number of patents. To test whether the abnormal returns of the sub-samples differ significantly we apply the Anova and Kruskal Wallis test. In case of significant differences we also use a pair wise parametric t-test for the differences between means and a non parametric Wilcoxon test for the differences of the medians. In the cross-sectional regression analysis we focus on the BHAR for the periods of 123 (6 months) and 500 trading days (24 months) after going public.

### 4.2 Fama and French Three-Factor Model

To check for the robustness of our results but also to account for the differences in style and risk of the firms we apply the three-factor model of Fama and French (1993). For this we estimate the following time series regression:

$$(4) \qquad R(t) - R_f(t) = \alpha + \beta_1\big(RM(t) - R_f(t)\big) + \beta_2 SMB(t) + \beta_3 HML(t) + \varepsilon(t)$$

where R(t) is the day t stock return and $R_f$ is the risk-free rate. RM(t) denotes the day t value-weighted market return ("NEMAX Allshare" index). $SMB_t$ (small minus big) and $HML_t$ (high minus

low) are the day t returns of factor mimicking portfolios designed to capture size and book-to-market characteristics, respectively. We follow the approach of Bessler and Kurth (2006c) in that we use daily returns of Dow Jones style investment sub-indices to model the factors (small cap vs. large cap and value vs. growth).[6] The Fama-French three-factor model is also applied to test for the difference in IPO performance for the sub-groups of firms with patents and firms without patents. For this we first estimate the intercept coefficient (α) for every IPO and then calculate the average alphas for the portfolios of various sub-groups. Finally we test whether the abnormal returns of the portfolios (α) are different from zero and whether the alphas of various sub-groups are different from each other.

### 4.3 Cross Sectional Regression Analysis

In order to gain additional insights but also to check for the robustness and validity of our empirical results with respect to the long-run performance (6 and 24 months of trading) of high-tech and low-tech IPOs in Germany we perform some additional regression analysis. The dependent variables in our regressions are the abnormal returns from the long-run performance analysis. These are the BHAR after 123 (6 months) and 500 trading days (24 months) as well as the average daily abnormal returns (alphas) from the Fama-French model for the period of 123 and 500 trading days. The regression model includes the control variables "firm size" [size] and the natural logarithm of the "market-to-book-ratio" [ln mtb]. Firm size corresponds with the market value of equity. These two variables adjust the IPO performance for the well known impact of size and growth potential (Gompers and Lerner, 1999, Lyon et al., 1999). The firm-size and market-to-book-ratio are based upon the first market price of the IPO. To account for differences between rising and declining stock markets we include a dummy variable. The dummy combines the years 1997 to 1999 as the hot market phase and the years 2000 to 2002 as the cold market phase. A more detailed analysis did not offer additional insights.

## 5. Empirical Results

The results of our empirical analysis are presented in the various sections. In the first three sections the empirical findings for underpricing and buy-and-hold abnormal returns (BHAR) are pre-

[6] We repeated the analysis by employing the MSCI Euro Stoxx style indices for constructing the SMB and HML factors and found similar results. The MSCI results are not presented here but are available on request.

sented. Then the findings for hot and cold issue markets are analyzed. The results of the Fama-French three-factor model and the cross-sectional regressions are discussed thereafter. Thus, all three phenomena that are usually associated with IPOs, i.e. underpricing, long-run underperformance and market timing or hot issue market are all addressed. In most studies on initial public offerings the empirical findings are usually that IPOs are first of all underpriced, second have, on average, a long-run underperformance, and third firms time the market. A review of the literature is provided in Thies (2000) and Kurth (2005), who also present empirical findings on these issues for Germany for the periods 1980-1997 and 1997-2003, respectively. This study extends the current literature in that our focus is on the impact of innovation on underpricing and long-run performance while controlling for the other well known factors.

### 5.1 Underpricing

There have been a large number of different theories advanced in the literature to explain underpricing of initial public offerings. Underpricing represents the fact that on the first day of trading the price for the IPO is higher than the offer price. The average underpricing for IPOs at the Neuer Markt was about 50% (Kurth, 2005, p.341), which is relatively high even by international standards.[7] Guo et al. (2005) suggest that the underpricing should be higher for technology firms due to substantial information asymmetries. This should be especially relevant for those IPOs that have either high R&D-expenditures or that are considered to be more risky due to its R&D-intensity. For the period from 1980 to 1995 they find for high R&D firms an underpricing of 15% and for the firms without R&D of 8.7%. It could be argued that patents are a better innovation proxy than R&D. Thus, it seems possible that patent information reduces information asymmetries leading to different results and new insights.

Our own empirical analysis of IPOs at the “Neuer Markt” reveals that the underpricing of firms without patents is on average 56.24% compared to 45.39% for firms with patents (Table 2). Although the difference in underpricing appears large, the deviation between the two groups is insignifi-

[7] This figure for underpricing is much higher than that for other market periods. Thies (2000) finds an underpricing of 12.1% for German IPOs during the period from 1982 to 1995. Ritter and Welch (2001) report for IPO in the U.S. an underpricing of 18.8% for the period from 1980 to 2001.

cant. Thus, we cannot support the results of Guo et al. (2005) but have some indication to the contrary that IPOs with technology have a lower underpricing. However, there are many other factors that may cause a smaller or larger underpricing and may have a stronger impact than technology (Bessler and Kurth, 2006c, Bessler and Stanzel, 2006). One of these factors is hot and cold market periods. When we separate the sample into hot (1997 to Feb. 2000) and cold (March 2000 to Dec. 2002)[8] market periods and distinguish again between IPOs with and without patents, the results become significant.

First of all the underpricing in the hot issue market is 66.85% compared to 23.59% for the cold issue market. The difference is significant for these means (31.25%) as well as for the median (6.67%). An analysis of the hot-issue IPOs reveals that there is no significant difference in underpricing for firms with and without patents although the differences appear to be substantial. The IPOs without patents have a higher underpricing of 70.89% compared to 54.93% for the IPOs without patents. The respective medians are 32.76% and 21.88% for the hot issue period. For the cold-issue period the underpricing for IPOs with patents (33.99%) is significantly higher than for the IPOs without patents (15.39%) (median 10.34% vs. 4.47%) Thus, the results for the cold-issue market are similar to that of Guo et al. (2005).

*[Insert Table 2 about here]*

These results for German IPOs may be at first surprising because they are not in line of what one may have expected. Underpricing, however, is determined by a large number of factors besides technology such as ownership structure, bank relationship, venture capital, underwriter, lock-up periods, analyst coverage, etc. Some interactions between the parties involved suggest that there are severe agency problems in the German universal banking system (Bessler and Kurth, 2006c). Moreover, underpricing is a one day phenomenon. More relevant for our research question may be the long-run performance.

**5.2 Buy-and-Hold-Abnormal Returns**

8 In the underpricing study we consider the first three month of 2000 as hot-issue, because we analyze a single day. When we consider this timeperiod as cold-issue the results do not change but are weaker.

The buy-and-hold-abnormal returns (BHAR) are calculated by using the "NEMAX Allshare" index as a proxy for the market performance. The BHAR for both the groups of IPOs without patents (193 firms) and with patents (79 firms) are presented in Figure 3. Eight firms are excluded from the sample because of missing data due to bankruptcy. We also exclude firms with a single patent to avoid borderline interpretations.

*[Insert Figure 3 and Table3 about here]*

After the first 6 and 12 months of trading the group of initial public offerings with patents has BHAR of 51.90% (52.23% for all)[9] and 71.22%, respectively. In contrast, the group of initial public offerings without patents has a performance of 15.96% and -2.13% after 6 and 12 months, respectively. The difference in returns between these groups is statistically significant, indicating that firms with patents outperformed firms without patents significantly over that period. These empirical findings support the notion that technology and innovation was reflected in the valuation of IPOs in Germany and that innovation was an important factor for achieving a superior performance. After 24 months of trading (Table 3, column 5) the performance is lower compared to the 6 and 12 months periods for both groups. One possible explanation for this underperformance is that there may have been some over-valuation of all IPOs during the first year after going public. After 2 years the BHAR for the group of IPOs with patents is 14.51% (31.30% for all) whereas the IPOs without patents have a negative performance of -5.54%. The BHAR of the two groups (31.30% and -5.54%) are significantly different at the 10% level (t-test). Although both groups have a similar decline in market values over time, there is evidence that the IPOs with patents outperformed the IPOs without patents in the short and in the long-run.

The strong abnormal performance of IPOs over the first 6 and 12 months periods, independent of patents and technology, seems surprising. However, this may be explained with the special legal and tax environment in Germany. There was a 6 months mandatory lock-up period at the "Neuer Markt" for certain investor groups such as venture capitalists and management (Bessler and Kurth,

[9] Figures in parentheses are the means if we include also the firms that applied for only one patent. When we calculate the BHAR by using the DAX as the market index we find the following results for firms with more than one patent and for firms without patents, respectively: 123 trading days 45% vs. 22%, 250 trading days -65% vs. -3%, 500 trading days -11% vs. -36%.

2005b, 2005c). Moreover, there exists an exemption from capital gains taxation after a 12 months holding period for the private investor (Bessler and Kurth, 2006a). Both regulations had a significant valuation effect, especially a run-up before the end of both periods and a decline thereafter. Nevertheless, the focus and the important aspects in this study are to analyze the impact of technology on valuation, i.e. to compare the performance of IPOs with patents to IPOs without patents. Therefore, it is the relative performance that matters and not the absolute level of the stock market. Thus, there is significant evidence of a positive relationship between innovation (patents) and firm performance for IPOs at the Neuer Markt in Germany.

In order to gain additional insights into the valuation effects of innovation we further separate the group of firms with patents into two sub-groups of approximately the same size where the median (25 patents) is the cut-off point. The performance of the group with patents (39 firms) but with fewer patents (2-25) is 45.80% after 123 trading days and -1.64% after 500 trading days, respectively. In contrast, the performance of the group (40 firms) with more patents (26 and more) is 57.85% after 123 trading days and 29.45% after 500 trading days. The results are presented in Figure 4 and Table 3. The differences are substantial but not significant. Overall the empirical evidence suggests that patents have a positive impact on the performance of IPOs, especially in the long-run. In this BHAR approach differentiating by the number of patents does not offer additional insights. One reason for this result is that only proxies are available for measuring the patent value. The true patent value is usually unknown. Thus, the use of a commercial patent valuation models may offer additional insights. Another reason is that the investors, and especially analysts, are not in a position to estimate precisely the impact of innovation and technology on firm value.

*[Insert Figure 4 about here]*

**5.3 Hot and Cold Issue Market**

Previous research on IPOs reveals that the time period of the going public may have a significant impact on the future performance of firms. It seems especially important to distinguish between bull and bear markets or hot and cold issue markets, respectively (Bessler and Kurth, 2005 for Germany, Lowry and Schwert, 2002 for the U.S.). Although the absolute performance usually differs, the

relative performance should not be that different because returns are usually adjusted for by an appropriate market index, e.g. in our study the "NEMAX Allshare" index. However, if there are special valuation effects in up-markets compared to down-markets, then this should be revealed in the relative performance. One of the factors that may be overvalued in bull markets and undervalued in bear markets due to its risks is innovation or technology. This may be due to the fact that the value of a firm depends to a large extent on the expected growth rate of cash flows. It seems possible that analysts are positively biased in bull markets and overestimate the impact of innovation but negatively biased in bear markets with respect to technology. This clearly indicates that it is difficult to value the impact of innovation and technology.[10] The objective of this section is to investigate whether there are different valuation effects of innovation in hot and cold issue markets. For this we follow the approach in Bessler and Kurth (2005) and classify the period 1997 to 1999 as hot issue market and the period 2000 to 2002 as cold issue market. Of the 272 IPOs for which we have complete financial information, 152 occurred during the hot issue phase and 120 during the cold issue phase.[11]

As hypothesized, the valuation effects are different in up- and down markets as well as for IPOs with patents and IPOs without patents. In Figure 5 and Figure 6 the BHAR for the first 500 trading days are presented. After 6 months (123 trading days) the abnormal returns in the hot issue market for the firms with patents are 77% compared to 26% for the firm without patents. Both figures are significantly different from zero and the difference of 51% points between both groups is also significant. The valuation difference between the two groups becomes even more evident after 12 months (250 trading days). The IPOs with patents outperform the market index (NEMAX) significantly by 124% compared to an insignificant negative return of -7% for IPOs without patents. The difference of 131% points for the mean and 94% points for the median are both significant at the 1% level (Table 4, Figure 5). It appears that both the mandatory lock-up period after 6 months (Bessler and Kurth, 2006b) as well as the tax lock-up period after 12 months (Bessler and Kurth, 2006a) have an impact on the return behavior. In the long-run (24 months) the abnormal returns decline to 26% for IPOs with pat-

[10] Based on accounting data Ramb und Reitzig (2005) provide evidence that the magnitude and direction of the information effects can be differently depending on the market phase.

[11] Of the 120 IPOs that went public during the cold issue period, there are 39 IPOs that went public during the first quarter of 2000.

ents and to a negative 11% for IPOs without patents. There is still a relative difference of 37% points for the mean and a significant difference of 38% points for the median. Thus, in a hot issue market, IPOs with patents outperform IPOs without patents in the short and in the long run.[12]

*[Insert Figure 5, Figure 6 and Table 4 about here]*

In the cold issue market the BHAR after 6 months are much lower relative to the hot issue market with significant BHAR of 27% for IPOs with patents and BHAR of 2% for IPOs without patents (Figure 6, Table 4). The differences of 25% points for mean and median between both groups are significant both at the 1% level.[13] Thus, IPOs with patents outperform the IPOs without patents also in the cold issue market at least in the short run (6 months). A significant outperformance also exists after 12 months with significant differences of 15% points (mean) and 11% points (median). The outperformance as well as the differences between both groups decrease thereafter and totally vanish for the mean as well as for the median after 24 months.[14]

To investigate whether the market conditions have an impact on the valuation of firm with and without patents we separate the sample into firms that went public either during the hot or cold issue market periods (Figure 7, 8 and Table 5). When first analyzing firms with patents we find for the first year a superior performance in the hot issue period. The difference in performance is 50% ($\alpha$=0.1) and 105% ($\alpha$=0.05) after 6 and 12 months, respectively. However, we do not find any significant differences neither in mean returns nor in median returns after 18 and 24 months.

*[Insert Figure 7 and Table 5 about here]*

The results for IPOs without patents are different (Figure 8). There is some outperformance of the hot-issue IPOs compared to the cold-issue IPOs after 6 months (24%, $\alpha$=0.1). When analyzing the time period of the second year after IPO, the relationship between both groups inverts. Now IPOs

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[12] When we use the DAX to calculate the BHAR, results for hot-issue IPOs without patents vs. firms with more than one patent are as follows: 123 trading days 59% vs. 102%, 250 trading days 27% vs. 172%, and 500 trading days -30% vs. 20%.

[13] Interestingly, the median of the IPOs without patents is negative for both market phases.

[14] When we use the DAX to calculate the BHAR, results for cold-issue IPOs without patents vs. firms with more than one patent are as follows: 123 trading days -29% vs. -3%, 250 trading days -45% vs. -25%, and 500 trading days -44% vs. -37%.

without patents have a lower performance during the hot issue period than during the cold issue period. The differences in medians are significantly different (α=0.01).

*[Insert Figure 8 about here]*

**5.4 Fama and French Three Factor Model**

We extend our empirical analysis by employing the three-factor asset pricing model of Fama-French (1993) for estimating abnormal returns. In recent years this model has become a standard approach in the finance literature to test for the robustness of the empirical findings (BHAR). The alphas (abnormal returns) from the three-factor regression model are used as a measure for the abnormal performance of the two groups. The results are presented in Table 7. The empirical findings for the 123 trading day period as well as for the 500 trading day period are in accordance with our previous results. Firms with patents outperform firms without patents. The group of IPOs without patents has on average a daily abnormal performance of 0.06%. This amounts to 7.12% after 123 trading days (Figure 9, Table 6). In contrast, the group of IPOs that filed at least for one patent has on average a daily performance of 0.24%. This adds up to 34.74% after 123 trading days (Figure 9). When excluding the firms that filed for only one patent, the performance increases marginally to 35.82%. After 500 trading days the performance of the group without patents is significantly negative with cumulative abnormal returns of -18.88% (daily -0.04%) while the performance of the group with patents is positive with 39.01% after 24 months (daily 0.07%). The results are summarized in Figure 9, Table 6.

*[Insert Figure 9 and Table 6 about here]*

For a more detailed analysis of the hypothesis that firm performance is related to the number of applied patents the sample is divided into three groups: firms without patents (193), firms with 2-25 patents (39), and firms with more than 25 patents (40). When we separate the sample differently, for example into firms that filed for fewer patents and firms that filed for more patents, we find similar supporting evidence for our results. The returns for firms with 2-25 patents is 15.01% (0.11% daily) after 123 trading days and 1.52% after 500 trading days (0.003% daily). Interestingly and in accordance with our expectations, firms with more than 25 patents achieve a superior performance. The returns after 123 and 500 trading days are 59.70% (0.38%) and 89.75% (0.13%), respectively. The

results are presented in Figure 9 and Table 6. These results are all based on the idea that the numbers of patents that are counted from the patent stock are the appropriate measure for innovation. So far we did not use patent value indicators for measuring patent activity and quality. These factors are analyzed in the cross sectional regressions in the following section.

**5.5 Cross Sectional Regressions**

As the third approach we apply cross-sectional regressions for exploring the relationship between innovation and abnormal returns. We employ various specifications in the cross-sectional regressions in that different indicators for patent values are used. We analyze eight different models for each of the four different dependent variables. As dependent variables we include the buy-and-hold-abnormal return (BHAR) for 123 and 500 trading day periods as well as abnormal returns (alphas) estimated with the Fama-French three-factor model for periods of 123 and 500 trading days after going public. A variety of different control variables are included in model 1, model 2 and model 3. These control variables are: 1) the market-to-book value, 2) size as measured by IPO volume, 3) the year of the going public in order to differentiate between various market phases. Model 1 includes only control variables and none of the patent value indicators. Some of the control variables significantly influence the long-run performance as measured by BHAR and alphas from the Fama and French model (after 123 and 500 trading days, respectively). In the second model we add the specific patent factors while still controlling for the factors from the first model. In order to test for the importance of each factor we test each factor separately. In model 3 we finally include all patent variables simultaneously. Overall we employ six different factors in our models 2 and 3 which are separated into different groups labeled "patents", "patent breadth indicators" and "citation indicators". As patent factor we use patent counts as measured by the patent stock (a). This is the number of patents a firm has applied for since 1980. Later on we also differentiate the data by application year. As a second and third patent factor we employ the average amount of IPC-classes (b) and average family size (c) for the patents of a company, respectively. These factors are usually used as proxies for the patent breadth. The citation indicators are the factors (d), (e), and (f). First, we use the backward citations which are the number of patents a patent cites (d). Second, we include the forward citations (e) which are the number of patents citing the considered patent. Finally we use the frequency of cited articles (f)

which is the number of non patent literature a patent cites. All indicators are averaged by the patent counts of the firm. The control variables in model 1 almost all have a significant impact on firm performance. In models 2 and 3 we include a number of patent indicators as additional variables and test whether these factors have any explanatory power.

*[Insert Table 7 about here]*

In model 2, in which the dependent variable are the BHAR after 123 days and the control and patent variables are the independent variables, we find some evidence of a positive impact of innovation on performance. When the variables are included separately in the model, the coefficients are all positive and significant except for the citation indicators. The significant variables are (a) the patent counts, (b) the breadth indicators IPC, and (c) the family size (Table 7). In contrast, the BHAR after 500 trading days have hardly any explanatory power (Table 8).

*[Insert Table 8 about here]*

When the abnormal return (alphas) from the Fama-French model is used as the dependent variable in model 2, the patent counts and the patent breadth variables are significant, i.e. they have an impact on performance (Table 9). When the control variables (models 2 a-f) as well as each patent variable are included separately in the model, we find that (a) the number of patents has a positive impact on firm-performance for both the 123 trading day (t=5.51) and 500 trading day periods (t=5.15). In addition, the proxies for patent breadth are value enhancing. Moreover, the coefficients for the patent breadth indicators are significant for the 123 day period as well as for the 500 day period (Table 10). The same holds for the family coefficient (c) for both periods. In contrast, the citation indicators do not significantly impact firm performance.

*[Insert Table 9 and Table 10 about here]*

In model 3, in which the impact of the independent variables is explored simultaneously, we present only the results for the Fama-French alphas, because the BHAR analysis does not yield any significant results (Table 7 and 8.) After 123 days of trading we find a significant impact only for the number of patents. The $R^2$ (0.149) is marginally lower than that of Model 2a (0.155). For the 500 day period, the coefficients for patents and the IPC coefficient are significantly positive. This time the $R^2$

(0.132) is marginally higher than that of model 2a (0.116). The results are presented in Table 9 and Table 10.

The insignificant results for the forward citations could be due to several factors. First, the time period considered in this research is too short to find any impact of forward citations. Citations are usually spread over a longer time horizon than we are able to analyze in this study. Second, we do not correct for the truncation problem and the citation propensity. Third, there are no public databases for German patents from which the analysts and investors can extract easily the forward citations. Thus, it seems possible that the market is not aware of this information and therefore it is not immediately priced by the market. Fourth, as mentioned by Trajtenberg et al. (2002), forward citations should be interpreted as a measure for the social patent value. The relationship between the social value and the private value of a patent, however, could be opposite. These authors suggests as a measure for the private patent value the time distance between the patent application and self citations.

Overall, the empirical findings support the notion that the number and quality of patents have a positive impact on the capital market valuation of initial public offerings. The significant positive impact, however, decreases after one year. One possible explanation for this observation is that patents are an important early indicator for the success of an IPO, but that this is not sufficient for a superior long-run out-performance. In fact, new information and other measures become available over time and are used to value these IPOs. Another explanation is that the growth potential stemming from patents is overestimated at the time of the IPO. Consequently, it is adjusted downwards over time, leading to an underperformance. Thus, it appears that up to one year patents are useful in explaining the superior performance of IPOs. This results holds independent of the method employed (BHAR or Fama-French). Moreover, the patent indicators are valuable in explaining the performance of IPOs.

## 6. Conclusions

In this study we investigate the impact of the patenting behavior on the performance of German firms that went public at the “Neuer Markt” during the period from 1997 to 2002. The main focus of the empirical analysis is to examine whether companies that filed for patents outperformed those companies with no patented technology. Because the “Neuer Markt” was a stock exchange segment

especially for high-technology firms and patents are usually considered as a good measure for technical innovation, the German initial public offerings (IPOs) are ideal for analyzing the impact of innovation on firm value. In the empirical analysis both patents and patent indicators are used separately and simultaneously in order to measure the impact of patents on the firm value. These relationships are analyzed by employing various methodologies. We use buy-and-hold abnormal returns (BHAR) for the first two years after going public and control for the size and growth effects by estimating abnormal returns using the three-factor Fama-French model. In addition, we employ cross-sectional-regressions to control for certain valuation factors and include additional patent variables that may significantly impact the abnormal returns. As patent variables we include the number of backward- and forward citations, the number of IPC classes, the frequency of cited articles, and family size.

Overall the empirical analysis provides convincing evidence that innovation has a positive impact on the value and long-run performance of technology firms. In particular, the abnormal performance of IPOs with patents is positive and significantly higher than that of IPOs without patented technology after 123 and 500 days of trading. This result is independent of the market situation. However, the difference in valuation effects between these two groups is much more pronounced in hot issue markets. Moreover, the relative long-run performance is inferior for firms without patents especially when issued in a hot issue market. These results are robust when measuring the performance with BHAR as well as with alphas from the Fama-French three-factor model. The empirical evidence is also supported in cross sectional regressions where we control for size and book-to-market ratios and include patents and various patent indicator variables. The major result of this study is that innovation as measured by patents is an important factor that has a positive impact on the long-run performance of initial public offerings in Germany.

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## Figures and Tables

Figure 1: Number of IPOs per month and "Neuer Markt" Index (Nemax)

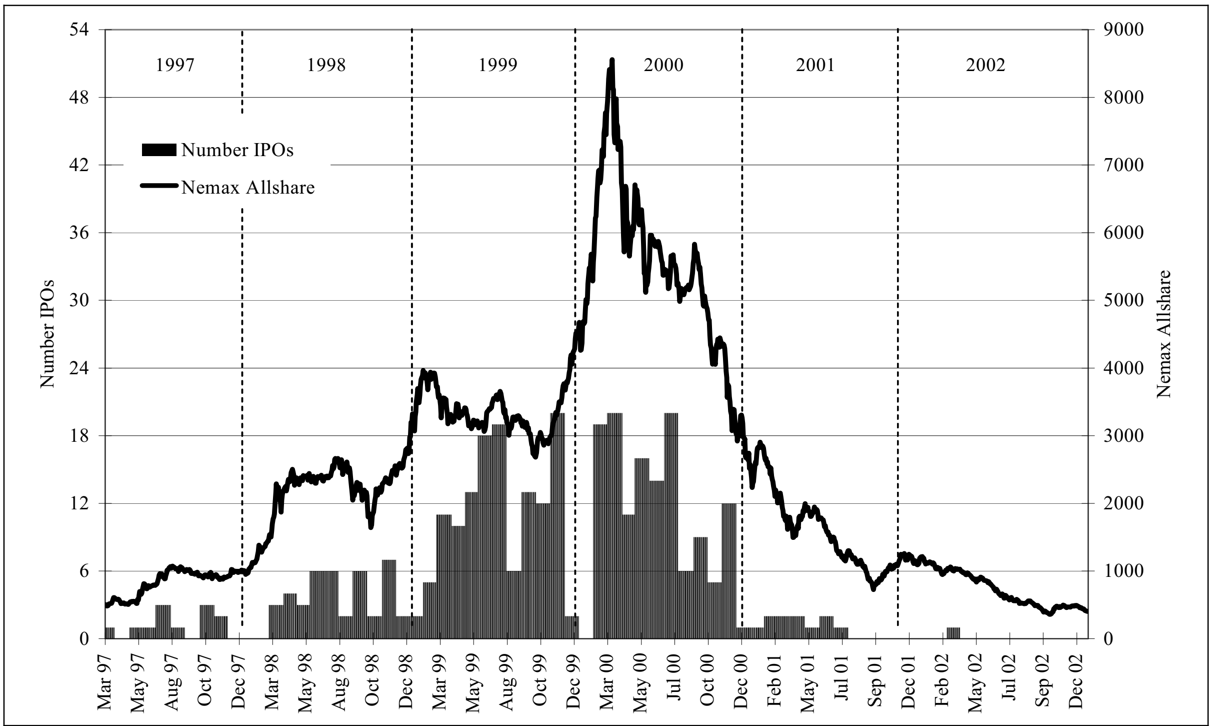


Figure 2: Patents filings per year per firm (left scale) – application and publication date (2 year lag), number of firms per year (right scale)

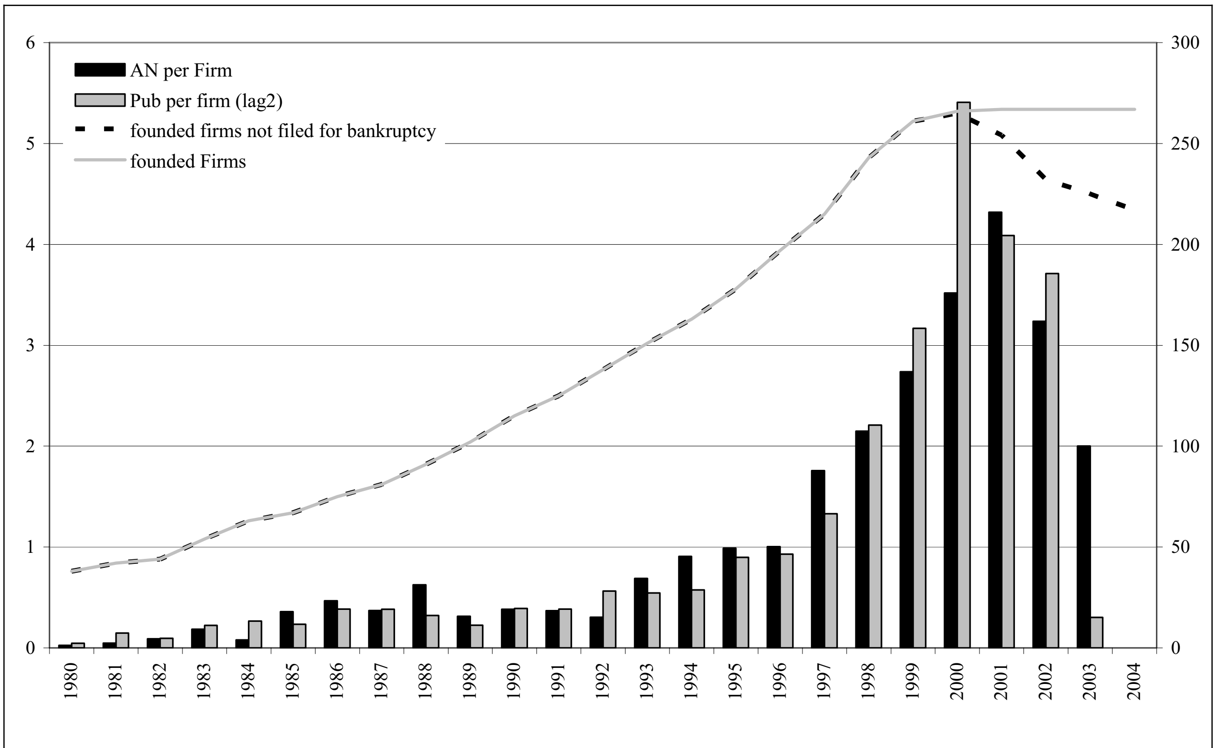

Figure 3: BHAR of the group with patents (black line) and the group without filed patents (grey line)

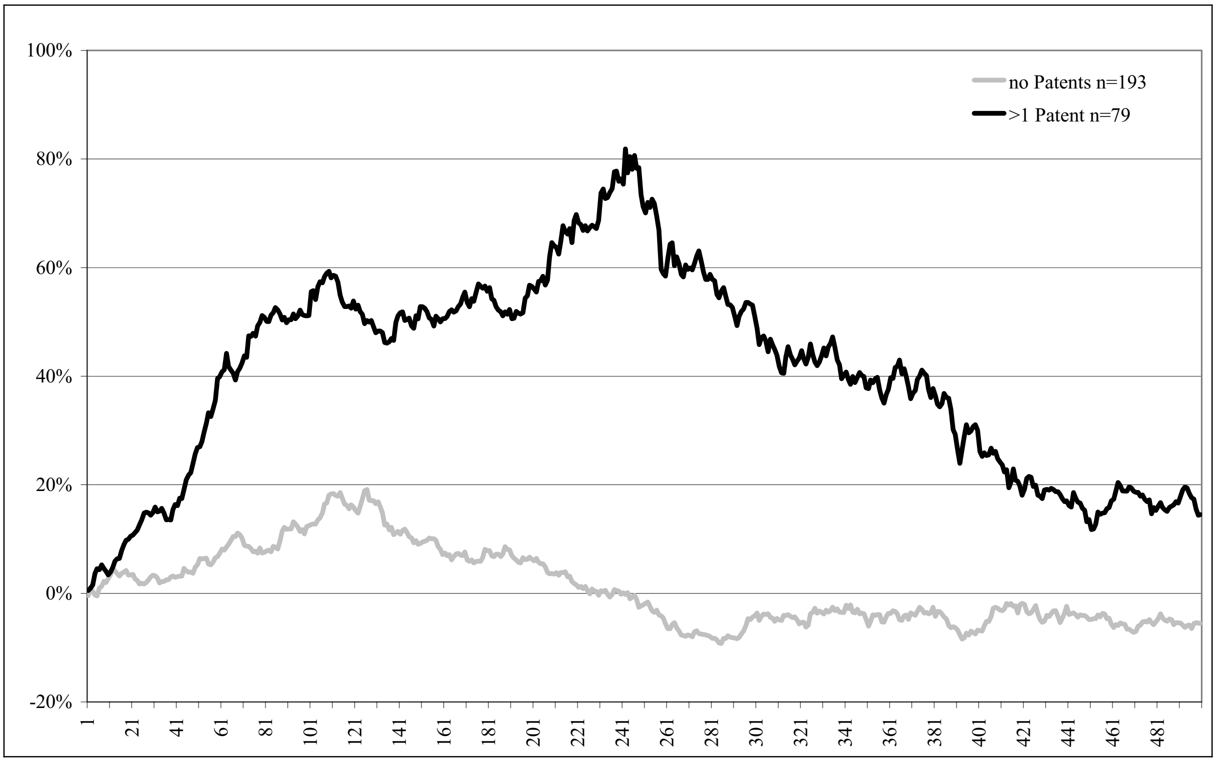


Figure 4: BHAR of the group without patents (dark grey line), with 2-25 patents (light grey line) and more than 25 patents (black line)

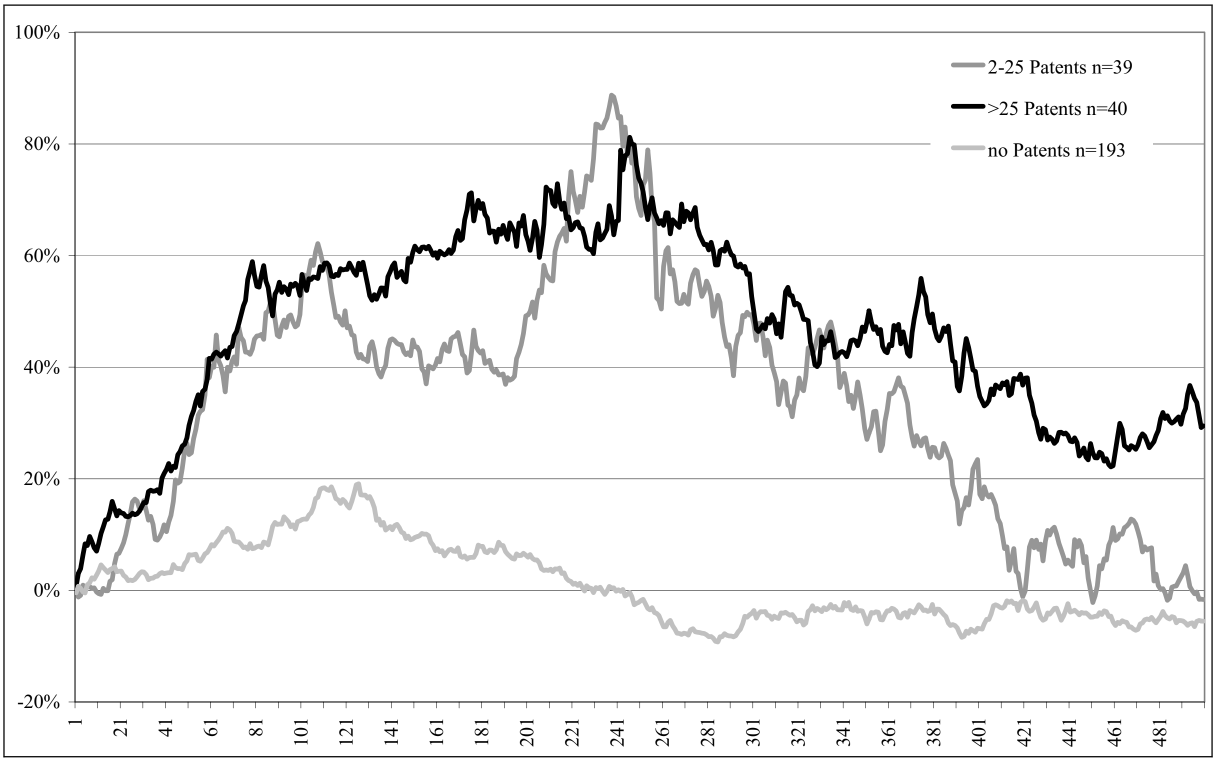

Figure 5: BHAR Hot-Issue IPOs with and without Patents

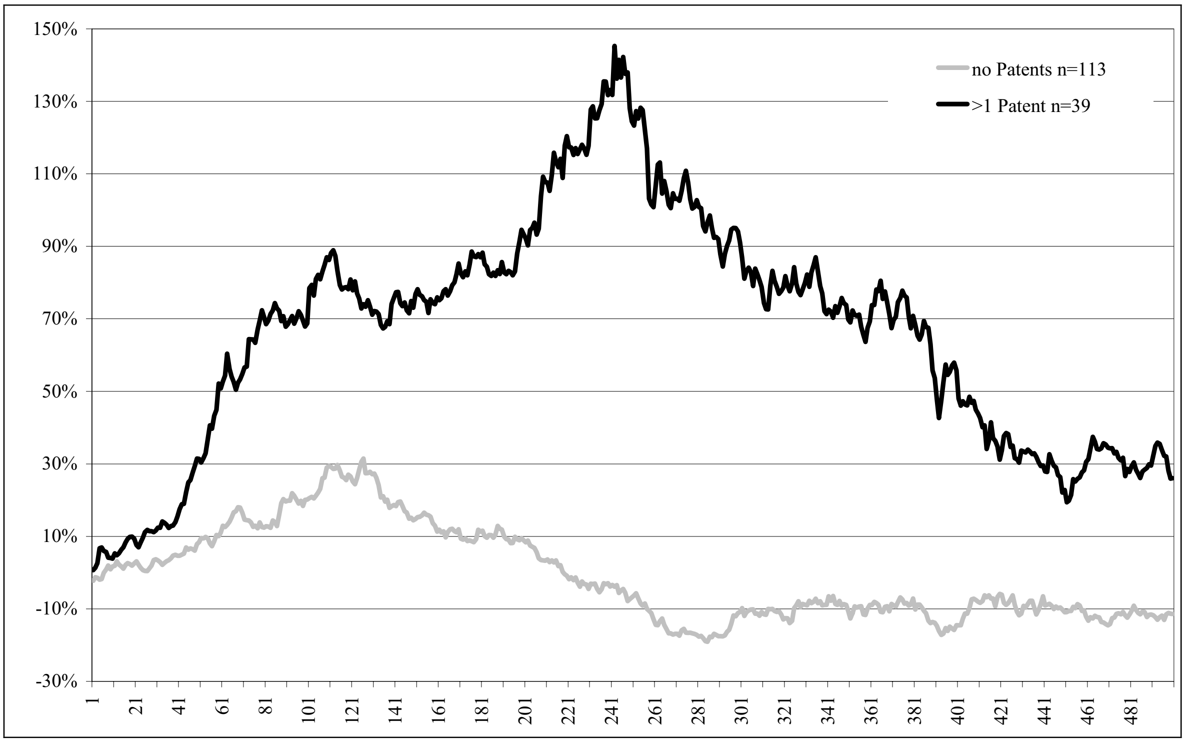


Figure 6: BHAR Cold-Issue IPOs with and without Patents

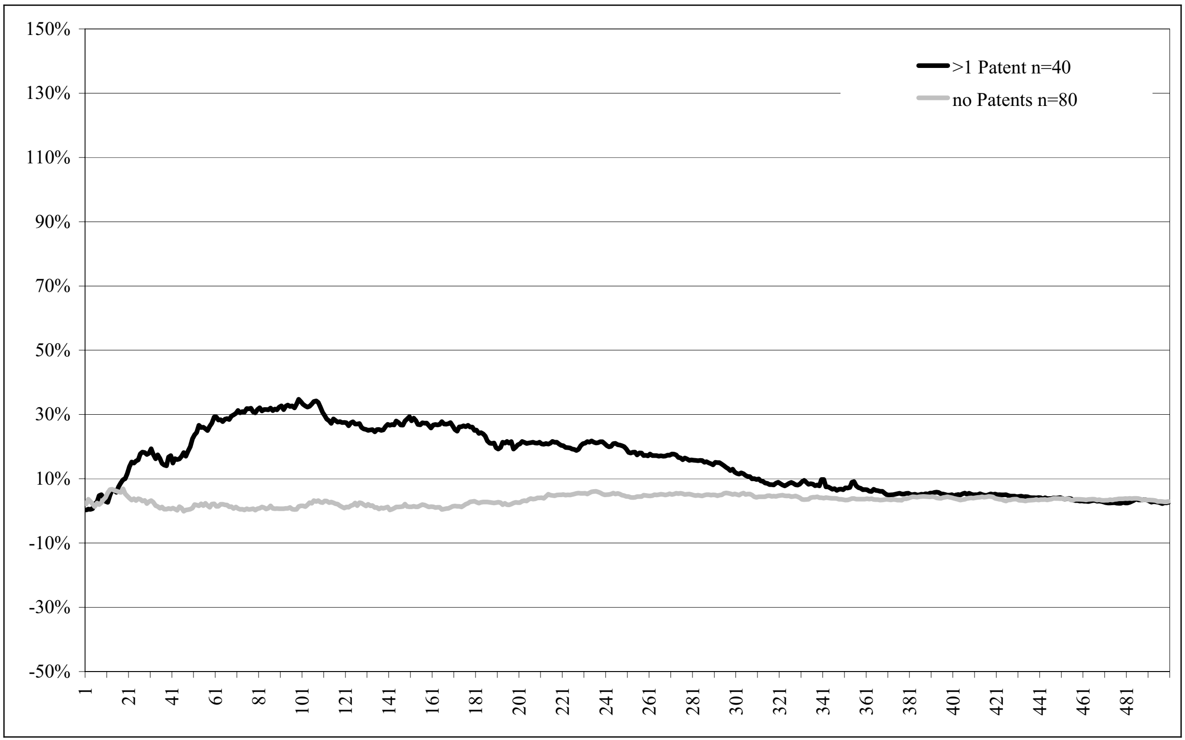

Figure 7: BHAR of Cold- and Hot-Issue IPOs with Patents

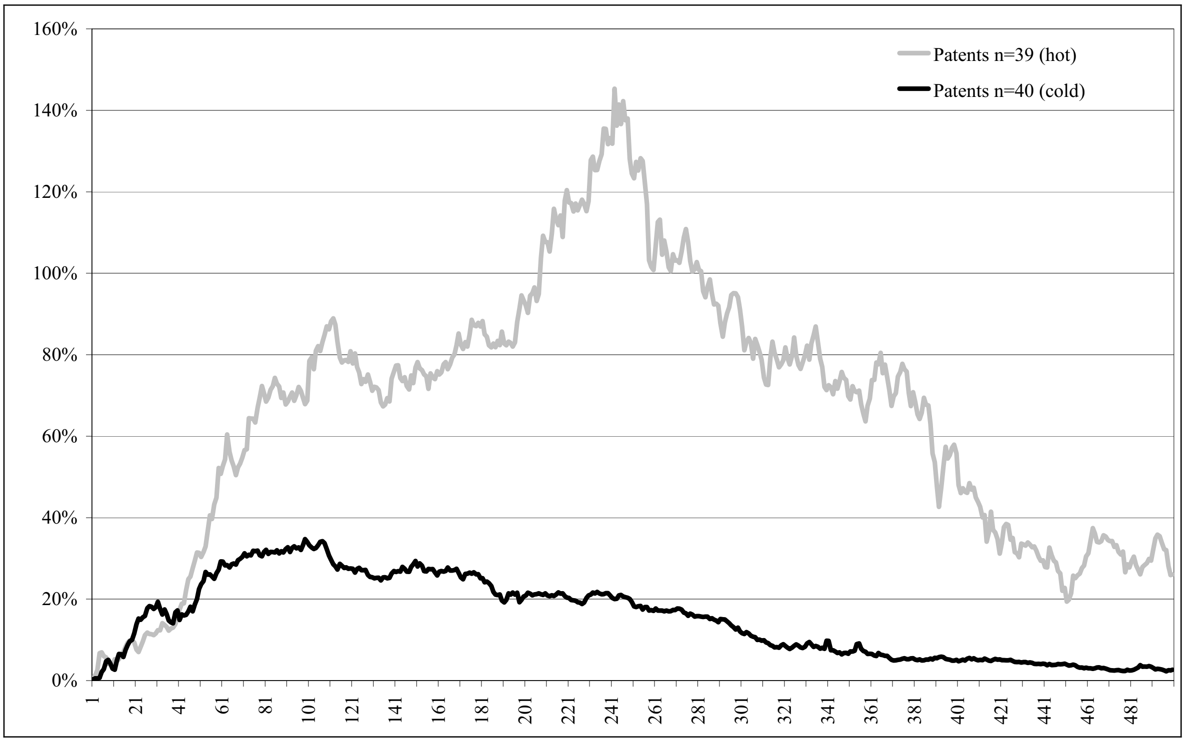


Figure 8: BHAR of Cold- and Hot-Issue IPOs without Patents

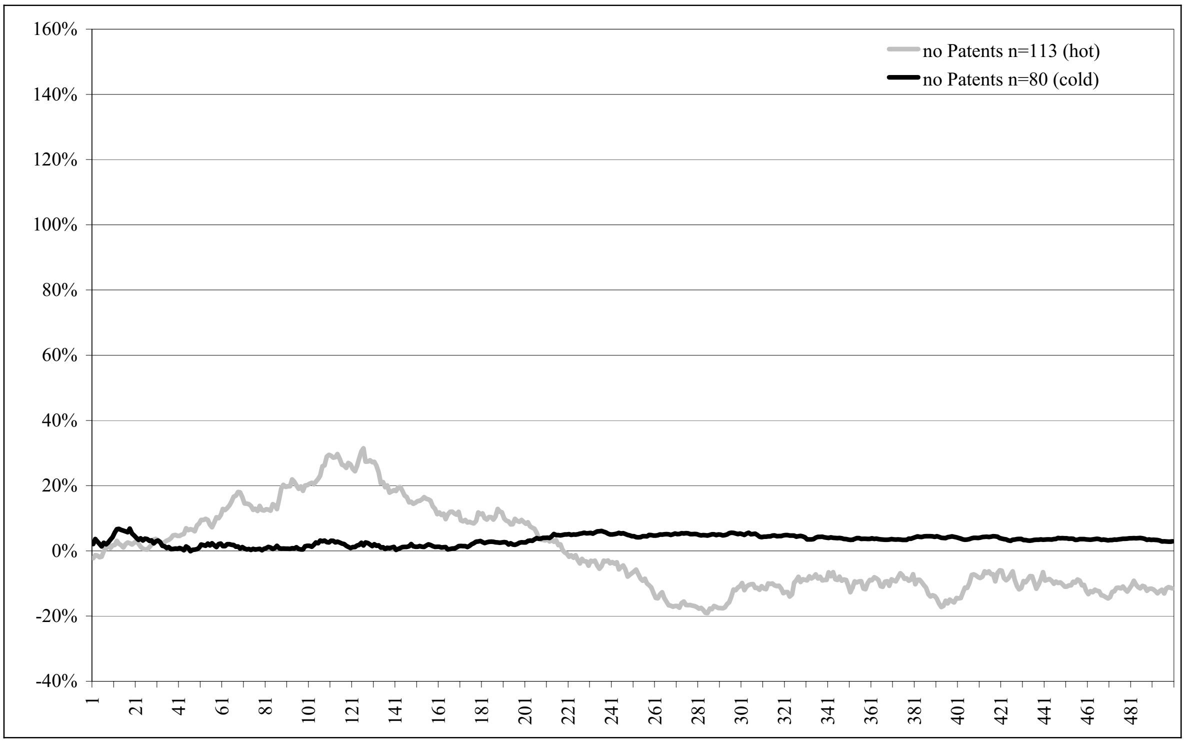

Figure 9: Abnormal returns (alphas) of the firms with no patents, more than one patent, 2 to 25 patents, and more than 25 patents for 123 trading days and 500 trading days. (full sample). 1=100%.

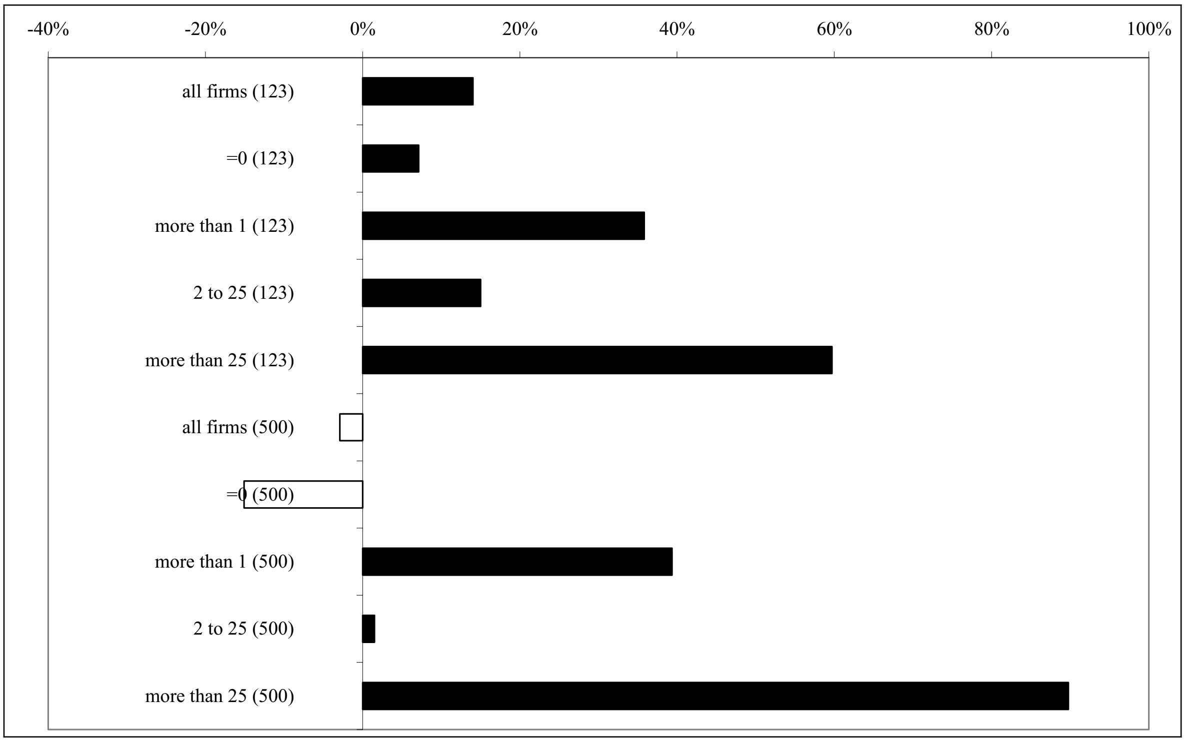

Table 1: Countries in which the priority patents are applied for

| Patent Office | DE | US | EP | WO | JP | IT |
|---|---|---|---|---|---|---|
| Priority Patents – (abs.) | 1039 | 250 | 97 | 20 | 9 | 7 |
| Priority Patents – (rel.) | 0.72 | 0.17 | 0.07 | 0.01 | 0.01 | 0.00 |
| Priority Patents – (cum.) | 0.72 | 0.90 | 0.96 | 0.98 | 0.98 | 0.99 |

Table 2: Underpricing of the IPOs dependent of market phase and patent activity. Hot issue market until March 2000.

| Sample | N | Mean | t Diff. Mean | Median | z Diff. Median |
|---|---|---|---|---|---|
| no patents | 197 | 56.24% | 1.13 | 23.53% | 1.16 |
| patents | 90 | 45.39% | | 16.27% | |
| cold | 93 | 23.59% | 4.73*** | 6.67% | 5.17*** |
| hot | 194 | 66.85% | | 31.25% | |
| hot_nP | 145 | 70.89% | 1.16 | 32.76% | 1.76 |
| hot_P | 49 | 54.93% | | 21.88% | |
| cold_nP | 52 | 15.39% | 2.18** | 4.47% | 2.10** |
| cold_P | 41 | 33.99% | | 10.34% | |
| hot_nP | 145 | 70.89% | 4.75*** | 32.76% | 5.48*** |
| cold_nP | 52 | 15.39% | | 4.47% | |
| hot_P | 49 | 54.93% | 1.36 | 21.88% | 1.02 |
| cold_P | 41 | 33.99% | | 10.34% | |

*** Significant at the 1% level, ** significant at the 5% level, *significant at the 10% level

Table 3: BHAR after 123 and 500 trading days

| | BHAR 123 | | | t Diff. | BHAR 500 | | t Diff. |
|---|---|---|---|---|---|---|---|
| | N | Mean | t | Mean | Mean | t | Mean |
| > 0 patents | 87 | 52.23% | 4.14*** | 2.64*** | 31.30% | 1.36 | 1.81* |
| no patents | 193 | 15.96% | 2.28** | | -5.54% | -0.62 | |
| > 1 patents | 79 | 51.90% | 4.00*** | 2.61*** | 14.51% | 0.91 | 1.16 |
| no patents | 193 | 15.96% | 2.28** | | -5.54% | -0.62 | |
| more than 25 | 40 | 57.85% | 3.85*** | 2.46*** | 29.45% | 1.12 | 0.01 |
| no patents | 193 | 15.96% | 2.28** | | -5.54% | -0.62 | |
| 2-25 patents | 39 | 45.80% | 2.13** | 1.16 | -1.64% | -0.10 | 0.18 |
| no patents | 193 | 15.96% | 2.28** | | -5.54% | -0.62 | |
| more than 25 | 40 | 57.85% | 3.85*** | 0.46 | 29.45% | 1.12 | 0.01 |
| 2-25 patents | 39 | 45.80% | 2.13** | | -1.64% | -0.96 | |

*** Significant at the 1% level, ** significant at the 5% level, *significant at the 10% level

Table 4: BHAR after 123, 250, and 500 trading days, samples by issue phase

| Issue-Phase Trading days | Sample | N | Mean | Median | t | z | Diff. Mean Diff. Median |
|---|---|---|---|---|---|---|---|
| Hot 123 | Patents | 39 | 0.77 | 0.16 | 3.13*** | 2.39** | 2.09** |
| | no Patents | 113 | 0.26 | -0.12 | 2.25** | 0.10 | 1.62 |
| Hot 250 | Patents | 39 | 1.24 | 0.52 | 2.80*** | 2.52** | 3.92*** |
| | no Patents | 113 | -0.07 | -0.42 | -0.55 | 2.74*** | 3.09*** |
| Hot 500 | Patents | 39 | 0.26 | 0.12 | 0.83 | 0.79 | 1.19 |
| | no Patents | 113 | -0.11 | -0.26 | -0.76 | 4.41*** | 2.37** |
| Cold 123 | Patents | 40 | 0.27 | 0.16 | 3.56*** | 2.96*** | 3.16*** |
| | no Patents | 80 | 0.02 | -0.09 | 0.38 | 0.60 | 3.06*** |
| Cold 250 | Patents | 40 | 0.19 | 0.07 | 3.00*** | 2.75*** | 2.17** |
| | no Patents | 80 | 0.04 | -0.04 | 1.27 | 0.54 | 2.63*** |
| Cold 500 | Patents | 40 | 0.03 | -0.03 | 0.94 | 0.36 | 0.07 |
| | no Patents | 80 | 0.03 | -0.03 | 1.41 | 0.07 | 0.01 |

*** Significant at the 1% level, ** significant at the 5% level, *significant at the 10% level

Table 5: Abnormal returns after 123, 250, 500 trading days. Mean and median differences between hot and cold issue IPOs.

| hot vs. cold-issue with patents | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trading Days | N (H/C) | Mean hot | Mean cold | t Diff. Means | Median hot | Median cold | z Diff. Median |
| 123 | (39/40) | 0.77 | 0.27 | 1.95* | 0.16 | 0.16 | 0.21 |
| 250 | (39/40) | 1.24 | 0.19 | 2.37** | 0.53 | 0.07 | 1.32 |
| 375 | (39/40) | 0.78 | 0.04 | 1.39 | 0.07 | 0.00 | 0.01 |
| 500 | (39/40) | 0.12 | 0.03 | 0.73 | 0.09 | -0.03 | 0.57 |
| **hot vs. cold -issue no patents** | | | | | | | |
| Trading Days | N (H/C) | Mean hot | Mean cold | t Diff. Means | Median hot | Median cold | z Diff. Median |
| 123 | (113/80) | 0.26 | 0.02 | 1.71* | -0.12 | -0.09 | 0.65 |
| 250 | (113/80) | -0.01 | 0.05 | 0.76 | -0.42 | -0.04 | 4.78*** |
| 375 | (113/80) | -0.07 | 0.03 | 0.53 | -0.38 | -0.04 | 6.14*** |
| 500 | (113/80) | -0.12 | 0.03 | 0.79 | -0.26 | -0.03 | 6.37*** |

Table 6: Abnormal returns (alpha) after 123 and 500 trading days

| Alpha 123 | N | Mean | Mean daily | t | t Diff. Mean |
|---|---|---|---|---|---|
| > 0 patents | 87 | 34.73% | 0.24% | 3.99*** | 2.86*** |
| no patents | 193 | 7.12% | 0.06% | 1.63* | |
| > 1 patent | 79 | 35.82% | 0.25% | 4.17*** | 2.94*** |
| no patents | 193 | 7.12% | 0.06% | 1.63* | |
| more than 25 | 40 | 59.70% | 0.38% | 4.54*** | 3.86*** |
| no patents | 193 | 7.12% | 0.06% | 1.63* | |
| 2-25 patents | 39 | 15.01% | 0.11% | 1.42 | 0.69 |
| no patents | 193 | 7.12% | 0.06% | 1.63* | |
| more than 25 | 40 | 59.70% | 0.38% | 4.54*** | 2.30** |
| 2-25 patents | 39 | 15.01% | 0.11% | 1.42 | |

| Alpha 500 | N | Mean | Mean daily | t | t Diff. Mean |
|---|---|---|---|---|---|
| > 0 patents | 87 | 39.01% | 0.07% | 2.49*** | 3.81*** |
| no patents | 193 | -18.88% | -0.04% | -2.83*** | |
| > 1 patent | 79 | 39.01% | 0.07% | 2.42*** | 3.73*** |
| no patents | 193 | -18.88% | -0.04% | -2.83*** | |
| more than 25 | 40 | 89.75% | 0.13% | 3.61*** | 4.69*** |
| no patents | 193 | -18.88% | -0.04% | -2.83*** | |
| 2-25 patents | 39 | 1.52% | 0.00% | 0.08 | 1.19 |
| no patents | 193 | -18.88% | -0.04% | -2.83*** | |
| more than 25 | 40 | 89.75% | 0.13% | 3.61*** | 2.34** |
| 2-25 patents | 39 | 1.52% | 0.00% | 0.08 | |

*** Significant at the 1% level, ** significant at the 5% level, *significant at the 10% level

Table 7: Cross-sectional-regressions BHAR 123, White consistent standard errors cov. (t-values in italics).

| | Model 1 | Model 2 | | | | | | Model 3 |
|---|---|---|---|---|---|---|---|---|
| | | (a) Patent | (b) IPC | (c) Family | (d) Forward | (e) Backward | (f) Article | |
| Constant | -0.085 | 0.418 | -0.023 | -0.042 | 0.001 | -0.055 | -0.216 | 0.310 |
| | *-0.074* | *0.377* | *-0.020* | *-0.038* | *0.001* | *-0.049* | *-0.186* | *0.274* |
| ln_mtb | -0.311 | -0.294 | -0.292 | -0.300 | -0.309 | -0.326 | -0.308 | -0.293 |
| | *-1.747* | *-1.651* | *-1.643* | *-1.683* | *-1.730* | *-1.785* | *-1.726* | *-1.579* |
| ln_size | 0.037 | 0.003 | 0.027 | 0.029 | 0.030 | 0.035 | 0.043 | 0.008 |
| | *0.613* | *0.054* | *0.465* | *0.492* | *0.503* | *0.575* | *0.706* | *0.141* |
| d_hotissue | 0.330 | 0.347 | 0.353 | 0.350 | 0.338 | 0.345 | 0.339 | 0.350 |
| | *2.829* | *3.052* | *3.038* | *3.036* | *2.888* | *2.936* | *2.911* | *3.042* |
| Patent | | 0.003 | | | | | | 0.003 |
| | | *3.039* | | | | | | *2.101* |
| IPC | | | 0.053 | | | | | -0.011 |
| | | | *2.168* | | | | | *-0.304* |
| Family | | | | 0.051 | | | | 0.025 |
| | | | | *2.719* | | | | *0.745* |
| Forwards | | | | | 0.049 | | | -0.015 |
| | | | | | *1.054* | | | *-0.326* |
| Backwards | | | | | | 0.051 | | -0.003 |
| | | | | | | *1.321* | | *-0.062* |
| Article | | | | | | | 0.571 | 0.205 |
| | | | | | | | *0.914* | *0.397* |
| adj. $R^2$ | 0.033 | 0.066 | 0.045 | 0.049 | 0.035 | 0.036 | 0.031 | 0.049 |
| N | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |

Table 8: Cross-sectional-regressions BHAR 500, White consistent standard errors cov. (t-values in italics).

| | Model 1 | Model 2 | | | | | | Model 3 |
|---|---|---|---|---|---|---|---|---|
| | | (a) Patent | (b) IPC | (c) Family | (d) Forward | (e) Backward | (f) Article | |
| Constant | -0.825 | -0.727 | -0.764 | -0.783 | -0.836 | -0.825 | -0.976 | -1.058 |
| | *-0.559* | *-0.488* | *-0.519* | *-0.534* | *-0.564* | *-0.557* | *-0.648* | *-0.683* |
| ln_mtb | -0.319 | -0.315 | -0.300 | -0.309 | -0.319 | -0.318 | -0.315 | -0.288 |
| | *-1.277* | *-1.262* | *-1.204* | *-1.238* | *-1.277* | *-1.257* | *-1.259* | *-1.119* |
| ln_size | 0.076 | 0.069 | 0.066 | 0.068 | 0.077 | 0.076 | 0.083 | 0.082 |
| | *1.033* | *0.930* | *0.916* | *0.947* | *1.040* | *1.029* | *1.109* | *1.065* |
| d_hotissue | 0.059 | 0.062 | 0.081 | 0.078 | 0.058 | 0.059 | 0.069 | 0.076 |
| | *0.426* | *0.450* | *0.580* | *0.557* | *0.417* | *0.426* | *0.494* | *0.553* |
| Patent | | 0.001 | | | | | | -0.001 |
| | | *0.893* | | | | | | *-0.659* |
| IPC | | | 0.052 | | | | | 0.019 |
| | | | *1.661* | | | | | *0.291* |
| Family | | | | 0.049 | | | | 0.069 |
| | | | | *1.645* | | | | *0.970* |
| Forwards | | | | | -0.006 | | | -0.039 |
| | | | | | *-0.194* | | | *-1.002* |
| Backwards | | | | | | -0.001 | | -0.045 |
| | | | | | | *-0.026* | | *-0.938* |
| Article | | | | | | | 0.660 | 0.401 |
| | | | | | | | *1.205* | *0.780* |
| adj. $R^2$ | 0.008 | 0.005 | 0.014 | 0.017 | 0.004 | 0.004 | 0.006 | 0.007 |
| N | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |

Table 9: Cross-sectional-regressions alpha 123, White consistent standard errors cov. *(t-values)*. Coeff. *100

| | Model 1 | Model 2 | | | | | | Model 3 |
|---|---|---|---|---|---|---|---|---|
| | | (a) Patent | (b) IPC | (c) Family | (d) Forward | (e) Backward | (f) Article | |
| Constant | -0.367 | -0.026 | -0.318 | -0.338 | -0.332 | -0.348 | -0.453 | -0.111 |
| | *-0.593* | *-0.046* | *-0.544* | *-0.572* | *-0.551* | *-0.578* | *-0.724* | *-0.190* |
| ln_mtb | -0.260 | -0.249 | -0.246 | -0.253 | -0.260 | -0.270 | -0.258 | -0.247 |
| | *-4.166* | *-4.000* | *-3.948* | *-4.056* | *-4.098* | *-4.286* | *-4.132* | *-3.882* |
| ln_size | 0.044 | 0.021 | 0.036 | 0.038 | 0.041 | 0.042 | 0.048 | 0.024 |
| | *1.248* | *0.643* | *1.099* | *1.152* | *1.199* | *1.237* | *1.353* | *0.745* |
| d_hotissue | 0.230 | 0.241 | 0.248 | 0.243 | 0.233 | 0.240 | 0.236 | 0.248 |
| | *3.835* | *4.176* | *4.182* | *4.141* | *3.835* | *3.927* | *3.973* | *4.222* |
| Patent | | 0.002 | | | | | | 0.002 |
| | | *5.505* | | | | | | *3.761* |
| IPC | | | 0.041 | | | | | 0.019 |
| | | | *2.425* | | | | | *0.560* |
| Family | | | | 0.034 | | | | 0.001 |
| | | | | *3.139* | | | | *0.023* |
| Forwards | | | | | 0.020 | | | 0.010 |
| | | | | | *0.500* | | | *0.518* |
| Backwards | | | | | | 0.032 | | -0.037 |
| | | | | | | *1.171* | | *-0.901* |
| Article | | | | | | | 0.377 | 0.113 |
| | | | | | | | *0.676* | *0.222* |
| adj. $R^2$ | 0.092 | 0.155 | 0.127 | 0.124 | 0.093 | 0.099 | 0.093 | 0.149 |
| N | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |

Table 10: Cross-sectional-regressions alpha 500, White consistent standard errors cov. *(t-values)*. Coeff. *100

| | Model 1 | Model 2 | | | | | | Model 3 |
|---|---|---|---|---|---|---|---|---|
| | | (a) Patent | (b) IPC | (c) Family | (d) Forward | (e) Backward | (f) Article | |
| Constant | -0.464 | -0.310 | -0.434 | -0.448 | -0.438 | -0.456 | -0.548 | -0.401 |
| | *-1.644* | *-1.097* | *-1.544* | *-1.598* | *-1.563* | *-1.632* | *-1.910* | *-1.376* |
| ln_mtb | -0.091 | -0.086 | -0.082 | -0.087 | -0.091 | -0.095 | -0.089 | -0.079 |
| | *-3.613* | *-3.455* | *-3.241* | *-3.383* | *-3.534* | *-3.718* | *-3.551* | *-3.103* |
| ln_size | 0.032 | 0.022 | 0.028 | 0.029 | 0.030 | 0.032 | 0.036 | 0.026 |
| | *2.010* | *1.360* | *1.718* | *1.826* | *1.892* | *1.988* | *2.223* | *1.536* |
| d_hotissue | 0.057 | 0.062 | 0.068 | 0.064 | 0.059 | 0.061 | 0.063 | 0.068 |
| | *2.098* | *2.391* | *2.616* | *2.444* | *2.178* | *2.228* | *2.317* | *2.617* |
| Patent | | 0.001 | | | | | | 0.001 |
| | | *5.152* | | | | | | *3.298* |
| IPC | | | 0.025 | | | | | 0.018 |
| | | | *5.437* | | | | | *1.657* |
| Family | | | | 0.019 | | | | 0.000 |
| | | | | *3.893* | | | | *-0.025* |
| Forwards | | | | | 0.015 | | | -0.009 |
| | | | | | *1.001* | | | *-0.577* |
| Backwards | | | | | | 0.013 | | -0.006 |
| | | | | | | *1.373* | | *-0.640* |
| Article | | | | | | | 0.370 | 0.213 |
| | | | | | | | *1.907* | *1.407* |
| adj. $R^2$ | 0.048 | 0.116 | 0.121 | 0.102 | 0.056 | 0.054 | 0.065 | 0.132 |
| N | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |