The relation between innovation and stock market return: an event study on patents publication in the Automotive & Aerospace industries

Bachelor Thesis
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Abstract

This bachelor thesis examines the effects of innovation activities on the value of publicly traded firms. The main focus is on the automotive and aerospace industries in Europe during the period 2009-2014. Patent publications serve as a proxy for innovation activities. According to current literature it is still unclear what the true value of patents is. This thesis contributes to existing literature through examination of market reaction. It seems that there is no significant reaction to patent publication by automotive and aerospace firms. Furthermore, the results show that there is no difference in appreciation among these industries.

Keywords: Automotive, Aerospace, Innovation, Market Value, Patents

"Mark my word. A combination airplane and motorcar is coming. You may smile. But it will come."

Henry Ford (Founder of Ford Motor Company, 1863 – 1947)

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1 Introduction

Innovation can be defined as means of improving the performance of a company. For example, through the development of new products and services a firm can create higher productivity, which leads to greater profit margins and thereby to an increase in their own competitiveness. Innovation does not only play an important role on micro-level, but also on macro-level. It raises competitiveness between countries because policy makers try to create a landscape where innovation is stimulated.

One of the industries where innovation is playing a key role is the automotive industry. Within this sector there seems to be a transition from being the traditional mechanically based industry towards a more software-based business. Car companies are busy with the development of the next generation of vehicles that is a better fit for our modern society. According to the latest Thomson Reuters innovation data and the worldwide patent fillings records, the automotive industry belongs to the top twelve innovative technology sectors (Thomson Reuters, 2015). It is considered as one of the most attractive innovative industries in the world.

Since the beginning when the first automobile was invented, some already speculated about flying cars. While it still seems a long ride to the mass-production of flying cars, the automotive industry has changed a lot through innovation. Not only the automotive industry but also other sectors experience rapid changes through innovative activities.

Innovation is a complex and intensive process made from lots of different activities. Patents are often referred to as a proxy indicator for innovation (Kleinknecht, 2000). A patent can be seen as the exclusive right to the inventor that created something new and useful. In other words, patents are the monopoly right given by the national or intergovernmental patent office to something that offers a new product, solution or process. For example, new innovative designs in the aerospace industry that result in lower carbon emission or the development of new technology that is used in the computer hardware for vehicles.

Past studies indicate that patents bring additional value to the issuing company. However, the relationship between patents and stock market reaction has not been supported unambiguously by empirical work, which suggests that there is a need for further research in this particular field. Therefore, this research focuses on whether innovative activities of companies are appreciated in the stock market. Various studies report the weakness of patents as instrument to protect innovation (Arundel, 2003). However, there still seems to be a growing number of patent applications. This is the so-called 'patent paradox' (Hall, Thoma, & Torrisi, 2007). The paradox makes it even more interesting to research whether or not the stock market appreciates the growing number of patents. Next to that, the need to value patents in the right way has been increased through the fact that patents are being exchanged more often between companies. Companies see Intellectual Property Rights as corporate assets and use intellectual properties as collateral for secured financing (Nguyen, 2008).

1.1 Research question

This bachelor thesis researches the relationship between innovative activities and the reaction on stock market, where patents publications are used as a proxy indicator for the innovativeness of firms. In order to examine if patents publications lead to a higher share price this research focuses on companies in the automotive industry and aerospace industry in Europe.

The research question is as follows: "How does the stock market reacts to innovation activities, measured by patent publications, in the automotive and aerospace industry in the period 2009-2014 in Europe."

It is reasonable to assume that granted patents positively affect firm performance. Firstly, patent output can be a positive signal to the market because higher sales volume and profits are expected (Ernst, 2001). Secondly, patents granted might prevent smaller potential competitors from entering the relevant market. Thirdly, patents can be used to create larger patent portfolios. These are especially useful for strategically purposes (Blind et al. 2006). Therefore, the first hypothesis will be:

H1: patents have a positive effect on the issuing firm's stock price.

1.2 Motivation for the particular research question

Past studies have researched the relationship of patents and firm performance. Those mainly examined the relationship between patents and expected firm performance in patent sensitive industries. An example is the study of Narin and Noma, where patents issued in the U.S. pharmaceutical sector seem to have a strong correlation with an increase in profits (Narin and Noma,1987). It is interesting to see whether European patents are valued in industries that are less patent sensitive with the proof of stock market data.

The industries of interest for this thesis are the automotive and aerospace industries. Justification for this choice is twofold. Firstly, both industries serve as a good sample to examine the relationship between innovation and stock market return. Automotive and aerospace industries are the two major mature manufacturing industries and throughout the last decades both industries have drastically evolved in terms of product performance and technology input. Both industries have to comply with strict regulations, which puts constraints on their ability to innovate. Nevertheless, both the automotive and the aerospace industries invest a lot of their resources in R&D and can thus be considered very innovative industries. Secondly, they are not as similar as might seem, which gives perspective on an insightful comparison. The automotive industry is considered as the largest private investor in R&D in Europe. The automotive industry recently doubled its amount of patents fillings worldwide (Thomson

Reuters, 2015). Stronger put, in the period 2009-2014 there were twice as much patents published in the automotive industry than in the aerospace industry. That is why this particular time period is chosen. The efficient market hypothesis states that market expectations are reflected in stock prices (Basu, 1977). This means that investors react differently to the publication of a new patent in an industry with a history of many patent publications compared to the publication of a new patent in an industry that has experienced fewer publications. Thus the second hypothesis states:

H2 There is a difference in appreciation of patents between the automotive industry and the aerospace industry.

1.3 Research methodology

There are several ways to examine the impact of patents on stock prices. When there is new information available through for example new patent publications, the stock market immediately adjusts itself. By looking at the reaction of the security's price to the publication of new patents, one can examine if investors and analysts appreciate patents. With an event study, the main goal is to look at differences between the returns that would have been expected if the analysed event had not taken place and the returns that are caused by the specific event. In the academic world this methodology is well known for measuring price reaction of stocks and market securities to specific events e.g. earnings announcement (Fama et al., 1969). The specific event date in this paper is the date of publication of the patent. By choosing the methodology of the event study this paper only captures the effects of patents publications and their reaction measured in the financial market. Event studies are often used for testing market efficiency and the finance theory indicates that if the financial markets are efficient, than there should be an immediate reaction to the event on the date of announcement. In addition to the event study, a regression analyses is conducted to find out what factors influence the reaction in stock price.

1.4 Required data and sources

This paper requires a quantitative analysis of data. To perform the event study and regression analysis, different sources of information are used. First of all, the information on publications of patents by firms in the automotive and aerospace industries is needed. This data is acquired from the European Patent Office. Thereby the date of publication on the EPO database serves as the event date. Secondly, stock data on every firm that issued patents in this industry is needed; this is derived from DataStream. When all the data is acquired, the event study tool from the Erasmus University data team is used to perform the event study. Next to that, the computer program SPSS is used to perform the regressions analysis.

1.5 Outline

The outline of this thesis is as follows: Chapter 2 provides an overview on the theoretical background of patents and the previous literature in this particularly field. In chapter 3, the method of an event study is more thoroughly explained. Chapter 4 covers the data section, in which the sample of firms for this research is presented and further data sources to conduct this research are discussed. Thereafter, in chapter 5, the results are analysed. Chapter 6 states a conclusion to the research question and indicates limitations of this study and suggestions for further research.

2 Literature review

This section presents the relevant information on patents and academic literature on patent performance. Firstly, the application process for a European patent is explained. This literature review continues by discussing the patent paradox and managerial incentives that could lead to patent fillings. Since innovation of firms is difficult to measure in absolute terms, past literature can give more insight about the measurement of innovation. Lastly, past studies in the field of patent valuation are evaluated.

2.1 Criteria of applying for an European patent

The very first patent granted in Europe was in Middle Ages (Fisher, 2016). Since 1421 patents encourage innovation by individuals or companies through offering them the exclusive right of using the patented invention. Nowadays, applying for patents is a legal process at the national or intergovernmental patent office (e.g. European Patent Office). European patents are published as soon as possible after the expiry of eighteen months from the date of filing or the earliest priority date. Patents publication are mentioned in the European Patent Bulletin and published on the EPO's publication server where the information contains an abstract, the description and any drawings of the patents (European Patent Office, 2016). According to the European Patent Office (EPO) an invention is only patentable if it match the following criteria:

- *The invention has to be new*
- *Distinguished by an invented step*
- *Capable of industrial application*

Article 54 of the European Patent Convention (EPC) states that the information of the patented invention must not already be disclosed at a previous date. According the European patent law, patents must contain an inventive step. This has to be a non-obvious step that one person in any related field of the invention shall not be able to derive at unless he acquired special insights. On top of that, the patentable subject or invention needs to be physically possible to make. Furthermore, it is good to know that not all innovative techniques can be protected with patents. Inventions that are offensive, immoral or anti-social are not patentable. Also, it is worth mentioning that patents should not be confused with other kinds of Intellectual Property Rights. Trademarks for example, do not necessarily have to have the same objective as patents. Trademarks can be described as a characteristic or distinctive sign that someone uses to identify the brand, product or service. Another Intellectual Property Right that is easily confused with patents is copyright. Copyright protects against unauthorised copying of artistic works. The difference between patents and copyrights can be made clear by the following example. Patents are not used to protect computer software, but these are protected by copyrights. However, when software is an invention that is implemented in hardware (e.g. a new system on the computer), it is patentable.

2.2 Patent paradox

One of the goals of this research is to give a further explanation of the 'patent paradox'. The paradox highlights the counterintuitive fact that there still is an increase in the number of patent applications at the European Patent Office, despite the fact that patents are actually a fairly weak means of protecting innovation (Cohen et al., 2000; Arundel, 2003). The increase in applications suggests patents have value. This would be the case if managers take into account the total costs, when deciding on whether or not to file a patent. Managers would only apply for patents with potential to generate future cash flows higher than €5.710, which is the total cost of a successful application process (European Patent Office, 2016). However, managerial incentives can be designed to push innovation. In such a case, the number of patent fillings is used as proxy to measure managerial performance. This indicates that patent fillings do not necessarily have value, since the above-mentioned financial trade-off is a lesser concern for the managers; since their performance bonus is solely based on the amount of patents filed, the associated costs become a side-concern. Managerial incentives for patent filling are empirically verified by Bill et al. (2011). They highlight that after controlling for specific firm characteristics, managerial incentives matter when it comes to patent applications. Thus it is worth noticing that the economic value of patents cannot be assessed without being aware of the managerial incentives and processes that contribute to the patent filing process.

2.3 Patents as proxy for innovation

Innovation seems to be a key factor in the growth opportunities of firms, but it can also have substantial impact on the whole economic structure of the industry (Schumpeter, 1942). The innovativeness of firms is measurable in different ways, for example through R&D expenses or through patent count. This thesis uses the patent output as a proxy of innovation. That patents reflect inventive activity is a well-known assumption in the academic world. According to academic literature the very first use of patents in studies with statistical analyses goes back to more than sixty years ago (Schmookler, 1951). The research conducted by Schmookler can be seen as the starting point that examines patents inventive activity and its relationship to economic growth. A well-known study in the field of patents found that there is a significant relationship between the market value and past R&D expenditures for American companies. The same research also found that the relation exist with the number of patents (Griliches, 1981). Most of the studies related to patents and innovation use patent count as a proxy for R&D output or the technological activity of firms (Griliches, 1981; Hirschey, 1982; Jaffe, 1986; Hall, 1993). Patent data is widely used in academic literature and over time it has become an acknowledged manner to evaluate the innovation output for firms.

2.4 Value of patents

In order to assess the economic value of patents, some studies examine the financial performance of companies. Empirical finding suggests that patents are not only signs of the research productivity of firms, but also an indicator that promises future economic benefits. An American research paper presents that almost 75% of all patents were assumed to have economic importance. Paradoxically, the same paper concludes that only less than 57% of the patents were actually in use (Sandor 1971). In line with this, an European study presents that on average 36% of the European patents are never used for commercial purposes (Gambardella, 2005). Past studies show that the distribution of patent value is skewed. The large majority of patents seems to have limited value (Harhoff et al. 1999). In line with other studies, Scherer & Harhoff find that in their sample the top 10% of patents account for 80-90% of the returns (Scherer & Harhoff, 2000). There seems to be differences in patents that are commercially used by companies and those that are not exploited. The explanation for this phenomenon might be that some patents are the basis for a new product or the development of changes for the whole industry, while others are only small improvements (Hall, Jaffe & Trajtenberg, 2005). This can easily lead to different values for each individual patent. To have a better insight in the performance of patents, indicators as patent quality are useful to deal with the difficulty that one patent might be more valuable than the other (Ernst, 2001). Patent citations measure the patent importance of each patent (Trajtenberg, 1990). Pakes and Schankerman (1984, 1986) have developed a model to measure the patent quality. According to a research done by Bloom & Van Reenen, patents that are frequently cited seem to be more innovative (Bloom & Van Reenen, 2002). Also, other studies for example find that the quality of patents is positively associated with the stock price of companies (Lanjouw & Schankerman, 2004). Other scholars like Raghu et al. use citations as an indicator for firm's growth potential (Raghu et al., 2008). When the methodology of past studies is examined, the most popular methodology in describing the relationship of patent with market value seems to be the regression model instead of an event study. Table 1 provides an overview of previous studies that describe the relationship between market value and patents (Czarnitzki, Hall & Oriani, 2005). Furthermore, there are a couple studies focusing on the relation between patenting and market value for European firms (Blundell et al., 1995; Toivanen et al., 2002; Bloom and Van Reenen, 2002; Greenhalgh and Rogers, 2006; Hall and Oriani, 2006; Hall et. al., 2007). When looking at industry specific results, Ernst shows that for German manufacturing firms patent applications lead to higher sales volume (Ernst, 2001). The following studies about industry are all suggesting that patents contain positive value. Raghu argues that for some specific sectors, the stock price performance where positively correlated with patent citations (Raghu et al., 2008). For firms in the IT industry Hall described that the market value are higher for companies with software patents compared those companies without software patents (Hall and MacGarvie, 2010). Another very interesting study that is definitely worth mentioning suggests that firms strategically disclose patent information (Lansford, 2005).

With the use of strategic patent disclosures companies could manage the response of the stock prices. Through disclosing newly issued patents just before a negative earnings announcement is expected, the market reaction to this particular negative event of earnings announcement will be weaker and damped by disclosing positive news about patents.

Study	Dependent variable	Patent Coefficient (Std. err)	Sample characteristics (country, no. of firms, years, data sources)
Griliches (1981)	log Q	Pat/assets: 10-25?	US, 157 firms, 1968-1974, Compustat and USPTO
Ben-Zion (1984)	log V	Pat/assets: 0.065 (0.055)	US, 93 firms, 1969-1977, Compustat and USPTO
Connolly *et al.* (1986)	Value/sales	Pat/sales: 4.4 (0.6)	US, 376 firms, 1977, Compustat and Fortune Magazine, USPTO
Cockburn and Griliches (1988)	log Q	Pat stk/assets: 0.11 (.09)	US, 722 firms, 1980, Compustat and USPTO
Connolly and Hirschey (1988)	Value/sales	Pat/sales: 5.7 (0.5)	US, 390 firms, 1977, Compustat and Fortune Magazine, USPTO
Megna and Klock (1993)	Q	Pat stk: 0.38 (0.2)	US semiconductor, 11 firms, 1972-1990, Compustat and USPTO
Blundell *et al.* (1995)	log V	Pat stk/R&D stk: 1.93 (0.93)	UK, 340 firms, 1972-1982, LBS Share Price database and Datastream, NBER patent database
Shane and Klock (1987)	log Q	Pat/assets: -0.41 (.25) Cites/assets: .012 (.005)	US semiconductor, 11 firms, 1977-1990, Compustat and CHI Research
Haneda and Odagiri (1998)	log Q	Pat stk elasticity: ~0.3	Japan, 90 firms, 1981-1991, NEEDS database
Deng *et al.* (1999)	Q	Pat elasticity: .007 Cite elasticity: .165	US, 411 firms, 1985-1995, Compustat and CHI Research
Hirschey and Richardson (2001)	V/A	Pat/assets: 2.8 (0.2) US ~0 Japan	US, 256 firms, 1989-1995, Compustat and CHI Research Japan, 184 firms, 1989-1995, not given
Bloom and Van Reenen (2002)	log Q	Pat stk elasticity: 0.08 (.03) Cite stk elasticity: 0.12 (.03)	UK, 172 firms, 1969-1994, Datastream and NBER patent database
Toivanen *et al.* (2002)	log V	Pat/assets insignificant	UK, 877 firms, 1989-1995, Extel financial company analysis
Hall *et al.* (2005)	log Q	Pat/assets: .607 (.042) Cite stk/assets : .108 (.006)	US, 4800 firms, 1965-1995, Compustat

Table 1. An overview of previous studies and their methodology is given (retrieved from Czarnitzki, Hall & Oriani (2005))

3 Methodology

This chapter explains the research approach of the study in more detail. Since most of the papers discussed in the literature overview use a different methodology in describing the relationship of patents with market value (e.g. survey based or regression), the event study is explained in more detail. Next to that, different test-statistics are discussed. Furthermore, the regressions analysis is explained.

3.1 The event study approach

In general the corporate finance literature suggests that stock prices reflect all information that is publicly and sometime privately available, and expectations about the firm's prospects in the future. With an event study one can investigate the influence of a particular event (MacKinlay, 1997). In other words, the event study methodology is typically used to examine the return for a sample of firms that are all experiencing a common event (e.g. patent publication). According to Bloom & Van Reenen the market values are immediately affected from the date the patent is granted (Bloom & Van Reenen, 2002). Before the event study can be performed, the events of interest have to be defined. The event of interest in this paper is the date that the patent is granted by the European Patent Office. Next to the event date an event window needs to be defined to successfully perform an event study. The event window is the period over which the stock prices of the firms are examined. There are several rules for determining the length of an event window (MacKinlay, 1997). Generally, the event window consists of multiple days around the event date in order to capture the complete effect of the event. With a window of multiple days, one has a bigger chance of capturing the effect of information that has leaked before the actual announcement and the closing day fluctuations in price. The most common event window in academic papers is a three-day event window with start date one day before the event (t_1=−1) and end date at one day after the particular event (t_2=+1). In this paper the following event windows are examined: [-1+1] [-3+3] [0+1] and [0+3]. Within the event study there is the statistical analysis where the study calculates the returns that would have been observed if the specific event had not taken place. These returns are then compared to the returns that are actually realized in the event window, in order to examine whether the returns are abnormal (MacKinlay, 1997). One of the most common ways to estimate the normal return is the use of the market model. This model directly estimates the relation between the return on firm X and the return on the market.

$$R_{Xt} = \alpha_X + \beta_X R_{mt} + \varepsilon_{Xt} \ (1)$$

In the above formula R_{Xt} is the return on stock X at time t and R_{mt} is the return on the market portfolio at time t [1]. To estimate the abnormal return (AR) for a specific firm X, the relation between the actual returns and predicted returns is calculated with the following formula.

$$AR_{it} = R_{xt} - \hat{\alpha}_x - \widehat{\beta_x} R_{mt} \ (2)$$

Besides the market model mentioned in the above formula, the mean adjusted return model is used to check for robustness. The main difference between the mean adjusted and market model return is that by the mean adjusted model the abnormal returns are calculated as deviation from the stock's own average return. MacKinlay (1997) shows that the mean adjusted method is less sophisticated but often leads to the same result as the market model. In order to capture the total effects of patents publications the cumulative abnormal returns (CAR) are estimated. CAR is the sum of the abnormal returns for a specific firm in the whole period. For a three-day event window of [-1,1] CAR for firm X is denoted as follows:

$$CAR_{-1,1} = \sum_{t=-1}^{t=+1} AR_{x,t} \ (3)$$

The focus of this bachelor thesis is not the individual effect of patents on stock returns for a single firm, but the total effect for all European automotive firms

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[1] The parameter alfa and beta (α_X , β_X) assess the relation between the stock and the market portfolio. Since we are using the market model the parameters α_X *and* β_X are both estimated with OLS regressions, were the residual is noted as ε_{Xt}. In this bachelor thesis the residual is assumed to be normally distributed for both the prediction and control period and that there is none correlation between residuals over time.

and aerospace companies. Therefore the total effect of patents on stock prices is estimated. This is done with the average abnormal return (AAR) across all firms.

$$AAR = \frac{1}{N}\sum_{x=0}^{N} AR_{x,t} \quad (4)$$

Since there are multiple observations of one event type for all firms, the cumulative average abnormal returns (CAARs) are calculated to capture the total impact of the multiple observations over the whole time period with the following formula:

$$CAAR_t = \sum_{t=0}^{t} AAR_t \quad (5)$$

3.2 Parametric test statistics

With the use of different test statistics, the calculated CARs and CAARs are examined in order to see if they are significantly different from zero. The Z-test statistic assumes that the cumulative abnormal returns follow a normal distribution. According to the central limit theorem, this assumption holds when the sample size is sufficiently large. Since the use of the Z-statistic requires compliance with a set of strong assumptions, T-tests are used as well. Since the assumptions for these kinds of tests are less strong, they might give a more realistic representation of the significance of results.

$$t_{student\ t-test} = \frac{CAR}{SE\ (CAR)} \quad (6)$$

$$t_{sample\ one} = \frac{CAAR}{\frac{SE\ (CAAR)}{\sqrt{N}}} \quad (7)$$

An assumption of the standardized t-test is that the cumulative abnormal returns (CAR) of the individual firms in the sample are normally distributed. Furthermore, it is important to notice that the original student t-test is not designed for event studies. That is why other parametric test statistics are also conducted in this bachelor thesis. Brown & Warner and MacKinlay developed test statistics especially designed for event studies (Brown & Warner, 1985; MacKinlay, 1997). The Brown and Warner test statistics is particularly useful in short-run event studies.

$$t_{Brown\ and\ Warner} = \frac{CAAR}{SE\left(AAR_{t+l,t+k}\right)} \quad (8)$$

$$t_{MacKinlay} = \frac{CAAR}{\frac{SE\left(AAR_{t+l,t+k}\right)}{\sqrt{l+|k|}}} \quad (9)$$

3.3 Non parametric test statistics

Brown & Warner found that daily returns differ from normality (Brown & Warner, 1985). Therefore non-parametric tests are recommended for robustness against non-normally distributed data. The advantage of non-parametric tests is that they also identify small levels of abnormal returns. The sign test is often applied in event studies. In this paper the general binominal sign test is performed.

$$t_{sign\ test} = \sqrt{N}\left(\frac{\hat{p}-p}{\sqrt{p(1-p)}}\right) \quad (10)$$

The parameter $\hat{p}$ captures the ratio of positive cumulative abnormal returns. Under normal circumstances this parameter should not significantly differ from 0.5. In the research of Cowan, Nayar and Singh (1990) a complex version of the sign test is developed, which allows the null hypothesis to be different from 0.5. The modified approach by Cowan is known as the generalized sign test. In this test the number of stocks with positive abnormal returns is expected to be in line with the parameter $\hat{p}$ that estimates the average fraction of stocks with positive abnormal returns in the estimation period. The actual number of positive AR should be in line with the number expected from the estimated fraction.

$$t_{generalzed\ sign\ test} = \frac{(w-N\hat{p})}{\sqrt{N\hat{p}(1-\widehat{p)}}}\ with\ \hat{p} = \frac{1}{N}\sum_{t=1}^{N}\frac{1}{L_1}\sum_{t=T_0}^{T_1}\varphi_{i,t} \quad (11)$$

3.4 Parametric and non parametric test statistics for group samples

Hypothesis 2 of this bachelor thesis, as mentioned in the introduction, focuses on whether there are differences in appreciation between the two industries. In order to examine industry differences, test statistics for group testing are used. The extra parametric test statistic is called the paired two-sample t-test and tests for equality of means of the two samples. If the test statistics are significant it means that the groups are significantly different from each other. Formula (12) is used when the variances of both groups are not equal to each other, whereas formula (13) is applicable if the variances of the automotive industry are equal to the aerospace industry.

$$t_{two\ sample\ on\ equal\ means} = \frac{\bar{Y}_1 - \bar{Y}_2}{\sqrt{(s_1^2/n_1 + s_2^2/n_2)}} \quad (12)$$

$$t_{with\ equal\ variances} = \frac{\bar{Y}_1 - \bar{Y}_2}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (13)$$

$$with\ s_p^2 = \frac{(n_1 - 1)s_1 + (n_2 - 1)s_2}{n_1 + n_2 - 2}$$

Again, to check if the results of this test are robust, a non-parametric test is conducted. The non-parametric test statistics for group testing is called the Mann-Whitney U-test. As mentioned before the main benefit of non-parametric tests is that they are useful to conduct when the levels of abnormal returns are small. Another benefit is that this test corrects for non-normality of the data, which means there is no need to assume that the data is normally distributed. The difference between the paired two-sample t-test and the Mann-Whitney U-test is that the first one test for equal means, while the second test statistic tests for equality of medians.

$$Mann - Whitney\ _{U-test\ on\ equal\ medians} = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - \sum_{i=n_1+1}^{n_2} R_i \quad (14)$$

3.5 Regression analyses

The parametric and non-parametric test and measurement of the CAR around the event are used to either accept or reject the hypothesis. Assuming that there is a valuation change as a result of patent publication, a linear regression model is built. This allows for further examination of the variables that influences abnormal returns. This regression analysis is based on statistical methods that formulate the relationship between the dependent variable and the independent variables (Sykes, 1993). Different regressions are conducted. Dummy variables are included to check for industry differences and firm differences. The purpose of the regression analysis is twofold. First of all, it explains which factors influence the cumulative abnormal return (CAR). Secondly, the regression shows the relative magnitudes of these influences. It is important to notice that patent characteristics that are known after the publication date are not added to the regression model. This is done to counteract inconsistency with the event study methodology. The aim of this regression is to explain the CAR (e.g. market reaction). The market can only react to information available at that particular time. Therefore, measures of patent value that are not known ex-ante, such as the number of citations the patent will receive, cannot be used to properly explain the CARs around the publication date. The regression model is built using the following three factors:

- The firm that issued the patent (dummy)
- How much patents are issued
- To which sector the firm belongs (dummy)

In formula (16) the coefficients $\beta_1, \ldots, \beta_i$ represent the magnitude that the independent variables have on the dependent variable. With the use of SPSS these coefficients are estimated.

$$CAR_{i0} = \beta_0 + \beta_1 industry_i + \beta_2 patent\ counts_i + \beta_3 Dummy\ firm_i + \cdots + \beta_i Dummy\ firm_i + \varepsilon_i \quad (15)$$

CAR_{i0} = The cumulative abnormal return of stock i over the event period.

β_0 = A constant term

β_1 = The coefficient of $industry_i$

β_2 =The coefficient $patent\ counts_i$

$industry_i$ = Dummy variable that represents (1) if the firm is an aerospace company and (0) when it belongs to the automotive industry

$patent\ counts_i$ = Number of patent issued during the event date

$Dummy\ firm_i$ = A dummy variable where the value is (1) if the firm is $firm_i$ and for all other firms the value is (0)

ε_i = error term that reflects other factors that influence CAR_{i0}

4 Data

This chapter contains information about all the data sources that where used. Different information sources are used for the purpose to construct the database. Furthermore, an overview of the constructed database is given.

4.1 Constructing the data

First of all, the sample of representative firms is constructed. Different criteria have to be met in order to select the right sample. The first and foremost criterium is that stock prices can be obtained for the period of interest (2009-2014). Besides that, the firm has to operate in either the automotive or aerospace industry sector. In addition, the company has to posses a decent amount of European patents granted by the European Patent Office, of which the date of publication is known. Relevant patent data is retrieved from the "EPO Worldwide Patent Statistical Database" (PATSTAT). This is a well-known database that provides information about published patents collected from more than 81 patent authorities worldwide. Since the main focus of this research is the European market only patents issued by EPO where taken in account, in order to ensure that analyses are performed for a consistent and homogeneous patent system. The date of publication of patents mentioned in the PATSTAT database is considered as the event date. Financial data as daily historical stock prices of the companies of sample firms are collected from the DataStream database. The main reason for this specific database is because the Erasmus University data team made an event study tool in which this database can run event study analyses. The criteria mentioned above are cumulative. The final database consists of 5 automotive firms and 4 aerospace companies located registered at either the DAX, EuronextCAC40 or FTSE100 stock exchange market.

4.2 Data sample

Figure 1 presents the distribution of patents for each firm in the sample. During the period 2009-2014 the total amount of patents published by all the firms together is 2929 patents. This means that on average each company issued approximately 325 patents in the period 2009-2014. Automotive company

Renault is, with 518 patents, the firm with the most patents in this sample, where BAE System PLC only received for 91 patents in 5 years. The average amount of patents published in the automotive industry is 399 and in the aerospace industry on average 233 patents where published by each firm.

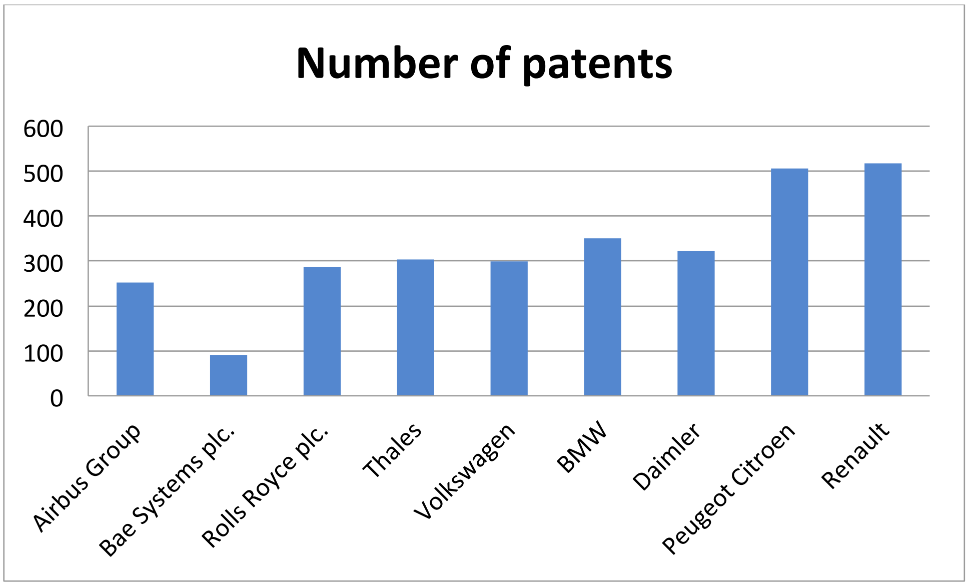

Figure 1. The final sample of all companies and the amount of patents is presented

In the event study all 2929 patents where examined. Of particular importance is that there during some days multiple patents where published. Therefore, the sample contains only 1520 individual event date. Mackinlay performed his event study with 600 event dates (MacKinlay, 1997). In this respect, this sample is fairly large and thus representative for the industries.

5 Results

This chapter presents and interprets the results of the event study and regression analyses [2]. The reaction of stock prices to the publication of new patents is examined. The following critical values for the Z-tests and t-tests are particular important: 1.645*, 1.960** and 2.576***. Throughout this chapter, the following indicators of significance are used

* significant at 10% level

** significant at 5% level

*** significant at 1% level

5.1 Results for parametric test

The results of the event study as mentioned in the methodology section are provided in this paragraph. In table 2 the total sample average abnormal returns (AARs) and cumulative average abnormal return (CAARs) are presented. The highest cumulative average abnormal return (CAAR) is reached at t = -1 and at t= +1 the effect seems to be negligible. The stock prices tend to have a stronger reaction in the days before the event date. All CAAR before t= 0 are relatively high (CAAR> 0.001) compared to the CAAR after t= 0. However, none of the Z - score is significantly different from zero. The same conclusion holds for the t-test on AAR. With a significance level of 10% all the t-statistic of AAR are lower than the critical t=1.645. Therefore the AARs are not significantly different from zero.

Event day	**AAR**	**CAAR**	**sAAR**	**AR t-test**	**Z-score CAAR**
-3	0,001	0,001	0,001	0,822	0,822
-2	-0,002	-0,001	0,002	-1,238	-0,581
-1	-0,001	-0,002	0,002	-0,545	-1,146
0	0,001	-0,001	0,001	0,961	-0,827
1	0,001	0,000	0,001	0,928	-0,039
2	0,001	0,001	0,001	0,787	0,748
3	-0,002	-0,001	0,002	-1,026	-0,704

Table 2. Event study results for the whole sample.

[2] The results of all the test statistics with the mean adjusted model are attached in the appendix

Table 3 presents the cumulative average abnormal returns (CAARs) and multiple parametric tests on the different event windows. Considering the student t-test the CAAR with event window [0+1] is significant at 10% significant level. This means that the market incorporates the information on patent publications in the prices at the moment of publication and one day after the publication. When this test is corrected for the number of firms the event window [0+1] is still significant, but now also at 1% significant level. All other values have also increased, but those are still insignificant. As already mentioned in the methodology section the standard t-test is not designed for event studies. For robustness MacKinlay test statistic and Brown and Warner t-test are also presented. With the corrections for event studies none of the test statistics are significantly different from zero.

Event window	**CAAR**	**StDev CAAR**	**Student t-test**	**Sample one**	**Brown Warner**	**Mac-Kinlay**
(-1+1)	0,001	0,002	0,429	1,287	0,521	0,903
(-3+3)	-0,001	0,005	-0,275	-0,826	-0,379	-1,002
(0+1)	0,002	0,001	1,722*	5,165***	0,887	1,254
(0+3)	0,000	0,002	0,193	0.580	0,138	0,276

Table 3. Event study results for event windows. Different t-values are presented (df>1000)

As mentioned in the methodology section the abnormal returns are checked for robustness. Besides the well-known market-model, the mean adjusted model is used to calculate the abnormal returns. The results with the mean adjusted model are presented in table 11, *see appendix A***.** The results between the two different models are quite similar to each other Again, the highest cumulative average abnormal return (CAAR) is reached at one day before the event date and at t= +1 the CAAR is the lowest. Also, the AAR is not significantly different from zero. These findings are in line with Brown and Warner (1985). They argue that both methods often lead to the same result. However, it is worth mentioning that with the mean adjusted model the CAAR of -0.002 at t= -1 is significantly different from zero with a 10% significant level. The Z-score at t= -1 is 1.941 it is higher than the critical z-value of 1.645. This means that the market reacts in significantly negative to the publication of patents on one day before the patent is issued.

Regarding the cumulative average abnormal return for the whole event window, almost the same results are found with the mean-adjusted model, *see table 12 in appendix A*. None of the student t-test are significantly different from zero. When the test is corrected for the number of companies both event window [-1+1] and [0+1] are significantly different from zero. However with the robustness check of Brown and Warner none of the results are significant. MacKinlay test statistics shows that event window [-1+1] is significantly different from zero at 1% significant level. Altogether, the mean adjusted model shows that there is no significant reaction on the event day itself, but that a significant positive reaction to the event is achieved during the three-day event window.

5.2 Results for non-parametric test

Table 4 summarizes the results of the non-parametric test. The advantage of non-parametric test as mentioned before is that they identify small levels of abnormal returns. Considering the sign test on the event dates -3,-2,-1 and +3 significantly less positive abnormal returns are received then what should be normal. The same conclusion holds when the sign test is corrected for the chance on a positive abnormal returns based on the estimation period.

Event day	**Positive AR**	**% positive AR**	**% positive AR in estimation period**	**Z-score sign test**	**Z-score generalized sign test**
-3	798	52,5%	49,7%	1,949*	2,192**
-2	703	46,3%	49,7%	-2,924***	-2,681***
-1	711	46,8%	49,7%	-2,514**	-2,271**
0	779	51,3%	49,7%	0,975	1,218
1	761	50,1%	49,7%	0,051	0,294
2	771	50,7%	49,7%	0,564	0,807
3	706	46,4%	49,7%	-2,770***	-2,527**

Table 4. Non-parametric sign-test

When the non-parametric tests are performed, with the mean-adjusted model, slightly different results are obtained. Table 13 gives an overview of these results, *see appendix A*. Only on two days before and three days after the event date (t=-2 and t=+3) significant negative test statistics are obtained. This means that the reaction of the market is mainly negative on these days.

5.3 Results for parametric test on groups

The second hypothesis states that there is a difference in appreciation of patents between the automotive industry and the aerospace industry. Table 5 gives an overview of the AAR and CAAR for the different groups. For aerospace companies the highest CAAR (0.002) is reached at the day of the publication. It seems that the reaction to the event is delayed for automotive companies. The highest CAAR (0.006) is reached three days after the patent is published. Overall, the CAARs for automotive industry for each day are higher than for firms operating in the aerospace industry. This could indicate that the second hypothesis is true. However, the test statistics for CAAR gives a mix result. When also the individual AARs are taken into account then only at t=-2 the CAAR and AAR of the automotive industry is significantly different from zero, while aerospace firms are not different from zero.

In order to find out if the individual AAR and CAAR are also significant on the whole event window table 6 is presented. An overview of multiple test statistics is given for both groups. It is important to notice that even after the t-values are corrected for event studies some values are still significant. This is remarkable. When the whole sample was corrected for robustness none of the values were significant, see table 3**.** The grouped samples present significant effects. This is especially true for the MacKinlay t-statistics. In the event window [0+1] the CAAR for aerospace companies are significantly different from zero for all test statistics. Combined with the findings of table 5 it means that effect of patent publication on aerospace firms does not take place directly on the event date. Apparently the market needs one day to correct itself. When the automotive companies are examined only the CAAR for event window [-1+1] are significant.

Event Day	Sample	AAR	CAAR	sAAR	AAR t-test	Z-score CAAR
-3	Aerospace	0.000	0.000	0.001	0.229	0.239
	Automotive	0.000	0.000	0.003	0.068	0.068
-2	Aerospace	-0.001	-0.000	0.001	-1.015	-0.590
	Automotive	-0.003	-0.003	0.001	-2.708***	-2.535**
-1	Aerospace	-0.000	-0.001	0.000	-0.955	-1.977**
	Automotive	-0.000	-0.003	0.002	-0.135	-1.230
0	Aerospace	0.001	0.002	0.001	1.448	0.315
	Automotive	0.001	-0.002	0.003	0.255	-0.652
1	Aerospace	0.001	0.001	0.001	0.509	0.725
	Automotive	0.001	-0.001	0.001	1.374	-2.122**
2	Aerospace	0.000	0.001	0.000	0.484	3.047***
	Automotive	-0.001	-0.003	0.003	-0.464	-0.936
3	Aerospace	-0.000	0.001	0.001	-0.360	0.505
	Automotive	-0.003	-0.006	0.003	-1.169	-2.109**

Table 5. Event study results for grouped samples.

Event window	Sample	CAAR	StDev CAAR	Student t-test	Sample one	T-test brown	Mac Kinlay
(-1+1)	Aero-space	0.001	0.000	6.100***	12.199***	0.936	1.621
	Auto-motive	0.002	0.003	0.562	1.123	1.364	2.363**
(-3+3)	Aero-space	0.001	0.000	1.639	3.279***	0.324	0.857
	Auto-motive	- 0.001	0.005	-0.115	-0.231	-0.126	-0.335
(0+1)	Aero-space	0.002	0.000	4.813***	9.627***	1.812*	2.563**
	Auto-motive	0.002	0.002	1.382	2.763***	0.970	1.372
(0+3)	Aero-space	0.001	0.001	1.081	2.161**	1.092	2.185**
	Auto-motive	0.001	0.002	0.321	0.641	0.245	0.491

Table 6. Event study results for grouped samples on event windows.

The results with the mean adjusted model are presented in table 14, *see appendix B*. The most important findings are that the CAAR for event day (t=-1) are still significant for the aerospace industry. On top of that also the AAR-test are significant at 1% significant level. Therefore the conclusion is that on one day before the publication (t=-1) for all aerospace companies in the sample the abnormal returns are significantly different from zero. It seems that the reaction to the publication of patents is one day before the event day. An explanation could be that on that day information about the patent is leaked.

When the mean-adjusted model is used to calculate the abnormal returns, the results are very interesting, that is why this table is not shown in the appendix but in the main text. Table 7 shows significant results for both groups. First of all, the CAAR for aerospace companies in the event window [-1+1]. This CAAR (0.001) is significantly different from zero for all test statistics. In this window also the t-values for automotive firms are significantly different. The main reaction of the market to the event does not take place on the event date itself but in the days around the publication. Next to that, the CAAR in the event window [0+1] for automotive firms are significantly different from zero even for t-statistics that correct for event studies.

Event window	Sample	CAAR	StDev CAAR	Student t-test	Sample one	T-test brown	Mac Kinlay
(-1+1)	Aero-space	0.001	0.000	6.714 ***	20.143 ***	1.980 **	3.430 ***
	Auto-motive	0.002	0.003	0.841	2.522 **	10.584 ***	18.333 ***
(-3+3)	Aero-space	-0.001	0.000	-1.673	-5.020 ***	-0.238	-0.630
	Auto-motive	-0.003	0.011	-0.263	-0.790	-1.174	-3.105 ***
(0+1)	Aero-space	0.001	0.000	2.504	7.513 ***	0.409	0.578
	Auto-motive	0.002	0.001	1.960	5.880 ***	1.722 *	2.436 **
(0+3)	Aero-space	0.000	0.001	0.086	0.258	0.047	0.094
	Auto-motive	-0.002	0.006	-0.292	-0.875	-1.028	-2.056 *

Table 7. Event study results for grouped samples on event windows where the daily (cumulative) abnormal returns are calculated using the mean adjusted model.

5.4 Results for equality of means and median test

With the t-test on equality of means the two samples are compared to see whether there are differences in CARs for each event window between the two groups. The results of this specific test are summarized in table 8. Before the CARs of the two groups can be compared the Levene's test for equal variances is conducted. The outcome of this test shows that for all event windows the variances are not equal between the groups. When the t-test on equality of means for unequal variances is conducted the results shows that none of the t-values are significant. This means that the mean of the CARs does not differ for the two groups. There are no significant differences in the reaction to publications of patents between the automotive firms and aerospace companies based on the equality of means test.

Event window	Sample	Mean	StDev	Levene's F-test (significance)	T-statistic (significance)
(-1+1)	Aerospace	0,001	0,024	27,149	-0,268
	Automotive	0,002	0,033	(0,000)	(0,789)
(-3+3)	Aerospace	0,001	0,035	43,973	0,346
	Automotive	0,000	0,056	(0,000)	(0,729)
(0+1)	Aerospace	0,001	0,022	17,459	-0,581
	Automotive	0,002	0,028	(0,000)	(0,562)
(0+3)	Aerospace	0,001	0,027	45,122	0,077
	Automotive	0,001	0,043	(0,000)	(0,938)

Table 8. Group sample t-test on equality of mean.

Next to the group test for equality of means a non-parametric test on equality of medians is performed to check if the results are robust. The results of this test, also called the Mann-Whitney U-test, are presented in table 9. The results of the Mann-Whitney U-test show that none of the z-values are significant. This means that the medians on all event windows do not differ for the two groups. These results are consistent with the test on equality of means, see table 8. So there are no significant differences in the reaction to publications of patents between the automotive firms and aerospace companies.

Event window	Sample	Mean rank	Sum of the ranks	Mann-Whitney U	Z statistic (significance)
(-1+1)	Aerospace	765.06	427667.00	266052.00	-0.309
	Automotive	757.85	728293.00		0.758
(-3+3)	Aerospace	770.79	430874.00	262845.00	-0.697
	Automotive	754.51	725086.00		0.486
(0+1)	Aerospace	769.08	429913.00	263806.00	-0.581
	Automotive	755.51	726047.00		0.561
(0+3)	Aerospace	779.08	435507.00	258212.00	-1.259
	Automotive	749.69	720453.00		0.208

Table 9. Mann-Whitney test on equality of medians for CARs

5.5 Results of the regression analysis

The cumulative abnormal return (CAR) as calculated in the event study represents the difference between the estimated and realized return on company stock during the event window. As described in the methodology section, the regression analysis is used to further examine the CAR. The analysis measures the impact that independent variables have on the cumulative abnormal return. The coefficient for every independent variable has been estimated multiple times with the use of different regressions. For example, the industry variable has been regressed in the simple regression alone with the dependent variable (CAR), but also in the multiple regression together with other independent variables, *see appendix C*. In both cases the coefficients are very small. The same small results were found with the other independent variables (amount of patent published and the firm that issued the patents).

In table 10 a regression with all independent variables is shown. The values of R Square (0.007) and the value of Adjusted R Square (-0.006) are very small. This number presents the percentage of variation that is explained by the model. Normally, regression models have high R Square and Adjusted R Square values. This does not mean that a model with low R Square is bad. A regression model with low R-squared can still give useful insights when statistically significant coefficient are involved. When the regression models are examined none of the coefficients seems to be significant. This means that the variation in CARs cannot be adequately explained by the number of patents, the industry or the firm. The dummy variable VOLKSWAGEN has the highest t-value (t=-1,037), however this is not significantly different from zero. The coefficients of all factors are very small and all the p values are greater than 0.10. Altogether, the regression analysis shows that all variables in the models are not related to the valuation change (CAR) of the company. This means that other factors influence the company cumulative abnormal returns. Thus, the cumulative abnormal returns are not influenced differently among the automotive industry and aerospace industry.

R square	Adjusted R square
0,007	-0,006

Coefficients	Value	t-value	Significance level*
(Constant)	0,003	0,402	0,688
Patent counts	-0,001	-0,410	0,682
Dummy_BAE SYSTEM	0,010	0,582	0,561
Dummy_ROLLS-ROYCE	-0,009	-0,879	0,380
Dummy_THALES	0,002	0,234	0,815
Dummy_VOLKSWAGEN	-0,010	-1,037	0,300
Dummy_BMW	-0,003	-0,297	0,767
Dummy_DAIMLER	-0,006	-0,533	0,594
Dummy_PEUGEOTCITROEN	0,002	0,260	0,795
Dummy_RENAULT	0,001	0,091	0,928

Table 10. Regression analysis with a linear regression model in the following form: $CAR_{i0} = \beta_0 + \beta_1 patent\ counts_i + \beta_{xi} Dummy\ firm_i + \cdots + \varepsilon_i$
*Significant level of 5%

6 Conclusion

This bachelor thesis measures the effects of innovation activities on the value of publicly traded firm in the automotive and aerospace industry. Innovation activities are measured with patent publications as proxy indicator. This paper contributes to existing literature with the reaction of investors to new patents with the use of the event study methodology. After excluding firms that do not have data available on the publication date of patents, a sample of 9 firms with in total 2920 patent publications was examined. The results show that the stock market does not value innovative activities when this is measured by patent publication. This chapter discusses the results regarding the two hypotheses. Thereafter a final conclusion on the whole study with its limitations is given.

6.1 Conclusion regarding hypothesis 1

Hypothesis 1 states that patents have a positive value on the firm stock price. Regarding the first hypothesis the results of the parametric and non-parametric test do not suggest a positive effect of patent publication on stock prices. The results of the test statistics were not robust when other models or t-test designed for event studies where performed. This indicates that the cumulative abnormal return (CAR) and cumulative average abnormal returns effects (CAAR) are not significantly different from zero. Based on both the parametric and non-parametric results there are no significant reaction to the publication of patents for all firms in the sample. An explanation could be that around the announcement date it is hard to estimate to the value of the patents. Investors might need more time to come up with the fair value of the published patents. This means that a longer event window is needed, however event studies are often limited in detecting long-term stock market performance (Brown & Warner, 1985). An explanation for the relative small cumulative average abnormal returns could be that investor expectations about patents are already incorporated in the stock prices. This means that the financial markets wont react to every single patent that is published and therefore no significant reaction is shown at the event date. Regarding the results of the regression patents has no significant impact on the CAR, which means that the cumulative abnormal return are influenced by other factors then patent publications. Thus, the first hypotheses can be rejected.

6.2 Conclusion regarding hypothesis 2

The second hypothesis is designed to measure differences between the automotive and aerospace industry. Both sectors are quite similar to each other and have drastically evolved in terms of product performance and technology input throughout the decades. According to the results of the test for groups it is worth mentioning that the outcomes are mixed. The test on equality of means and Mann-Whitney U test on equality of medians show that there are no differences between the groups, whereas the event study outcomes (see table 6 and table 7) indicate different significances of CARs among the group. However, since these differences in the event studies are not structural and robust for both models, one can conclude there is no real difference between the groups. The finding of statistically equal means and medians supports this. When the regression results are taken into account, the dummy variable Industry has no significant impact on the CAR either, which means that the cumulative abnormal return is influenced by other factors and that it does not matter whether the company is active in the automotive industry or the aerospace industry. Regarding the second hypothesis and based on the test results there are no significant differences in appreciation between the automotive and aerospace companies. This means that hypothesis 2 has to be rejected.

6.3 Conclusion to the research question

The main research question of this bachelor thesis is: "How does the stock market reacts to innovation activities, measured by patent publications, in the automotive and aerospace industry in the period 2009-2014 in Europe." This research was motivated by the uncertainties about the value of patents (Hall, Jaffe & Trajtenberg, 2005). More than 2900 patents publications are examined and the results are tested for robustness with different models and for different test- statistics. The results of this study indicate that the market does not react to the publication of patents, since values of ARs and CARs are very small and not significant. Moreover, the financial reaction to patent publications does not differ between the automotive industry and the aerospace industry.

The results of this research practically show an "enlarged" case of the parent paradox. The theoretical framework explains that managers often file for patents due to their incentives, not because those patents have the potential to generate actual economic value. The outcome of this thesis takes this reasoning a bit further. Even if the patents the managers file for are actually granted (which is only the case if the technology is new, un-obvious and applicable), they are not rewarded with an increase in market value of the firm. Taking this into account, managerial rewards based on patent activity are not in the best interest of the shareholders. The corporate world should thus use a certain precaution when adopting these kinds of reward mechanisms, to avoid (or even end) a patent bubble in which patents are mainly used by managers to receive higher bonuses, instead of reflecting the innovative capabilities of firms.

6.4 Shortcomings and suggestions for further research.

This thesis has several shortcomings. The first shortcoming is that a relative small sample is used to represent two whole industries. For example, only 9 listed companies are included. This sample is rather small to be representative for the whole automotive or aerospace industry. It would be interesting to perform the same analyses as in this thesis, but then which larger samples. Moreover, the analyses can be repeated for other industries. One can even analyse the matter not on an industry level, but on a country level. This would be interesting since there is not one authority that grants all patents.

The second shortcoming is that innovation activities are measured with only one proxy. Patens, as mentioned in paragraph 2.3, are an acknowledge manner to evaluate the innovation output, but calculating the stock returns to patent publication is not the same for innovation activity. An innovation activity is more than only patents. Therefore other factors like R&D input and patent fillings should be taken into account when innovation activities are measured. This circumvents the problem of the patent paradox as discussed in the previous subsection 6.3.

The third shortcoming is due to the fact that not every patent can be treated in the same way. Many patents only contribute to minor improvements while other patents are extremely innovative. A suggestion for further research is to construct an ex-ante proxy for the innovativeness of a particular patent, and then to see whether more innovative patents are rewarded with a larger increase in stock price. Furthermore, it might be interesting to find out whether there is a significant difference in patent appreciation between days on which a lot of patents publications take place and dates on which only one patent is granted.

Lastly, with respect to the regression analysis, a more advanced regression could be performed. A suggestion could be to investigate a non-linear relationship and adding other independent variables, if these are available and are ex-ante known by the market.

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Appendix A Results event study with mean adjusted model

Event day	AAR	CAAR	sAAR	AR t-test	Z-score CAAR
-3	0,001	0,001	0,002	0,312	0,312
-2	-0,003	-0,002	0,002	-1,305	-1,003
-1	0,000	-0,002	0,001	-0,096	-1,941*
0	0,001	-0,001	0,001	1,445	-0,862
1	0,000	0,000	0,001	0,430	-0,326
2	0,000	0,000	0,001	0,162	-0,169
3	-0,002	-0,002	0,002	-1,120	-1,224

Table 11. Daily (cumulative) abnormal returns are calculated using the mean adjusted model.

Event window	CAAR	StDev CAAR	Student t-test	Sample one	Brown Warner	Mac-Kinlay
(-1+1)	0,002	0,002	1,157	3,470***	1,459	2,527**
(-3+3)	-0,002	0,006	-0,377	-1,131	-0,578	-1,529
(0+1)	0,002	0,001	1,579	4,738***	0,915	1,294
(0+3)	0,000	0,003	-0,006	-0,019	-0,005	-0,011

Table 12. Cumulative abnormal returns are calculated with the use of the mean adjusted model. Different t-values are presented (df>1000)

Event day	Positive AR	% positive AR	% positive AR in estimation period	Z-score sign test	Z-score generalized sign test
-3	772	50,8%	49,7%	0,616	0,859
-2	691	45,5%	49,7%	-3,540***	-3,297***
-1	747	49,1%	49,7%	-0,667	-0,424
0	742	48,8%	49,7%	-0,923	-0,680
1	767	50,5%	49,7%	0,359	0,602
2	754	49,6%	49,7%	-0,308	-0,065
3	712	46,8%	49,7%	-2,462**	-2,219**

Table 13. Non-parametric sign-test with abnormal returns calculated by the mean adjusted model.

Appendix B Results for group samples with mean adjusted model

Event day	Sample	AAR	CAAR	sAAR	AR t-test	Z-score CAAR
-3	Aerospace	0.001	0.001	0.002	0.452	0.452
	Automotive	0.001	0.001	0.002	0.484	0.484
-2	Aerospace	-0.002	-0.001	0.001	-1.870*	-1.164
	Automotive	-0.002	-0.001	0.001	-1.244	-0.538
-1	Aerospace	0.001	-0.001	0.000	5.407***	-6.478***
	Automotive	0.000	0.000	0.000	1.230	-1.233
0	Aerospace	0.001	0.000	0.001	0.434	-0.106
	Automotive	0.000	0.000	0.001	0.337	0.049
1	Aerospace	0.000	0.000	0.002	-0.002	-0.093
	Automotive	0.001	0.001	0.002	0.382	0.422
2	Aerospace	0.000	0.000	0.000	-1.117	-2.648***
	Automotive	0.000	0.001	0.000	0.196	1.829
3	Aerospace	0.000	-0.001	0.001	-0.355	-0.591
	Automotive	0.000	0.000	0.001	-0.342	0.390

Table 14. Daily (cumulative) abnormal returns are calculated using the mean adjusted model.

Appendix C Results regression analysis

R square	Adjusted R square
0,000	0,001

Coefficients	Value	t-value	Significance level*
(Constant)	0,000	0,043	0,965
Industry	0,000	-0,137	0,891

Table 15. Regression analysis with a single linear regression of the following form: $CAR_{i0} = \beta_0 + \beta_1 industry_i + \varepsilon_i$
*Significant level of p< 0,05

R square	Adjusted R square
0,000	-0,003

Coefficients	Value	t-value	Significance level*
(Constant)	0,001	0,156	0,876
Industry	-0,001	-0,120	0,904
Patent counts	0,000	-0,168	0,867

Table 16. Regression analysis with a multiple regression of the following form: $CAR_{i0} = \beta_0 + \beta_1 industry_i + \beta_2 patent\ counts_i + \varepsilon_i$
*Significant level of p< 0,05

R square	Adjusted R square
0,000	-0,003

Coefficients	Value	t-value	Significance level*
(Constant)	0,001	0,106	0,916
Industry	-0,001	-0,127	0,899
Ln_patent counts	-0,001	-0,099	0,922

Table 17. Regression analysis with a multiple regression of the following form: $CAR_{i0} = \beta_0 + \beta_1 industry_i + \beta_2 Ln(patent\ counts)_i + \varepsilon_i$
*Significant level of p< 0,05

R square	Adjusted R square
0,007	-0,006

Coefficients	Value	t-value	Significance level*
(Constant)	0,003	0,358	0,720
Ln_patent counts	-0,002	-0,306	0,760
Dummy_BAE SYSTEM	0,010	0,585	0,382
Dummy_ROLLS-ROYCE	-0,009	-0,875	0,816
Dummy_VOLKSWAGEN	0,002	0,233	0,301
Dummy_BMW	-0,010	-1,034	0,767
Dummy_DAIMLER	-0,003	-0,296	0,596
Dummy_PEUGEOTCITROEN	0,002	0,531	0,803
Dummy_RENAULT	0,001	0,079	0,937

Table 18. Regression analysis with a multiple regression of the following form: $CAR_{i0} = \beta_0 + \beta_1 industry_i + \beta_2 \ln(patent\ counts)_i + \beta_3 Dummy\ firm_i + \cdots + \beta_{xi} Dummy\ firm_{xi} + \varepsilon_i$
*Significant level of p< 0,05