Stock price dynamics of Nordic pharmaceutical firms – An event study of scientific announcements

Abstract

The pharmaceutical industry is characterized by advanced preclinical and clinical scientific research with the utmost goal to develop new drugs that can improve human health. There is currently lack of comprehensive information on how the stock market values different scientific achievements in relation to the development phase of pipeline drugs. In this thesis it is therefore investigated and analyzed how the stock price of pharmaceutical firms develops in relation to a diverse range of scientific announcements. By integrating data from Swedish, Norwegian, Danish and Finnish stock markets, a total of 66 pharmaceutical companies are analyzed using event study methodology and regression models of cumulative abnormal returns. 714 scientific announcements are analyzed and grouped into nine different categories of positive and negative announcements. In general, reporting of scientific data was found to result in various stock market responses. Abnormal returns could be observed for all nine announcement groups at the announcement date. The magnitude of abnormal return was found to be larger for negative announcements than their positive counterparts. The highest cumulative abnormal return following a positive announcement was unexpectedly noted for preclinical data release. Furthermore, significant cumulative abnormal returns were observed in the pre- and post-event window for many types of announcements. The data indicates that the market overreacts to positive scientific announcements in early phases of the drug development process, with subsequent negative cumulative abnormal return in the trading days following the positive announcement. This event study also shows signs of information leakage a few trading days before positive and negative clinical trial announcements. Taken together, this study provides valuable information to investors on how the stock market values scientific achievements and questions the strong efficient market hypothesis.

Keywords:

Pharmaceutical industry, scientific announcements, trading strategy, market efficiency

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Contents

1. Introduction

The pharmaceutical industry encompasses companies that are in the field of developing and producing drugs. Their utmost goal is to develop new therapies that can improve human health, prolong life and decrease morbidity. This industry has been subject to substantial economic growth and expansion during the last decades, mainly due to unprecedented scientific achievements and healthcare system improvements. Thus, the role the pharmaceutical industry plays in modern economies cannot be neglected.

From a financial point of view, investments in the life science sector and, in particular, the pharmaceutical industry, attracts investors due to various reasons. In contrast to other industries, the pharmaceutical industry is not as sensitive to business cycles and macroeconomic factors, and the demand for new products that cure disease and improve health will most probably remain at a high level (Cleeren, Lamey, Meyer, & De Ruyter, 2016). Investors have thus the chance to earn substantial returns on investments. However, in the majority of cases this comes at a cost. Investments in pharmaceutical firms are indeed risky which is displayed by the riskiness of the drug development process. Volatility of stock prices is high and the stock price dynamics differs from other sectors due to the long and risky product development phase of new drugs, which can take several years (Dowden & Munro, 2019). In order for a molecular compound to succeed, it must pass a number of preclinical and clinical trials. The final regulatory approval of a new drug requires both positive efficacy results from all trials as well as acceptable safety data. Thus, these firms are dependent on advanced preclinical and clinical research and the release of new information from milestones in the drug development process might have major impact on return on investment and stock price volatility.

The outcome of having relevant information about companies has been a central theme in finance research, where Fama (1970) proposed different hypotheses regarding efficiencies of financial markets. The strong efficient market hypothesis argues that the release of new company information should have no impact on stock prices, however empirical evidence does not fully support the strong form of the hypothesis (Basu, 1977; Chan, Gup, & Pan, 1997; Fama & French, 1992). In their search to beat market return,

investors therefore struggle to interpret various types of company information, including those announced by pharmaceutical companies throughout different phases of the drug development process. Extracting relevant information from such reports and interpreting these from a scientific context may influence the future returns from investment portfolios, and at the same time being a source of potential abnormal return. Consequently, the question arises how outside investors can interpret scientific announcements at different timepoints in the drug development process in order to maximize their stock return. Pharmaceutical firms belong to a sector where there is an opportunity to explore the intersection between scientific research, innovation and the corresponding market response. It also allows the study of announcements effects and the impact on public equity value.

There is scarce previous research with a focus on the role of pharmaceutical scientific announcements in relation to stock price dynamics and how investors can interpret such company reporting. The vast majority of research on scientific announcements has either focused on specific scientific announcements or on a narrow therapy area. To the best of this author's knowledge, no previous published paper on the Nordic market has attempted to analyze the stock price dynamics in relation to both positive and negative scientific announcements. In the light of scarcity of previous studies and lack of overview of the stock price dynamics of Nordic pharmaceutical companies, this thesis aims to complement this existing knowledge gap and provide a comprehensive overview of different scientific announcements and their effect on abnormal stock return at different event windows.

In this thesis, results from an event study analysis of scientific announcements in Nordic pharmaceutical firms are presented and it is concluded which scientific announcements affects the stock return of pharmaceutical firms at specific event windows. The findings suggest that investors could earn abnormal returns at different time horizons due to scientific announcements. In general, reporting of scientific data was found to result in stock market responses in both the pre- and post-event trading window. Significant abnormal returns could be observed for almost all studied announcement types at the announcement date. The magnitude of abnormal return was shown to be larger for negative announcements than their positive counterparts, in line with previous research. The highest cumulative abnormal return following a positive announcement was

unexpectedly noted for preclinical data release, the earliest phase in the drug development process. Furthermore, significant cumulative abnormal return could be seen in the pre- and post-event window for many types of announcements. The results indicate that the market overreacts to many positive scientific announcements with resulting negative cumulative abnormal return in the trading days following the positive announcement. The present event study also shows signs of information leakage a few trading days before some types of positive and negative clinical trial announcements.

This paper proceeds by giving a background to the pharmaceutical industry and the drug development process with a focus on the Nordic countries and the rules that regulate the process of developing a new drug. The risks associated with drug development are highlighted and analyzed from the context of firm valuation. The remainder of this thesis is structured in the following manner: a theoretical and conceptual framework together with a literature review is presented in section 3. This section delves into drug development and the scientific announcements as signal to investors and the effects on the stock market price. A motivation with incremental contributions of this thesis are presented in section 4. Hypotheses are presented in section 5. Next, in section 6, methodology aspects are provided. This section is divided into several parts, including selection of pharmaceutical companies, sources of stock and financial information as well as event study methodology. The results are presented in section 7, which contains both descriptive results as well as regression results. The discussion section summarizes the results, discusses implications and their relation to previous literature. The last section contains conclusions from the study as well as potential further research on the research topic. Finally, the last section contains the appendix where the remainder of tables and supplementary calculations are to be found.

2. Background

2.1. Pharmaceutical industry and general trends

Pharmaceutical firms are part of the life science sector, which has been growing steadily during the last decades, alongside new scientific and technological advances in medical treatments, drug development and healthcare advancements. The global revenue in the healthcare and life science sector is expected to rise from around 1,600 billion dollars in 2015 to almost 2700 billion dollars in 2025, thus an increase of almost 70% (Chang, 2019). Coupled to the increase in healthcare spending, there has also been a rise in the private life-science sector which provides novel medical, biotechnological and pharmaceutical products which further augments the care provided by healthcare providers. One reason for increasing revenues is the increased lifespan and a demographic shift towards an aging population, which creates a demand for novel and optimized pharmaceutical drugs (Lutz, Sanderson, & Scherbov, 2008).

Europe and North America are currently the central hubs for pharmaceutical firms and leading markets for pharmaceutical products. However, the role of emerging markets cannot be neglected with continuous increases in buying power and welfare. The Nordic pharmaceutical industry is dominated by several multinational corporations, alongside smaller firms that focus on a narrow therapeutic area or on a specific drug molecule. Generic companies are also present which focus on the production of drug analogues which have the same mode of action as the original drugs. The Nordic pharmaceutical firms are mostly found in Sweden, which holds the majority of publicly listed pharmaceutical companies.

2.2. Innovation and drug development

Novel drugs are based on scientific advancements and new insights of human disease biology in various aspects. This include enhanced understanding of molecular biology, the complex processes controlled by the genomic code (DNA) and how the cellular machinery is regulated by means of the genetic code and environmental factors. How and to what extent all these processes play a role in disease development has been elucidated for many human diseases. This can help researchers both in academia and in

pharmaceutical firms to emulate molecular mechanisms of disease initiation and progression and find potential treatments. The integration of competences from academia produces a synergistic environment and thus may aid in the drug development process. Collaboration is one key to success; almost one half of all new drugs are derived from universities in partnership with biotechnological companies (Kneller, 2010).

The pharmaceutical industry is thus driven by innovation and scientific advancements are an important determinant of success and value creation. The relationship between innovation, research and development expenses as well as the resulting stock price have been studied in previous research. It is evident that innovation is coupled to research and development and thus such activities are regarded as an investment rather than an expense (Pindado, Queiroz, & Torre, 2010). In fact, the pharmaceutical industry is among the most research-intensive in the global economy and is a major contributor to innovation in the world economy. It is estimated to hold around 20% of all business spending on research and development (DiMasi, Hansen, & Grabowski, 2003; Kneller, 2010). Data is supporting the notion that a higher level of research and development activity is linked to a higher firm value and therefore also stock price in general (Cockburn & Griliches, 1987; Griliches, 1981). Other studies only find a significant link between research and development expenses and future stock price, hence the current level of investment in research is not necessarily reflected in the stock price today (Lev & Sougiannis, 1996).

2.3. Drug development process and regulations

The drug development process is extensively regulated and there is a broad legal framework that companies need to adhere to in order to successfully launch a new drug. In many countries in the industrialized world, the human clinical trials proceed through four clinical phases apart from the basic preclinical phases that underlie the development of the new molecular compound. During the different steps in the drug development process, the drugs are evaluated for safety and efficacy. Human biology is highly complex and therefore drug characteristics can only be determined from accumulated experience throughout the different study phases (see Figure 1). During all these phases, the drug is tested on both isolated cells (*in vitro*) as well as in animals and humans (*in vivo*) and the effect and safety of the compound is monitored in a structural manner. During the

development process, companies also engage in important scientific activities such as participation at scientific congresses, giving poster presentations and presenting new data to get valuable feedback from the scientific community.

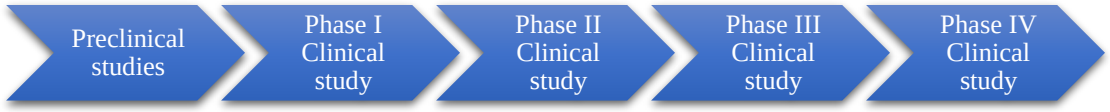

Figure 1. Overview of the drug development process. The development of a new drug is regulated by authorities and in order to get approval of new drugs, the pharmaceutical companies need to follow different phases in the drug development process. Preclinical studies on cells and animals are followed by clinical studies on humans (phase I-IV).

The development of a new molecular compound is initially based on preclinical *in vitro* and *in vivo* studies in cell lines and animals respectively. Before a new drug can be developed, a biological target needs to be addressed and its role in disease development and pathogenesis needs to be clarified. When this has been accomplished, further testing of the compound's efficacy in different animal models is required. Moreover, its safety must be addressed during toxicological studies to determine the lack of unwanted side-effects.

Following the preclinical stage with a wide array of *in vitro* and *in vivo* tests, the next steps in the development process are the clinical phase studies *in vivo* in humans. The first is the phase I clinical study where the new drug is tested in humans for the first time. Here, the compound is most often tested in healthy volunteers to investigate the safety of the compound and in order to determine pharmacokinetics which will guide the safe dosage regimens for the compound. In some cases, phase I studies are immediately done on patients suffering from the disease the molecular compound is intended for, most often for oncology drugs. Following the acquired data from the phase I clinical studies, a group of patients are randomized to either get the new drug or a placebo-compound in the subsequent phase II study. This is done to determine the efficacy of the drug and the study design is commonly a double-blind randomized control study. The number of patients required for a study is set before the study begins by calculating the power (statistics) and the resulting number of patients required to get a significant result based on efficacy estimates. Phase III studies are the critical last step before the regulatory approval of

drugs. They are designed to investigate the efficacy of the molecular compound and therefore often require several hundred patients in order to get a significant result. These studies are also randomized control trials where patients are at random assigned to receive the treatment or the conventional treatment/placebo. Following successful phase III studies, a formal application to national regulatory bodies in the respective Nordic country is required. In order to get market approval, comprehensive data on safety, efficacy and quality of the new drug must be demonstrated through the above-mentioned studies. Lastly, phase IV studies are done after a drug has been approved by regulatory agencies. These studies are designed to assess the effectiveness of the newly approved drug and collect reports and incidents regarding adverse effects. Moreover, the phase IV studies allow for investigation of potential interactions with other drugs and thereby enabling early intervention in case concerns arise that have not been detected in previous studies.

The whole drug development process is time consuming. The timescales for preclinical studies are between 1-5 years, for the clinical phase I-III trials the time necessary is also between 5-10 years. The time to get regulatory approval by the agencies ranges from a couple of months up to two years (DiMasi et al., 2003). Thus, the total timescale for the development of a new drug from idea to possible revenue is at least 7 years.

2.4. Costs and risks of drug development

The cost of developing a new drug that reaches the market and gets approved is on average $800 million (DiMasi et al., 2003). In contrast to medical technology firms, the time frame and costs associated with the development of a drug are more extensive. By contrast, the return on investment in medical technology firms is often lower due to shorter product cycles (Stern, 2017). Apart from costs, there is high risk present behind the development of a new drug, mainly due to the complexity of biology and thus efficacy and safety of new drugs. Not only must the drug have beneficial effects for what it is intended for, but also have minimal side-effects. Drug approval is therefore a complex procedure and there are many stages throughout the development of process of a new drug that can go awry. Clinical trials may fail to show efficacy or unwanted side-effects which will unable regulatory approval and market launch of the new drug. The

complexity and uncertainty of the process makes the development of a new drug a highly risky project. Firms in other sectors selling non-regulated products may generate revenue within months. By contrast, pharmaceutical typically earn no profit for many years. However, if the projects succeed and the drug gets approved by regulatory agencies, the revenues are high due to patent protection for several years.

The riskiness of the drug development process is illustrated by failure examples of past clinical trials. Lack of efficacy has been demonstrated in a multitude of trials, including drugs targeting the central nervous system, such as the case of Alzheimer disease. Even though animal models have shown promising results from preclinical testing, the human clinical trials have not demonstrated any significant value or effect of the tested compounds so far (Mehta, Jackson, Paul, Shi, & Sabbagh, 2017). Yet, efficacy is solely not enough. Safety is also a prerequisite for market launch as illustrated by the case of the drug fialuridine which was designed to treat hepatitis B infection. It turned out to have severe drug effects in humans and resulted in death (Tujios & Fontana, 2011). Later, it was found that the drug had unwanted toxicological properties and affected the mitochondria of liver hepatocytes. This adverse effect had not been noticed beforehand in animal studies, indicating that human biology and drug efficacy is far more complex and unpredictable than what can be expected at first glance.

The CMR international consortium is an organization compiling statistics on the success rates throughout different stages during the drug development process. The statistics indicate that success rates in later stages of the development phase have increased from below 50% to over 70% during the last decade (Dowden & Munro, 2019). On the other hand, success rates in the phase II development phase have remained more or less the same and only one in four projects succeed in this phase and can progress to phase III. Phase I studies are even more risky with a failure rate of 90%, which has remained stable (Dowden & Munro, 2019). The failure of a drug in a specific phase is in the majority of cases associated with lack of safety or efficacy (almost 80% of failures), whereas the rest includes technical failures or economic reasons (Graul, Dulsat, Pina, Cruces, & Tracy, 2019; Graul, Dulsat, Pina, Tracy, & D'Souza, 2018; Graul, Dulsat, Tracy, & Cruces, 2017; Harrison, 2016). Pharmaceutical companies put enormous resources to ensuring that their drug meet the defined criteria and requirements before entering the clinical trial program. Therapy area has been also shown to affect the

probability of success. Some therapy areas have been shown to have lower success rates, including cardiovascular and nervous system targeted drugs (Harrison, 2016).

3. Literature review

In this section, a literature review is presented. This literature review presents previous research that has contributed to new knowledge at the intersection between announcements and stock return effects. Moreover, the efficient market hypothesis and research concerning insider trading and information leakage is reviewed.

3.1. Predicting firm success

Investors struggle to gain superior information that could potentially lead to abnormal return. Such information can stem from many sources. However, stock prices are the result of a complex reality and the factors that underlie stock price in a given moment are hard to emulate. The literature on financial indicators that could determine security price is rich, yet the life science sector has not been the main focus of the majority of papers. The analysis of financial indicators for predicting stock price is the so-called fundamental analysis. These variables could be market equity (Banz, 1981) and book-to-market equity (BE/ME) (Rosenberg, Reid, & Lanstein, 1985), Some of these financial parameters have been shown to be important for predicting long-term stock return in the pharmaceutical industry (kebriaeezadeh, Zartab, Fatemi, & Radmanesh, 2013).

Instead of analyzing complex financial data with often loose connection to the true value driving factors of a firm, one can measure the innovativeness. Pharmaceutical firms rely on innovative products and ideas to develop their product offering which is a prerequisite for sustained profitability. There is no doubt that new technologies and scientific advancements play an important role for the valuation of a firm and have therefore widespread valuation consequences for publicly listed firms. Previous studies have shown evidence that a high level of innovation and clinical trial success is indeed related to profitability in the pharmaceutical industry (Roberts, 1999). Scientific innovation is thus a corner-stone for maintenance of profitability and, in the end, survival of firms in the pharmaceutical industry.

3.2. Announcements and abnormal return

As stated above, research and development events such as release of new research data or regulatory approval can have major impact on the value of pharmaceutical firms. Positive news might have substantial positive effects on the stock price of pharmaceutical firms. By contrast, negative results may result in devastating reduction of the market value. Below is a review of the research that have examined this topic.

One of the earliest studies on the relationship between Food and Drug Administration (FDA) decisions and the market value of firms was conducted in an American context (Bosch & Lee, 1994). This study covered approvals and negative decisions by the regulatory agency between the years 1962 to 1989. The authors found significant changes in the stock price and firm valuation following the official release of such regulatory information. Moreover, there was indication of information leakage before the regulatory decision. The results from Bosch et al (1994) have been replicated in two other studies which also examined the impact of FDA decisions on stock price (Sarkar & de Jong, 2006; Sharma & Lacey, 2004). Sharma et al (1994) had a sample of 344 FDA approvals and 41 negative regulatory decisions. In line with Bosch et al (1994), this study found evidence that official release of new information led to changes in the market value of firms. Taken together, the data indicated that unanticipated positive news were eventually merged into the market valuation of firms.

In addition to FDA approvals, release of information from clinical trials and its impact on stock return has also been the focus of previous research. Rothenstein et al (2011) investigated how the stock prices of pharmaceutical firms responded to the release of phase III trial reports (Rothenstein, Tomlinson, Tannock, & Detsky, 2011). In total, 23 positive and 36 negative oncology drug trials were investigated and their respective impact on the stock price of the company. Their conclusion was that abnormal return could be seen in several event windows. The shortcoming of this study was the inclusion of large pharmaceutical companies, which had many drugs in pipeline or already regulatory approved. Thus, the market response in terms of percentage change in stock price would be very small and thus less sensitive to the scientific news from one single drug in pipeline. Another drawback was the sole focus on phase III results and lack of exploration of other scientific announcements that could influence the stock price. A

similar study examined stock prices of biotechnology products before and after announcement of phase III clinical trial results as well as regulatory outcomes of drug approvals (Overgaard, van den Broek, Kim, & Detsky, 2000). They found that positive trial results were significantly different from the negative announcements up to 120 days before the official press release. The regulatory outcomes of drugs approvals were not statistically different between the positive and negative announcements during the same time window. Hwang et al (2013) investigated the abnormal returns preceding or following public announcements for clinical trials of 24 different drugs. The majority of the announcements were also phase III trials. The median cumulative abnormal return for positive and negative scientific announcements were 0,8% and -2,0% respectively, even though the results could not reach statistical significance due to a small sample size (Hwang, 2013).

Some studies have shown that investors overreact to the release of new scientific information in the pharmaceutical industry and that the magnitude of abnormal return differs depending on announcement type. For example, Chan et al (2003) as well as Sharma et al (2004) found that extreme price changes are reversed after some time, which indicates the presence of investor overreaction to news, which could be explained by behavioral theories (Daniel, Hirshleifer, & Subrahmanyam, 1998). These theories about market overreactions are believed to be due to two well-known psychological biases: investor overconfidence and biased self-attribution. This is in line with previous literature that shows that markets can overreact to information (DeBondt & Thaler, 1985; Fischer, 2012), and that negative information gives a larger overreaction and correction than positive news.

3.3. Efficient market hypothesis

A market in which prices are continuously completely reflect all available information is efficient (Fama, 1970). The efficient market hypothesis states that public information released by firms should be incorporated efficiently in stock prices and returns. There are different forms of the hypothesis. According to the strong form of the efficient market hypothesis, current share prices should incorporate all sorts of information, both public and private. Meanwhile, the semi-strong efficient market hypothesis states that share prices only incorporate all publicly available information. According to the weak form of the efficient market hypothesis, only past publicly available information is reflected in the stock price.

Since investor meticulously seek for information to get an advantage over other investors, it is reasonable to assume that they disbelief the strong and semi-strong efficient market hypothesis. Company announcements regarding important news would under the strong efficient market hypothesis result in no net changes in stock price. There is however no doubt that new information and announcements have wide economic effects. Some researchers explain this by the stock market overreaction hypothesis which challenges the efficient market hypothesis in the way that new information can lead to exaggerated responses that eventually correct themselves ((Ma, Tang, & Hasan, 2005).

3.4. Insider trading and information leakage

Insider trading is based on agency problems. Managers may have significant insights into company business which is not available to the public. Therefore, a situation of asymmetric information appears, and this superior information can be used when making trades of publicly listed firms. Insider trading can be done in a legal and illegal manner. Legal insider deals have to be reported to a regulatory agency, in Sweden this is the financial supervisory authority, Finansinspektionen.

Evidence of information leakage and illegal trading in the pharmaceutical industry have been shown in previous studies. Having superior information about scientific achievements, especially clinical trials, can indeed be lucrative (Benowitz, 2002; Ferguson, 1997; Steinbrook, 2005; Topol & Blumenthal, 2005). As the stock price diverge between positive and negative news in the trading days before the official event,

it has been proposed that illegal insider trading underlies this phenomenon. Individuals can make stock trades on their own before the news are released to the public or leak information to secondary parties. Many parties are involved in producing scientific data and work on clinical trials and therefore have superior information regarding the prospects of a firm. There is a multitude of examples of how principal investigators have affected to firm's stock price (Overgaard et al., 2000; Roush, 1995; Skolnick, 1998). In one study by Overgaard et al (2000), the difference between average stock price change from 120 to 3 days before public announcement of positive versus negative announcements was highly significant with an average increase of +27% for positive and decrease of -4% for negative announcements respectively. There have also been cases of disclosing secret information by patients participating in clinical trials (Helft, Ratain, Epstein, & Siegler, 2004).

4. Motivation

Investors in pharmaceutical companies should understand characteristics and the nature of the companies they invest in. Specifically, they should have a thorough understanding of the product development pathways, the regulatory framework and policies that constitute the drug development pathway. Moreover, they should have understanding on how scientific results affect the stock returns of pharmaceutical firms which might improve their investment strategies.

As outlined, only few previous studies have investigated the relationship between scientific announcement and their incremental effect on stock prices at different time horizons and event windows. The literature on pharmaceutical firms in this context is limited, and the bulk of research has been conducted on the U.S stock market. The drawback of existing literature is the narrow focus and a lack of comprehensive analysis. For instance, some papers focus on one therapy area such as oncology-drugs (Rothenstein et al., 2011). Thereby, information about other therapy areas is lost. Moreover, the majority of papers focus only on specific announcements such as phase III clinical trial results or regulatory FDA approvals (Hwang, 2013). In other words, there is a lack of comprehensive information regarding different scientific announcements and their relative importance.

To the best of this author's knowledge, nothing similar has been done in a Nordic setting. This thesis wants to bridge the knowledge gap by exploring the role of clinical trials and other scientific announcements in determining the stock price returns. This has the potential to provide outside investors with information on how to extract relevant information and pinpoint trading strategies that could be predictive of abnormal return.

5. Hypotheses

The following hypotheses related to the market valuation of pharmaceutical firms in response to a wide range of scientific announcements were defined.

> *Hypothesis 1:* The market's reaction following scientific announcements is abnormal.

After answering this question of abnormal return in response to scientific announcements, the analysis is deepened and the thesis sets out to distinguish the difference between positive and negative scientific announcements, thereby distinguishing which phases in the drug development process lead to significant abnormal returns and in which predefined event window these abnormal returns can be observed.

> *Hypothesis 2:* Positive scientific announcements are associated with positive abnormal return
>
> *Hypothesis 3:* Negative scientific announcements are associated with negative abnormal return

Previous literature indicates that the stock market reacts more to negative news than to positive news and that the magnitude of abnormal returns differ between these two types of announcements. Therefore, it is hypothesized that this could also be the case in the present study and hypothesized that the sample of firms in this study behaves differently following positive and negative announcements.

> *Hypothesis 4:* The abnormal stock market returns following negative announcements are significantly larger than those for positive events.

The success rate is higher for drugs in pipeline that are in later phases of the drug development program. Therefore, it is hypothesized that abnormal return is higher and at a higher significance level following late-stage announcements.

Hypothesis 5: The abnormal stock market returns are larger for scientific announcements related to later phases in the drug development process

Previous research indicate that stock prices diverge already 60 days before the announcement of a positive versus a negative announcement (Rothenstein et al., 2011). This could be due to legal or illegal insider trading and information leakage and therefore it is hypothesized that it has an impact on abnormal returns in the pre-event window and the trading days leading up to the scientific announcement.

Hypothesis 6: There are abnormal returns in the trading days leading up to the event day, indicative of insider trading and information leakage.

Lastly, market overreaction to positive and negative news is a well-known phenomenon that has previously been described in the literature review. Hence, it was hypothesized that market overreacts to various types of important scientific announcements.

Hypothesis 7: There are signs of market overreaction and positive (negative) abnormal returns are followed by negative (positive) abnormal returns.

6. Data & Methodology

6.1. Sample selection

The companies included in the analysis are publicly noted on the Nordic stock exchanges in Sweden, Denmark, Norway and Finland. Companies were searched on each stock exchange, filtered based on industry and all that belonged to the healthcare or life science industry were selected. A second filtration was done to include only pharmaceutical firms. Only pharmaceutical firms that were listed at the respective stock exchange at September 15th, 2019 were included in the analysis in order to find information and press releases concerning scientific announcements on the websites of each respective firm.

6.2. Data collection

For the Swedish pharmaceutical firms, daily closing stock data was downloaded from the FinBas database at the Swedish House of Finance. The dataset included the daily closing stock price, company name, the ISIN number and company ticker. Swedish firms that were not present in the FinBas database or firms that lacked ISIN number were excluded from the analysis. Since the FinBas only had data to December 28, 2018, this date was used as the last day for the analysis. The FinBas only contains data on stock prices for the other Nordic countries to 2016. Therefore, for the companies listed on the stock exchange in Denmark, Norway and Finland, daily closing stock prices were manually downloaded from Yahoo Finance from listing date of the respective firm to December 28, 2018.

Pharmaceutical companies having more than 10 drugs in development were excluded from the analysis, since the stock price sensitivity towards a positive or negative press release would presumably be small. Data on firm characteristics, type of life science firm as well as different scientific announcements were extracted from each company's website using a pre-defined extraction template. This template contained information on: company name, country stock exchange, company ticker, company ISIN number, stock exchange list date and disease focus. In addition, information on the dates of the different press releases for the following events was noted: positive preclinical data, positive phase I trial, positive phase II trial, positive phase III trial, negative phase I trial, negative phase II trial, negative phase III trial, conference or poster presentation and study initiation.

Study initiation was defined as a start of a clinical phase study. Conference or poster presentation was defined as an announcement to present new data on an upcoming conference. The extracted data were filtered and ordered chronologically. The press releases were either positive or negative for phase trial reporting, expect for preclinical data reporting which is in most cases only reported if it is positive. A phase trial announcement was regarded as positive of the primary endpoint of the study was met, if the safety and efficacy of the drug allowed for further continuation of the study or reports of positive interim results. Negative results from studies was assessed as failure to meet primary endpoint in study, safety or efficacy concerns or discontinuation of study due to other reasons. If the scientific announcement of a firm occurred during a weekend, the announcement date was transferred to the next following trading day (usually a Monday).

Descriptive statistics of the firms meeting the criteria and included in the final analysis is shown in the descriptive statistics section.

6.3. Event study methodology

In order to assess how the stock market values scientific announcements by firms, the market responses need to be monitored when such information is released. This can be done by the calculation of abnormal returns using event study methodology. Briefly, the event study methodology is a way of investigating the abnormal return of a firm due to a specific event. A defined time period, an event window much first be decided upon which defines the days during which the abnormal returns are calculated. Then an estimation window is necessary which allows for the investigation of returns when no event is taking place. It is then investigated how the firm deviate from its expected performance due to the event.

The event window was here defined as the press release at the website of each firm. Thus, it should be the true publication date of the information and no delay to the market should therefore be noticed. The market effects are observed both at short term event windows as well as longer investment horizons before and after the event. In order to calculate abnormal return, one is dependent on an estimator of normal return. Various variants have been proposed for estimating normal returns, including formal asset pricing

models and firm-specific portfolios. However, there is no golden standard model for estimating normal returns and there are both advantages and disadvantages with different models.

The capital asset pricing model was the first sophisticated model to estimate normal turn and was widely used by several researchers in the previous century to estimate the normal return (Lintner, 1965; Sharpe, 1964). It served as an estimator to several event studies in the following decade. However, the capital asset pricing model is not flawless as it has received numerous critique since it is inferior to explain expected returns of small stocks (Fama & French, 1992). The model's residuals are on average positive for small firms and could therefore overestimate the abnormal returns. Thus, the market model was later applied in finance research. The market model, in contrast to the capital asset pricing model, is a statistical model that assumes joint normality distribution and has no expected prediction error. Thus, the market model was applied in this event study. It is the most frequently used expected return model. The model is based on returns of a reference market and the correlation of the companies' stock with the reference market. The risk with the market model is the estimation period of normal returns, since the stock price can start to show abnormal returns in the estimation window. To overcome this bias, estimation windows can be defined at trading days separated enough in time.

In this thesis, the event study methodology of previous papers is followed for investigating abnormal return at multiple days around the event date ((Panattoni, 2011; Perez-Rodriguez & Gonzalez Lopez-Valcarcel, 2012; Sharma & Lacey, 2004).

The event study is performed according to the following steps:

- Step 1: Identification of the event
- Step 2: Specification of the market returns (index)
- Step 3: Calculation of abnormal returns around the event date based on an estimation window where firm returns are regressed to market returns
- Step 4: Calculation of cumulative abnormal return and testing for significance

In the present study, the event window were defined based on previous literature regarding event studies in the pharmaceutical industry (Hwang, 2013; Rothenstein et al., 2011). In order to capture differences in abnormal returns, the announcement day was

regarded as day 0 and several event windows were used, see Table 1 for an overview of the event windows used in the present study. The event windows were chosen in order to observe both information leakage the days before the scientific announcement (event date) as well as the effects of the announcement on the event date and the immediate trading days surrounding the event date. Moreover, in order to investigate late responses to an announcement, event windows with trading days after the event dates were also defined.

Table 1. Overview of the different event windows used to analyze abnormal return. The number of trading days in relation to the event date are specified. Trading day 0 represents the event date.

Event window	**Trading days in relation to event date**
1	-30 to -1
2	-9 to -1
3	-2 to -1
4	-1 to 0
5	Event date (0)
6	0 to 1
7	1 to 2
8	1 to 9
9	5 to 10
10	10 to 100

In order to decrease the probability of confounding events and thereby bias, events were excluded that were overlapping five trading days with other types of announcements which could potentially limit the interpretation of the results.

For each company i at time t at the estimation window, the two coefficients a and b of the market model were estimated by ordinary least squares. Formally the equation is:

$$R_{it} = \alpha_i + \beta_i R_{Mt} + e_{it}$$

where R_{it} is the company stock return and R_{Mt} is the index market return. The Nordic OMX40 index was used as a proxy for market return since it captures all the Nordic markets and data for the index exists from from year 2001, thus enabling the study of abnormal return following scientific announcements from this year.

6.4. Abnormal and cumulative abnormal returns

For each trading day, the abnormal return was computed by subtracting the predicted normal return from the actual return of the specific firm in the event window. The cumulative abnormal return was calculated as the sum of the abnormal return over the event window. The methodology of event studies relies on the assumption that capital markets are efficient and since all the firms were listed on the Nordic stock exchanges and had sufficient trading volumes, it was assumed that the capital markets were so.

Abnormal returns were calculated by estimating the returns that would have been realized if the event of interest would not have happened. The daily abnormal returns are calculated by comparing company stock return during the event window to the expected market return if the event had not occurred. The equation describes the model and the abnormal return ($AR_{i,t}$) on a predefined day in the event window:

$$AR_{i,t} = R_{i,t} - (\alpha_i + \beta_i R_{m,t})$$

where $R_{i,t}$ is the actual stock return, $R_{m,t}$ the actual market return and α and β represents the relationship between the firm's stock price and the market index that is used in the model.

Finally, the cumulative abnormal returns (CARs) were calculated the during the days in the event window t_1 to t_2 by the following equation:

$$CAR_{it} = \sum_{t=t_1}^{t_2} AR_{it}$$

6.5. Testing for significance

In order to test for significance, a test statistic was computed. The purpose was to investigate whether the mean abnormal return for each company stock was significantly different from zero.

$$TEST = ((\Sigma AR)/N) \; / \; (SD/sqrt(N))$$

where AR is the abnormal return and SD is the standard deviation of abnormal return.

6.6. Regressions

In order to determine the relationship between cumulative abnormal returns and the prespecified announcements, fixed effect regression analyses were performed. Traditional regression which is based on ordinary least-squares calculations assume that there is a normally distributed error term which implies homoscedasticity. Since this was not present in the data, heteroscedasticity was compensated for and robust regression analyses were used in the analysis (Li, 1985). As a result, the least square estimates for regression models are not as sensitive to outliers. A p-value below 0.1 was considered significant. All statistical analyses were performed using STATA16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LP).

6.7. Sensitivity analyses

In order to measure the robustness of the results and the sensitivity towards a change in estimation window, different estimation windows were defined and the effects on the cumulative abnormal returns and significance levels were analyzed.

6.8. Multiple testing p-value correction

Performing numerous statistical tests imposes a risk that some p-values will be lower by chance even though the null hypothesis cannot be rejected. Therefore, in order to correct for this, the Benjamini Hochberg procedure can be applied (Chen, Feng, & Yi, 2017). By integrating this method into a list of p-values, the false discovery rate (FDR) for each of the p-values can be calculated. Thus, this method will aid in discovering the p-values that are false rejections of the null hypothesis, thereby reduce the number of type I errors. FDR can be calculated with the following equation:

$$\mathrm{FDR} = Q_e = \mathrm{E}[Q] = \mathrm{E}\left[\frac{V}{V+S}\right] = \mathrm{E}\left[\frac{V}{R}\right]$$

where S represents the number of true positives and V false positives, i.e. false discoveries.

7. Results

7.1. Descriptive statistics

The sample comprised in total 714 scientific announcements from 66 Nordic pharmaceutical firms, specified in Appendix Table A1. These announcements were released from the respective company's website as press releases. The scientific announcements where matched and grouped into 9 different groups that characterized the type of announcement, specified in Table 2. There were in total 6 positive announcement groups (preclinical data presentation, clinical phase I data presentation, clinical phase II data presentation, clinical phase III data presentation, study initiation, poster/conference presentation) as well as 3 negative announcement groups (negative phase I data presentation, negative phase II data presentation, negative phase III data presentation).

Table 2. Overview of the nine groups of scientific announcements and the number of announcements per group.

Type of scientific announcement	Number of announcements
Preclinical data	139
Positive phase I study	80
Positive phase II study	104
Positive phase III study	44
Negative phase I study	2
Negative phase II study	13
Negative phase III study	11
Conference/poster presentation	135
Study initiation	186

The oldest company used in the analysis was listed on the stock exchange in November 1998 whereas the newest company had been listed December 2018. The average listing age at the stock exchange of the companies in the complete sample was 5,7 years and the median 3 years. Thus, the pharmaceutical companies in the analysis had been listed a relatively short time in comparison to other sectors.

The drug therapy areas of the companies were found to be diverse (Figure 1). Most of the companies were specializing in oncology (21 companies) and immunology (12 companies) disease areas. It was also common to be involved in multiple therapy

areas (16 companies). Eight companies focused on a specific area that did not involve the regular organ system classification, such as orphan diseases.

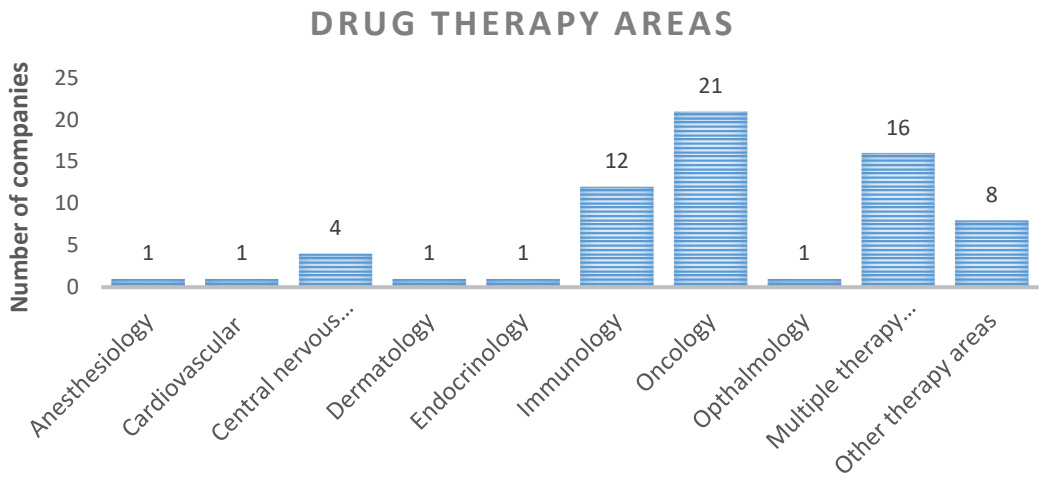

Figure 1. Overview of the drug therapy areas of the companies in the study. A total of 66 Nordic pharmaceutical firms were analyzed and their disease therapy specialization area is displayed in the graph.

7.2. Event study analysis

Event study methodology was applied to study the announcement effects for the 66 pharmaceutical firms in the sample. For each announcement group, cumulative abnormal return was calculated using different event windows surrounding the announcement date, in line with previous literature (Hwang, 2013; Overgaard et al., 2000; Rothenstein et al., 2011).

At the event date, the cumulative abnormal return was found to be significant for all the studied announcement types, except negative phase I trial reporting due to a small sample size, see Figure 2. Positive announcements yielded a positive abnormal return whereas negative announcements were found to be associated with a negative abnormal return. Among the positive announcements, preclinical data was associated with the highest abnormal return on the event date, whereas announcement of conference participation or study initiation had the lowest abnormal return. For the negative announcements the magnitude of abnormal return was found to be much higher compared to the positive announcements, in line with previous research (Perez-Rodriguez & Gonzalez Lopez-Valcarcel, 2012).

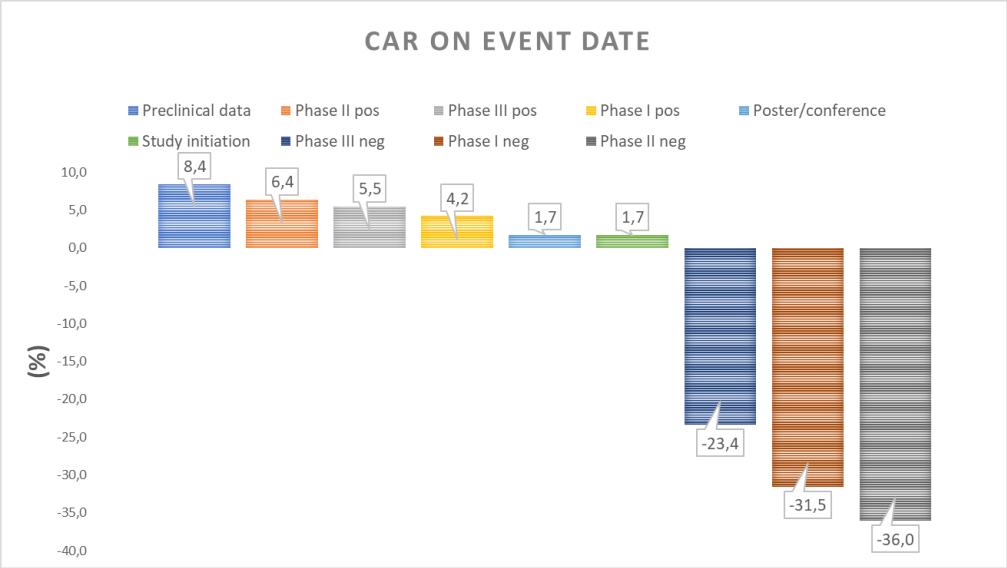

Figure 2. Cumulative abnormal return on the announcement date for all nine studied announcements. The mean of cumulative abnormal return is displayed for each of the announcement type. See Appendix for confidence intervals and significance values.

In the next sections, the results from the different scientific announcement groups at different event windows are reported. Figure 3 depicts the mean cumulative abnormal return (CAR) for company stock prices after positive phase I clinical trial announcements. Before the announcement, there was a significant ($p<0.1$) positive abnormal return in the stock price 30 trading days leading up to the announcement date (for p-values, see Appendix). On the event date, the mean CAR was 4.2%. In the event windows following the event date, all cumulative abnormal returns were significantly negative. The companies had -23.2% negative abnormal return between trading day 10 and 100 after the announcement date of the phase I clinical trial.

Next, positive phase II trials were assessed and the stock dynamics were analyzed (Figure 4). In contrast to phase I clinical trials, there was no significant change in CAR in the trading days leading up to the announcement date, thus indicating the absence of information leakage. In analogy to phase I announcements, there were significant decreases in CAR in the trading days after the announcement dates, indicative of market overreaction.

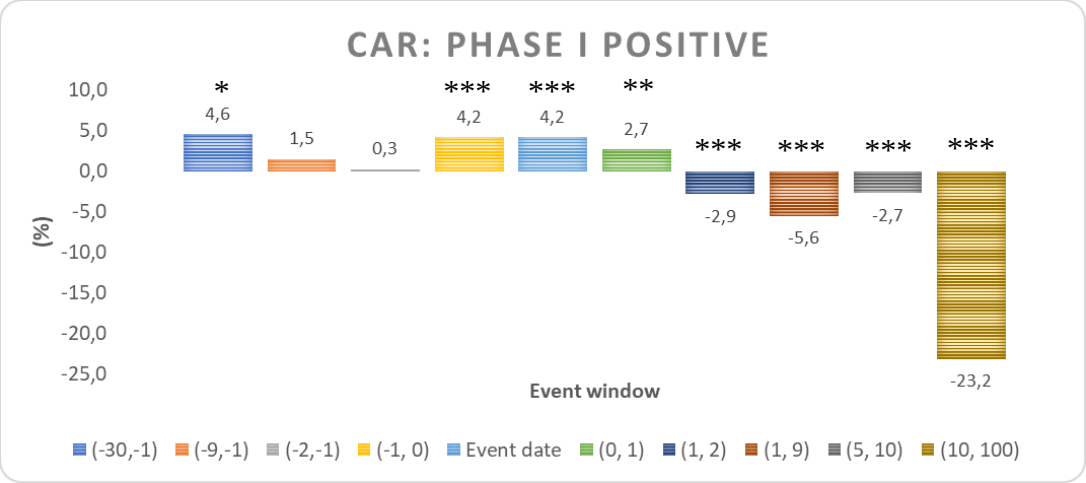

Figure 3. Cumulative abnormal return (%) surrounding positive phase I trial announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

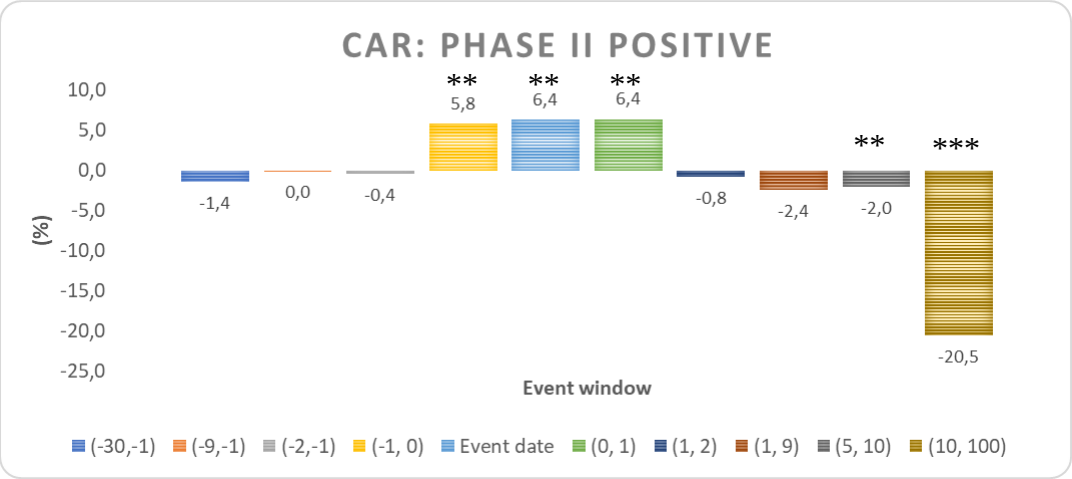

Figure 4. Cumulative abnormal return (%) surrounding positive phase II trial announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

The last step in the drug development process, phase III clinical trials, were analyzed hereafter and figure 5 depicts CAR dynamics for this scientific announcement. In the pre-event trading window 30 trading days before the event, there was a significant positive CAR of 5.6% (p<0.1). The mean CAR on the event date was 5.5% (p<0.01), which is more or less the same magnitude as for earlier phase clinical trials. In the post-event window, there was only significant negative CAR during trading day 1 and day 2 following the announcement, and no significant negative CAR up to 100 days after the event date could be observed in contrast to the earlier clinical trial phases.

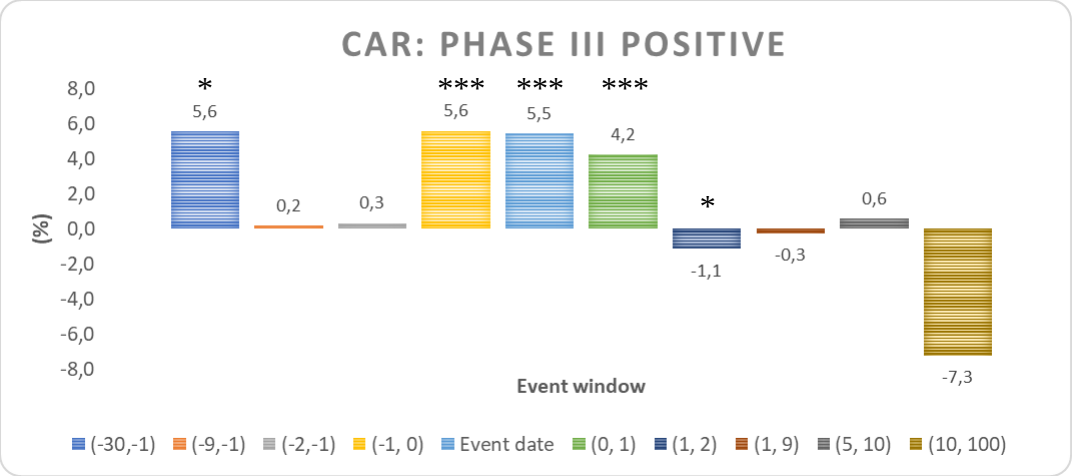

Figure 5. Cumulative abnormal return (%) surrounding positive phase III trial announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

Following the clinical phase studies, cumulative abnormal return for preclinical data was analyzed (Figure 6). The analysis showed a positive CAR of +8.4% ($p<0.01$) for all the studied pharmaceutical firms. In other words, this was found to be higher than the clinical trial announcements. Moreover, a significant negative CAR was observable during the first nine trading days after the announcement date. The announcement of a start of a clinical trial showed a similar pattern to preclinical data announcement, however the CAR was found to be lower (Figure 7). Positive cumulative abnormal return for an announcement of poster or conference presentation was significant in event windows that overlapped the announcement date (+1.7% at the announcement date, $p<0.01$), see Figure 8. By contrast, in the pre- and post-event window showed no significant cumulative abnormal returns.

Next, negative announcement were evaluated and the CAR was calculated over the different event windows. Only two firms reported a negative phase I clinical trial and therefore no significant results were obtained, however the results show a trend towards a strong negative CAR in all event windows (Figure 9).

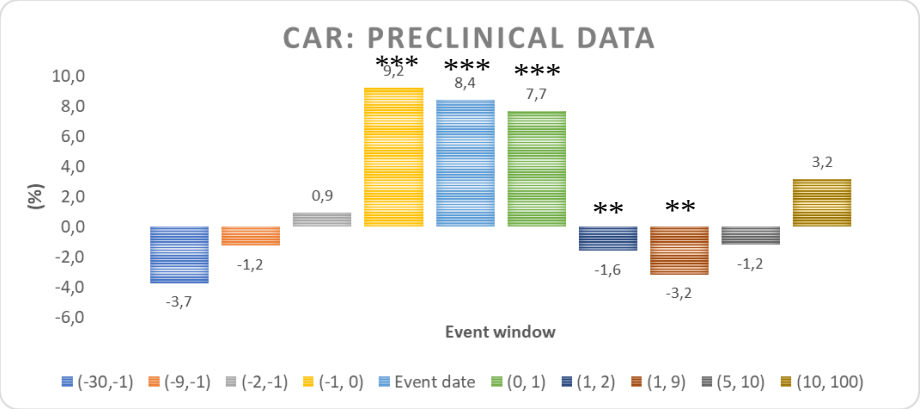

Figure 6. Cumulative abnormal return (%) surrounding positive preclinical data announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

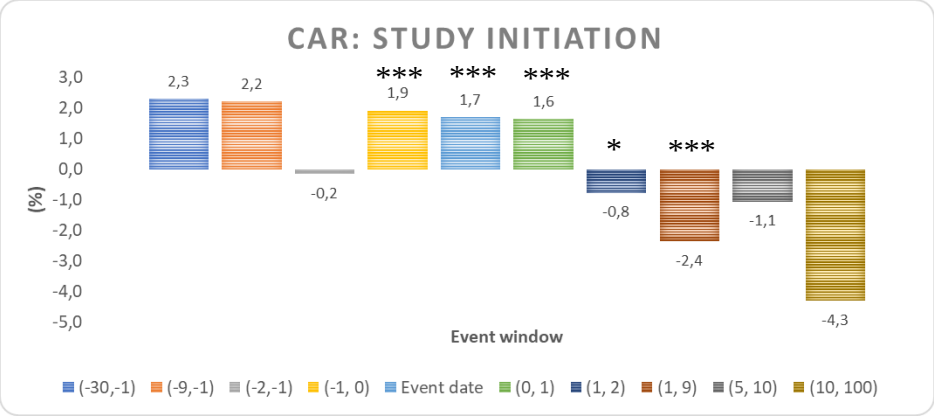

Figure 7. Cumulative abnormal return (%) surrounding study initiation announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

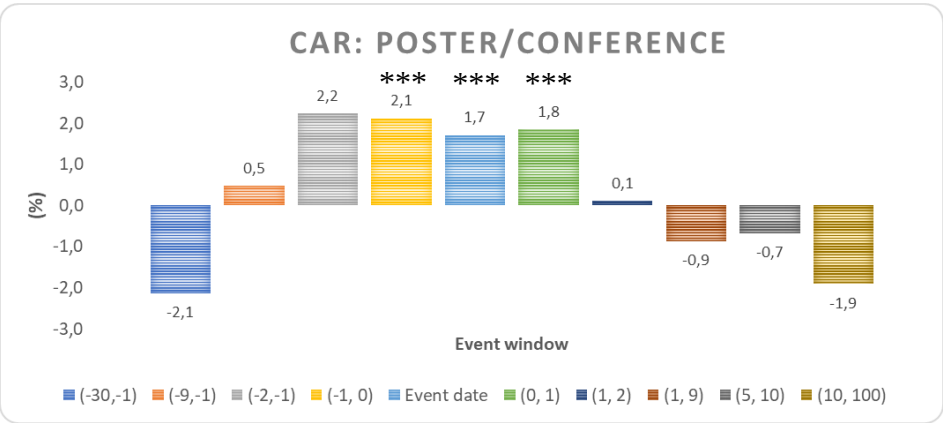

Figure 8. Cumulative abnormal return (%) surrounding poster/conference presentation announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

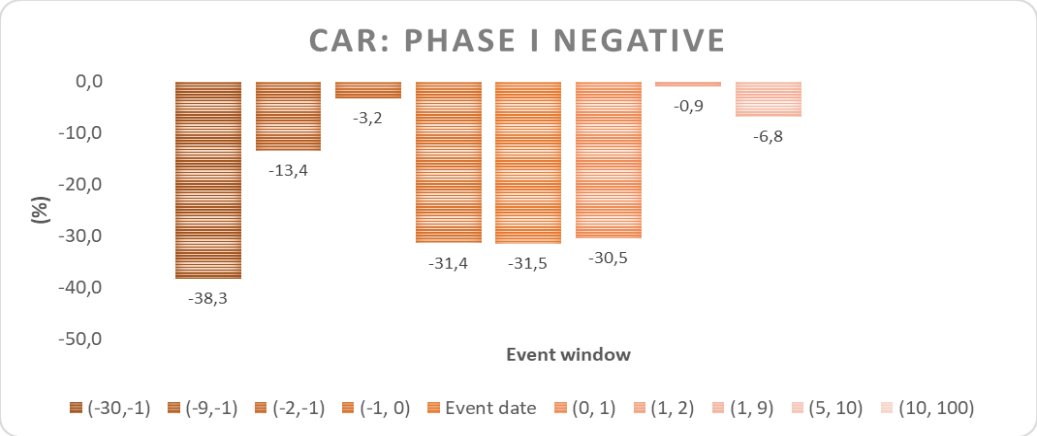

Figure 9. Cumulative abnormal return (%) surrounding negative phase I trial announcements. Different event windows were used. Day 0 represents the event date. Note: n=2 and thus no cumulative abnormal returns are significant.

By contrast, negative phase II clinical trial results had more observations and therefore obtained a higher significance level, see Figure 10. Significance negative CAR could be observed during two trading days preceding the announcement of the negative trial outcome (-3.9%, $p<0.05$). The market reactions to the negative announcements were of greater magnitude than the positive counterparts. On the event date, the mean CAR was -36.0% ($p<0.01$). No significant changes in CAR could be observed in the post-event window.

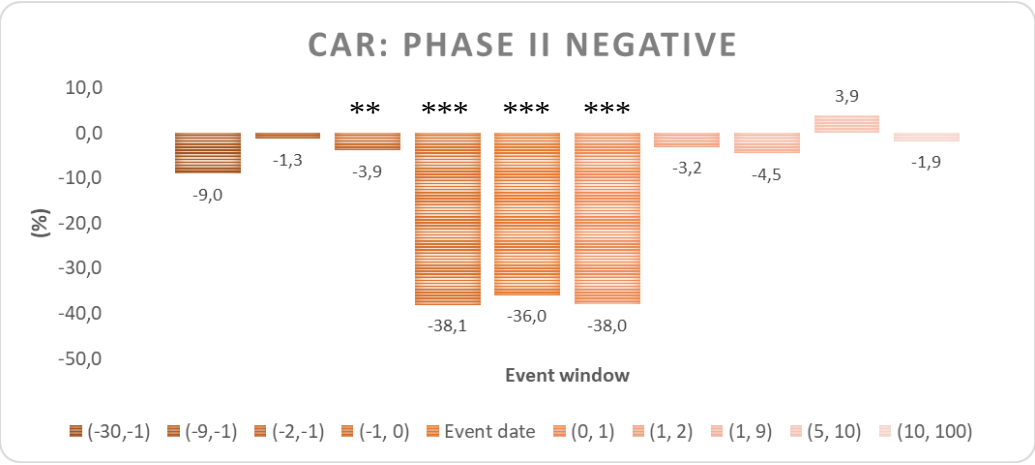

Figure 10. Cumulative abnormal return (%) surrounding negative phase II trial announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

Lastly, negative announcements of phase III clinical trials were scrutinized (Figure 11). Here, no significant deviations in CAR could be observed in the pre-event window. By contrast, there was a significant decrease between day 1 and day 9 after the negative announcement. On the announcement date of the negative clinical trial, there was a significant negative mean CAR of -23.4% ($p<0.05$), indicative of severe market value losses.

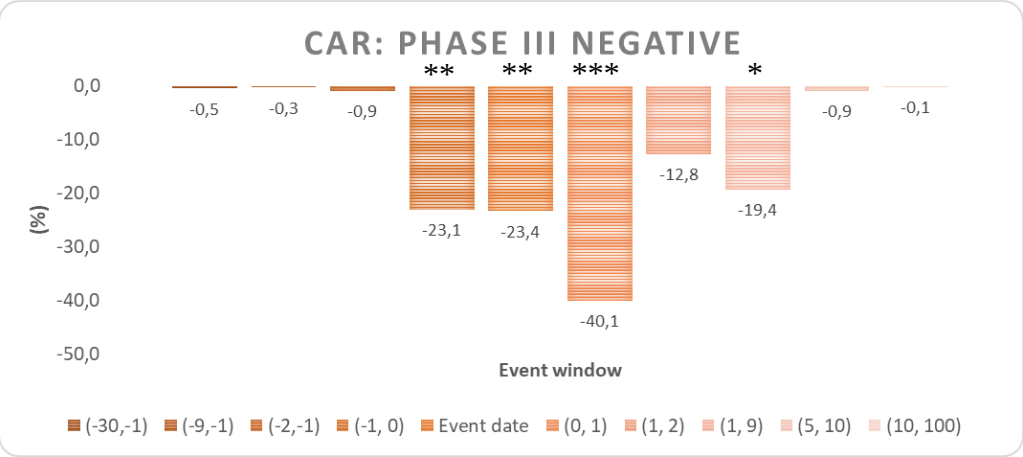

Figure 11. Cumulative abnormal return (%) surrounding negative phase III trial announcements. Different event windows were used. Day 0 represents the event date. *=p<0.1,**=p<0.05,***=p<0.01. Corresponding p-values and supporting data can be found in the Appendix.

7.3. Sensitivity analysis

The choice of estimation windows can have an impact on the results in the event window since abnormal returns can be observed weeks before the release of new company information, mainly due to insider trades. Thus, the data could be biased when the estimation window was as close as 10 days to the event date in the event study analysis in the previous section. Thus, in order to investigate whether the results would differ, it was tested whether an estimation window between 120 and 60 days before the event date would change the event study results. It turned out that the change of estimation window did not significantly affect the cumulative abnormal return nor significance levels for the different scientific announcements. In other words, the results were robust to the use of an estimation period of 100 to 10 days before the event (Appendix Table A13) rather than 120 and 60 days (Appendix Table A14) before the event. For all announcement groups, the significance level (*=p<0.1,**=p<0.05,***=p<0.01) did not change with the different estimation window. Significance was reached in the following groups with both estimation windows: positive phase II, positive phase III, preclinical data, poster/conference presentation, negative phase II and negative phase III. The cumulative abnormal return change differed in the majority of cases with less than 10%, providing further evidence of robustness of the results.

8. Discussion

In this study, it was evaluated whether and to which extent scientific announcements affect the stock return of pharmaceutical companies. The scarcity of literature linking announcements and press releases regarding scientific progress of drug development programs to stock return highlights the importance of the present study. Previous research on scientific announcements have primarily been produced in the United States, while this paper adds value by examining the Nordic market. The lack of comprehensive information in studies in other countries and the lack thereof in a Nordic setting justifies the incremental contribution of this paper to the literature. The present study expands and complements the literature by investigating the importance of multiple scientific announcement in a Nordic context by using pharmaceutical firms with less than 10 drugs in pipeline in the Swedish, Norwegian, Danish and Finnish stock exchange markets. In addition, this paper provides additional insights to how different types of scientific announcements affect stock return as well as an analysis of the period leading up to the event as well as the period afterwards. Pharmaceutical firms are an important player at the crossroads between high quality science and commercialization of products. Therefore, this paper thoroughly analyzes the dynamics of market valuation of 66 listed Nordic pharmaceutical firms and 714 scientific announcements and analyzes abnormal returns at varying event windows. A sensitivity analysis was conducted which confirmed the robustness of results in relation to the choice of estimation window and therefore reliability of results.

The analysis shows that the industry is very dynamic and responds to announcements in various ways. The results show that there are significant positive and negative cumulative abnormal returns at the announcement date for positive and negative scientific announcements respectively. This finding was consistent with the primary hypothesis that the market's reaction following announcements is abnormal. Given the complex factors that affect a company's stock price and the diverse range of scientific announcement types that were analyzed, it was interesting that all the announcement led to significant abnormal return at the event date (except negative phase I reporting due to a small sample). Moreover, the results are consistent with the second and third hypothesis that positive (negative) announcements lead to a positive (negative) cumulative abnormal

return. However, interestingly the market responded asymmetrically to positive versus negative announcements and negative results lead to a disproportionately larger magnitude of abnormal return, confirming the fourth hypothesis. This has been proposed be due to a reputational effect on company and decrease in confidence by investors and shown by previous research in the pharmaceutical industry (Demortain, 2012; Perez-Rodriguez & Gonzalez Lopez-Valcarcel, 2012; Pérez-Rodríguez & Valcarcel, 2012).

The risks associated with development of a new drug are highest in the early phases of drug development. Thus, it is reasonable to assume that the stock market values later clinical trials compared to early trials. Interestingly, the results in this thesis shows that preclinical data announcement yields a higher cumulative abnormal return compared to clinical trials. Furthermore, phase III clinical trials, did not yield larger cumulative abnormal return than for example phase II clinical trials. These results may be explained by the fact that the announcement of positive preclinical data could imply new projects and thus new drugs added to the pipeline of the company. Thus, the market values these announcements as new projects and values them accordingly. In contrast, phase III trial reporting may be anticipated by investors which could further explain the results. Thus, the data does not support the fifth hypothesis that abnormal stock market returns are larger for scientific announcements related to later phases in the drug development process and is an interesting observation for the sample of firms in this study.

Abnormal returns could be observed in the trading days leading up to the event day for some scientific announcements, i.e. positive phase I and III trials as well as negative phase II trials, thus confirming the sixth hypothesis. This is in line with previous literature such as the study by Rothenstein et al (2011). Outlined explanations in the literature argue that this could be a sign of illegal insider trading and information leakage. Thus, informed individuals make stock trades based on information before results are public. Clinical trials are complex processes and many people are involved in executing clinical trials. For example, it has been estimated that up to one in ten physicians has a consulting relationship with entities that provide investment advice (Topol & Blumenthal, 2005). Hence, the results highlight the importance of clinical investigators to follow ethical and legal guidelines regarding divulgements of nonpublic information. There are numerous examples of information leakage in the literature and how the massive effects on stock price (Helft et al., 2004; Roush, 1995; Skolnick, 1998).

The data shows strong evidence that firms reporting phase I and phase II positive trials experience negative cumulative abnormal return in the post-event window after the announcement date, confirming the seventh hypothesis. One interpretation of this phenomenon is market overreaction (Ma et al., 2005; Tang et al., 2013). Another interpretation is that the firms require new capital to continue with new clinical studies and therefore perform equity emissions, which was not controlled for in the present study. There was no negative cumulative abnormal return in the stock price in the post-event window after the release of phase III clinical trial reports. This is possibly due to the fact that this is the last step before market approval of drugs, hence stock price is stabilized at a price level and there is less room for speculation.

The present study has several limitations. To begin with this study analyzed a variety of announcements where interim reporting is common. It was not distinguished whether scientific announcements were completely new to the public or whether the results were partly new (i.e. interim reporting of some of the results of a scientific study). Since interim reporting is common for clinical trials, it is reasonable to assume that the results could underestimate the abnormal returns. However, it would be practically hard to distinguish interim reports from other types announcements and therefore for the sake of completeness, the present study analyzed all press releases. Another limitation is the exclusion of large pharmaceutical firms. Therefore, the results are not generalizable to larger companies where the incremental effect on abnormal return by a single scientific announcement can be presumed to be smaller. In addition, the present study only used the market model without controlling for daily Fama-French Factors to adjust for the small-firm effect. Another limitation is that the number of announcements was relatively small for some announcements, thus giving insignificant results. This was especially observed for negative phase trial announcements in the later stage of the drug development process. One explanation to this could be survivorship bias, i.e. only firms which report positive news survive in the end. Another limitation is the analysis of only closing prices. By analyzing solely the closing price, one may omit the volatility in price that takes place during a trading day and this consequently generates a bias in computed returns. Finally, although the data was checked for overlap in event windows between different scientific announcements at a short trading horizon, it cannot be excluded that other

announcements, such as equity issuance and spillover effects from other firms could affect abnormal return.

9. Conclusions and future research

This paper seeks to provide insights into stock price dynamics of Nordic pharmaceutical firms and the effects of a wide range of scientific announcements. The topic is of relevance due to the importance of the life science industry for the Nordic economy as well as for this region's competitiveness. Moreover, the life science sector attracts numerous investors. The evidence presented in this thesis indicates that outside investors could potentially earn economically meaningful abnormal returns and avoid losses for their portfolio of pharmaceutical companies by the insights of this event study.

All positive announcement types (preclinical data, phase I clinical trial results, phase II clinical trial results, phase III clinical trial results, poster/conference presentation and study initiation) yielded mean positive abnormal return on the announcement date. Interestingly, the results highlight the importance of preclinical data reporting by pharmaceutical firms, which resulted in the highest positive mean cumulative abnormal return and no significant negative abnormal return in the trading days following the announcement. By contrast, phase I and phase II clinical trial reporting resulted in significant negative cumulative return in the trading days following the announcement, which could partly be explained by market overreaction of positive news in the early phases of drug development. Positive phase III data did not result in negative CAR in the post-event window. Moreover, for phase I and phase III clinical trials there were significant positive abnormal returns in an event window encompassing trading days before the announcement, indicative of information leakage. This thesis also highlights the importance of poster presentation at scientific conferences as well as the announcement of study initiation which yielded positive cumulative abnormal return at the event date.

Negative announcements regarding clinical trials resulted in heavy losses and negative cumulative abnormal return, the magnitude being higher than the corresponding positive announcements, which is in line with previous literature. Both phase I, phase II and phase III clinical trial reporting resulted in negative cumulative abnormal return on the event date and negative phase II trials showed a significant negative cumulative abnormal return during the trading days preceding the announcement date. There were

also signs of continuing losses in the post-event window following the announcement of negative phase III clinical trials, but not the other trial types.

Future research to be added to this field include the analysis if different therapy areas yield different cumulative abnormal return and the market valuation of therapy areas. Furthermore, it would be interesting to investigate whether similar results could be observed in other countries throughout the whole drug development process. In addition, the indication of information leakage before the release of official information warrants further investigation on how such leakage can be avoided and the role regulatory aspects play in preventing illegal insider trading.

Taken together, the results show that scientific announcements for a Nordic sample of pharmaceutical firms, operating in a diverse range of therapy areas, are indeed important for stock market valuation. The stock market was shown to react to these announcements. In line with previous research on announcements in the pharmaceutical industry, the results strengthen the view that scientific announcements are essential to consider for investors when investing in the pharmaceutical industry and questions the strong efficient market hypothesis. The study contributes to the broader research topic on the interplay between information and financial markets. It is reasonable to assume that these results may hold external validity, provide novel insights as well as have implications for investors in the pharmaceutical industry.

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11. Appendix

Table A1 – Total list of all examined pharmaceutical firms

Firm	Country (stock exchange)	Therapy area
Active Biotech	Sweden	Multiple areas
AcuCort	Sweden	Other areas
ALK-Abelló B	Denmark	Immunologi
Alligator Bioscience	Sweden	Oncology
Alzinova	Sweden	CNS
Annexin Pharmaceuticals	Sweden	Cardiovascular
Aptahem	Sweden	Immunology
Bavarian Nordic	Denmark	Oncology
BerGenBio	Norwegian	Oncology
BioArctic B	Sweden	CNS
Biohit Oyj B	Finland	Multiple areas
BioInvent International	Sweden	Multiple areas
Biotec Pharmacon	Norwegian	Immunology
Camurus	Sweden	Multiple areas
Cantargia	Sweden	Oncology
Combigene	Sweden	Oncology
Corline Biomedical	Sweden	Multiple areas
Cyxone	Sweden	Immunology
DexTech Medical	Sweden	Oncology
Diamyd Medical B	Sweden	Endocrinology
Double Bond Pharmaceutical B	Sweden	Oncology
Eurocine Vaccines	Sweden	Immunology
Follicum	Sweden	Multiple areas
Hamlet Pharma	Sweden	Oncology
Hansa Biopharma	Sweden	Immunology
Idogen	Sweden	Immunology
Immunicum	Sweden	Oncology
InDex Pharmaceuticals Holding	Sweden	Immunology
Infant Bacterial TherapeuticsB	Sweden	Other areas
Initiator Pharma	Sweden	Other areas
Isofol Medical	Sweden	Oncology
ISR Holding	Sweden	Other areas

Kancera	Sweden	Multiple areas
LIDDS	Sweden	Multiple areas
Lundbeck	Denmark	CNS
Medivir B	Sweden	Oncology
Nanologica	Sweden	Multiple areas
NeuroVive Pharmaceutical	Sweden	Other areas
NextCell	Sweden	Other areas
Nordic Nanovector	Norwegian	Oncology
Oasmia Pharmaceutical	Sweden	Oncology
Oncology Venture	Sweden	Oncology
Oncopeptides	Sweden	Oncology
Onxeo	Denmark	Oncology
Orexo	Sweden	CNS
Orion Oyj A	Finland	Multiple areas
Orphazyme	Denmark	Other areas
PCI Biotech Holding	Norwegian	Oncology
PharmaLundensis	Sweden	Multiple areas
PledPharma	Sweden	Multiple areas
Promore Pharma	Sweden	Dermatology
Redwood Pharma	Sweden	Opthalmology
Respiratorius	Sweden	Multiple areas
RhoVac	Sweden	Oncology
Saniona	Sweden	Multiple areas
Sedana Medical	Sweden	Anesthesiology
Spago	Sweden	Oncology
Sprint Bioscience	Sweden	Oncology
SynAct	Sweden	Immunology
Targovax	Norwegian	Oncology
Toleranzia	Sweden	Immunology
Veloxis Pharmaceuticals	Denmark	Immunology
Vicore Pharma Holding	Sweden	Other areas
Xbrane Biopharma	Sweden	Multiple areas
Xspray Pharma	Sweden	Immunology
Zealand Pharma	Denmark	Multiple areas

Table A2. Overview of scientific announcements. Event window: -30 to -1 days. Estimation window - 120 to - 60 days.

	Phase I (n=78)	**Phase II** (n=102)	**Phase III** (n=43)	**Preclinical** (n=136)	**Study start** (n=181)	**Poster** (n=129)
CAR	4.605517	-1.381435	5.586243	-3.731397	2.312561	-2.1290
p-value	0.086*	0.691	0.072*	0.221	0.426	0.526
t-value	1.74	-0.40	1.85	-1.23	0.80	-0.64
Std. Err.	2.649346	3.461783	3.027179	3.032762	2.90132	3.35154

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-38.3202	-8.993749	-.4726068
p-value	0.216	0.406	0.940
t-value	-2.84	-0.86	-0.08
Std. Err.	13.50977	10.43349	6.085219

Note: CAR=cumulative abnormal return, *=p<0.1,**p=<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A3. Overview of scientific announcements. Event window: -9 to -1 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	1.485247	-.0247273	.1744129	-1.248565	2.208806	.471043
p-value	0.277	0.984	0.902	0.279	0.366	0.834
t-value	1.09	-0.02	0.12	-1.09	0.91	0.21
Std. Err.	1.357238	1.234458	1.413481	1.149325	2.43553	2.24307

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-13.4317	-1.313606	-.3107907
p-value	0.383	0.669	0.895
t-value	-1.46	-0.44	-0.14
Std. Err.	9.216091	3.000061	2.291861

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A4. Overview of scientific announcements. Event window: - 2 to + 2 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	1.620068	5.208368	4.64203	7.758891	.7447128	4.08076
p-value	0.264	0.070*	0.001***	0.001***	0.230	0.069*
t-value	1.12	1.83	3.44	4.05	1.20	1.83
Std. Err.	1.44092	2.843006	1.347908	1.916807	.6187367	2.2257

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-35.6295	-43.0989	-37.04177
p-value	0.229	0.001***	0.001***
t-value	-2.66	-6.16	-4.44
Std. Err.	13.39691	6.993692	8.344263

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A5. Overview of scientific announcements. Event window: - 2 to -1 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	.2570336	-.3889741	.3331001	.9210928	-.1608417	2.24529
p-value	0.664	0.467	0.532	0.166	0.674	0.264
t-value	0.44	-0.73	0.63	1.39	-0.42	1.12
Std. Err.	.5886082	.5329678	.5291598	.6622123	.3820676	1.99990

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-3.187518	-3.904391	-.9058123
p-value	0.684	0.020**	0.160
t-value	-0.54	-2.67	-1.52
Std. Err.	5.883981	1.460545	.5972317

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A6. Overview of scientific announcements. Event window: - 0 to 0 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	4.215428	6.366972	5.455434	8.428712	1.690296	1.71583
p-value	0.004***	0.013**	0.001***	0.001***	0.001***	0.001***
t-value	2.97	2.52	4.50	4.29	4.71	4.13
Std. Err.	1.420181	2.526874	1.213649	1.96541	.3587466	.415251
CI low	1.388629	1.355513	3.007878	4.542501	.9825354	.8945337
CI high	7.042227	11.37843	7.902991	12.31492	2.398056	2.537126

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-31.54042	-36.0325	-23.3672
p-value	0.154	0.001***	0.025**
t-value	-4.06	-5.36	-2.63
Std. Err.	7.767978	6.727443	8.896706
CI low	-130.2419	-50.69034	-43.1903
CI high	67.1611	-21.37466	-3.544106

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. CI low= lower 95% confidence interval. CI high= higher 95% confidence interval. Poster= announcement of poster presentation or conference participation

Table A7. Overview of scientific announcements. Event window: - 1 to 0 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	4.219307	5.776854	5.600854	9.234465	1.915364	2.12365
p-value	0.006***	0.026**	0.001***	0.001***	0.001***	0.001***
t-value	2.80	2.25	4.67	4.84	4.32	3.30
Std. Err.	1.507296	2.565971	1.199629	1.907231	.4432788	.644286

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-31.38266	-38.12256	-23.12128
p-value	0.142	0.001***	0.027**
t-value	-4.40	-5.57	-2.60
Std. Err.	7.131168	6.847054	8.90931

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A8. Overview of scientific announcements. Event window: 0 to 1 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	2.706594	6.371486	4.237905	7.673064	1.632426	1.84781
p-value	0.043**	0.019**	0.001***	0.001***	0.001***	0.002***
t-value	2.06	2.38	3.76	4.14	3.96	3.17
Std. Err.	1.314579	2.682467	1.125799	1.854537	.4117308	.582632

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-30.4706	-38.03004	-40.13506
p-value	0.102	0.001***	0.002***
t-value	-6.21	-5.57	-4.20
Std. Err.	4.905006	6.823528	9.553129

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A9. Overview of scientific announcements. Event window: 1 to 2 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	-2.852394	-.7696295	-1.146504	-1.590914	-.7847412	.119640
p-value	0.001***	0.308	0.053*	0.016**	0.068*	0.802
t-value	-3.34	-1.02	-1.99	-2.45	-1.83	0.25
Std. Err.	.8546271	.7509309	.5756767	.6506431	.4277962	.475395

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-.9015628	-3.162017	-12.76876
p-value	0.176	0.142	0.173
t-value	-3.53	-1.57	-1.47
Std. Err.	.2550479	2.010308	8.709047

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A10. Overview of scientific announcements. Event window: 5 to 10 days. Estimation window - 100 to - 10 days.

	Phase I (n=79)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=138)	**Study start** (n=184)	**Poster** (n=135)
CAR	-2.719161	-2.036034	.574912	-1.209359	-1.063723	-.67332
p-value	0.002***	0.043**	0.540	0.236	0.122	0.412
t-value	-3.25	-2.05	0.62	-1.19	-1.55	-0.82
Std. Err.	.8369085	.9941253	.9301315	1.015135	.6847389	.817393

	Negative phase I	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-	3.930494	-.8546472
p-value	-	0.678	0.812
t-value	-	0.43	-0.24
Std. Err.	-	9.22522	3.494968

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A11. Overview of scientific announcements. Event window: 1 to 9 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR	-5.572583	-2.446449	-.260787	-3.183442	-2.376101	-.86274
p-value	0.001***	0.129	0.801	0.012**	0.002***	0.425
t-value	-3.92	-1.53	-0.25	-2.53	-3.08	-0.80
Std. Err.	1.421888	1.598469	1.029917	1.256492	.7703775	1.07850

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-6.780535	-4.507155	-19.3603
p-value	0.468	0.427	0.099*
t-value	-1.11	-0.82	-1.82
Std. Err.	6.13402	5.483509	10.63655

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A12. Overview of scientific announcements. Event window: 10 to 100 days. Estimation window - 100 to - 10 days.

	Phase I (n=79)	**Phase II** (n=104)	**Phase III** (n=43)	**Preclinical** (n=138)	**Study start** (n=183)	**Poster** (n=133)
CAR	-23.20996	-20.54501	-7.251788	3.160451	-4.316473	-1.9102
p-value	0.001***	0.002***	0.181	0.480	0.311	0.697
t-value	-3.39	-3.25	-1.36	0.71	-1.02	-0.39
Std. Err.	6.840552	6.326058	5.326285	4.463333	4.248543	4.88942

	Negative phase I	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR	-	-1.876893	-.1479355
p-value	-	0.919	0.988
t-value	-	-0.10	-0.01
Std. Err.	-	18.14256	9.9917

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A13. Overview of scientific announcements. Event window: - 2 to + 2 days. Estimation window - 100 to - 10 days.

	Phase I (n=80)	**Phase II** (n=104)	**Phase III** (n=44)	**Preclinical** (n=139)	**Study start** (n=186)	**Poster** (n=135)
CAR (%)	1.620068	5.208368	4.64203	7.758891	.7447128	4.08076
p-value	0.264	0.070*	0.001***	0.001***	0.230	0.069*
t-value	1.12	1.83	3.44	4.05	1.20	1.83
Std. Err.	1.44092	2.843006	1.347908	1.916807	.6187367	2.2257

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR (%)	-35.6295	-43.0989	-37.04177
p-value	0.229	0.001***	0.001***
t-value	-2.66	-6.16	-4.44
Std. Err.	13.39691	6.993692	8.344263

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation

Table A14. Overview of scientific announcements. Event window: - 2 to + 2 days. Estimation window - 120 to - 60 days.

	Phase I (n=78)	**Phase II** (n=102)	**Phase III** (n=43)	**Preclinical** (n=136)	**Study start** (n=181)	**Poster** (n=129)
CAR (%)	1.339273	5.515067	5.40824	7.691847	.8394766	4.23147
p-value	0.310	0.063*	0.001***	0.001***	0.171	0.073*
t-value	1.02	1.88	3.95	3.92	1.37	1.80
Std. Err.	1.31183	2.934038	1.367519	1.961983	.6112168	2.34445

	Negative phase I (n=2)	**Negative phase II** (n=13)	**Negative phase III** (n=11)
CAR (%)	-37.63568	-43.23838	-36.67597
p-value	0.211	0.001***	0.001***
t-value	-2.90	-5.98	-4.54
Std. Err.	12.96204	7.229058	8.082437

Note: CAR=cumulative abnormal return, *=p<0.1,**=p<0.05,***=p<0.01. Poster= announcement of poster presentation or conference participation