INTRADAY AND INTERDAY RETURNS AT THE SCANDINAVIAN STOCK INDICES

An empirical study of the return and volatility distributions at the Scandinavian indices

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Abstract

The thesis reviews the intraday and interday returns and volatilities at the three main Scandinavian stock indices, and whether it exists differences between these markets. Previous research document that the close-to-close returns the last decades are mainly positive due to the positive interday returns, whereas the intraday returns are negative. These differences are important for the investors, as it might prove profitable or unprofitable to hold positions in the financial markets at specific times during a day.

The thesis explores structural differences between the indices, and discuss whether these might offer explanations for the differing results. OSEBX yields a positive intraday return, and a interday return close to zero. In contrast, S30 and C20CAP yield a negative intraday return, and a positive interday return throughout the period. Further, we decompose the indices to investigate whether segments and industries prove to affect the overall performance. We find that size and segments offer explanations for the original findings at the indices. The thesis examines extensively the intraday and interday returns and volatilities for seasonality, the weekend- and holiday effect and the differences between individual trading days. We find seasonality, and a positive interday return after a weekend when omitting the holidays at all indices. We find various volatilities for different trading days, and based on this we elaborate whether options are over- or underpriced. The market incorporates a higher volatility when pricing options, which may be a result of low liquidity or not considering the various volatility. Based on the findings throughout the thesis we construct two trading strategies, where the thesis elaborates whether the findings are proof of market inefficiency. The strategies do not outperform the market, and this might prove market efficiency.

We find significant differences between OSEBX, S30 and C20CAP, which might be due to the structural differences and the composition of the indices. Even though the indices are different, the findings throughout the thesis indicate that these markets are efficient.

Contents

1 Introduction

1.1 Introduction

The international financial markets have been investigated and researched for many decades. This has also been the scenario for the Scandinavian financial markets, but not on the same scale. We investigate whether there are any differences between the intraday and interday returns for the main indices in Scandinavia; OSEBX, OMXS30 and OMXC20CAP. In order to explain these potential differences, we consider the structural differences between the indices and market efficiency.

Oslo Stock Exchange is the only Scandinavian stock exchange which is not owned by the American company Nasdaq. Oslo Stock Exchange is regulated by the Norwegian Law of Security Trading, while both Stockholm and Copenhagen are regulated by the European Securities and Market Authority (ESMA). As these two regulations are not identical, they result in differences regarding timing of publishing company specific news. We believe that this may be a factor that lead to differences in intraday and interday returns between the three Scandinavian stock exchanges.

During a trading day, investors are able to react on news and information when deciding whether to invest in a stock or sell it. Since investors have different perceptions of a firm's outlook, potential, news and other factors, the price of the stock will fluctuate to meet the supply and demand. News and other factors that may affect an investor's perception, are not only limited to the trading hours of the stock exchange. New input for the investor is continuously published, which in turn may change whether an investor wishes to buy or sell a stock. However, the investor's opportunity to react on this information may be limited due to the opening hours of the stock exchange. An investor may be able to trade using Over-the-Counter (OTC) markets. The OTC-markets are trading financial instruments outside the exchanges, but they have its limitation. OTC markets are presented and discussed throughout the thesis.

We observe that the closing price of the exchange is not the same as the opening price of the exchange. This is simply because the first trade of the day incorporates information and events that have occurred during the non-trading hours.

An investor has the opportunity to trade during the opening hours of the stock exchange, and be able to react on changed perceptions as he can sell and buy shares instantly. The investor can also choose to keep his positions over the night. He or she will not be able to sell or buy shares on the exchange during these hours, and we believe that the investors are therefore more exposed to an unfavorable movement in the share price since they cannot liquidate their positions directly on the exchange. Unfavorable movements may be a result of negative information or news published during the non-trading hours. However, by keeping these positions over night, the investors might also be able to gain as a result of positive information. For instance, positive performance of commodities or international exchanges during the non-trading hours.

We believe that one of the main reasons for variation in stock prices between closing and opening of the market is related to the information published during non-trading hours. As explained by Oslo Stock Exchange, a functioning capital market is characterized by good information flow from the listed companies (Circulars, decisions and statements, 2016). It is important that the participants in the market have access to correct, complete and timely information from the listed companies in order to make qualified investment decisions.

A reason for dissimilarities between the Scandinavian stock exchanges might be the composition of the indices. The indices consist of different industries and are exposed to various factors, which in turn might lead to different intraday and interday returns.

The thesis highlights the differences between holding positions in the financial market during the trading hours, versus holding on to them during the non-trading hours. These findings are investigated in depth to observe whether there exist similarities and differences between time periods. We discuss whether the findings are related to the ownership of the exchanges, and in turn the regulations on the exchanges. We decompose the indices to highlight how the various industries affect the overall performance of the indices. Throughout the thesis we discuss the findings related to the efficient market theory.

1.2 Research question

In this section, we present the primary research question and sub-questions that arises throughout the research.

- Do differences exist between intraday and interday returns in the three main Scandinavian stock indices, and what are the implications in terms of structural differences and market efficiency?

In addition to the main study question, we discuss several sub-questions where we examine the data more closely, and discuss whether there exist differences at a more detailed level. These questions are discussed in both a practical way regarding the implications for the investor, and using the theoretical framework of market efficiency.

- Does seasonality exist in the three main Scandinavian stock indices, and is it possible to obtain a profit using trading strategies based on seasonality?
- Do differences exist between the individual trading days during a week in the three main Scandinavian stock indices, and is it possible to obtain a profit using a trading strategy involving these potential differences?
- What are the implications of varying volatility during a day for pricing options?

The intraday and interday return is defined, respectively, as the return obtained during the opening hours of the stock exchange, and the return obtained during the closing hours of the stock exchange. The primary research question is inspired by previous research. In contrast to earlier research, this thesis focus on the Scandinavian stock market. We analyze the most recent available data, which distinguishes this thesis from previous research.

1.3 Thesis Limitations

In this section, we discuss the limitations regarding the thesis. Previous research on intraday and interday returns has been conducted on US stock exchanges, where the researchers have based their research on the opening and closing prices of individual stocks, and constructed an index based on this. This research is based on the three main Scandinavian stock indices. In turn, this implies that when we use the opening and closing price of the index, there are several stocks represented in the index that has not yet been traded when the opening price is set.

The thesis is based on a four-year period from 2013-2016. For statistical analysis, this represent a quite small sample, which may lead us to draw wrong conclusions. We have not been able to extend the data set, as OSEBX changed their trading system in 2013, resulting in that the opening price was equal to the closing price in the data from before 2013. Obviously, the data before 2013 is useless in terms of the research question.

We limited the research question partly to the approach used by Cooper, Cliff, & Gulen (2008) and partly to the approach used by French (1980) as these two approaches differs, and in turn lead to differing results. We discussed the findings using the financial theory, regarding efficient markets and behavioral finance. Behavioral finance is by many regarded as a natural counterparty to the theories concerning efficient markets, since it provides plausible explanations for market anomalies, such as the January effect, momentum effect, etc. This being said, the markets may appear inefficient and still not be explained by the theories regarding behavioral finance as there may be other factors explaining inefficiencies. The thesis will, however, use the two theories as a framework in explaining the findings.

1.4 Literature Review

Fama (1970) propose a central concept regarding the financial markets. This is concerning whether markets are efficient or not, and therefore if investors are able to systematically profit based on available information in the market. He proposes three types of efficiency: strong-form, semi-strong and weak efficiency. This is explained in chapter 2.2.

Sewell (2007) define that behavioral finance is the study of how the behavior of financial practitioners is affected by psychology, and how this affects the financial markets. He states that this is of interest for financial practitioners, since it is an explanation for why and how the markets might be inefficient.

Ricciardi & Simon (2000) state that behavioral finance explains finance and investment from a human perspective. They explain that behavioral finance provides explanations for anomalies in the stock market, where psychological and sociological factors influence the decision making of individuals. More recent research like Yusuf (2015), demonstrates that the average investor makes decisions based on emotions.

French & Roll (1986) present patterns on asset prices during trading hours and non-trading hours. During trading hours, the asset prices are more volatile than during non-trading hours. They have three main explanations for these findings. The first explanation is that during trading hours, investors are more likely to receive public information. The second factor is that when informed investors trade, this private information they trade on, causes volatility. The last explanation is that pricing errors occur when the asset is traded, since the process of trading introduces noise. For instance, investors might over-react to each other's trades.

Fama (1965) presents the Calendar Time Hypothesis, which discuss the stock return generating process. This theory states that the variance should be proportional with the number of days elapsed, rather than the number of trading days. Therefore, it should be differences in variance between Mondays and the rest of the days during the week, as the Monday variance represent the weekend.

Clark (1973) presents the Trading Time Hypothesis. This hypothesis discusses a model where the returns are generated in trading time and tests whether the variance is linearly related to the volume of trading. Thus, it should be no returns generated in non-trading hours, and therefore no variance as well.

French (1980) tests these hypotheses using another approach. He compares the stock returns on different days during a week and whether these are proportional to time. However, he finds that the Monday return is negative and therefore not consistent with either the calendar or trading time hypothesis.

Although previous empirical evidence indicates that volatility is higher during trading-hours, recent research find that overnight returns are higher than intraday returns. Cooper et. al., (2008) find that the US equity premium the last decade has been solely due to overnight return.

Lou, Polk & Skouras (2015) provide one of the newest articles about interday and intraday returns. They use different strategies to investigate at what time of the day, the abnormal returns were occurred. The momentum effect had remarkably returns during the non-trading hours, where the other strategies resulted in the opposite. This article also mention that a significant amount of news is released after markets close, which is contradictory to the findings from French & Roll (1986).

Kelly & Clark (2011) provide findings in line with the empirical evidence presented above. They highlight that risk-adjusted return on stocks held during intraday is significantly lower than risk-adjusted returns on stocks that are held overnight. They think these results are caused by the behavior of undiversified active traders. Undiversified investors are liquidating their portfolios at the end of day, since they feel that they have less control during non-trading hour. This expression is called the "illusion of control" (Langer, n.d.)

Ahoniemi & Lanne, p.2 (2011) highlight the importance of the overnight period. "*The overnight period is becoming more and more important due to the integration of global financial markets, and many news releases are also timed to occur during non-trading hours. During market closures, investors are not able to garner information about asset prices by observing executed trades.”*

The concept January effect has been tested in several stock markets through the years, and the seasonal effect in January has empirically outperformed the other months. Rozeff & Kinney (1976) test this phenomenon on an equal-weighted index on New York Stock Exchange in the period 1904-1974. They find that January had an average monthly return of approximately 3.5%, while the other months had an average return of approximately 0.5%.

Thaler (1987) provide an explanation to this phenomenon to occur in the stock market. The prices of the shares will further decline in the end of the year, as investors will realize their capital losses due to reorder their portfolio. Then, in the beginning of the new year, the price of the stocks will increase in the absences of selling pressure.

In this section, we presented several research articles that have worked as a base for this thesis. In addition, this earlier research has also been motivation and inspiration for us to transfer this to other indices. This paper is focusing on the Scandinavian indices, rather than the more global markets. Hence, there is less research related to these indices. This may yield contradictory results.

1.5 Thesis Structure

After presenting the research questions, highlighting the thesis limitations and the review of previous research related to the research topic, the further structure in the thesis is presented. We have illustrated the structure below.

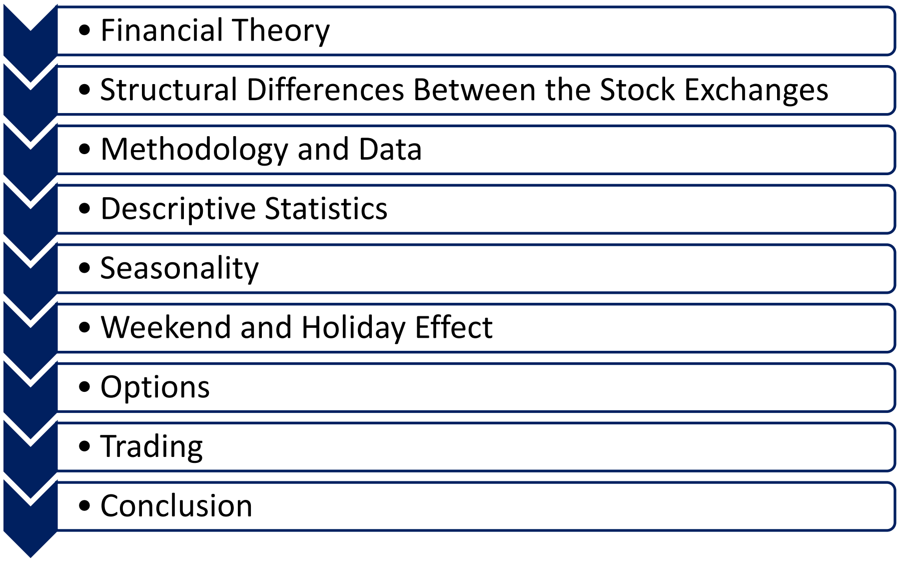


Figure 1: Thesis Structure

First, we present traditional financial theory that has implications and explanations for the findings in the analysis. We focus on both the efficient market theory and the behavioural finance, which is by many regarded as a natural counterparty to the efficient market theory. We investigate the Calendar Time and Trading Time Hypothesis, before finishing with the theory regarding different volatility throughout the day.

Further, we present the structural differences between the Scandinavian stock exchanges. This will be discussed and may offer explanations for the findings in the analysis.

The chapter regarding methodology and data will present the foundation for the quantitative analysis, and the data that we base the research on. In the end, we present some practical implications for the thesis regarding real-life trading and how this may affect our results.

After presenting the methodology, we present the descriptive statistics for the three stock indices. We discuss the robustness of the findings, and compare and discuss the results from each index. In the end, we decompose each index and discuss the impact of different industries.

Further on, we go deeper into the data set. We explore whether there exist differences between months and trading days, and whether weekends and holidays have an effect on the expected return and volatility.

After discussing the expected returns and volatility for the three indices, we use the findings regarding varying volatility throughout different days and present the implications for an investor buying and selling options. First, we use tailor-made options to highlight the differences, before we use observed options in the market in order to highlight these differences.

In the chapter about trading, we use the various returns from the findings to exploit two trading strategies. We use this to illustrate how an investor can exploit differences between trading days. In these two strategies, we also add transaction costs to make it more relevant for an investor.

In the last chapter, we summarize the thesis and answer the initial questions that we presented in section 1.2.

2 Financial theory

2.1 How is the price of a stock determined?

The value of a stock, at any time, is the price an investor is willing to pay for the stock. The value, therefore, varies due to differences in supply and demand for the stock. When we buy a stock we are not buying it from the actual company, but second hand from another investor. Therefore, the price we have to pay is determined by the variation in supply and demand for the stock in question. This can be represented by the classic supply and demand model originally developed by Antoine Augustin Cournot in 1838.

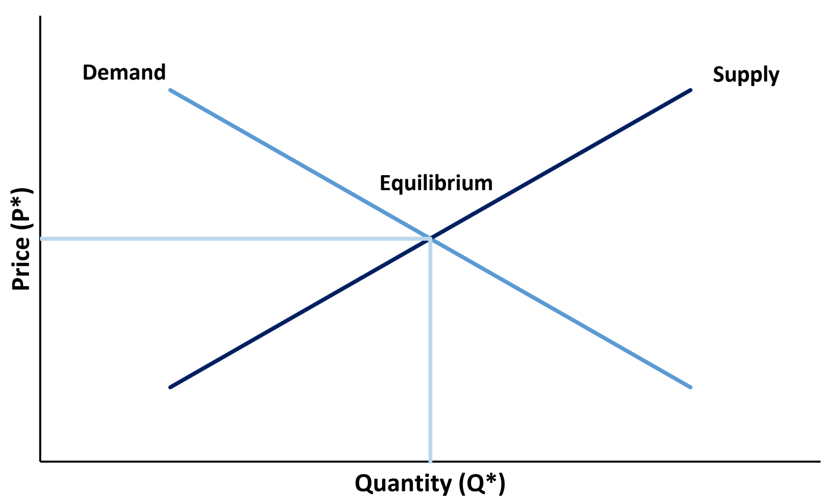


Figure 2: Supply and Demand

The demand curve represents the intentions and willingness of the investors in the market to buy a particular stock at a specified price. The demand curve has a negative slope as it is cumulative. This means that the investors that is willing to pay a price P* for the stock, is certainly willingly to pay a lower price than P*. Therefore, the lower the price, the higher quantity of the share will be demanded in the market.

The supply curve represents the intentions and willingness of the investors, who already hold the particular stock, to sell the stock at a specified price. The supply curve has positive slope since it is cumulative. In the same way as the demand curve, investors willing to sell the stock at the price P*, will certainly be willing to sell the stock at a higher price than P*.

Adding these curves together, the price of a stock is determined by finding the point where these two curves cross. At this point, we find the price for the maximum number of shares that will be transacted. The transaction is complete when the price is found, and this happen continuously throughout the trading day.

We know that the supply and demand curves fluctuate during a day due to news, information, trends and anything else that change the sentiment of investors. The price movement will therefore reflect the movement in the supply and demand.

The model represents single stocks, but this is also used at indices, since an index is composed by several stocks. The value of an index is determined by the trading and value of the stocks included in an index. The opening and closing price of the index is determined by the first and last trade in a firm represented in the index.

What we should be aware of, is that both the supply and demand curve are different for each single investor in the market. Everyone assesses firms differently, and may be more or less willing to buy and sell at a specific price. An investor considers a firm's current situation, prospect, macro-variables, etc. Together, all of these different assessments generate the common supply and demand curve. In other words, the share price is determined by the opinions that everyone has about the firm today, the firm's future, and all other factors an investor find relevant. This leads to the theory about the efficient market hypothesis.

2.2 Market Efficiency

Fama p.383 (1970) describes the concept of market efficiency. He defines this as " *A market in which prices always fully reflect available information is called efficient*". Efficient market hypothesis (EMH) is a frequently discussed topic in finance academia.

The hypothesis is based on the lack of abnormal returns. In other words, it is not possible to get expected returns which are greater (or less) than the risk-adjusted cost of capital. The value of a stock should equal the fundamental value of the asset if there is a competitive efficient market (Brealey, Myers & Allen, 2011). Hence, there is no arbitrage in an efficient market. Arbitrage is defined as "*Purchase of one security and simultaneous sale of another to give a risk-free profit*" (Brealey et al., P. 931 2011).

Angenfelt (2013) provides findings that violates against the EMH. In other words, it is possible to earn abnormal returns in the stock market. We present the topic, absence of market efficiency, later.

2.2.1 Weak-form efficiency

In the efficient market theory, we distinguish between three different forms of market efficiency. The first is the weak form efficiency, and this claims that past price movements and volume do not affect stock prices. Weak form efficiency is also known as the random walk theory. The random walk theory states that the future prices follow a random walk and is not influenced by the previous movements. If there is not a random walk of stock prices, these prices are autocorrelated. However, if an investor was able to predict the future stock prices by looking at historical prices, all investors would trade equally. Thus, from the random walk perspective, an investor cannot profit by using historical information.

The concept of weak-form efficiency is based on the theory that nobody can earn profits from public information. In contrast to the weak-form efficiency, there are many traders that use past stock price series and trading volume as a technique to beat the market. Clarke, Jandik & Mandelker (2001) call this technical analysis. We are not explaining technical analysis further, although this is an interesting topic.

2.2.2 Semi-strong efficiency

The second efficiency-form is the semi-strong. This theory states that all public information is calculated into the current stock price. This implicates that an investor cannot profit by trading on announcements, recommendations, etc., as the information is already reflected in the stock price.

Clarke, Jandik & Mandelker (2001) state that an investor must be able to interpret macroeconomic factors, in addition to financial information, to understand the market and the direction of stock prices. The public information is not only newspapers and company-produced news, but an analysts have to include all relevant factors related to each company and its industry.

2.2.3 Strong efficiency

The third efficiency form is the strong. This type of efficiency states that all available information, both public and private, are reflected in the current stock price. Berk & Demarzo (2011) explain that an investor cannot profit beyond normal returns, regardless of the information the investor may have. The strong form states that the company's management cannot earn profit on inside information since the market already know. Not surprisingly, empirical research by Clarke et al., (2001) find that this is not consistent with the strong form of efficiency.

Ever since the theory of market efficiency was presented in the 1970s this theory has been tested in several ways. Researchers find evidences that the markets are efficient. Due to these findings, individual and professional investors are convinced that they are not able to make abnormal returns. The solution is to buy index funds, which maximizes diversification of the index and also cut the costs to a minimum (Brealey et al., 2011).

2.2.4 Are markets efficient?

Evidences of efficient markets have changed the view for both professional and individual investors. Many invest in funds that only follow one specific index with a relative low risk. This is a cheap alternative to be in the stock market with low effort. However, not all investors can be invested in only index funds since an efficient market has to have some smart investors who try to profit from information. Prices cannot reflect all information, since it should be incentives for investors to gather costly information (Brealey et al., 2011).

If the theory of efficient market holds, then it is not possible to get an expected return that is greater than the risk-adjusted opportunity costs of capital. If the fundamental value is the same as the price of an asset, then the investors will earn exact the same as the opportunity cost of capital. However, if the price is different from the fundamental value, then an investor can profit from this by buying at a low price and selling at a high price (Brealey et al., 2011).

Angenfelt (2013) published the book "The world's 99 greatest investors – The secret of success". In this book, he highlights 99 different investors where everyone has outplayed the market for several years. For instance, the well-known investor Carl Icahn is an example of this. He had an annual return of 32% on a 31 years' perspective, while the benchmark was 10%. Angenfelt provides also a list of 98 other investors that are have outperformed the market. These evidences are questioning how efficient the market is.

In a real world setting, it is very difficult to define whether a market is entirely efficient or entirely inefficient. It might be a mixture of both, since if all participants in the market believe that the market is efficient, no one would seek abnormal returns. To explain why stock prices might depart from the fundamental value and why some investors are able to beat the market, we present the theory, behavioral finance.

2.3 Behavioral finance

The theory we presented above is based on the concept of rational investors and their ability to react correctly on information in the market. As many knows, investors are also affected by psychological factors. This theory adds cognitive psychology to financial theory to explain why investors sometimes take irrational or emotional decisions. The behavioral finance pursues to understand the behavior in the financial market. By understanding how the behavioral finance works in practice, it will help investors to make decisions that are not based on emotions or irrationality.

Ricciardi & Simon (2000) state that behavioral finance explains finance and investment from a human perspective. They explain that behavioral finance provides reasons for anomalies in the stock market, where psychological and sociological factors influence the decision-making of individuals. Sewell (2007) elaborates that the behavioral finance is interesting, since it explains why and how markets might be inefficient. Yusuf (2015) demonstrates that the average investor makes decisions based on emotions.

Behavioral finance can be divided into several theoretical aspects. Prospect theory is often mentioned as an explanation of why investors make emotional decisions rather than rational. The value an investor place on a specific outcome is determined on how the investor has done it in the past, on the same outcome. If the investor has suffered a large gain or loss in the past, it will affect the decision of today. This is called prospect theory. The second behavioral finance theory we present is based on probabilities. Usually investors tend to focus too much on the recent observations rather than having a long-time perspective. Even though an investor beat the market for the last years, there is no insurance that it will happen again. Overconfidence is a well-known expression in the behavioral theory. In the next section the focus is changed from basic financial theory to the calendar time and trading time hypothesis, which will be a widely discussed topic in the thesis.

2.4 The Calendar time and trading time hypothesis

The Calendar Time Hypothesis was first presented by Fama (1965) and Trading Time Hypothesis was later presented by Clark (1973). These papers discuss the stock return generating process. The Calendar Time Hypothesis states that the variance should be proportional with the number of days elapsed, rather than the number of trading days. Hence, there will be differences in the variance between Mondays and the rest of the days during the week. This is due to the longer investment horizon during a weekend where the investor is not able to react and change his or her positions in the stock market. The hypothesis states that it is news that generates changes in the stock prices, and that it is the calendar time that generates returns. Fama (1965) tests this hypothesis by comparing the variances for each of the days during a week. His hypothesis is that if the variance on Monday is three time as large as the variance at the other days, we accept the calendar time hypothesis.

Clark (1973) tests the trading time hypothesis by developing a model where the returns are generated in trading time and tests whether the variance is linearly related to the volume of trading. The hypothesis states that returns are only generated during trading time, and therefore the variance during non-trading hours should equal zero. The hypothesis states that it is trading that generates changes in the stock prices, and that it is the trading time that generates returns.

In order to test these hypothesis, French (1980) uses another approach. He tests the stock return generating process by comparing the stock returns on different days during a week and whether these are proportional to time. He tests whether the expected return is a linear function of time, measured in calendar time, or if it is a function of trading time. This means that if the expected return on a Monday is three times the expected return of the other days in a week the return is a linear function of calendar time, as it represents a three-day investment. If the expected return is the same for each day, the return is a function of trading time. French points out that, if the calendar time model is correct, the return on trading days following a holiday should also be larger than for a normal day.

However, French finds in his research that throughout his data set the Monday return is negative and therefore not consistent with either the calendar and trading time models. In French's model, he defines the return as the daily return from each day. This implies that the weekend return is based on both Monday and Friday closing level. By using such data, he includes the intraday trading during Monday when calculating the weekend return.

Cooper et al., (2008) find, however, that the weekend effect is positive. The difference from French's (1980) research is that Cooper et al., (2008) calculate the weekend return using the opening level on Mondays. The weekend return therefore omits the Monday intraday trading.

As a difference to French's (1980) model we use the same approach as Cooper et al., (2008) when calculating the returns. We use the closing level Fridays and days before holidays, and the opening price on Mondays and days after holidays. In that way, we are able to omit the intraday trading and not include the activity during the first day of trading after a weekend and holiday.

2.5 Different volatilities throughout the day

French & Roll (1986) present different reasons and explanations for why the volatility differs between intraday and interday. They find that during trading hours, asset prices are much more volatile than during non-trading hours. They discover this phenomenon by using the American stock market as a source, and present three explanations for the findings.

The first explanation, for higher volatility during trading hours, is that the public information is more likely to arrive in this time span. Public announcements and tender offer tends to be published during normal opening hours, and these factors cause volatility. The second explanation highlights the importance of private information. French & Roll (1986) argue that private investors that trade on inside information cause volatility. If these investors are more likely to trade during ordinary trading hours, this will cause volatility.

The third and last explanation is that volatility is caused by the pricing error that occurs during trading. This hypothesis is difficult to test, but it is reasonable to assume that the market tends to overreact to news, other's trades and changes in different commodities price. The stock price is often driven by two factors, information and an error component which we call "noise". This "noise" factor can be considered as the daily pricing error and is more likely to occur during the trading hours due to higher market activity. Since these pricing errors are more likely to appear during the trading hours, they assume that this is one explanation for the high intraday volatility.

The last explanation is consistent with the findings by Ahoniemi & Lanne (2011), where they argue that companies should publish news outside the trading hours. This is based on the argument that investors are not able to garner information about other trades, which might lead to pricing errors as explained by Fama & Roll.

3 Structural differences between the stock exchanges

The three Scandinavian stock exchanges have different owners. This create structural differences between the exchanges, which in turn may lead to differences between the financial markets. These variations may be in how the trading day is organized, how the opening and closing price is set or regarding the rules of duty of disclosure. In this chapter, we examine these differences, and discuss whether this could lead to dissimilarities in the financial markets.

3.1 Oslo Stock Exchange

The benchmark index at Oslo Stock Exchange is called OSEBX, and consists of 62 different companies (per 31.12.2016) (Endret utvalg i Hovedindeksen, 2016). The purpose of OSEBX, is to be made up of a number of representative shares at Oslo Stock Exchange that is easily traded at any time. It is revised two times a year, so the number of firms included in the index will change throughout the years.

Trading Hours Oslo Stock Exchange		
	Start	**End**
Pre-Trading	08.10	08.15
Opening Auction Call	08.15	09.00*
Regular Trading	09.00	16.20
Close Auction Call	16.20	16.25
Post Close	16.25	17.30

Table 1: Trading Hours at Oslo Stock Exchange. (*): + up to 30 seconds random time

The trading hours at Oslo Stock Exchange is from 09.00 to 16.25 GMT+1. The day is divided into different parts. From 08.10 – 08.15, it is a pre-open section where the orders are placed, but not closed. From 08.15 it is an opening call auction. During this auction, the orders are not executed but is displayed if the orders are allowed to be displayed. Throughout this session, the indicative price and volume will be continuously calculated and published (OSLMIT Oslo Børs Market Model Equities, 2017).

At the end of the opening call auction, there is an uncrossing. This happens a random time between 09.00.00 and 09.00.30. During the uncrossing, suitable orders are executed, and orders at equal price levels or higher than the calculated equilibrium price are closed. The equilibrium price is the price where the highest value of an instrument can be closed. For instance, if broker A has put in an order to buy 100 stocks in company X for a specified price, the system will match this order automatically with broker B that has put in an order to sell 100 stocks in company X for the same price. As soon as the financial instrument has been uncrossed and the opening price is set, the instrument is subject to continuous trading throughout the day.

Mallikarjunappa & Haris p. 2 (2011) explain that *"The objective of Call Auction are to increase the price efficiency in the opening session, minimize the volatility and to make prices reflect the overnight information"*. The open call auction section was established to foster efficient markets.

The trading close at 16.20. From 16.20 - 16.25 it is a close auction. During this session there are no continuous trading and no closed deals, but an order can be registered, changed or deleted. The orders will be published in accordance with their visibility, and the indicative price and volume will be continuously calculated and published in the same way as during the opening auction call. From

16.25.00 to 16.25.30, the orders are closed in a random order. After the close, there is a post close session where members are able to cancel orders, but they are not able to insert or adjust orders. (OSLMIT Oslo Børs Market Model Equities, 2017).

3.2 Stockholm Stock Exchange

Stockholm Stock Exchange has been a part of Nasdaq Inc. since 2008. The exchange is regulated by the rules issued by the European Securities and Market Authority (ESMA). We take a closer look at the index, OMX Stockholm 30 (OMXS30) Index, which includes the 30 largest companies listed at Stockholm Stock Exchange. In the thesis, we use OMXS30 and S30 among each other.

Trading Hours Stockholm Stock Exchange		
	Start	**End**
Pre-open session	08.00	09.00
Regular Trading	09.00	17.25
No Order Matching	17.25	17.30

Table 2: Trading Hours at Stockholm Stock Exchange

The trading hours at Stockholm Stock Exchange is from 09.00 to 17.30 GMT+1. As a result of the globalization of the stock markets, Stockholm Stock Exchange extended the trading hours with one hour after the merging with Nasdaq. Hence, Stockholm is the Scandinavian stock exchange with the longest opening hours. These additional opening hours means that foreign investors have more access to trade during their own opening hours and, that the exchange has longer trading hours overlapping with the US Stock Exchanges.

The Stockholm Stock Exchange has a pre-open session from 08.00 - 09.00, where the traders are allowed to send in orders for the intraday call. During this session, there is market transparency, meaning that all orders are displayed with volume. From 08.45 - 09.00, the equilibrium price is also shown. The equilibrium price is displayed with the bid/offer volume. Once the trading begins at 09.00, it is an opening call. During the first five seconds of the opening call, the exchange has something called an uncross. Through this uncross, there is a randomization among the order books.

After the uncross, the trading turn back to continuous trading, where buy orders and sell orders are continuously matched in order to fill as much as possible of the volume in the incoming order, until 17.25. From 17.25 to 17.30, it is a pre-close period where there is no auto matching for the orders.

This continue until the closing call uncross which takes place randomly among the order books during 17.29.30 and 17.30. (Market Model, 2012)

3.3 Copenhagen Stock Exchange

The benchmark index at Copenhagen Stock Exchange is called OMX Copenhagen 20 CAP (C20CAP). Until 1st of February 2013, the benchmark was the C20 index, which is a weighted market value index of the 20 largest companies listed at the exchange. The weights of each company are decided as the total market cap of the firm relatively to the total market cap of C20. This means, that the largest firms as Danske Bank A/S, Novo Nordisk A/S, A.P. Møller-Mærsk A/S account for a large portion of the index.

C20CAP is a capitalization limited index. This is due to the growth in Novo Nordisk A/S, which at one point accounted for over 45% of C20. C20CAP is limited in such a way that a company cannot account for over 20% of the index. Once a company reach this, it is set back to a 15% weight (OMXC20CAP, n.d.). In this thesis, we use OMXC20CAP and C20CAP among each other

Trading Hours Copenhagen Stock Exchange		
	Start	**End**
Pre-open session	08.00	09.00
Regular Trading	09.00	16.55
No Order Matching	16.55	17.00

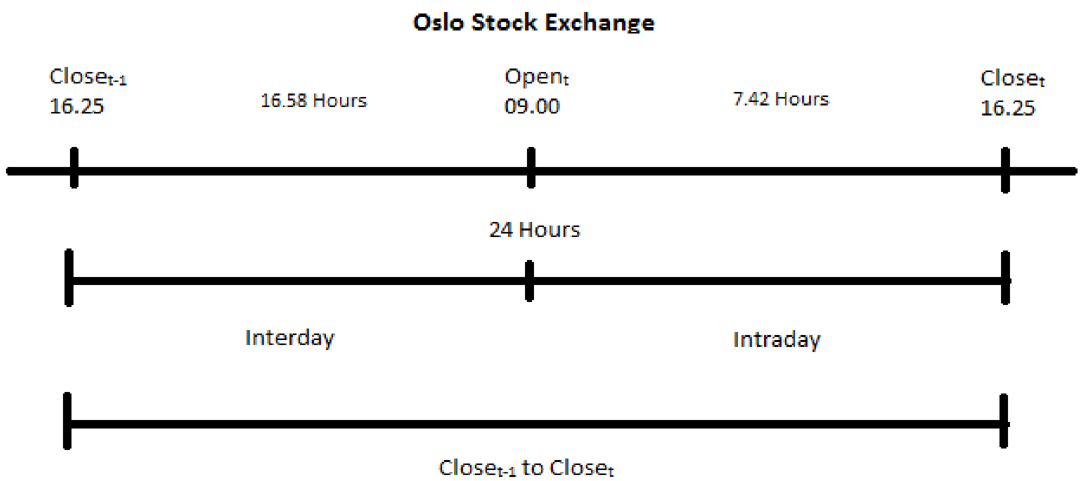
Table 3: Trading Hours at Copenhagen Stock Exchange

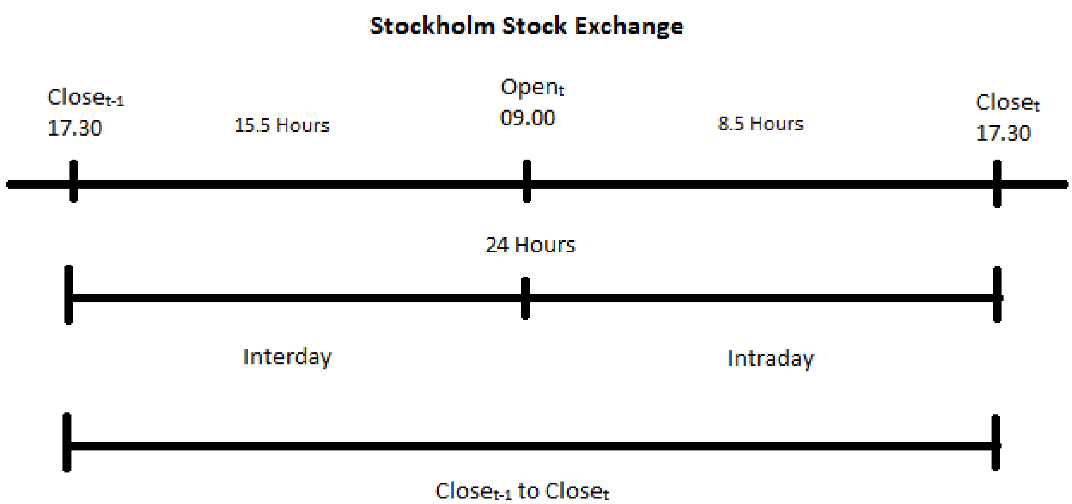
The trading hours at Copenhagen Stock Exchange is from 09.00 to 17.00 GMT+1. The exchange has not incorporated the same opening hours as Stockholm Stock Exchange. However, they have longer opening hours than Oslo Stock Exchange, which they argue as necessary since half of the daily investors are foreign and C20CAP are largely influenced by the American stock market. (Nasdaq holder fast i sine åbningstider, 2013)

By having the same owner as Stockholm Stock Exchange, the trading day is organized in the same way. The day starts with a pre-open session, where the opening is started with an uncross. The day is settled with a closing call uncross at 17.00 (Market Model, 2012).

3.4 Trading time and the implications for the volatility

The trading hours at the exchanges in Oslo, Stockholm and Copenhagen differ slightly. The intraday trading accounts for about one third of the day, while the interday trading accounts for about two thirds of the day. We must also be aware of the interday weekend, where the interday is calculated over an even longer period than the rest of the interday returns. The different trading hours for each stock exchange are illustrated below.





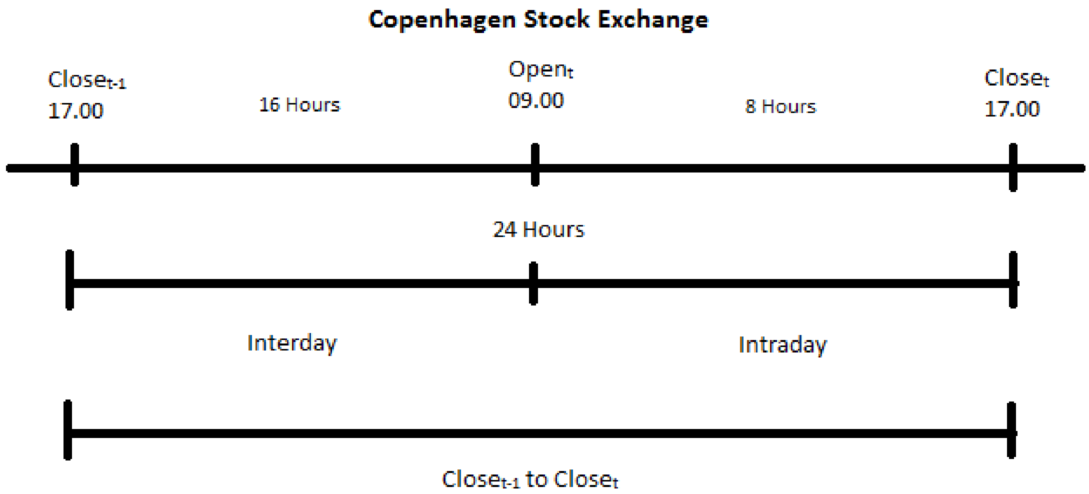


Figure 3: Trading day for each index

The figures above illustrate how we define the intraday and interday periods we use throughout the analysis. The daily open and close level are set based on the first and last trade at the exchanges. The intraday period at Oslo Stock Exchange represents 7.42 hours, while the interday period represents 16.58 hours. The Stockholm Stock Exchange is open for trading 8.5 hours during a normal day, and therefore is closed for 15.5 hours. The intraday period at Copenhagen Stock Exchange represents 8 hours, while the time span for the interday period is 16 hours.

During the intraday, the prices will change as the stocks are traded, whereas through the closing hours there are no transactions on the exchange. Investors may, however, trade directly with each other during the closing hours outside the exchanges trading systems at the OTC-markets. This is reported as off-book trades, and may affect the opening level of the stocks due to change in investors' perception regarding the value of the company. The change in perception may be due to news, regulations, performance reports, etc. The OTC-market is a less liquid market, but it is a possibility for investors if they want to change their positions during the closing hours. Therefore, investors that do not use the OTC-market, are exposed to changes in the stock price without having the ability to react on this before the exchange opens.

In order to compare the variance between the intraday, interday and weekend returns we adjust for time. It is a longer time-span during the interday compared to intraday. Thus, the variance cannot be compared directly. We adjust each one individually since there are differences between the stock exchanges. The formula for the adjusted variance is presented in chapter 4.3.2. The different time spans are illustrated in the following table.

	Oslo Stock Exchange			Stockholm Stock Exchange			Copenhagen Stock Exchange		
	Hours and minutes	Hours	Days	Hours and minutes	Hours	Days	Hours and minutes	Hours	Days
Intraday ($Open_t$ – $Close_t$)	7 Hours and 25 Minutes	7.42	0.31	8 Hours and 30 Minutes	8.5	0.35	8 Hours	8	0.33
Interday ($Close_{t-1}$ – $Open_t$)	16 Hours and 35 Minutes	16.58	0.69	15 Hours and 30 Minutes	15.5	0.65	16 Hours	16	0.67
Weekend (Fri_{close} – Mon_{open})	64 Hours and 35 Minutes	64.58	2.69	63 Hours and 30 Minutes	63.5	2.65	64 Hours	64	2.67

Table 4: Overview of Trading Hours

3.5 Shares traded on several exchanges

There are several stocks that are listed on multiple stock exchanges, also called cross-listed. At Oslo Stock Exchange; Marine Harvest ASA, Statoil ASA, Seadrill Ltd. and Frontline Ltd. are listed at the New York Stock Exchange (NYSE), while Norsk Hydro ASA is listed at the London Stock Exchange. Besides these companies, several Norwegian companies have also issued American Depositary Receipts (ADR) in the US. An ADR is a certificate issued by a US Bank representing one or several shares in a company outside US (Berk & Demarzo, 2009). ADR's exist as many foreign companies want to be tradeable for investors in the US, but the firms do not want to take the cost and work that follows a listing on a foreign stock exchange.

This means that some of the stocks are traded in an extended period outside the trading hours at the Oslo Stock Exchange. If both markets are integrated, we could expect the trading at NYSE as an extension of the trading at Oslo Stock Exchange. Lowengrub & Melvin (2002) explain that we would expect that the variance for stocks that are cross-listed to be lower compared to stocks that are not cross-listed. The reason for this is that the firms that are not cross-listed have a longer time span to accumulate information affecting the share price before the opening of the exchange.

A lot of the companies, on both the Stockholm Stock Exchange and the Copenhagen Stock Exchange are listed on other exchanges, or they have issued ADR's. If one of the indices have many companies that are cross-listed, we could expect a lower variance. Companies that are cross-listed are often very large companies. Large companies tend to have a low variance compared to smaller companies, since their shares are more liquid. Therefore, it is hard to separate whether the lower variance is due to the cross-listing or the liquidity.

3.6 The duty of disclosure

In order to have a functioning financial market, the information flow between the listed companies and the investors have to be good. Investors must have access to correct, complete and timely information from the listed companies with the purpose of make qualified investment decisions. Information that is mandatory to share with investors should at first be published through a stock exchange announcement, such that every participant gets the information at the same time. This information is also known as insider information. These rules and principles are similar for both the Oslo Stock Exchange and the Nasdaq-owned exchanges.

Oslo Stock Exchange is regulated by the Norwegian Law of Security Trading, while both Stockholm and Copenhagen are regulated by the European Securities and Market Authority (ESMA). Even though these two regulations are close to identical, there are some minor differences. Norway is not a member of the European Union, but the European Economic Area. Thus, they are obligated to follow the purpose of European law, but not necessarily the identical text in the law. This is stated in TFEU article 288 third sentence.

"A directive shall be binding, as to the result to be achieved, upon each Member State to which it is addressed, but shall leave to the national authorities the choice of form and methods."

One of the main difference between the three stock exchanges is regarding the timing of publishing stock exchange announcements, and this may be a factor that can lead to differences in intraday and interday returns between the three indices.

At Oslo Stock Exchange, information which is subject to the duty of disclosure is defined in the Securities Trading Act ("STA") § 5-2 (1) cf. continuing obligations para. 3.1.1 which states that listed companies should on its own initiative and immediately publish inside information which concerns the issuer directly. Inside information is defined at STA 3-2 (1) as: *"Inside information means any information of a precise nature relating to financial instruments, the issuers thereof or other circumstances which has not been made public and is not commonly known in the market and which* *is likely to have significant effect on the price of those financial instruments or of related financial instruments."*

The definition implies three demands that must be fulfilled to be recognized as inside information. First, the information must be precisely related to the financial instruments. Second, the information must have an affection on the price of the financial instruments. Thirdly, the information is not commonly known, or accessible for the market.

As stated by Oslo Stock Exchange, a functional capital market is characterized by a good information flow from the listed companies. In order to obtain a functional capital market, it is critical that the companies present inside information, as defined above, to the investors in a correct manner. Up until 1. April 2017, Oslo Stock Exchange has interpreted the regulations regarding information publishing in such way that inside information can be published during the opening hours of the exchange. In other words, a company that experience a circumstance that is characterized as inside information during the night, may delay the releasing of the information until the opening hours.

1st of April 2017 this changed. The Financial Supervisory Advisory of Norway states that the duty to publish inside information must happen without delay, and should not only be linked with the trading hours of the exchange (Oslo Stock Exchange, 4. January 2017). As a result of this, the companies' information distribution system, Newsweb, is available 24 hours a day. In addition, investors have one extra hour to publish announcements of large shareholdings. This time window is extended from 16.30 to 17.30 (Duty of disclosure extended, 2017)

The regulations regarding the timing of stock announcement at the Nasdaq-owned exchanges, state that the firms should inform the public as soon as possible. The business practice at these exchanges is that this is published even though the exchanges are closed. Nasdaq explains and defines the concept of duty of disclosure as, "*Issuers have a duty to disclose such information that would typical, reasonable investor to make a well-founded investment decision. This means that the disclosure must be detailed enough for the investor to assess the event's effect on the issuer and on the issuer's financial instrument"* (The Market Abuse Regulation and the Duty of Disclosure Inside Information, p. 5 2016).

The information which is subject to the duty of disclosure is very much alike on the three stock exchanges. The difference, as pointed out, is the timing of the publishing such information to the investors. By delaying the publishing to the trading hours, we expect a much lower variance during the non-trading hours at Oslo Stock Exchange, as the firms are able to delay publishing stock market announcements until the trading hours.

3.7 Differences between the stock exchanges

Even though the Oslo Stock Exchange and the OMX stock exchanges; Stockholm and Copenhagen, have different owners, the price setting of the opening and closing of the exchanges are very similar. Both systems and procedures at each exchange have the purpose of fostering market efficiency and equalize the available information for all investors. The intention of the auction process, for both the opening and closing of the exchange, is to facilitate trading in the quite complex financial market where there exist thousands of investors with different perceptions of the true value of the shares.

One of the most important structural differences between the exchanges is the length of the trading hours. Stockholm Stock Exchange is the exchange in Scandinavia with the longest opening hours, stretching from 09.00 to 17.30 on a normal trading day. Copenhagen Stock Exchange has the second longest trading day, with opening at 09.00 and closing at 17.00. Lastly, Oslo Stock Exchange is the exchange with the shortest trading day, which stretches from 09.00 to 16.25. The reason to incorporate this, is due to the globalization of the stock exchanges throughout the world. We know that the exchanges and the financial markets are interconnected, therefore, affected by macroeconomic shocks, performance of other exchanges, company specific news, and several other factors.

As a result of the longest opening hours at Stockholm Stock Exchange, this exchange has the longest overlapping trading hours with the US stock exchanges. This means, in the theory, that the prices in the financial market in Stockholm should in a greater degree reflect the performance of the US stock market, compared to the two other stock exchanges, since they are not able to react on the same information before the next morning.

The overnight information, that leads to differences between the closing and opening price, is composed by several elements and factors. It is hard to estimate the importance and the effect each single factor has on the investors perception of the true value of a share. Thus, we cannot build a quantitative model to test this effect. In theory, we would expect the interday variance to be smaller in Stockholm compared to the two other indices as a result of the longer overlapping trading hours with the US stock markets.

In the same way, the cross-listed companies at the different exchanges lead to an extended trading period in these selected shares. This is also a factor that may result in a lower interday variance as the investors are able to react on the overnight information, simply by trading the share on an open exchange.

Another important difference between the exchanges is the duty of the disclosure and the timing of publishing. The exchanges define information that is subject to duty of disclosure quite similar. However, there are differences in how "as soon as possible" are interpreted. In Oslo, the firms are able to delay publishing the announcement until the following morning, while at the Nasdaq-owned exchanges the firms must publish the information without delay. This may result in a relatively lower interday variance at Oslo Stock Exchange compared to the other exchanges, since they can delay announcements to the opening of the exchange. This would be possible to test, by simply using the data from before and after the introduction of the new rules at Oslo Stock Exchange. By conducting the same tests, we would be able to investigate whether the rules have had any affection. However, we have not tested this due to the low number of observations after the rules have been implemented.

4 Methodology and Data

Saunders, Lewis & Thornhill (2007) introduced a framework for developing and deciding upon methodology in research. The framework is called the research onion, and describes the different layers or stages in a research process. We use this structure to describe the progression throughout the research and what approach we use to answer the research questions.

After presenting the methodology and describing the different calculations we conduct in the analysis, we present some practical implications regarding trading in the real world, which may affect the findings and conclusions.

4.1 Research onion

The first layer is defining the philosophy regarding the research question. We distinguish between positivism and interpretivism, where the positivism is the best fit in this case, since we are observing and analysing data from the three Scandinavian indices. Monette, Sullivan & Dejong (2005) define positivism as a philosophy where we assume that we are able to observe and describe the reality from an objective viewpoint. The interpretivism is a subjective method where the researchers believe that individuals understand the reality in different ways, and therefore cannot draw general conclusions based on objective observations.

Further, we define whether the research approach is deductive or inductive. The deductive approach, develop a theory based on existing theory and previous research, then formulates the research question which is tested using observations. In the end, the hypothesis is either accepted or rejected. The inductive approach goes from the specific to the general, which in other words mean that we make observations and find patterns. Then create a hypothesis which we explore and create a theory out from this. Throughout the thesis, we use a deductive approach, as we base the research questions on previous findings and theories, and testing this on the Scandinavian stock exchanges.

We then choose the research strategy, which defines how we intend to conduct the research. We conduct both an experimental research and a survey study. In the experimental research the goal is to test different hypotheses. This is simply done by first formulating the hypotheses before collecting the evidence. In the end, we test the hypotheses based on the evidence.

In the survey study, we find different patterns in the data. We may be able to identify patterns which are not expected, and draw conclusions from this as well. By using two different research strategies, we are using a multi-method strategy. This means that we combine different quantitative approaches in order to draw conclusions and highlight findings.

Further, we define the time horizon for the data collection. The two types of time horizons, are the cross-sectional and the longitudinal. As we collect historical data from a pre-specified time horizon, we use the cross-sectional approach. In difference, the longitudinal is when we repeatedly collect data over time and is commonly used when investigating changes over time.

At last, we discuss the data collection and the analysis. This is important since it has a major effect on the research overall validity and reliability. In line with the importance of these choices, both data and calculations in the analysis will be detailed described and discussed in the following subchapters.

4.2 Data

Data can be separated into two different categories; primary and secondary data. Primary data is data which is collected from first-hand sources. This can be done in several ways, but the main characteristic of primary data is that we are able to do an analysis from the data itself, and not through the eyes of another person's research. This means that we do not have to consider opinions, miss-calculations and the interpretation done by others. Secondary data is data which is collected from other researchers' work. In contrast to the primary data, we must be aware of that secondary data is data which is already been processed by someone else, and therefore we must approach it with caution.

Throughout the analysis, we use primary data to conduct the statistical tests in line with the experimental research and survey study. However, we use secondary data to highlight possible explanations for the findings and observations from the primary data.

To do an analysis in accordance with the problem statement, we collected as much historical data as possible. We retrieved data for a four-year period for OSEBX, S30 and C20CAP. A consecutive four-period do not really enable us to see the differences under variating market conditions, since the Scandinavian stock exchanges have seen a steady increase and a "bullish" market from 2009 till 2016 after the dip in 2007 and 2008.

The reason for not including data in the period before 2013, is due to differences in the trading system. Until 9th of November 2012, Oslo Stock Exchange used a trading system where the opening price was equal to the previous day closing price. Therefore, we use data from 1st of January 2013 to 31st of December 2016, to highlight the differences between the closing prices and opening prices. Even though it exists data from a longer period on the Stockholm and Copenhagen exchanges, we use the same period in order to compare the findings.

To find interday and intraday returns across the three Scandinavian stock exchanges, we downloaded open and close data from S30, C20 and C20CAP from Bloomberg. These are, or have been, the main indices during the time period we are examining. The data from OSEBX was received directly from Oslo Stock Exchange. Due to the capitalization limitations on the Copenhagen Stock Exchange in 2013, which we described in chapter 3.3, we use data from both C20 and C20CAP.

An interesting difference between the three indices is the number of companies included. C20CAP consist of 20 firms, S30 consist of 30 firms, while OSEBX varies around 60 firms. Therefore, we considered using the OBX Total Return Index. OBX is an index that consists of the 25 most liquid shares at Oslo Stock Exchange. This index is more equal to S30 and C20CAP by comparing the number of companies in the index. However, we choose to use OSEBX in the analysis as main index since OBX is heavy weighted by the top three companies. Statoil ASA, Telenor ASA and DNB ASA represents 57% of the total market value at OBX.

OSEBX is the main index at Oslo Stock Exchange, which is used as the benchmark for the overall performance at the Oslo Stock Exchange. Thus, it is the most relevant index in Norway. In addition, there were very small differences in the average returns, variances and standard deviations between OBX and OSEBX, which strengthen our assumption to use OSEBX.

4.3 Analysis

In order to test the hypotheses and conduct the analysis, we need to carry out different calculations regarding returns and risk. We also test whether the data is stationary and have a deterministic trend. Finally, we present the framework for calculating option prices.

4.3.1 Computation of returns

First, we compute the daily returns and separate this in to intraday and interday returns. By separating the daily returns, we compare the differences between intraday and interday. The daily return is computed by using the close-to-close prices. Intraday is computed by using open-to-close prices. Interday return is calculated by close-to-open prices.

The returns are calculated as log returns. We use this approach since the return is computed over multiple periods. One of the advantages by using log returns is that the log return over *n* periods is simply the sum of the log returns in each of the periods. Although there are no large differences between the discrete rate of return and the log return when the returns are small, log returns have a time-additive property (Munk. 2015). This means that it does not lose information during the decomposition (Campbell, Lo & MacKinlay, 1997). The formulas used for calculating return for each time aspect are stated below:

$$Close - to - close\ return = \ln(\frac{Price\ close_t}{Price\ close_{t-1}})$$

$$Intraday\ return = \ln(\frac{Price\ close_t}{Price\ open_{t-1}})$$

$$Interday\ return = \ln(\frac{Price\ open_t}{Price\ close_{t-1}})$$

To make the findings easier to interpret and compare, we annualize the daily and monthly returns. Since we use the continuous compounded return instead of discrete compounded return, it is easier to annualize the return, due to this formula.

$$Annualized = Return * N$$

Where return is the calculated return for each scenario and *N* is the number of respective trading days. For instance, if the daily returns are calculated, *N* is the average number of trading days in a year.

4.3.2 Risk measures

All stocks and indices are driven by changes in the price. There are several measures that caption the changes in these prices. The variance and standard deviation are two common risk measures. They are both, by definition, non-negative. In addition to this, variance and standard deviation are equal to zero if there is no uncertainty related to the outcome. When talking about returns, standard deviation is also called volatility (Munk. 2015). These time periods are defined in chapter 3.4. The formula for sample variance is shown below.

$$Sample\ variance\ =\ \sigma^2 = \frac{\sum(X - \overline{X})^2}{n-1}$$

Where x is the observation, $\bar{x}$ is the average of all observations, and n is the number of total observations. Brealey et al., p. 163, (2011) define the variance of the market returns as *"the expected squared deviation from the expected return"*. We annualize the standard deviation to make the interpretation easier.

$$Annualized\ variance =\ Sample\ variance * N$$

Where *N* is the number of respective trading days. As discussed in chapter 2.4 the volatility of intraday, interday and weekend returns are calculated over different time-spans. In order to compare the variances, we adjust them such that they are weighted equally based on time. By comparing the variances directly, it may be inaccurate. For instance, the interday return is calculated over a longer time span than the interday return. The adjusted variance is calculated as following.

$$\sigma_t^2 adj = \frac{\sigma_t^2}{Days_t}$$

Where $\sigma_t^2 adj$ is the variance adjusted for period t, σ_t^2 is the original variance for period t and $Days_t$ is the number of days that for that specific period. Period t may be intraday, interday or weekend. We calculate the adjusted volatility using the formula below.

$$Sample\ standard\ deviation = \sigma = \sqrt{\frac{\sum(X - \overline{X})^2}{n-1}}$$

Standard deviation is the square root of the variance. When using variance and standard deviation for measuring risk, there are no specific rule of thumb. However, a low variance and volatility mean lower risk, while high variance and volatility indicate higher risk. High volatility indicates that the asset is subject to have larger changes in the asset price. It is also important to remember that even though an asset has a high volatility, it might also symbolize that there is a larger potential upside, not only downside, in the asset price.

4.3.3 Statistical tests and necessary assumptions

The data needs to fill the necessary assumptions in order to use different statistical tests. We investigate if the data is well fitted, by controlling for normal distribution, kurtosis and skewness. The data is sorted, such that the returns from intraday, interday and close-to-close are tested separately.

A normal distribution is symmetric about its mean. When the data is symmetric, it is called mesokurtic. This requires that the distribution has no tail that is longer than the other. Skewness is used as a measure to test the normality of the distribution and is explained as *"Skewness measures the extent to which a distribution is not symmetric about its mean value"* (Brooks, p. 161, 2008). Standard normal distribution is defined as *"a distribution with mean equal to zero and a variance of 1, denoted as N (0,1)" by* (Stock & Watson. p. 36, 2008).

Kurtosis is measuring how fat the tails of the distribution are. A normal distribution has a kurtosis of 3. A kurtosis that exceeds 3 indicates that the data is leptokurtic. This means that the distribution has fatter tails and the distribution are more peaked than the normal distribution. In addition to leptokurtic distribution, the platykurtic distribution occurs when the kurtosis is below 3. In this case, platykurtic distribution has thinner tails and is less peaked than the normal distribution (Brooks, 2008).

4.3.3.1 F-test

The F-test is used to test whether two samples have equal variances. We conduct a two-tailed test, where we simply test whether the variances are equal or unequal. The hypothesis can be formulated as.

$$H0: \sigma_1^2 = \sigma_2^2 \quad vs \quad H1: \sigma_1^2 \neq \sigma_2^2$$

The test statistic is calculated using the generalized formula below.

$$F = \frac{S_1^2}{S_2^2}$$

Where S_1^2 and S_2^2 are the sample variance. The more the F-ratio differs from 1, the more robust is the evidence that it is unequal variance between the samples. The F-test is not symmetrical and this test will only have positive values. Thus, the null hypothesis is only rejected if the test statistic exceeds the critical value. If the null hypothesis is rejected, we can say that there are unequal variances between the two groups. (Brooks, 2008).

4.3.3.2 T-test

In addition to the F-test, we use the t-test to determine whether the returns are statistically significant different from zero, and if the intraday returns are statistically significant different from interday returns. The hypothesis' can generally be formulated as.

$$H0: \mu_1 = \mu_2 \quad vs \quad H1: \mu_1 \neq \mu_2$$

The test statistic is calculated using the formula below.

$$T = \frac{\overline{Y}_1 - \overline{Y}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}$$

Where N_1 and N_2 are the sample sizes, $\overline{Y_1}$ and $\overline{Y_2}$ are the sample means and S_1^2 and S_2^2 are the sample variance. The t-test is a common statistically hypothesis test which follows the Student's t-distribution.

There are two main types of error when you use a statistical hypothesis test. Type I error, is when the null hypothesis is rejected when it is true. The type II error, is when the null hypothesis is not rejected when it is false. The significance level of the test is a pre-specified probability level of type I error. A common used significance level is 5%. The value of the statistic for which the test just rejects the null hypothesis at the given significance level, is called the critical value (Stock & Watson, 2008).

4.3.4 Time series

Stock & Watson, p. 9, (2008), define time series as *"data for a single entity that is collected over multiple periods."*. In our case, it is the prices of the main Scandinavian indices. In this part, we first test for stationarity in the indexed price time series, where the objective is to determine whether it exists a trend. A trend is defined as the long-term movement of a variable over time, where the time-series variable fluctuates around its trend. We distinguish between two types of trends; deterministic and stochastic. A deterministic trend is constant, positive or negative, and a non-random function of time. A stochastic trend is, in contrast, random and varies over time. Most of the trends discussed related to economics are stochastic. The reason for this, is that trends usually have a large unpredictable and a random component (Stock & Watson, 2008).

The random walk is considered as the simplest model of a stochastic trend. This model explains that a time series Y_t follows a random walk if the change in Y_t is independent and identically distributed. We write the random walk model as.

$$Y_t = Y_{t-1} + u_t$$

Where u_t is independent and identically distributed. The explanation behind the model is that the value of the series tomorrow, is the value today plus an unknown and an unpredictable change. The path of Y_t therefore follows steps of a random component and is hence called a random walk. Some time series have an obvious upward or downward trend.

The random walk is nonstationary as the variance of the random walk increases over time, and therefore the distribution of Y_t will change over time. In order to detect whether it exists a trend in the time series data, we use both informal and formal methods. The informal methods consist of investigating a time series plot of the data and computing the autocorrelation coefficients. If the first autocorrelation coefficient is near 1, then the series has a stochastic trend. The formal test we use to test for a trend, is the Adjusted Dickey-Fuller test. We explain the concept of the test, and the findings below.

The random walk is a specific case of the AR (1) model with β_1=1. If β_1=1, Y_t is nonstationary and contain a stochastic trend. Thus, within the AR (1) model, the hypothesis that Y_t has a trend can be tested by the following hypothesis:

$$H_o: \beta_1 = 1 \; vs. \; H_1: \beta_1 < 1 \; in \; Y_t = \beta_0 + Y_{t-1} + u_t$$

If β_1=1, the AR (1) has an autoregressive root of 1. The null hypothesis is that the AR (1) has a unit root, and the alternative is that it is stationary. If an AR (p) has a root equal to 1, the series is said to have a unit root. If Y_t has a unit root, then it contains a stochastic trend and is non-stationary. In contrast, if Y_t is stationary, it does not contain a stochastic trend and does not have a unit root.

The data contain values for both intraday and interday. Thus, we separate the two parts to determine if there is a trend in either of them. First, we index the intraday by setting the first intraday value equal 100. In order to calculate the next day value, we multiply todays value with the Log($\mathrm{Close_t}$/$\mathrm{Open_t}$). This is repeated until we reach 31st of December 2016. The formula is below.

$$Intraday_t = Value_{t-1} \; x \; (1 + Log\left(\frac{Close_t}{Open_t}\right))$$

Next, we index the interday by setting the first interday value equal to 100. When calculating the next day value, we multiply todays value with the Log($\mathrm{Open_t}$/$\mathrm{Close_{t-1}}$). This is repeated until we reach 31st of December 2016. The formula is below.

$$Interday_t = Value_{t-1} \; x \; (1 + Log\left(\frac{Open_t}{Close_{t-1}}\right))$$

At last, the close-to-close value is indexed by using the same approach as the intraday and interday. We set the value equal to 100, and calculate the next day value by multiplying todays value with Log($\mathrm{Close_t}/\mathrm{Close_{t-1}}$). The formula is below.

$$Close - to - close_t = Value_{t-1}\ x\ (1 + Log\left(\frac{Close_t}{Close_{t-1}}\right))$$

After the adjustments we have made above, the next step for us is to test if the time series are stationary. The graphical illustrations of the data plot are provided in appendix I-III.

Stationarity tests				
ADF-value: Prices				
	Intraday	Interday	Close-to-close	Stationary
OSEBX	-2.11	-2.31	-2.18	No
OMXS30	-0.86	-1.39	-1.49	No
OMXC20CAP	-1.18	-1.07	-2.55	No
ADF-value: Returns				
	Intraday	Interday	Close-to-close	Stationary
OSEBX	-9.63	-9.65	-9.63	Yes
OMXS30	-10.10	-10.18	-10.52	Yes
OMXC20CAP	-10.06	-9.53	-10.69	Yes

Table 5: Stationarity Tests

In table 5, we present the results from the ADF test. If the ADF-value is less than -3.41, then the hypothesis of a unit root is rejected at a 5% significance level. Since the observed ADF-values from the analysis of the indexed prices are higher than -3.41, these time series are non-stationary. We transform the time series to make it stochastic and stationary. The data set is an economic time series, and these time series have often a tendency to grow with a certain average percentage per year. Thus, it is most naturally to calculate the logarithmic returns.

In the second part of table 5, we test the adjusted time series by taking the logarithmic return. The observed ADF-values are less than the critical value. Hence, reject the null hypothesis of a unit root. In other words, the time series are stationary and stochastic.

One of the problems with time series is that the value of Y is often correlated with its value in the next period. This is called autocorrelation or serial correlation. At stock indices there is likely to find less serial correlation between the observations if these are in daily percent changes, as we calculated. If there were autocorrelation between the observations, then it would be possible to use these to predict the future changes, and make money on this strategy. Thus, we tested for autocorrelation in the time series. There was no evidence of autocorrelation in the returns, and this is therefore not included. In the next section, we present the basic theory of the option pricing formula, Black-Scholes-Merton.

4.3.5 Options

As a result of the empirical findings throughout the thesis, we use options as a measurement in order to describe the differences between volatilities. This section describes the theory and the methodology by using a Black-Scholes-Merton (BSM) option pricing model. In chapter 8, we use this BSM model for pricing options (Brealey et al., 2011).

Assumptions for the Black-Scholes-Merton model	
1. Volatility is constant over time	**5.** No dividend pay-out
2. The returns are log normal distributed	**6.** Efficient market
3. Short-sale is allowed	**7.** Continuous trading
4. No transaction costs or taxes	**8.** Risk-free rate is known, constant and equal for all options

Table 6: Assumptions for the Black-Scholes-Merton model

The BSM model is pricing a European option. A European option is an option that only can be exercised at the maturity date. The formula for Black-Scholes-Merton is presented below. *C* is the price of a call option while *P* is the price for a put option.

$$c = S_0 N(d_1) - Ke^{-rT} N(d_2)$$

$$p = Ke^{-rT} N(-d_2) - S_0 N(-d_1)$$

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Where,

C, P = Price of call and put option

S_0 = Price on the underlying share

K = Strike price

σ = Volatility

r = risk-free rate

N(x) = The cumulative normal distribution

T = Time to maturity

There are several factors that affect the option price. Share price, strike price, time to maturity, dividend, risk-free rate and the expected volatility are the main factors. In this thesis, we focus on the expected volatility. A higher expected volatility is increasing both the value of a call option and a put option. The reason for this, is that a higher volatility indicates that the possibility for a profitable option increases due to larger changes in the underlying.

An important aspect of options is the "moneyness", which measures the exercise value of the option. There are three general aspects, at-the-money, in-the-money, and out-of-money. When the price of the option is very close to the price of the underlying, this is called an at-the-money (ATM) option. An out-of-money (OTM) option has no exercise value if it is exercised immediately, while an in-the-money (ITM) option has an exercise value if it is exercised immediately (Alizadeh & Nomikos, 2009).

4.4 Transaction Costs

We have to consider the findings in a real world setting. An important factor to incorporate is the transaction costs. The findings may yield a positive result, but once we consider the costs regarding buying and selling a financial instrument, the findings may not be as profitable as we first thought. Transactions costs may take different forms. For instance, brokerage fees, taxes, account fees, and bid-ask spreads. Brokerage fee is a cost that accrue each time an investor either buy or sell a share or an asset. Brokerage fee is important, since it may have implications for the trading strategies.

Most brokers offer unequal prices to different type of investors, depending on the frequency of trading and the size of the trades. Hence, it is hard to estimate the impact for different types of investors, but we base the costs on whether the trading strategies incur a high frequency of trading or not.

In chapter 9 we create different trading strategies based on the findings. We use the brokerage fees from Nordnet, which is one of the leading internet-based brokers throughout Scandinavia. Nordnet offers the same brokerage fee in all the Nordic countries, which makes it easy to calculate the costs when we take positions in the different stock markets.

The fee at Nordnet differs depending on the frequency of trading. If the investors trade between 0-15 times during a month, the brokerage fee is 0.049% per trade with a minimum amount of 79 NOK. In order to avoid triggering the minimum fee, each trade must have a value of roughly 160,000 NOK. If the investor trade between 16-30 times a month, the fee is 0.04% with a minimum amount of 69 NOK. To avoid this minimum fee, the trade must have a value of 172,500 NOK. At last, if the investor trade 31 or more times during a month, he or she pays a fee of 0.035%. The minimum amount is 39 NOK, and to avoid this amount the trade must have a value of roughly 111,000 NOK. (Nordnet, n.d.)

The strategies result in a high number of trades, to exploit the differences between the returns throughout a day. Thus, we assume that all of the trades are of considerable size so we do not account for the minimum amounts. In order to profit from the strategies, the investor should invest a considerable amount of money to avoid the profit being "eaten up" by the brokerage fee.

5 Descriptive Statistics

In this chapter we present the descriptive statistics for each index and explain how they differ. We divide this chapter into four parts. First, we present the descriptive statistics for OSEBX before we continue with S30 and C20CAP. Second, the robustness of the findings is tested by graphical illustration of the distribution, F-tests and simple t-tests. The third part is a comparison of the findings and possible explanations in light of earlier research. In the last part, we decompose the indices to investigate the different industries and the effect they have on the performance. The average returns and volatilities are annualized to make the numbers more comparable. We adjust the variance for time, as the intraday and interday differs in the length of time they are calculated for.

5.1 OSEBX – Oslo

OSEBX is an index where a few companies are representing a large part of the market value. OSEBX consists of 62 different companies where the main sectors are energy and financials. However, there are large differences between how many companies that are categorized in the same sector and the market capitalization for each sector, as we illustrate in figure 4.

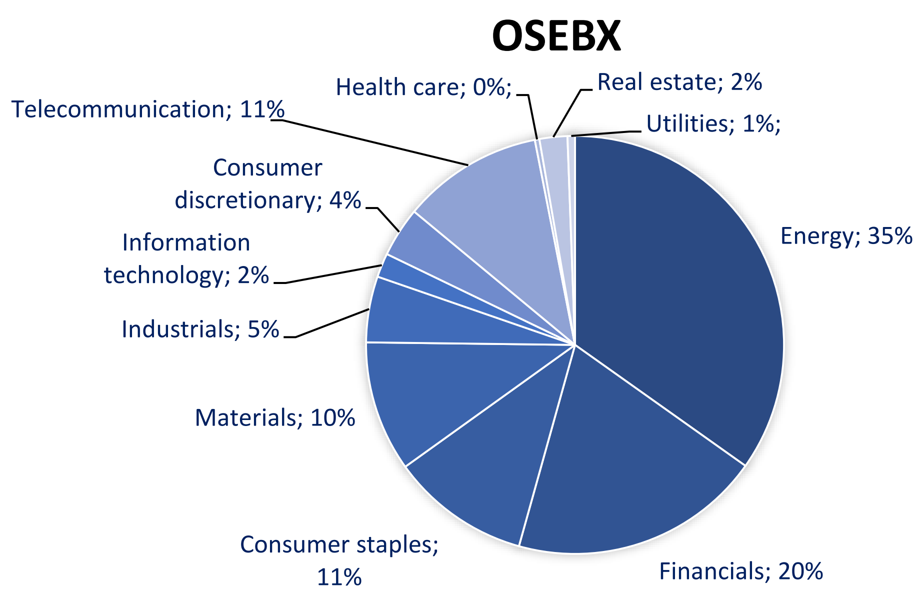


Figure 4: Sectors OSEBX

Energy is the largest sector. It contains 12 of 62 companies, and is also largest measured by market value. The sector represents 35% of the total market value at OSEBX, due to the high market value of Statoil ASA. It is worth to mention that the shipping industry is divided into energy and industrials, depending on which industry these companies are connected to. For instance, Frontline Ltd. is in the energy sector while Golden Ocean Group Ltd. is in the industry sector, although both are shipping companies.

In contrast to the energy sector, the telecommunication sector consists only of one firm, Telenor ASA. This company represents 11% of the total market value at OSEBX. At OSEBX, the top three companies, Statoil ASA, DNB Bank ASA and Telenor ASA, represents 48% of the total market value. Therefore, these companies are important for the performance of the index. In figure 5, we illustrate how the value of OSEBX has developed the last four years.

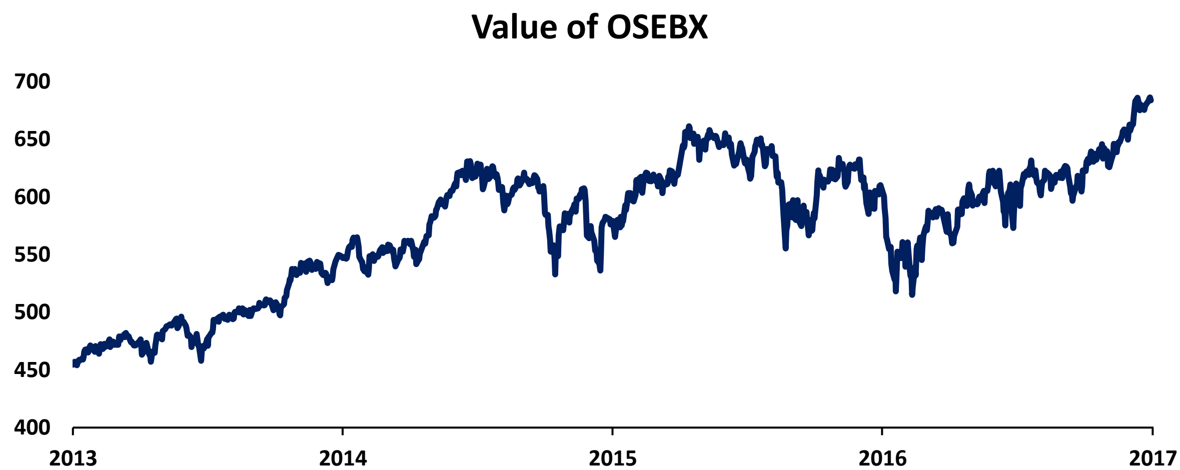


Figure 5: Value OSEBX

The chart illustrates the increasing trend the index had in the time period. From 2013 to 2016, OSEBX yielded a total return of 43.17 %, which results in a yearly return of 10.79%. The index had an opening price of 444.11 at 2nd of January 2013, while the closing price at 30th of December 2016 was 683.87. OSEBX has increased rapidly the last years and reached all time high at the last day of 2016. Further on, we split the returns in the data set into intraday, interday and close-to-close returns. We calculate the variance and standard deviation and annualize the numbers to investigate the differences between the returns.

OSEBX			
	Intraday	**Interday**	**Close-to-close**
Return	10.22%	0.57%	10.79%
Variance	2.61%	0.00%	2.66%
Std.dev	16.17%	0.54%	16.30%

Number of trading days	
2016	253
2015	251
2014	250
2013	249
Average	**250.75**

Table 6: Descriptive Statistics OSEBX

Most of the return at OSEBX is driven by the intraday returns. There was on average 250.75 trading days which are used as the annualizing factor. The close-to-close return in the period from 2013-2016 had a yearly average of approximately 10.79%. The average intraday return at OSEBX is 10.22% and the average interday return is 0.57%, on a yearly basis. In addition to the returns, we calculate the volatility for each time span. The intraday returns have a much higher volatility measured by the sample standard deviation. There is an average yearly standard deviation of 16.30% at OSEBX, which is mostly related to the trading hours.

Most time series of financial asset returns have a so called volatility clustering, which is also the case for close-to-close returns for OSEBX. This is illustrated in appendix I. This property indicates that large price movements tend to cluster together, of either sign, and a large change tend also to be followed by a large change.

Therefore, we question whether average is the correct approach in order to analyze the returns. Even if the yearly average for interday returns is very small, it could be the case that extreme positive and negative values oppose each other and create an average close to zero. This would, however, create a large variance. We analyze this by finding the minimum and maximum observations.

	Intraday	Interday	Close-to-Close
Min	-5.32%	-0.30%	-5.33%
Max	4.18%	0.30%	4.18%

Table 7: Minimum and Maximum Observations OSEBX

The difference between the absolute value between the minimum and maximum value of the intraday return is negative, while the same difference is close to zero for the interday return. Thus, it seems that there are more positive than negative intraday returns as we have previously observed that the average intraday return is positive. The small difference between the minimum and maximum interday return explains why the average is close to zero. It also explains the small variance, as the interday returns does not vary to much from zero. Further on, we use a scatter plot to investigate whether it exist any outliers for the two returns.

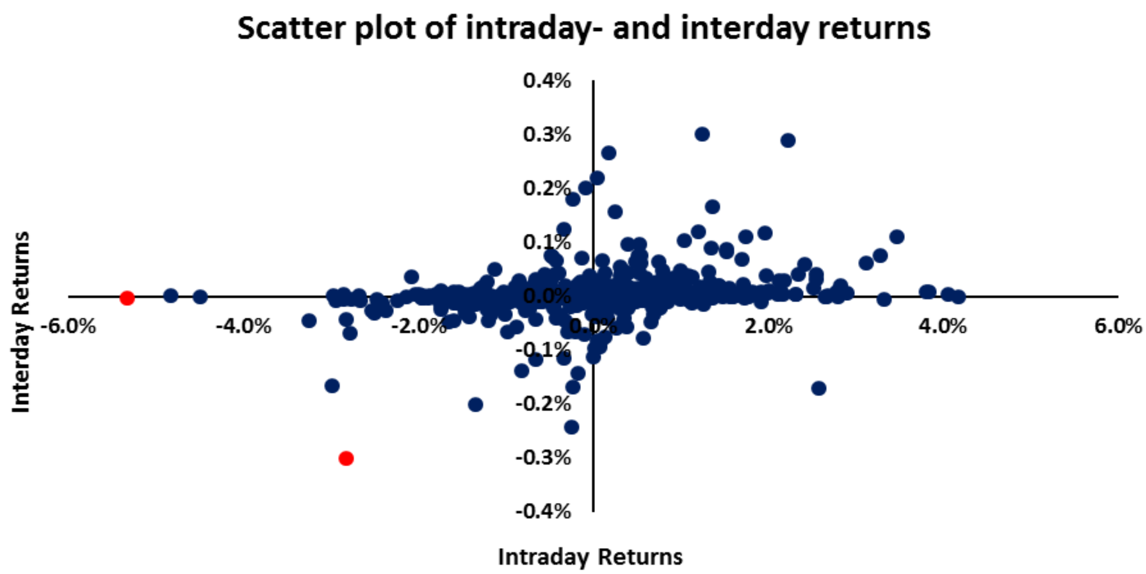


Figure 6: Scatter Plot of intraday- and interday returns OSEBX

In figure 6 the intraday returns are plotted at the x-axis, while the interday returns are plotted at the y-axis. Each point represents the intraday and interday return for an individual trading day.

The minimum intraday occurred Monday 24th of August 2015, when OSEBX declined with 5.32%. This movement was a part of a global market correction. This market correction was a result of the uncertainty regarding the growth in China, and was by many named “Black Monday” as a result of the rapid decline at the Asian Stock Exchanges. The negative sentiment was strengthened by a declining oil price, and uncertainty regarding a possible increase in the US interest rate. (Alt falt på Oslo Børs, untatt tre aksjer, 2015)

The minimum interday return occurred Friday 24th of June 2016, when OSEBX declined with 0.30% from Thursday close to Friday open. The reason for this was the news regarding Brexit, which was released during Thursday night/Friday morning. The investors at Oslo Stock Exchange reacted by sending OSEBX down from the start of trading. (Sender Oslo Børs dramatisk ned, 2016)

Another macroeconomic event that resulted in a decline at Oslo Stock Exchange, was the Grexit during the summer of 2015. After several weeks of speculations and negotiations between Greece, the International Monetary Fund (IMF) and the European Union (EU), the Prime Minster of Greece called for a referendum regarding a revised proposal from IMF and EU. This led to decreasing financial markets throughout Europe the following day. At Oslo Stock Exchange, OSEBX declined with 1.74% during the intraday trading, and only -0.03% during the interday trading. (Gresk fall på Oslo Børs, 2015)

From the scatter plot we observe that outliers happen rarely, and that most of the returns lie between -3% and 3% for the intraday returns, and between -0.1% and 0.1% for the interday return. We conducted the same tests without the outliers. This did not have any significant affection on the average returns, since the data set contains 1002 observations.

	Intraday	Interday	Close-to-close
Days with negative return	466	416	467
Days with positive return	536	586	535
Total days	1002	1002	1002
% days with negative return	47%	42%	47%
% days with positive return	53%	58%	53%

Table 8: Positive and Negative days OSEBX

There were a total of 1002 trading days at Oslo Stock Exchange in the period from 2013 to 2016. Approximately 47% of these days had negative return, measured by close-to-close returns. Interday returns was the category where most days had a positive return. Even though 47% of the days had negative return, measured by close-to-close returns, the index increased with 43%.

We adjust the variance in accordance with Fama's (1965) article regarding the calendar time hypothesis, which is described in chapter 2.4. The variance of intraday and interday returns are measured over different time periods. Thus, we adjust in order to compare them. The variance is adjusted by dividing the variance before adjustment with the time of the length in the period the variance is calculated for. This is, respectively, 0.31 days for intraday and 0.69 days for interday. We calculate the adjusted volatility to compare with the previous findings.

Adjusted and annualized		
	Intraday	**Interday**
Return	10.22%	0.57%
Variance	8.46%	0.00%
Std.dev	29.08%	0.66%

Table 9: Adjusted Variance OSEBX

After the adjustment we observe large differences between intraday and interday volatility. Before the adjustment, the volatility of intraday was around 29.7 times larger than the interday. After the adjustment the volatility is 44.4 times larger than the interday.

5.2 OMXS30 – Stockholm

S30 consists of the 30 largest companies listed at Stockholm Stock Exchange. This index differs from OSEBX since the largest sectors are industrial goods and service, and the banking sector. These two sectors are also largest measured by market capitalization. This is illustrated in figure 7.

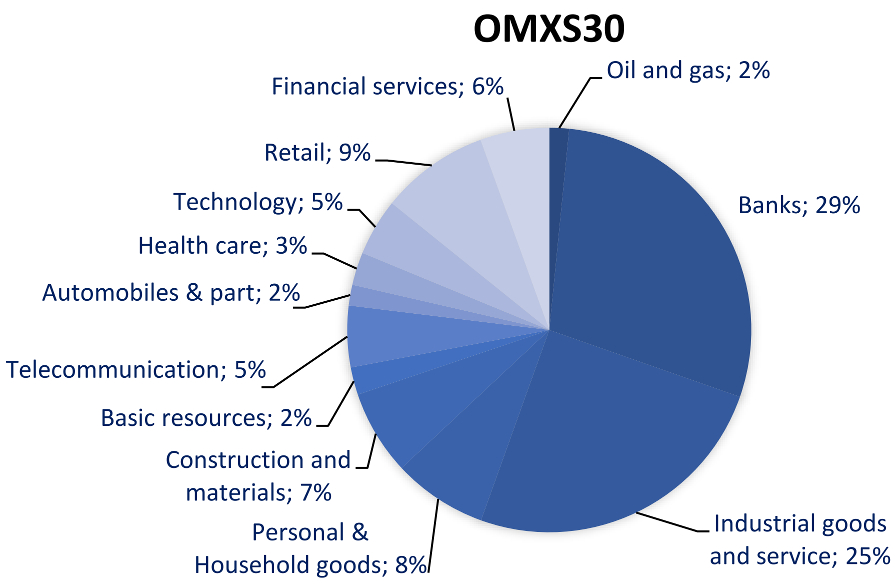


Figure 7: Sectors OMXS30

The banking sector represents 29% of the total market value at S30. In contrast to OSEBX, the top three largest companies have less impact on the whole index. Nordea Bank AB, Hennes & Mauritz AB and Swedbank AB represent 26% of the total market value. This indicates that the index is more diversified compared to OSEBX, and would be less exposed to independent factors, such as the oil price for OSEBX.

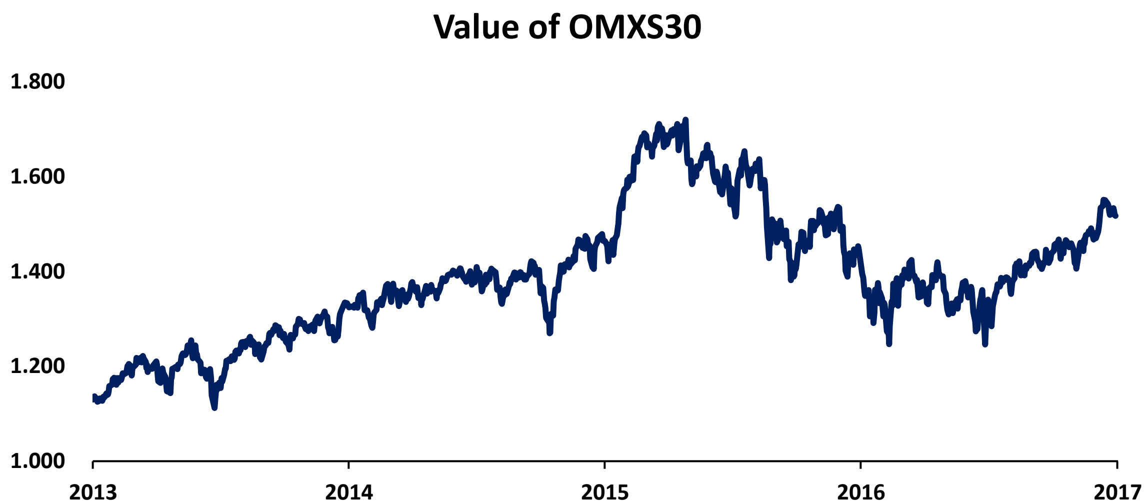


Figure 8: Value OMXS30

Figure 8 illustrates how the value of S30 has changed the last four years. The opening price of S30 at 2nd of January 2013 was 1,122.46 and this increased to 1,518.34 at 30th of December 2016. This resulted in a total return of approximately 30% for the whole period, which is an annual return of 7.53%. At the 27th of April in 2015, this index reached all-time high.

To investigate at what time the return has been accumulated, we separate the returns in intraday and interday. In the same way as at OSEBX, we calculate the average return for the intraday, interday and close-to-close, and annualize this in order to compare the numbers.

OMXS30			
	Intraday	Interday	Close-to-close
Return	-1.97%	9.34%	7.37%
Variance	2.25%	0.45%	3.02%
Std.dev	14.99%	6.70%	17.37%

Number of trading days	
2016	253
2015	251
2014	249
2013	250
Average	**250.75**

Table 10: Descriptive Statistics OMXS30

The findings from S30 are different from OSEBX. The total average close-to-close return at S30 is lower, and has an average return of 7.37%. At S30, the average annualized intraday return is -1.97%. This means that during the trading hours the index has, on average, decreased. The average interday return yields a positive return of 9.34% during the four-year period.

Even though the average return in the non-trading hours is higher than during the trading hours, the volatility is higher for the trading hours. The standard deviation for the total returns is 17.37%, where about 14.99% of these percentage points stems from the intraday volatility. The interday return is therefore more attractive for an investor, since it yields a higher return at a lower risk compared to the intraday return. The interday return is also better than holding the index from close-to-close for each day. Interday return has a higher return as well as a lower volatility.

The average yearly interday return was 9.34% from 2013 to 2016. In other words, during the non-trading hours, S30 has increased. In appendix II we highlight the volatility clustering, which occurs in the close-to-close returns from S30. To investigate whether either of the returns suffer from extreme positive or negative values, we examine the minimum and maximum values of the returns.

	Intraday	Interday	Close-to-close
Min	-8.25%	-3.67%	-8.80%
Max	3.47%	2.46%	3.80%

Table 11: Minimum and Maximum Observations OMXS30

The minimum value of the intraday, interday and close-to-close are more negative than the maximum value is positive for the same returns. In other words, the absolute value of the maximum value is lower than the absolute value of the minimum value.

We could therefore face a scenario where the reason for the average positive intraday return is a result of an extreme outlier that reduces the average intraday return. In order to observe whether there exist outliers, we use a scatterplot to observe all of the returns in the data set.

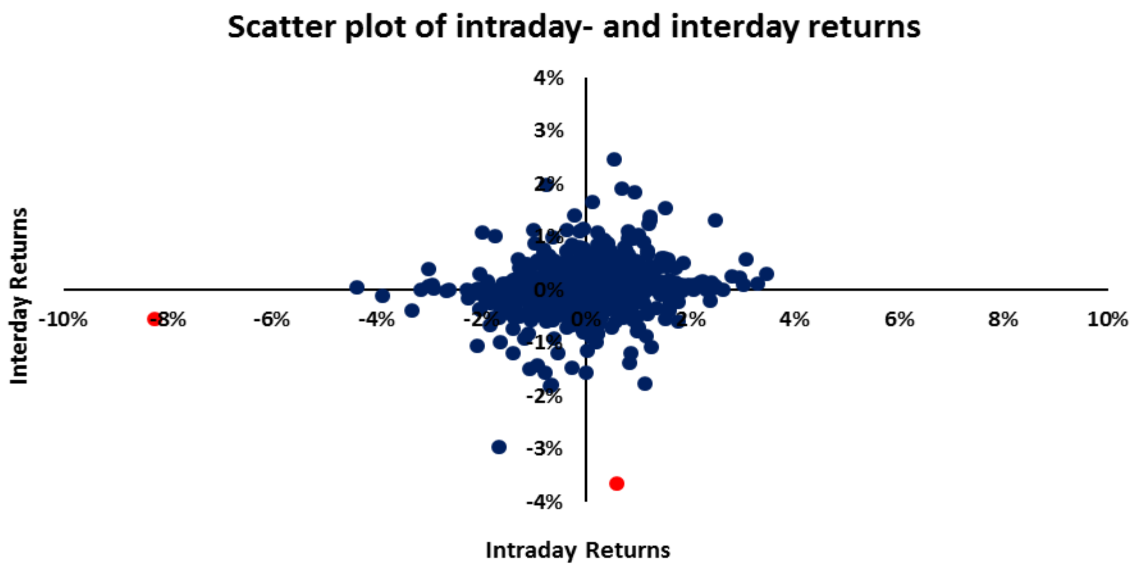


Figure 9: Scatter plot of Intraday- and Interday Returns OMXS30

The interday returns are plotted against the y-axis, while the intraday returns are plotted against the x-axis. We observe that most of the returns are scattered between -4% and 4% for the intraday returns, and between -2% and 2% for the interday returns. The minimum observations for both intraday and interday returns are highlighted as the red dots.

The minimum intraday return of -8.22% occurred Monday 27th of June 2016 which was a result of the Brexit. The news regarding Brexit was released during Friday morning the 24th of June 2016, but the financial markets in Stockholm was not open this day due to a holiday. Therefore, the investors at Stockholm Stock Exchange were no able to react on this information before the following Monday when the exchange opened. (Stockholmsbörsen rasar efter brexit, 2016)

The minimum interday return of -3.67% occurred Monday 29th of June 2015. This was in the middle of the Grexit speculations. Late Sunday 28th of June 2015, the Prime Minister of Greece called for a referendum regarding the revised proposal from IMF and EU. This was reflected in a negative interday return during the weekend at S30. (Oro för Grexit sänkte börsen, 2015)

We observe that the minimum observations for both the intraday and interday return is rare. They lie quite far away from where most of the plots that are scattered. The data series contain 1003 observations, and therefore by calculating the average return the minimum observations do not affect the average to a large extent.

For example, the fact that the absolute value of maximum interday return is less than the absolute value of the minimum interday return implies that there is more positive interday returns than negative interday returns. We further describe the returns by dividing all of the returns into positive and negative returns.

	Intraday	Interday	Close-to-close
Days with negative return	475	420	472
Days with positive return	527	582	530
Total days	1002	1002	1002
% days with negative return	47%	42%	47%
% days with positive return	53%	58%	53%

Table 12: Positive and Negative days OMXS30

Even though the index has on average increased yearly by approximately 9.8%, the percentage days with negative return is about 47%. In total, there are 59 more days with positive returns than with negative returns. In total, there is one more trading day at Stockholm Stock Exchange than Oslo Stock Exchange in the whole period from 2013 to 2016. 58% of the interday returns for this period yielded a positive return, while 53% of the returns for intraday returns were positive. Further on, we adjust the volatility for time as we did for OSEBX.

Adjusted and annualized		
	Intraday	**Interday**
Return	-1.97%	9.34%
Variance	6.42%	0.69%
Std.dev	25.34%	8.32%

Table 13: Adjusted Variance OMXS30

Similar to OSEBX, we observe large differences in the volatilities before and after the adjustment. Before the adjustment the volatility of intraday returns was around 2.2 times larger than the interday volatility, while after the adjustment the difference is 3 times larger. The variance at S30 is adjusted with respectively 0.35 days for the intraday variance, while the interday variance is adjusted with 0.65 days.

5.3 OMXC20CAP - Copenhagen

C20CAP is a bit different from the two other indices since it is capped. The index consists of 20 companies where the largest sector, measured by both number of companies and market capitalization, is health care. This sector represents 38% of the total market value of the index, where the largest firm is Novo Nordisk A/S. The two other large sectors are financials and industrials. We illustrate the composition of the index in figure 10.

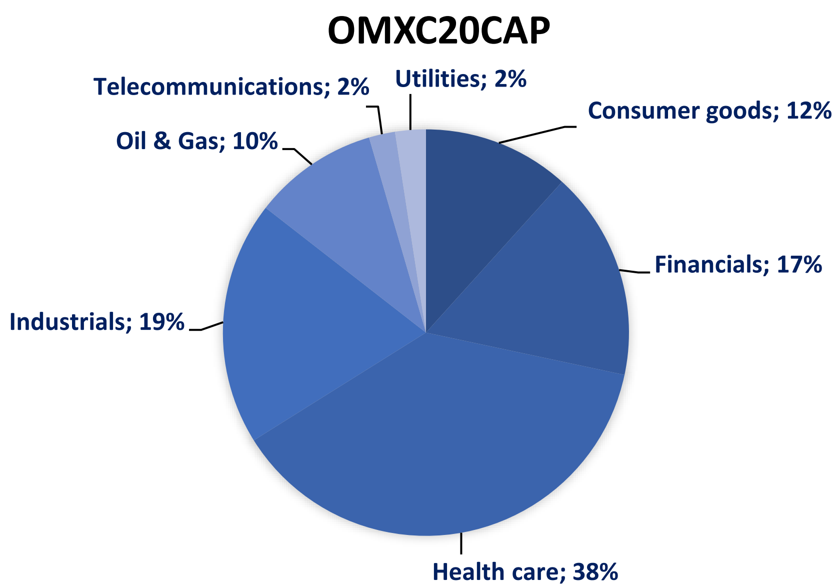


Figure 10: Sectors OMXC20CAP

Without the cap, C20CAP is more equal to OSEBX when considering the three largest companies. If the index has not been capped, Novo Nordisk A/S, Danske Bank A/S and A.P. Møller - Mærsk A/S would represent approximately 48% of the total market value. As a result of the capping, none of the companies can represent more than 20% of the market value at C20CAP.

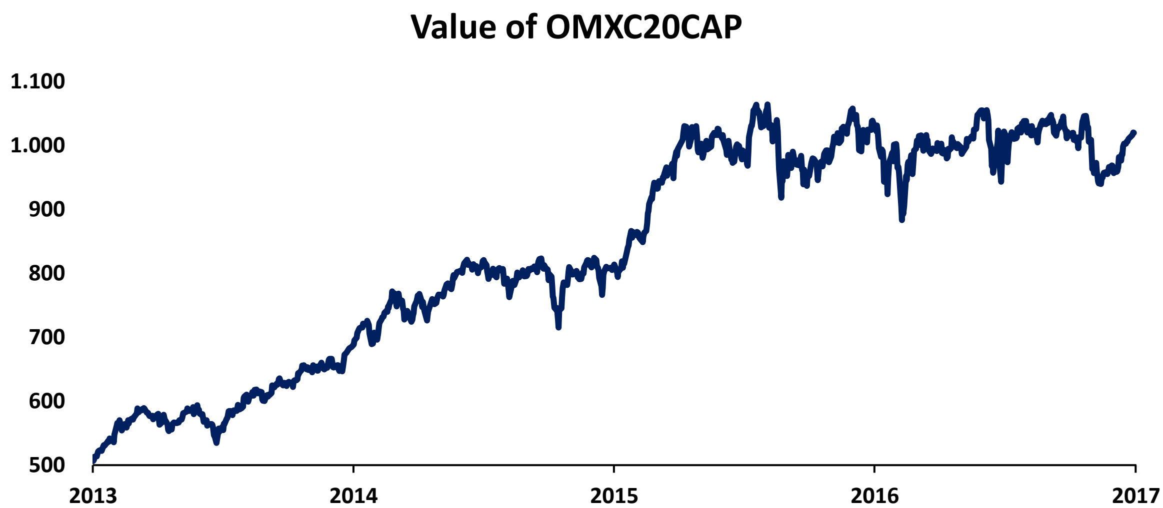


Figure 11: Value OMXC20CAP

The opening price of the index at the 1st of January in 2013, was 500.69. At the last trading day in 2016, C20CAP had reached a level of 1,019.65. During this four-year period, the index increased in total with approximately 70%, which results in a yearly return of 17.78%. In figure 11, the development of C20CAP is illustrated. Overall, there has been an increasing trend with a few negative setbacks.

Further on, we investigate at what time during a day the returns has been accumulated. In the same way as the other Scandinavian indices, we split the return to take a closer look at the intraday, interday and close-to-close returns. We annualize these numbers in order to compare them.

OMXC20CAP			
	Intraday	Interday	Close-to-close
Return	-5.62%	23.13%	17.51%
Variance	2.12%	0.54%	2.84%
Std.dev	14.54%	7.35%	16.86%

Number of trading days	
2016	252
2015	249
2014	248
2013	248
Average	249.3

Table 14: Descriptive Statistics OMXC20CAP

From this index we get interesting results, as highlighted in table 14. In contrast to OSEBX, average yearly intraday return at C20CAP is by approximately -5.62%, which is similar to S30. The average yearly interday return is 23.13% which resulted in a total close-to-close return of 17.51%. This indicates that the index was mostly driven by the returns outside the trading hours.

We observe the same pattern as earlier when considering the volatilities. The intraday volatility is higher than the interday volatility. C20CAP is the index with highest close-to-close standard deviation, but also highest average yearly return. The risk-adjusted return is highest for the non-trading hours, which is the same as we observed in Stockholm.

The returns are highlighted in appendix III, and this indicates that the property of volatility clustering occurs again. This pattern in typical for time series of financial asset returns. Further, we investigate the minimum and maximum observations for the three different returns in order to check whether there may exists some extreme values that affect the calculations.

	Intraday	Interday	Close-to-close
Min	-5.58%	-3.99%	-5.59%
Max	5.00%	2.98%	5.00%

Table 15: Minimum and Maximum Observations OMXC20CAP

We observe that the absolute value of the minimum value for both intraday and interday return are higher than the maximum observed value. In order to check whether the minimum and maximum values represent outliers, we use a scatterplot to observe all of the returns in the data set.

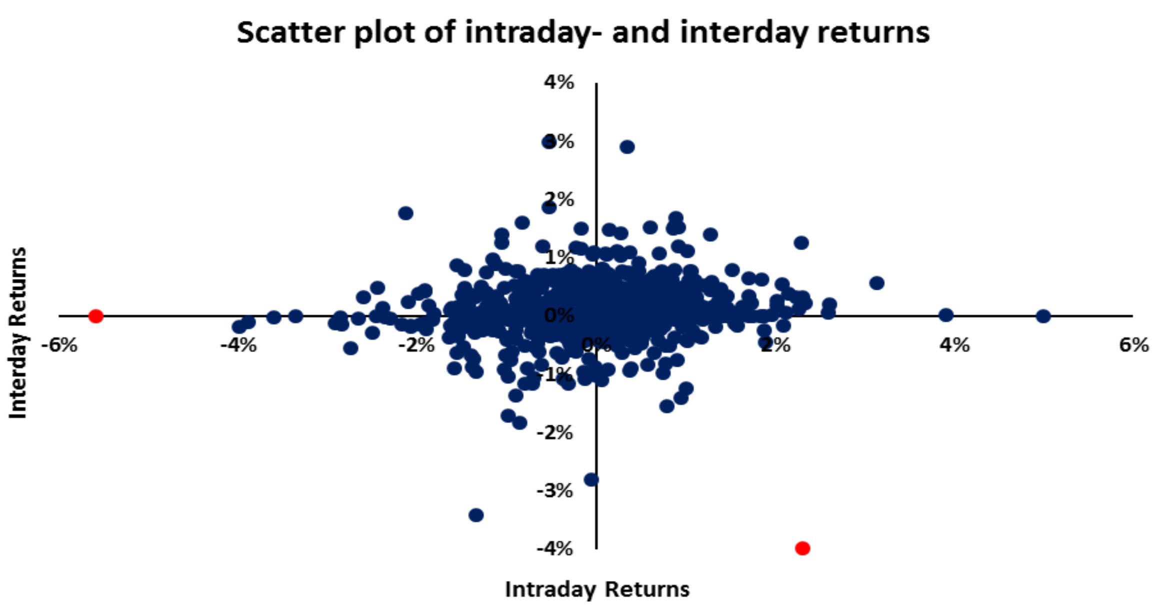


Figure 12: Scatter Plot of Intraday- and Interday Returns OMXC20CAP

The interday returns are plotted against the y-axis, while the intraday returns are plotted against the x-axis. Most of the returns are scattered between -2% and 2% for the intraday returns, and between -1% and 1% for the interday returns. The minimum observations for both intraday and interday returns are highlighted as the red dots.

The minimum intraday return of -5.58% occurred at Monday 8th of February 2016. The negative return this Monday was not a result of any macroeconomic events or special circumstances. It was mainly due to poor performance at the stock exchange the week before, and it was speculated that investors were positioning themselves before the release of quarterly reports.

The minimum interday return of -3.99% return occurred at Monday 29th of June 2015. In the same way as at the Stockholm Stock Exchange, this was a reaction due to the Prime Minister of Greece call upon a referendum of the revised proposal by the IMF and EU.

The Brexit does not stand out as outliers at C20CAP. However, as a difference to S30, the investors in Copenhagen was able to react on this event the day the news was released. C20CAP declined with 3.98% during the Friday intraday trading and declined with 3.88% during the Monday intraday trading.

In the same way as at S30, these outliers do only represent a few observations in a data set that contains 996 observations. Therefore, when calculating the average, these do not have a large impact on the calculations. We further describe the returns by dividing all of the returns into positive and negative returns.

	Intraday	Interday	Close-to-close
Days with negative return	493	356	444
Days with positive return	503	640	552
Total days	996	996	996
% days with negative return	49%	36%	45%
% days with positive return	51%	64%	55%

Table 16: Positive and Negative Days OMXC20CAP

There are a total of 996 trading days in Copenhagen, which is six days less than in Norway. 36% of all days had a negative return when considering the interday observations. The total percentage of days with negative return was approximately 45% in the period from 2013 to 2016. In contrast to earlier, intraday has almost a fifty-fifty distribution between positive and negative returns even though the average yearly return was -5.62%. This indicates that the absolute value of the positive returns was larger than the absolute value of the negative returns.

In order to compare the volatility between intraday and interday, we adjust the variances for time, as we did for OSEBX and S30.

Adjusted and annualized		
	Intraday	**Interday**
Return	-5.62%	23.13%
Variance	6.41%	0.81%
Std.dev	25.32%	8.98%

Table 17: Adjusted Variance OMXC20CAP

At C20CAP the proportionality between the volatility is closer to zero, compared to the other Scandinavian stock indices. Before adjustment, the intraday volatility is 2 times larger than the interday variance. After the adjustment the intraday volatility is 2.8 times larger. The intraday variance is adjusted with 0.33 days, while the interday variance is adjusted with 0.67 days. As we have seen throughout the descriptive statistics there are some differences between the Scandinavian indices. We control the robustness of the empirical findings in next sequence.

5.4 Robustness

In this sub-chapter we present the results in light of different statistical tests. We use several tests in order to check the robustness of the findings. The robustness of the results is important regarding how reliable the results are. The relevant methodology is described in chapter 4.3.3.

5.4.1 OSEBX – Oslo

To test if the findings are statistically significant, we control the data set for a normal distribution, before we use a F-test and t-tests to test the results. To find the distribution of the returns, we illustrate this by dividing the returns into a specific number of frequencies.

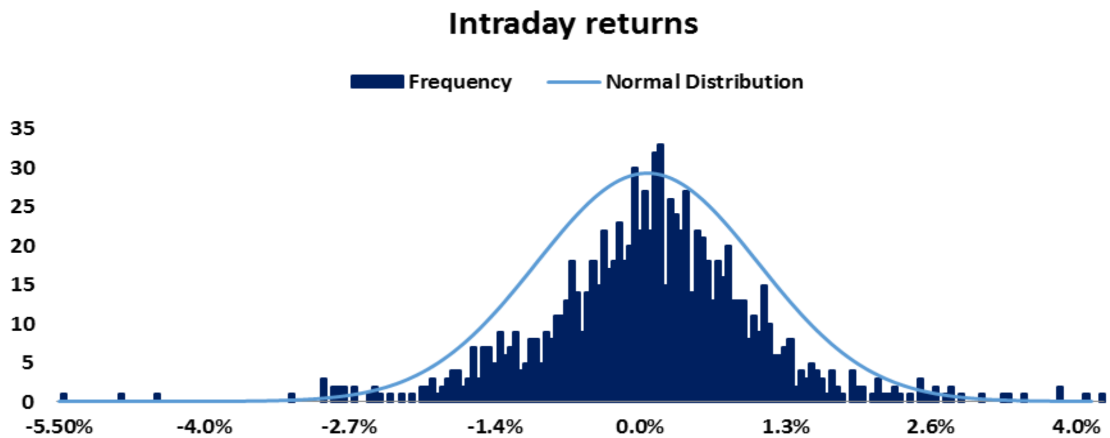


Figure 13: Intraday Returns OSEBX

The distribution for the intraday returns at OSEBX is highlighted in figure 13. Intraday returns have a kurtosis of approximately three, which indicates a normal distribution. The distribution for close-to-close returns are relatively equal to the intraday returns, and is illustrated in appendix IV.

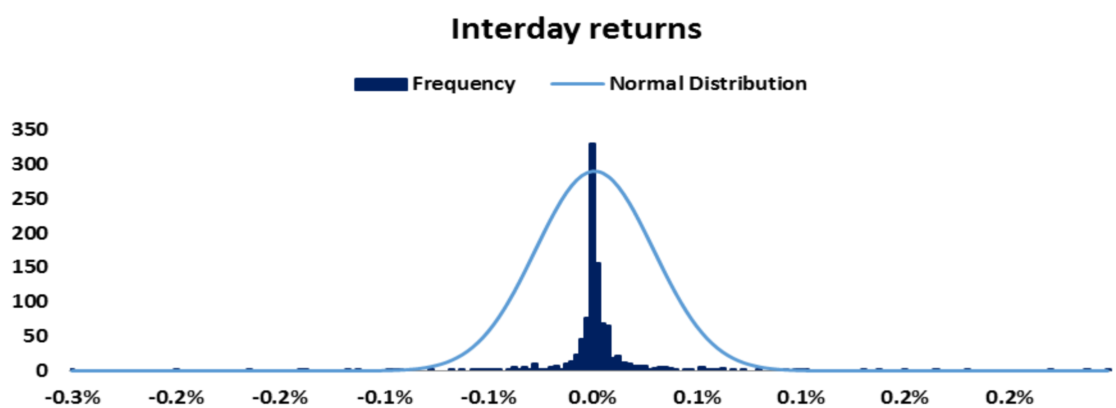


Figure 14: Interday Returns OSEBX

In figure 14, the distribution for interday returns is illustrated. The interday returns are different from intraday returns, since this distribution is much more peaked around zero. Thus, this distribution has more observations within in a less area. The kurtosis for interday return is approximately 30, which indicates a leptokurtic distribution.

In order to decide which t-test to use, we use a F-test to test if there are any differences in the variances between interday and intraday returns. From the F-test we get a F-critical value of 1.11. The F-value is 881.56, resulting in a rejection of the null hypothesis. Hence, we assume that there are differences in the variances in the two data series. Thus, we continue with a two-sided t-test assuming different variances.

	F-Value	F-Critical
F-test	881.56	1.11

	T-Value	T-critical (one-sided)	T-critical (two sided)	Significant?
Intraday vs 0	1.27	1.65	1.96	No
Interday vs 0	2.09	1.65	1.96	Yes
Close-to-close vs 0	1.32	1.65	1.96	No
Intraday vs interday	1.19	1.65	1.96	No

Table 18: Statistical Tests OSEBX

Table 18 presents the results from the t-tests. The respective hypotheses are:

H0: Intraday returns = 0 vs. H1: Intraday returns ≠ 0

H0: Interday returns = 0 vs. H1: Interday returns ≠ 0

H0: Close-to-close returns = 0 vs. H1: Close-to-close returns ≠ 0

H0: Intraday returns = Interday returns vs. H1: Intraday returns ≠ Interday returns

The interday returns are statistically different from zero at a 5% significance level. The reason for this, is the low variance. The other tests are not statistically significant even though average intraday return is much higher than average interday return. One possible explanation for this result is that intraday returns have a much higher variance than interday returns. Since most of the findings are not statistically significant, the reliability of the results is weaker. However, we use the empirical findings to compare the indices although the results are weak.

5.4.2 OMXS30 – Stockholm

We repeat the same procedure for S30 to test if the data is normal distributed and if the results are statistically significant.

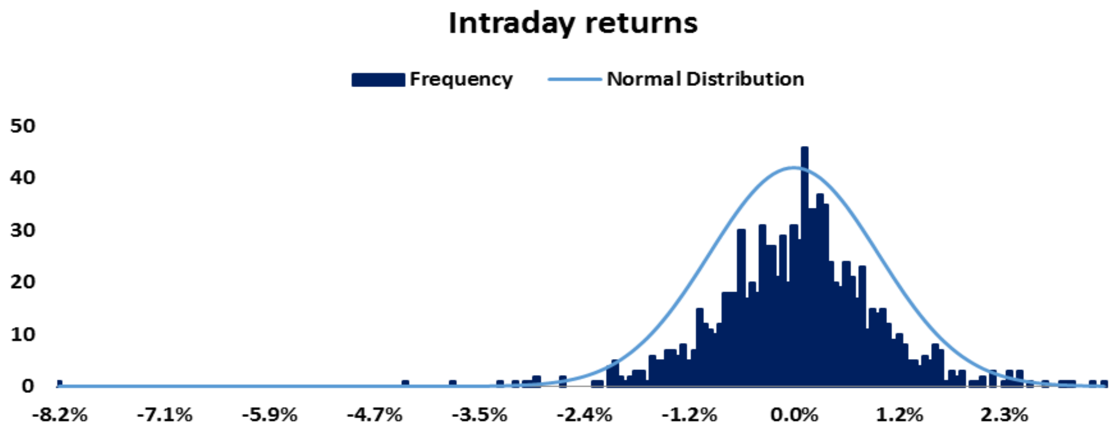


Figure 15: Intraday Returns OMXS30

The distribution for the intraday returns is illustrated in figure 15. The lowest observation is approximately -8.2%. However, the returns have a distribution that is not far from the normal distribution. The data is moderately skewed, with most of the observations at the right side of origin.

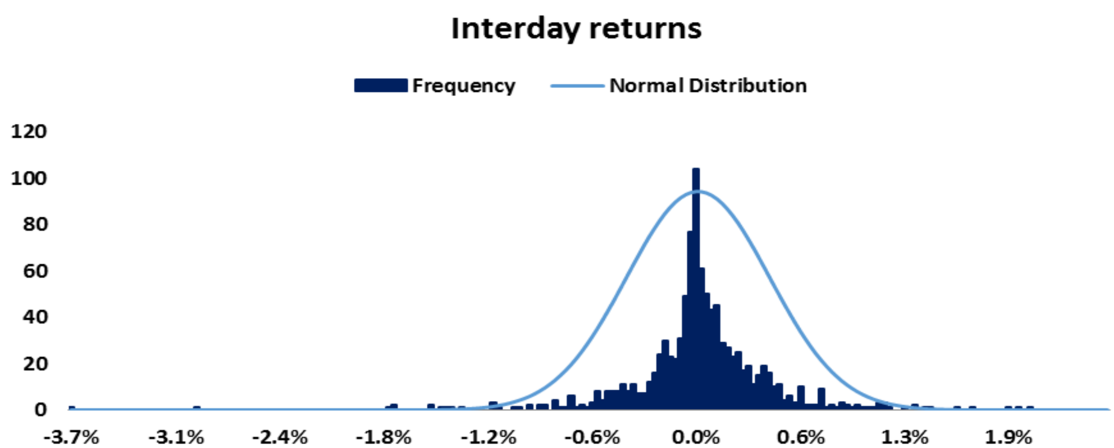


Figure 16: Interday Returns OMXS30

In figure 16, we illustrate the distribution of the interday returns. This distribution is relative peaked with a kurtosis of 12, and is skewed at the right side of origin. This indicates that the average is less than the median. The distribution of the close-to-close returns is illustrated in appendix IV. Even though the data is not perfectly normal distributed, we continue with the statistical tests in order to test whether the findings are statistically significant.

To test if there are unequal variances between intraday returns and interday returns we use a F-test. We reject the null hypothesis since the F-Value is larger than the F-Critical. Thus, there are different variances between the returns.

	F-Value	F-Critical
F-test	5.00	1.11

	T-Value	T-critical (one-sided)	T-critical (two sided)	Significant?
Intraday vs 0	-0.26	1.65	1.96	No
Interday vs 0	2.79	1.65	1.96	Yes
Close-to-close vs 0	0.85	1.65	1.96	No
Intraday vs interday	-1.38	1.65	1.96	No

Table 19: Statistical Tests OMXS30

The t-tests from S30 illustrate exactly the same as OSEBX. Interday returns are statistically different from zero due to high average return and relative low volatility. The intraday returns and close-to-close returns are not statistically different from zero.

5.4.3 OMXC20CAP – Copenhagen

The last index we consider is C20CAP. We use the same statistical tests to investigate the robustness of the empirical findings.

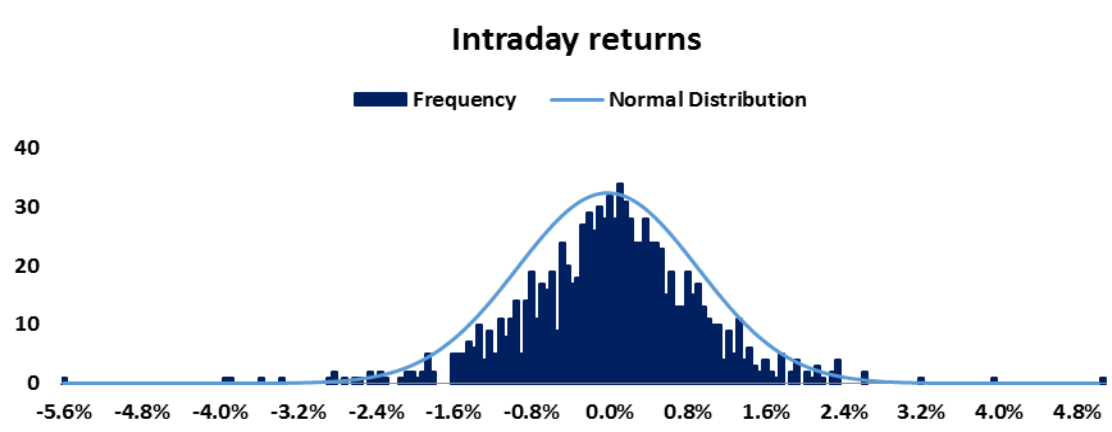


Figure 17: Intraday Returns OMXC20CAP

The distribution of intraday returns, in figure 17, indicates that the returns is relatively normal distributed. In addition to a low skewness, the kurtosis is approximately 3. The distribution of the close-to-close returns is equal to this distribution, and this is illustrated in appendix IV.

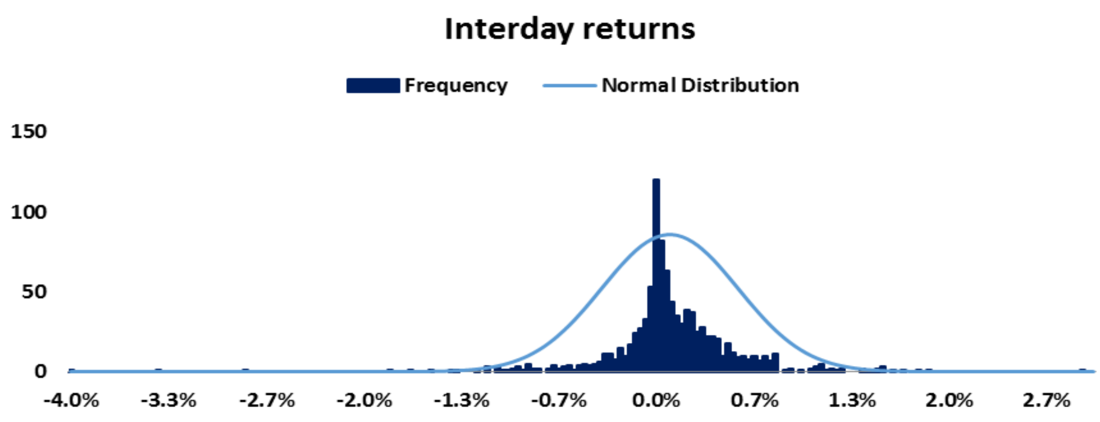


Figure 18: Interday Returns OMXC20CAP

The distribution in figure 18, illustrates the distribution for the interday returns. This distribution is relative peaked with a kurtosis of approximately 14. The negative skewness indicates that the distribution has most observation at the right side of origin. From these findings, we assume that the data is enough normal distributed in order to continue with different statistic tests.

The different statistical tests from C20CAP indicate that these findings are more robust compared to the previous findings from the other two indices. We reject the null hypothesis from the F-test, which means that the variance between intraday returns and interday returns is significantly different. Thus, we continue to use a t-test with two-sample assuming unequal variances.

	F-Value	F-Critical
F-test	3.91	1.11

	T-Value	T-critical (one-sided)	T-critical (two sided)	Significant?
Intraday vs 0	-0.77	1.65	1.96	No
Interday vs 0	6.29	1.65	1.96	Yes
Close-to-close vs 0	2.08	1.65	1.96	Yes
Intraday vs interday	-3.53	1.65	1.96	Yes

Table 20: Statistical Tests OMXC20CAP

The interday returns are statistically significant different from zero. Thus, the null hypothesis for the intraday returns cannot be rejected. We find that the interday returns and intraday returns are statistically significant different. With the observed t-value, the interday returns are statistically significant larger than intraday returns. In contrast to the other indices, the close-to-close returns are statistically different from zero.

In addition to the ordinary tests, we did an additional robustness test for C20CAP. As mentioned earlier, we used index prices from beginning of 2013 due to limitations in data from Oslo Stock Exchange. We added four more years for C20CAP to test the robustness. However, the similar tests resulted in the same conclusions as above. Hence, even though we extended the data, the results were not conflicting.

To conclude, the empirical findings from C20CAP are more robust than the findings from OSEBX and S30.

5.5 Findings

In this section, we summarize the findings from both the descriptive statistics and the robustness tests for all three indices. We compare them and in the next subchapter discuss potential reasons why it exists differences between them.

	OSEBX	OMXS30	OMXC20CAP
		Intraday	
Return	10.22%	-1.97%	-5.62%
Std.dev	16.17%	14.99%	14.54%
Adj. Std.dev	29.08%	25.34%	25.32%
		Interday	
Return	0.57%	9.34%	23.13%
Std.dev	0.54%	6.70%	7.35%
Adj. Std.dev	0.66%	8.32%	8.98%

Table 21: Descriptive Statistics Comparison Indices

The descriptive statistics indicate different results from each index. In total, all the indices increased from 2013 to 2016. C20CAP increased most in this period, by approximately 70%, while S30 increased less, by approximately 30%. S30 is the most diversified index in terms of measuring the top three companies total market capitalization.

The first large difference, is that it is only OSEBX that yield a positive average intraday return during the period. The index is also the most volatile during the trading hours. The indices in Stockholm and Copenhagen, have a negative average intraday return and a lower volatility compared to OSEBX.

On the other hand, OSEBX has the lowest average interday return compared to the other indices. The average annualized interday return is only 0.57% compared to 9.34% and 23.13% at the respective indices, S30 and C20CAP. The volatility is close to zero at OSBEX, while the volatility at S30 and C20CAP is approximately 7%.

The fact that the intraday volatility is larger than the interday volatility, even though it is a shorter period, is evidence against the calendar time hypothesis due to the lack of proportionality between volatility and time. After adjusting the variance for time, the proportionality between the adjusted volatility should equal 1 according to the calendar time hypothesis. Therefore, there is evidence on all indices that it exists differences in the volatility throughout night and day. It does not seem to exists a connection between volatility and time, which is consistent with the calendar time hypothesis.

Although there is no evidence for any proportionality between time and volatility, we cannot simply reject the thought behind the calendar time hypothesis; that news contributes to price changes. The stock market is forward looking, which in other words means that the price of the stock is affected by the investors' expectations. The stock price may, therefore, change due to changes in the expectations even though there are no trading. Thus, we cannot reject the statement that news contributes to the stock price movement although there is not a proportional relationship between the variance and the time frame.

French & Roll (1986) argue that it exists differences in volatility between intraday and interday. As described in chapter 2.5, there are three different explanations for this. First, public announcements and tender offers tends to be published during normal opening hours, and these are likely to create volatility. The second explanation is private information. Private investors trade on inside information, and therefore cause volatility. The third explanation is that pricing error occurs during trading, and therefore cause volatility.

We should bear in mind that the article by French & Roll was published in 1986. Since then, it has been an exceptional technology development and, nowadays, investors are able to gather information 24/7 from the whole world. Thus, public announcements and tender offers are released all day and not only during trading hours. We question whether the explanation presented by French & Roll is still valid in the 21st century, since the largest companies are often listed at several stock exchanges with different trading hours. However, Ahoniemi & Lanne (2011) argue that companies should rather publish information during non-trading hours due to pricing errors that might occur during trading hours. This is in line with a common observation that companies tend to publish annual and quarterly reports outside trading hours.

Private information and pricing errors are explanations that seem plausible to explain the differences between intraday and interday volatilities. These explanations are not tested specifically, but we believe that these may be some of the main factors that explain contrasting volatility.

	OSEBX		OMXS30		OMXC20CAP	
	T-Value	Significant?	T-Value	Significant?	T-Value	Significant?
Intraday vs 0	1.26	No	-0.26	No	-0.77	No
Interday vs 0	2.09	Yes	2.79	Yes	6.29	Yes
Close-to-close vs 0	1.32	No	0.85	No	2.08	Yes
Intraday vs interday	1.19	No	-1.38	No	-3.53	Yes

Table 22: Statistical Tests Comparison Indices

In table 22, we summarize the statistical tests from previous sections. The null hypothesis, that intraday returns are significant different from zero, are not rejected for any of the indices. Thus, we cannot claim that the intraday returns are statistically different from zero.

All of the t-tests regarding whether the interday return is significantly different from zero are accepted at 5% significance level. We accept the one-sided test, meaning that we claim that the interday return yields a positive return on a 5% significance level. The tests regarding whether the close-to-close returns are different from zero, is only accepted at C20CAP.

Finally, we tested whether the intraday returns are statistically significant different from the interday returns. As with the close-to-close returns, it is only at C20CAP we claim that they are different. By conducting a one-sided t-test, the interday returns are statistically significant larger than the intraday returns. C20CAP is the index with most significant findings compared to OSEBX and S30. The interpretation of these findings is discussed further below.

5.6 Comparing the different indices

From the findings, we observe differences regarding the interday and intraday returns. As discussed in section 3.6, the indices have had different regulations regarding the duty of disclosure. This might result in less continuously information flow in Oslo, where most of the information is published during the trading hours. This may explain the higher return and volatility during the intraday period at OSEBX compared to the two other Scandinavian indices. The interpretation of the rules at Oslo Stock Exchange was changed 1st of April 2017. These changes led to the rules being interpreted in same way as at the exchanges in Stockholm and Copenhagen. A more common interpretation of the rules regarding the timing of the duty of disclosure will lead to less structural differences between the exchanges. This may in turn lead to less differences between the intraday and interday returns and volatilities.

The findings from S30 and C20CAP are consistent with the earlier research of the US equity market where Cooper et.al., (2008) find empirical evidence that the US equity premium was solely due to overnight return. The findings from Stockholm and Copenhagen indicate that the total return the last four years is solely driven by the interday returns since the intraday returns have, on average, been negative. This is contrary to the findings from OSEBX, where the market is almost only driven by the intraday returns.

By looking at the minimum observations for the intraday and interday returns, we observe that the three indices reacted different on large macroeconomic events. The worst intraday return at OSEBX was due to the "Black Monday" event in China the 24th of August 2015. This day, OSEBX declined with 5.32% intraday. In comparison, S30 and C20CAP declined with 1.65% and 1.35%. However, by considering the related interday returns we observe that the difference is a bit evened. At OSEBX, the interday return declined with 0.01% resulting in a close-to-close return of -5.33%. S30 declined with 2.96% during the interday resulting in a close-to-close return of -4.60%. C20CAP declined with 3.24% during the interday, resulting in a close-to-close return of -4.77%. Therefore, what in the beginning seems like large differences between how the stock exchanges react on news, may simply be because of different trading pattern on the intraday and interday phase.

Another explanation for these findings may be due to market inefficiency. In an efficient market, we would expect all investors to react and trade on the same information at the same time. However, at OSEBX, it seems like the investors do no trade on the information regarding "Black Monday" from the beginning. They rather trade on this during the intraday phase. An explanation for this, may be that some investors do not know how to react on this information, and follows the market sentiment once the market opens. They do not simply know how to react on the information they have gathered during the night. If this is the case, then these findings support the Fama & Roll´s third explanation of higher volatility during trading hours; that pricing errors create volatility.

Another interesting event was the Brexit in the summer of 2016. At Thursday night/Friday morning, the results of the referendum regarding Britain's exit from EU was published. Most stock indices around the world reacted negatively on this news when they opened Friday morning. However, at Stockholm Stock Exchange, there was no trading this day due to the holiday "Midtsommarafton". Therefore, it was not possible to react on this specific news at the stock exchange in Stockholm.

OSEBX had a close-to-close return of -3.12% on this Friday. The close-to-close return on Monday was -3.29%, resulting in a total decline of 6.41 percentage points. C20CAP had a close-to-close return of -4.17% on Friday, and a close-to-close return of -3.98% on Monday. This resulted in a total decline of 8.16 percentage points.

When Stockholm Stock Exchange opened after being closed throughout Friday to Sunday, the investors had already observed a decline in the stock markets around the world. Even if they had this information, the interday return was -0.55%. This is quite puzzling as it is close to zero. One would expect that since the investors already had observed a decline between 3% and 4% at the other Scandinavian indices the index would open with a larger decline. However, throughout the trading day the index reached roughly the same decline as the other indices, as the intraday return was -8.25%, resulting in a close-to-close return of -8.80%.

The Swedish and the Danish index declined with roughly the same amount, so in total the two markets reacted in the same way. After observing a decline of 4% at C20CAP, one could question why the interday return is not lower at S30. An explanation may be that the markets are inefficient, and people simply do not react in the same way on the available information. However, we observe that S30 decline with approximately the same amount during one day of trading, as C20CAP does throughout two days of trading. This may be evidence of market efficiency in a longer run, since the investors at S30 react in the same way as the investors at C20CAP after a while. In other words, we could speculate that in the short run S30 market proved to be inefficient since the investor did not react instantly on the information available. However, after a day of trading the market reacted the same way as C20CAP, which may be interpreted as efficiency.

We investigated whether the findings were statistically significant, and the empirical findings from S30 and C20CAP were more robust than the findings from OSEBX. An alternative way of interpreting the tests, is to consider insignificance as a sign of market efficiency. If the findings were significant, then it would be possible to trade on this information to earn abnormal returns. Thus, the lack of significant findings might indicate efficient markets.

One possible explanation for the large differences between intraday returns and interday returns might be due to the composition of OSEBX. Therefore, in the following sub-chapter, we decompose the indices in order to investigate how the different composition affect the indices.

5.7 Decomposing the indices

As described throughout section 5.1-5.3, the three indices differ in both size and industries. There are two main differences between OSEBX and the two other indices that stand out. First, OSEBX consist of over 60 firms, while S30 and C20CAP consist of 30 and 20 firms, respectively. Second, OSEBX is highly exposed to different commodities; the oil price and salmon price. By decomposing the indices, we are able to investigate whether these differences have any influence on the previous findings.

To investigate the first difference, we construct three portfolios consisting of the five largest companies at each index. The companies are weighted according to their market capitalization relatively to the other companies in the portfolio.

Decomposing the indices			
	Intraday	**Interday**	**Close-Close**
	OSEBX Big 5		
Average	-5.42%	14.69%	9.27%
Std.dev	16.05%	11.30%	20.10%
	OMXS30 Big 5		
Average	-4.50%	14.83%	10.36%
Std.dev	15.12%	10.20%	19.07%
	OMXC20CAP Big 5		
Average	-18.38%	8.09%	-10.30%
Std.dev	16.72%	42.83%	45.27%

Table 23: Big 5 portfolios

The findings indicate that OSEBX Big 5 have the same characteristics as the two other portfolios; a negative intraday return and a positive interday return. This indicates that it is the smaller companies at OSEBX that affects the original findings and create differences between the three indices. This is further discussed throughout the sub-chapter.

The Big 5 companies at each index have a considerable lower intraday return than the respective index they are listed in. In the same way, the Big 5 have a higher interday return than the index, besides the Big 5 portfolio at C20CAP. The reason for the differing results at C20CAP is due to the performance of Novo Nordisk A/S. The company is heavily weighted in the portfolio, and had a poor interday return during the period and therefore affects the portfolio return. To investigate the effect of smaller companies on the intraday and interday returns on OSEBX, we construct another portfolio where the five second largest companies are added.

OSEBX Big 10			
	Intraday	Interday	Close-Close
Average	-3.73%	13.69%	9.97%
Std.dev	14.48%	11.90%	19.27%

Table 24: OSEBX Big 10

The returns and volatilities from the ten largest companies at OSEBX are highlighted in table 24. If we compare to the Big 5 portfolio, the intraday return increases whereas the interday return decreases. The average intraday volatility decreases, while the average interday return increases. A reason for this might be the size and the globalization of the companies. Smaller companies might be less affected by events and shocks happening during the closed trading hours, and therefore not generate as much variations between closing price and opening price. This may add some explanation to the original findings at OSEBX, since the expanded portfolio converges to the original results from OSEBX.

Even though there are many different industries at the three indices, the banking sector is quite homogeneous although the firm size differs. To investigate whether the observed differences between the indices are due to the structural differences or the composition of the indices, we compare the banking sector at each index.

Banks			
	Intraday	Interday	Close-close
OSEBX			
Average	-1.82%	15.77%	13.96%
Std.dev	18.22%	11.76%	22.03%
OMXS30			
Average	-1.25%	14.01%	12.82%
Std.dev	16.95%	11.07%	21.32%
OMXC20CAP			
Average	3.56%	15.83%	19.39%
Std.dev	17.88%	12.67%	21.62%

Table 25: Banks

In comparison, the results are similar. The only difference is the positive intraday return at C20CAP. We believe, however, that this might be due to the exceptional performance by Danske Bank A/S during the period. The volatility among the indices are very similar which is highlighted in table 25. The findings from above indicate that if there had been a more homogenous composition at the indices, the differences would be smaller. Thus, we believe that one of the reasons for the differences is due to the composition at the stock exchanges. Further, we decompose OSEBX and investigate two of the main industries at this stock exchange; oil and seafood.

Decomposing oil			
	Intraday	Interday	Close-Close
Oil companies at OSEBX			
Average	-6.65%	7.77%	1.12%
Std.dev	22.18%	15.74%	27.64%
OSEBX Big 5 - Oil excluded			
Average	-7.16%	15.98%	8.83%
Std.dev	14.30%	10.08%	17.89%

Table 26: Decomposing oil OSEBX

We know that OSEBX is heavily exposed to the oil price, as a result of the large number of companies in the energy sector. To investigate this effect, we compare a portfolio consisting of the largest companies which are directly exposed to the oil price, with a portfolio consisting of the five largest companies that is not exposed to the oil price. This comparison illustrates that the intraday return is higher and the interday return is lower for the companies exposed to oil. A reason for this, might be due to the stocks sensitivity to fluctuations in the oil price. In the end of July 2014, the Brent

Crude Oil price dropped below 100$ per barrel, and declined rapidly. As a result of this, the share price of most oil companies worldwide declined.

By splitting the period into two periods, we investigate the intraday and interday returns and volatilities before and after the decline in the oil price. We find that the returns were less volatile during the period of a high oil price. From August 2014 until the end of 2016, the returns have been twice as volatile compared to before. This indicates that the sensitivity for changing oil price has increased during these years. We investigated the same periods at OSEBX, and found that the returns were better prior to the drop in the oil price. This makes sense, since the major firms at OSEBX are oil companies. The descriptive statistics can be found in appendix V. This may add an explanation for the differing results between OSEBX and the two other indices, as they are not as heavily exposed.

However, as previously illustrated, both size and oil exposure might be an explanation for a higher intraday return and a lower interday return. Some of the largest companies at OSEBX are oil companies and, therefore, we cannot be sure whether it is the size of the firm or the exposure which is the reason for the results. Thus, to investigate this, we compare the portfolio consisting of oil companies to Lundin Petroleum AB, which is the only company directly exposed to the oil price listed at S30. We do not do the same comparison at C20CAP since the only company, which is directly exposed to the oil price, is A.P. Møller - Mærsk A/S. As this company is also heavily exposed to shipping rates, we are not able to distinguish whether the performance is due to the exposure to oil or freight rates.

Lundin Petroleum AB			
	Intraday	Interday	Close-Close
Average	-2.71%	9.76%	7.04%
Std.dev	26.09%	13.95%	30.86%

Table 27: Lundin Petroleum AB

The results, presented in table 27, from Lundin Petroleum AB illustrate the same behavior as OSEBX. The intraday return is higher, while the interday return is lower, compared to the Big 5 portfolio at S30 which is not exposed to oil. Therefore, these results may strengthen the belief that oil may be a reason for the differing results, but we should be aware of the low reliability to this comparison, as we are only comparing to one company.

Another difference between OSEBX and the two other Scandinavian indices is the seafood companies. This sector is relatively small compared to other sectors in the index, but it attracts much attention at Oslo Stock Exchange and the listed companies are very liquid.

OSEBX Seafood			
	Intraday	**Interday**	**Close-Close**
Average	11.08%	26.94%	38.01%
Std.dev	21.90%	10.86%	24.78%

Table 28: OSEBX Seafood

The seafood portfolio stands out from the other highlighted portfolios, as they yield a positive intraday return in the period. The intraday returns are also more volatile compared to the other portfolios, while the interday returns are less volatile. A reason for this might be due to the opening hours of the fish and seafood exchange, Fish Pool ASA (Product Specifications and Trading Schedule for Trading at Fish Pool Markets, 2015). It exists several seafood exchanges throughout the world, but Fish Pool ASA is a regulated marketplace for financial contracts on seafood produced in the Nordic countries. The opening hours of the market place overlaps with the trading hours at Oslo Stock Exchange, and may therefore explain the intraday volatility observed for these shares since there are no large movements in the salmon price during the interday period. These findings indicate that the seafood companies, with its popularity and liquidity in the market, might contribute to the original findings at OSEBX.

After decomposing the indices, we identify some explanations for why the previous results differs. By only comparing the largest companies at the three stock exchanges, we observe that the intraday and interday returns are behaving in the same way. As OSEBX is a smaller index and consist of several small companies, the intraday and interday returns differs, compared to the larger and more liquid indices in Stockholm and Copenhagen. OSEBX consists of 62 companies whereas most firms are considerable small. Thus, the interday return will have a very small return and variance if the first trade of the day is in one of the smallest companies in the index. It will hardly affect the opening price of OSEBX, due to the low weighting in the index. S30 and C20CAP are, however, not dominated by a few large companies, and the weighting of each company is more evenly distributed. Therefore, a move in either of the firms will affect the price of the index.

We should, however, be aware that we cannot directly compare the portfolios with the indices. The interday returns in the portfolios are calculated using the last and first trade of each of the company, where the interday returns in the indices are based on the last and first trade in any company listed at the index. If we wanted to replicate the indices by holding positions in each company, we would be in a situation where we would have to rebalance the portfolio each morning and night. In turn, this would lead to a high amount of trades, and the brokerage fee would result in a very high cost for the investor. Therefore, we continue the analysis using the three indices, as they appears as cheaper and easilier traded financial instrument.

After highlighting the implication of different compositions at the three indices, we split the different returns to investigate whether there are some patterns that repeats itself between the different indices, also called seasonality.

6 Seasonality

In order to find out whether it exists different patterns in the data, we first investigate if there is any relationship between the returns for each month before continuing with days, weekends and holidays. We examine if the trading strategy, based on seasonality, "Sell in May, go away" is relevant for the Scandinavian indices. After including brokerage fee, we discuss whether there is sign of market inefficiency in the indices. Additionally, we investigate whether there is evidence of the well-known January effect.

To find if there are any empirical evidence of seasonal effect in the Scandinavian stock market, we use the lognormal returns in the period from 2013-2016. The average intraday, interday and close-to-close returns are separated for each month and index. The results of the calculations are presented in appendix VI, whereas we illustrated the intraday and interday returns graphically. The robustness is tested using ordinary t-tests.

6.1 OSEBX – Oslo

In this section, we comment the findings from OSEBX when considering the monthly seasonality and different trading strategies based on these findings. We analyse how each month differs from each other in sense of intraday and interday returns and volatilities. The graph is only including returns, while volatility for the respective stock exchanges are presented in appendix VI.

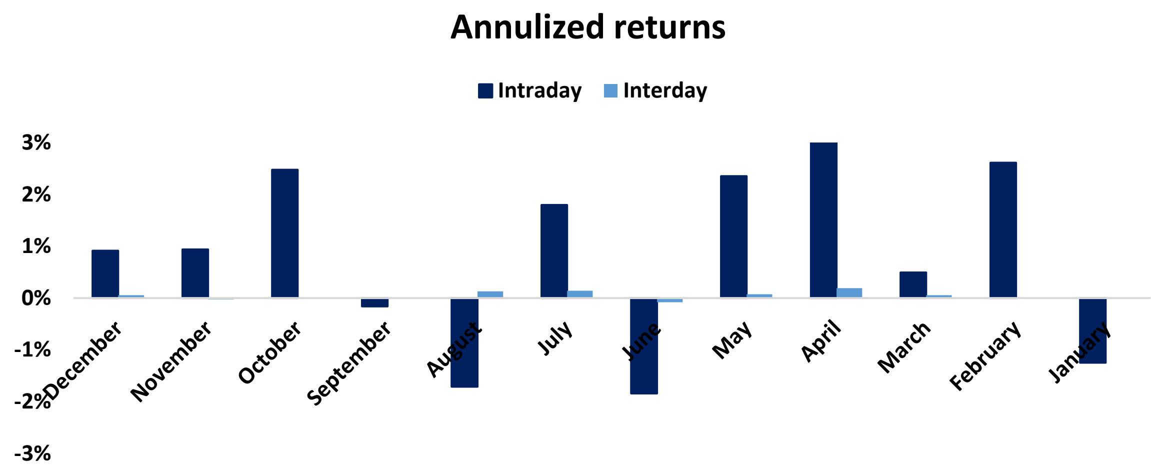


Figure 19: Monthly intraday- and interday returns OSEBX

Figure 19 illustrates how each month performs regarding average annualized returns. The returns are separated in two scenarios; intraday and interday. This illustration indicates that OSEBX is mostly driven by the intraday returns.

From the graph above, we observe that April is the month with highest average intraday return. April has statistically been the month with highest return at OSEBX since 1983, which is consistent with the findings. April has historically the highest return for both intraday and interday returns (Jeg velger meg April, 2016). Equity analyst in DNB, Paul Harper, mention one possible explanation for the historical positive return in April. This is often due to company quarterly reports, which is often better than the expectations (Historiens dårligste børsmåned forvirrer ekspertene, 2016).

June is the month with lowest average return for intraday and interday returns, thus also close-to-close returns. June has historically been a month with low (negative returns) in several years (Jeg velger meg April, 2016). To investigate why June is historically a month with low returns, we calculate the correlation between volume and returns. The correlation between volume and returns is 0.39, which might explain some of the positive relationship between low returns and low volume. June is one of the months with lowest volume, while February is the month with highest volume. Figure 19 illustrates that February is, contrary to June, a month with relative high return.

In addition to the returns, we analyse how the volatilities have changed from month to month. Intraday and close-to-close returns are most volatile in February, which might be caused by the high volume in this month. This is illustrated in appendix VI. May is the month with lowest volatility for the respective returns. Regarding the interday returns, the month with highest volatility is June, while October has the lowest volatility.

There is no evidence of the January effect at OSEBX. Figure 19 illustrates that the average annualized intraday return is -1.25%, whereas the average interday return is very close to zero. Further, we investigate whether there is a relationship between the volatility and the volume at OSEBX.

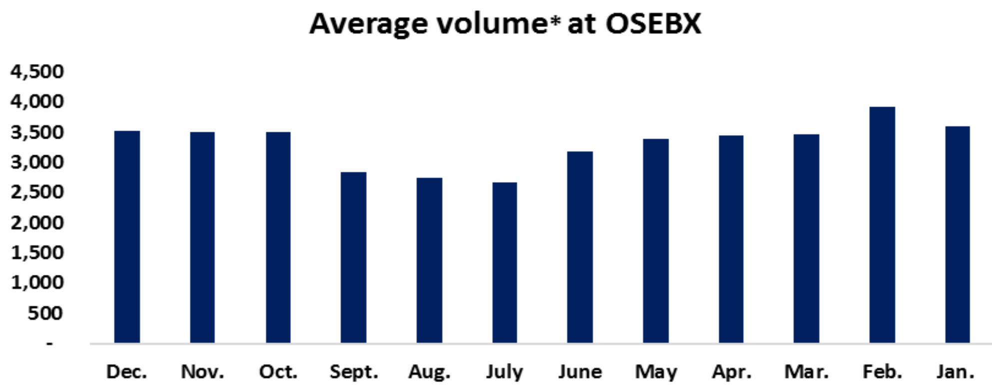


Figure 20: Average volume at OSEBX (*): Numbers in millions

The average monthly volume at OSEBX in figure 20 illustrate a pattern. In the months from November to February there are much activity, with a total volume of approximately 14 billion NOK. During the period from June to September the activity is lower. On average, the volume is about 20% lower in this period than in the period from November to February. In addition, we investigate the relationship between volume and volatility. A correlation coefficient of a nearly 0.45 indicates that volume and volatility has a moderate positive correlation. This means that a higher volume indicates a higher volatility, or vice versa.

Further, we examine a trading strategy called “Sell in May, go away”. This is a famous expression in the equity market. The concept is to sell in May due to a traditional seasonal decline in the stock market, buy back in the autumn and sell it again in May next year. This phenomenon is tested on OSEBX, where we find the average yearly returns for these two periods. The first period is from the beginning of June to the end of September, while the second period is from the beginning of October to the end of May. Since the data set is from 1st of January 2013, we use this date as a starting point for the combined trading strategy. In addition, this strategy ends at 31st of December 2016.

"Sell in May, go away"		
Initial investment	1,000,000	
Brokerage fee	0.049%	
OSEBX	**Total return**	**Yearly return**
October-May	43.92%	**10.98%**
June-September	-8.98%	**-2.24%**
Long-Short strategy	48.76%	**12.19%**
OSEBX	35.83%	**8.96%**

Table 29: "Sell in May, go away" OSEBX

Table 29 is based on an example where the initial investment of 1,000,000 with a brokerage fee of 0.049%, since there are only four trades a year. By using this trading strategy, the annualized return for holding OSEBX from October to May is 10.98%, whereas June to September results in a return of -2.24%. In addition to discover the differences in historical returns, we combine these two periods. If an investor goes long in the index from October to May and short from June to September, the historical annualized return is 12.19%, including brokerage fees. Thus, an investor could yield a return which is approximately 3.2 percentage points higher than holding the index in the entire period.

6.2 OMXS30 - Stockholm

In this section, we present the results from S30. The results are presented in the same structure as earlier, except the trading volume which is not included for the next two indices since there was no available data. The daily returns are annualized with the intention of make it easier to interpret.

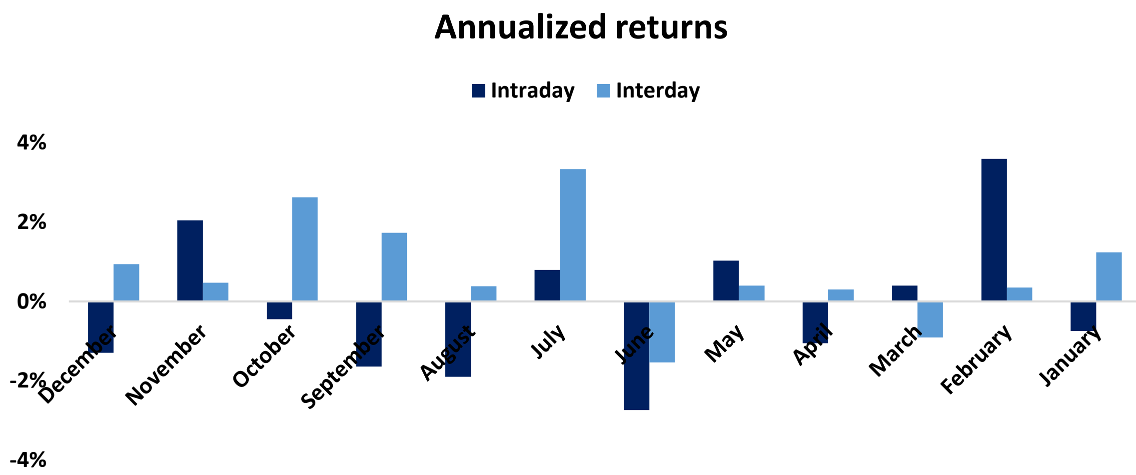


Figure 21: Monthly Intraday- and Interday Returns OMXS30

Figure 21 illustrates how each month at S30 has done it historically. February is the month with highest average return during the trading hours. Since this return is noteworthy higher than the other months, February is also the month with highest return measured by close-to-close returns. July is the month with highest average return for the non-trading hours. For all time-scenarios, June is the month with lowest average return.

There is no sign of a January effect at S30 even though the average interday, and close-to-close, return is positive. This month is not outperforming other months measured by average return, since there are five months that yielded a higher return than January. In other words, there is no clear evidence of a January effect. The volatility for each month is illustrated in appendix VI. The average monthly intraday volatility is clearly highest for June and February, which are the two months with, respective, lowest and highest intraday return. We investigate if the trading strategy, "Sell in May, go away", is outperforming the market.

"Sell in May, go away"		
Initial investment	1,000,000	
Brokerage fee	0.049%	
OMXS20	**Total return**	**Yearly return**
October-May	31.75%	**7.94%**
June-September	-9.14%	**-2.29%**
Long-Short strategy	35.22%	**8.81%**
OMXS20	23.40%	**5.85%**

Table 30: "Sell in May, go away" OMXS30

Table 30 highlights that this trading strategy is profitable. The average annualized return, by holding the index from the beginning of October to end of May, is 7.94%. Whereas the average annualized return, by holding S30 from the beginning of June to end of September, is -2.29%. This gives a total historical annualized average return of 8.81% if an investor had taken a long position in October to May while a short position in June to September each year. This long-short strategy is outperforming the market with approximately 2.9 percentage points. Hence, an investor who had followed this strategy, which includes transaction costs, would beat the market.

6.3 OMXC20CAP - Copenhagen

The last index we present and analyse, is the main index at Copenhagen Stock Exchange. The findings are presented in the same structure as earlier. The daily returns are annualized with the intention of make it easier to interpret.

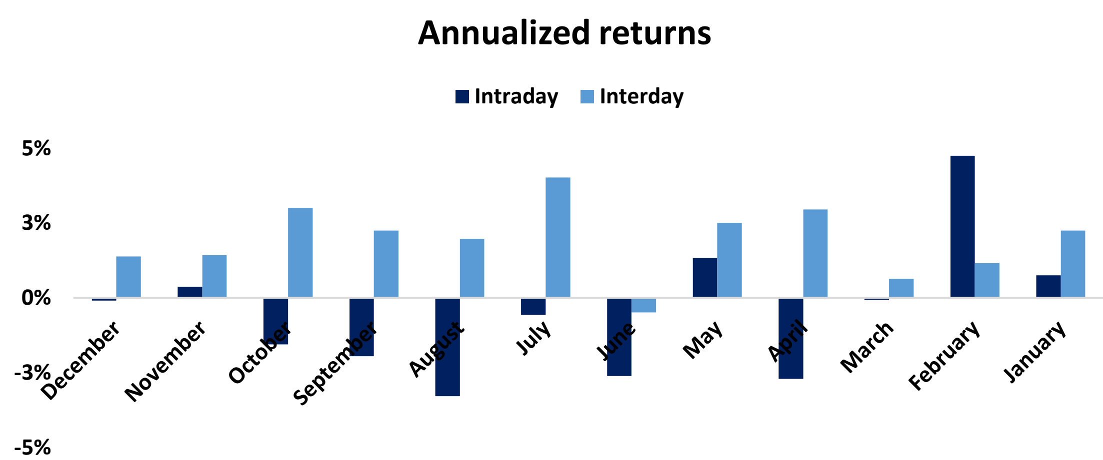


Figure 22: Monthly Intraday- and Interday Returns OMXC20CAP

Figure 22 illustrates the average intraday and interday returns for each month. February is the month with highest average return for the trading hours, whereas July is the month with highest average return for the non-trading hours. In contrast to these months, June is the month with lowest average return for interday and close-to-close, whereas August is the month with lowest average return during trading hours. In addition, we illustrate the annualized volatility for each month in appendix VI. June and February have a much higher annualized intraday volatility than the other months.

From the graph above, there is no sign of a January effect, even though January has historically been a month with positive returns. January is ranked as the fourth best month, measured by average return. There is no evidence that indicates that January is historically better than the other months. In the section Comparing the indices, the absence of abnormal returns in January is discussed. Further, we investigate the "Sell in May, go away" strategy.

"Sell in May, go away"		
Initial investment	1,000,000	
Brokerage fee	0.049%	
OMXS20CAP	**Total return**	**Yearly return**
October-May	68.60%	**17.15%**
June-September	-5.09%	**-1.27%**
Long-Short strategy	68.62%	**17.16%**
OMXS20CAP	64.27%	**16.07%**

Table 31: "Sell in May, go away" OMXC20CAP

This trading strategy is profitable, as illustrated in table 31. The annualized average return for the period from October to May is 17.15%, whereas the period June to September yields a return of -1.27%. Due to these findings, we test the long-short strategy for this index, with the same assumptions as earlier. The total yearly return is 17.16%. Thus, if an investor had followed this strategy he would outperformed the market by approximately 1.1 percentage points.

6.4 Robustness

In this section we test if the findings are statistically significant in order to determine if the results are reliable. To test if the findings from the indices and the observed seasonal effects are robust, we use a two-sided t-test. The reasons why we only test some months are explained for the respective section.

6.4.1 OSEBX – Oslo

	T-value	T-critical (one sided)	T-critical (two sided)	Rejected
April close-to-close vs 0	1.389	1.664	1.990	**No**
February close-to-close vs 0	0.881	1.664	1.990	**No**
June close-to-close vs 0	-0.733	1.663	1.989	**No**

Table 32: Statistical Tests Seasonality OSEBX

From table 32, the results from the different t-tests are presented. We test whether the close-to-close returns for April, February and June at OSEBX are statistically significant different from zero. The reasons for including these months are a result of either high returns, measured by absolute value, or low standard deviation.

In this case, none of the null hypothesis are rejected. In other words, April, February and June close-to-close returns are not statistically significant different from zero. This might be caused by the relative small data set. There are only 80, 81 and 84 observations for the respective months, which must be considered as a weakness. Even though the results are not robust, there is a tendency of seasonality at OSEBX which is interesting. April outperformed the other months, which is in line with the statistic Oslo Stock Exchange presents (Jeg velger meg April, 2016).

6.4.2 OMXS30 – Stockholm

	T-value	T-critical (one sided)	T-critical (two sided)	Rejected
February close-to-close vs 0	1.318	1.664	1.990	**No**
July interday vs 0	3.713	1.662	1.987	**Yes**
June close-to-close vs 0	-1.215	1.665	1.991	**No**

Table 33: Statistical Tests Seasonality OMXS30

In table 33, the t-tests for S30 are presented. We test February close-to-close returns since this was the month with highest average daily return. This is not statistically significant at a 5% level. However, July was the month with highest interday return and relative low volatility compared to the other months. Therefore, this month is included and the interday returns are statistically significant different from zero. The finding from July is more reliable. Lastly, we test the close-to-close returns in June since this month had the most negative average daily return. These returns are not statistically significant different from zero.

6.4.3 OMXC20CAP –Copenhagen

	T-value	T-critical (one sided)	T-critical (two sided)	Rejected
February close-to-close vs 0	1.761	1.664	1.990	**No**
July interday vs 0	4.451	1.662	1.987	**Yes**
June close-to-close vs 0	-1.045	1.664	1.990	**No**

Table 34: Statistical Tests Seasonality OMXC20CAP

Table 34 highlights the findings from C20CAP. February was the month with highest close-to-close return, and thus included in the test. The returns are not statistically significant different from zero at a 5% level. The interday returns in July are statistically significant at a 5% level. We test this month due to high average daily interday return, and a relative low volatility. In addition, we test June close-to-close returns since this was, on average, the lowest. These returns are not statistically significant different from zero at any relevant level.

6.5 Comparing the indices

After describing each index and testing the robustness in the findings, we conclude that there are some common and uncommon patterns at the Scandinavian indices. The findings are discussed in relation to each other and financial theory, such as market efficiency and behavioral finance.

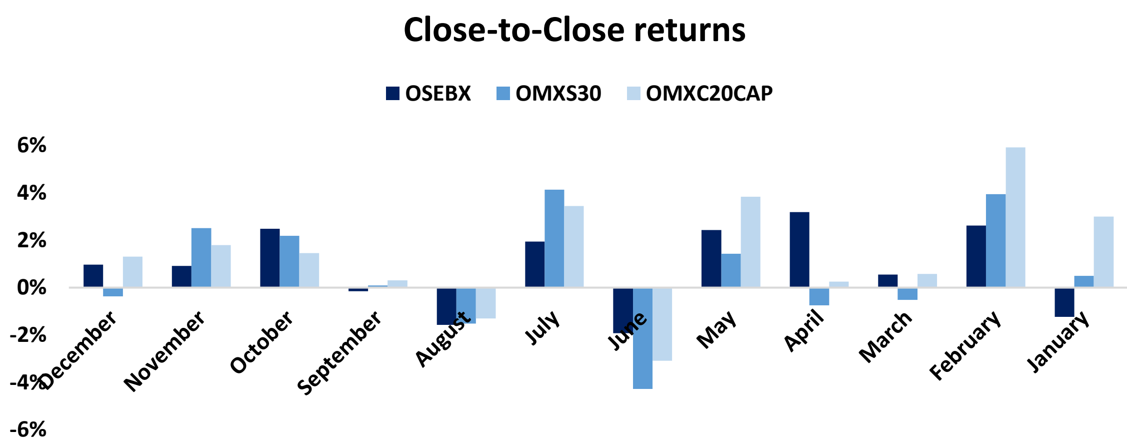


Figure 23: Monthly Close-to-close returns

Figure 23 illustrates the annualized close-to-close returns for the three indices. By combining the intraday and interday returns, we observe that both S30 and C20CAP yield a positive return in January, while OSEBX yields a negative return. February has been pointed out as the strongest month at both S30 and C20CAP, while this is the second best month at OSEBX. At OSEBX, April is the month with highest average return, which is consistent with the statement provided by Oslo Stock Exchange (Jeg velger meg April, 2016).

June is the month that perform worst at all three indices. This finding is different from the earlier research from US, where September has consequently been the month with lowest return (September is the worst month for U.S. stocks, and no one knows why. 2016). However, June has been a turbulent month for the last two years in Scandinavia due to the Brexit in 2016 and the Greek debt crisis in 2015. This may affect the findings as a result of the low number of observations.

January does not outperform the other months. However, both S30 and C20CAP have a positive average return during this month. The findings from these indices are consistent with the findings Rozeff & Kinney (976). In contrast, OSEBX has no sign of the January effect due to negative average return. Thus, OSEBX is not consistent with Rozeff and Kinney's (1976) findings.

Thaler (1987) provides explanations for why the January effect occur in the stock market. This might be the case for S30 and C20CAP. However, this month is not outperforming the other months and is negative at OSEBX. One possible reason for not observing this at OSEBX might be the presence of market efficiency. Since the January effect is a well-known trading strategy, investors might take this into consideration. This is public information, which is available for all market participants. The observations that January does not outperform the other months might be evidence of market efficiency.

In contrast to the findings and the possible evidence of market efficiency at OSEBX, there is a sign of market inefficiency at all the indices by considering the trading strategy "Sell in May, go away". In chapter 5.3, we found that the index in Copenhagen had the highest return. However, the index in Oslo had the highest abnormal return using this strategy. "Sell in May, go away" outperformed the market on all indices, which might indicate market inefficiency.

One interesting observation from figure 23, is that there are only two months where all the indices have negative average returns; June and August. These findings, in addition to the "Sell in May, go away" trading strategy, indicate that it was possible to get abnormal returns as a result of the seasonality at the Scandinavian stock markets. From financial theory, stock prices, and thus stock indices, should follow a random walk based on a random component. The findings indicate that it is possible to follow a non-random walk by exploiting the observed seasonalities. If we had analyzed the seasonality for a longer time-period and the results were the same, the findings would be more reliable. However, even though these patterns have been consistent during the last four years, there is no guarantee for this to occur again.

Behavioral finance is often discussed in context with market efficiency. If the stock is not following a random walk, there have to be other aspects that affect the stock price. Seasonality is often caused by general expectations. For instance, before the summer, investors might believe that the short-term market outlooks will be affected by less volume and higher volatility. Kelly & Clark (2011) explain that these two factors indicate risks, since less liquidity often increase the volatility. As a result of these expectations, investors know that other market participants have the same information. Due to this, investors will be less involved in the market. Thus, a higher selling pressure results in a decreasing index.

There is often an observed phenomenon in financial stock market, that if the market is falling rapidly, it will affect all the shares in an index even though not all companies are affected by the same news. This observation might be related to behavioral finance, where an investor's thoughts is affected by the behavior of other investors. This might be one reason for why the indices have historically performed worse during the summer. Since an investor expects that other investors are expecting a decline during the summer, this effect leads to a period of lower returns. Although all investors have the same information, it is not granted that everyone interpret the information in the same way.

In addition to the psychological aspect of financial theory, there are several other reasons why one might observe signs of market inefficiency. Characteristics such as liquidity, caused by low trading volume, and risk must be considered in order to continue the discussion of market inefficiency. Further, we present the average close-to-close volatility in figure 24. This figure illustrates how the volatility various from month to month with the purpose of describing the risk.

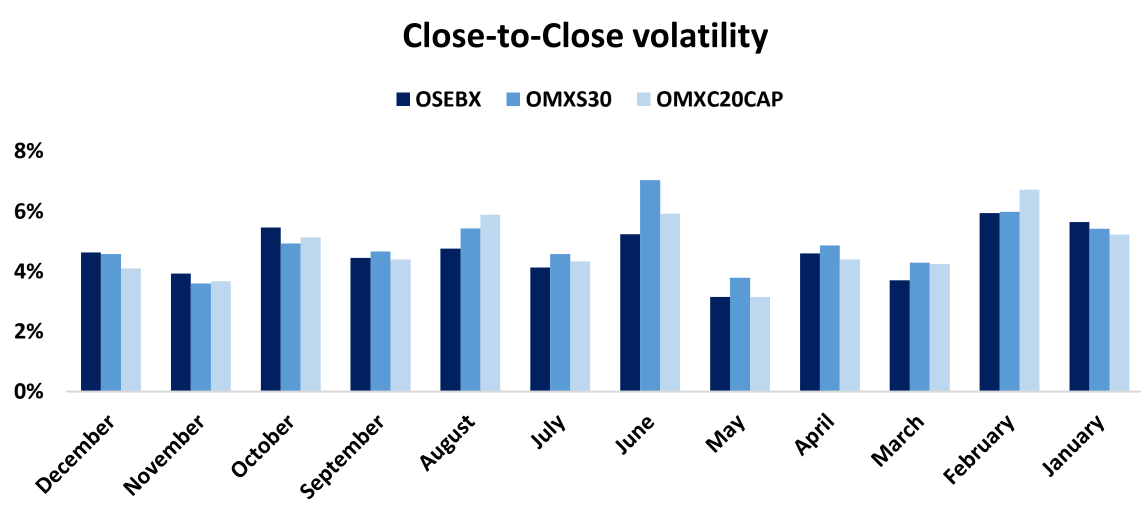


Figure 24: Monthly Close-to-close volatility

From figure 24, we observe that June and February are months with highest historical average volatility. Earlier, we found that June was a month with negative returns for all indices. However, it is difficult to say something about the relationship between high volatility and negative returns since February also have a relative high volatility and, in contrast, high returns. At OSEBX, there is a positive correlation between volatility and volume. If this finding is representative for the other two indices, it might explain why there is seasonality in the data and therefore evidence of inefficiency.

Another aspect of market inefficiency is the liquidity in each market. OSEBX is the index with lowest market capitalization, whereas S30 is the index with highest market value. By using market capitalization as a proxy for liquidity, this indicate that the liquidity in Stockholm is higher than in Oslo. Lower liquidity may lead to a less efficient market, since it is more difficult to find a match between a buyer and a seller. In a less efficient market it would be possible to obtain a higher abnormal return, compared to a more efficient market.

From the trading strategy “Sell in May, go away”, OSEBX had higher abnormal return than S30. Despite these findings, we cannot conclude that this is a sign of inefficiency since all the Scandinavian indices must be considered as liquid due to high trading volume, even though there are differences in the market capitalization.

7 Weekend and Holiday effect

The weekend effect is a phenomenon on the stock exchanges and other financial markets that is widely discussed. The theory behind the effect, is that the return on Mondays are significantly lower than the returns on the other days during a week. One would believe that the expected returns on Mondays would be larger compared to other days due the longer period and the greater risk. A common explanation is that companies tend to publish negative information on Friday after the market has closed. The idea behind this is that the investors forget the negative information during the weekend. Therefore, the stock price reaction will not be as large as it would, if the news were published during the trading week. Publishing news after the market has closed is consistent with the findings by Lou et. al., (2015). It is also consistent with Ahoniemi & Lanne (2011) explanation for the importance of the overnight period.

As described in chapter 2.4, the weekend effect has been tested in several ways. We start by splitting the intraday, interday and close-to-close return into different days. Then, we observe whether the interday returns on Mondays are larger compared to the other days, which are consistent with French's (1980) approach to the calendar time hypothesis. We observe whether the average returns are equal each day, which is consistent with the trading time hypothesis.

By omitting the holidays, we are able to illustrate whether it exists a holiday effect in line with French's (1980) findings. At last, we once more investigate the weekend effect and split the returns into intraday, interday and close-to-close, when at the same time omitting the holidays. By doing this we are able to test whether the findings are due to the holiday effect or not. We test the weekend effect by adjusting the variance for time, which is consistent with Fama's (1965) paper.

By conducting these tests, we observe if it exists any weekend, holiday, or day effect on any of the three indices. If there are any proofs of such effects, that there exist market abnormalities, it indicates market inefficiency. In an inefficient market, an investor is able to trade systematically on these effects. The returns and the standard deviation is annualized by using the average number of the specific day throughout the four-year period.

7.1 OSEBX - Oslo

The first step in the analysis is to split the intraday, interday and close-to-close returns into individual weekdays, to examine whether there are differences in the average return for different days.

	All		
		Intraday	**Interday**
Monday	**Return**	-3.02%	0.04%
	Std.dev	7.28%	0.19%
Tuesday	**Return**	3.26%	0.06%
	Std.dev	7.22%	0.24%
Wednesday	**Return**	5.58%	0.22%
	Std.dev	7.12%	0.26%
Thursday	**Return**	0.76%	0.16%
	Std.dev	7.48%	0.22%
Friday	**Return**	3.06%	0.09%
	Std.dev	6.96%	0.29%

Table 35: Days OSEBX

On average there is a historical negative intraday return on Mondays at OSEBX, while there is a positive return at remaining days. None of the days stand out regarding volatility, meaning that the risk is very much the same each day. Thursdays yield quite a lower return compared to Tuesdays, Wednesdays and Fridays, even if the volatility is similar to the other trading days. For an investor, it seems that intraday trading on Thursdays yield an unfavorable risk-return. Investors would, therefore, prefer to do their intraday trading on Tuesdays, Wednesdays and Fridays. These findings are not statistically significant on a 5% level since the t-values are within the critical value of ±1.96. The t-values and close-to-close returns are presented in appendix VII.

There is a positive average interday return each day during the trading week. Wednesdays and Thursdays stand out with the highest average return, while Fridays has the highest volatility. Overall there are no large differences between the days, but Wednesdays and Thursdays offers the best risk-reward return. The findings are consistent with the findings in Cooper et al., (2008) paper, where the interday weekend return is positive. However, it is a bit surprising that the interday over a weekend has the lowest volatility. It would be expected that this period might have a higher volatility due to the longer period of investment. Yet, none of the interday returns are significantly different from zero on a 5% level. The average Wednesday interday return is significantly positive if we conduct a one-sided t-test at a 5% significance level. We question the reason behind this result, as there is no previous research or obvious logical reason that Wednesdays should yield a positive return compared to the other days.

The average annualized close-to-close returns, in appendix VII, illustrate that the average weekend return from Friday close to Monday close is negative. This is consistent with French's (1980) findings, where he finds a negative return following weekends. French (1980) and Cooper et al., (2008) find contradictive results. After splitting the returns into intraday and interday returns, the same results are observed in the data set. The negative return French (1980) highlights is not due to the interday weekend return, but the intraday trading the first day after a holiday. The interday weekend return is positive as Cooper et al., (2008) state. In line with the previous t-tests, none of the average returns are significantly different from zero on a 5% level.

7.1.1 Holiday effect

The first analysis did not exclude holidays from the data set. As French (1980) discuss, we cannot be sure whether the negative returns on Mondays are because of the weekend-effect, or whether it is a "closed-market" effect. The "closed-market" effect raises the question whether the findings systematically happen every Monday, or something that reoccurs every time the market has been closed over a longer period of time. The "closed-market" effect is defined as the returns after a holiday, where the market has been closed over a longer time-period. If it is a case of a "closed-market" effect the average return, on a day following a holiday, would yield the same results as the weekend effect.

The following data is filtered in the way that only the returns for the specific day are shown if there has been a holiday in the days before. For instance, the Monday holiday return is only calculated if there has been a holiday on the Friday in the previous week. This means that the regular weekend effect is excluded from the calculations.

Holidays			
		Intraday	**Interday**
Monday	**Return**	-0.36%	-0.02%
	Std.dev	1.40%	0.04%
Tuesday	**Return**	0.91%	0.03%
	Std.dev	2.73%	0.06%
Wednesday	**Return**	1.34%	0.00%
	Std.dev	NA	NA
Thursday	**Return**	-0.57%	0.01%
	Std.dev	0.24%	0.05%
Friday	**Return**	0.45%	0.02%
	Std.dev	0.76%	0.02%

Table 36: Holidays OSEBX

Table 36 illustrates the average returns and volatilities for intraday and interday trading, the day after a holiday. Mondays and Thursdays yield, on average, a negative intraday return, while Tuesdays, Wednesdays and Fridays yield a positive return. This indicates that there is not a specific "closed-market" or holiday effect for the intraday trading at OSEBX. From the four-year period, there is only one observation where Wednesday is the first trading day following a holiday, which make us unable to calculate the volatility and t-statistic.

Further, we observe the interday returns during a holiday. Four out five days yield a positive interday return, where Monday has an average negative return. There are no large differences in the volatility for the different days. The close-to-close returns and t-values are presented in appendix VII. The close-to-close returns illustrate that there is no specific "closed-market" or holiday effect at OSEBX, since the different days indicate different returns when we combine the intraday and interday returns.

We should be aware of the low number of observations in this test. During the four-year period, there are only 22 observations where it is trading after a holiday. Therefore, there is chance that we encounter a type II error in our test. This means that we fail to reject a false null hypothesis, which in this case is, that the average returns equal zero.

7.1.2 Weekend effect

The last step in the analysis is to omit the holidays, to specifically look at individual trading days. By omitting the holidays, we are able to exclude the effect of holidays from the data set, and test both the weekend effect and whether there are differences in returns between the trading days during a week.

Weekend effect when holidays are omitted					
		Before adjusting		After adjusting	
		Intraday	Interday	Intraday	Interday
Monday	**Return**	-2.75%	0.05%	-2.75%	0.05%
	Std.dev	7.20%	0.18%	**12.94%**	**0.11%**
Tuesday	**Return**	2.35%	0.03%	2.35%	0.03%
	Std.dev	6.73%	0.24%	**12.08%**	**0.28%**
Wednesday	**Return**	5.25%	0.22%	5.25%	0.22%
	Std.dev	7.09%	0.26%	12.74%	0.32%
Thursday	**Return**	1.05%	0.15%	1.05%	0.15%
	Std.dev	7.47%	0.22%	**13.42%**	**0.27%**
Friday	**Return**	2.61%	0.07%	2.61%	0.07%
	Std.dev	6.92%	0.29%	**12.43%**	**0.35%**

Table 37: Weekend effect when holidays are omitted. OSBEX

In table 37, we present the intraday and interday returns for different weekdays after omitting holidays. The table also presents the volatility after adjusting for time, to test the calendar time hypothesis. The intraday variance is adjusted using 0.31 days, to reflect the actual time span of the variance. Further, we adjust the interday variance for both the weekend and overnight time span.

The interday variance after a weekend is adjusted using 2.69 days, while the other interday variances are adjusted using 0.69 days. This is then adjusted and presented as volatility.

The historical average intraday return on Mondays is negative, while the other days are positive. Compared to the first analysis, the Monday and Friday intraday return are lower, while the return on the other days' increase. We observe that Thursdays yield a lower risk-reward, compared to the other days that yield a positive return. This means that by investing intraday at OSEBX, the investor will take approximately the same risk as the other days, but still yield a lower return. Overall the t-statistics for the different days, except Thursday, are lower compared to the first test. The returns are not statistically significant different from zero when omitting the holidays. The t-values and close-to-close returns are presented in appendix VII.

After omitting the holidays, the interday return after a weekend increase. The average returns for the four remaining trading days are reduced. An interesting observation is that the weekend return yield a higher return at a lower risk, compared to Tuesday. The average Wednesday return is, despite the reduction, still significantly positive on a 5% level.

The overall findings, when excluding the holidays, are not statistically significant. However, we observe that the average intraday trading after a weekend yields a negative return, whereas the average interday return over a weekend is positive. This is consistent with the previous discussion regarding the difference between French's (1980) and Cooper et al., (2008) papers. Although the holidays are omitted, the findings are consistent.

When comparing the volatilities after adjustment, we observe that the intraday volatility is quite higher than the interday volatility. The interday volatility over the weekend is also lower compared to the other days. This is not consistent with the calendar time hypothesis as Fama (1965) states. The t-values and close-to-close returns for the calculations that are adjusted for time, are presented in appendix VII.

7.2 OMXS30 - Stockholm

In order to compare OSEBX with the other Scandinavian indices we conduct the same tests at S30.

		All	
		Intraday	**Interday**
Monday	**Return**	-1.82%	1.38%
	Std.dev	7.40%	3.92%
Tuesday	**Return**	0.48%	1.26%
	Std.dev	6.79%	2.34%
Wednesday	**Return**	-0.09%	0.76%
	Std.dev	6.56%	2.65%
Thursday	**Return**	-1.11%	2.38%
	Std.dev	6.63%	3.22%
Friday	**Return**	0.57%	3.55%
	Std.dev	6.12%	2.60%

Table 38: Days OMXS30

In table 38, we illustrate the average intraday and interday returns for all weekdays. Compared to OSEBX, S30 has a larger share of its total return coming from the interday trading. The intraday returns at S30 show a mixed pattern with three out of five days with a historical negative return. Mondays intraday return are negative, the same as at OSEBX, while Fridays yield the highest intraday return with the lowest risk and therefore offers the best risk-return reward for the investor. None of the findings regarding intraday returns are statistically significant different from zero on a 5% level. The t-values and the close-to-close returns are presented in appendix VII.

The interday returns yield higher returns compared to OSEBX, and have a positive average return during the period. In line with the findings at OSEBX, Friday close to Monday close yield a negative return. However, by splitting it into intraday and interday we observe that this is due to the negative intraday trading during Monday, while the interday return during the weekend is positive. The weekend return has the highest volatility compared to the weekdays. This is different from OSEBX, where the weekend return had the lowest volatility.

7.2.1 Holiday effect

Further, we compare the returns after a holiday at S30. We calculate and filter this data in the same way as with the data from OSEBX.

Holidays		Intraday	Interday
Monday	Return	-2.98%	0.44%
	Std.dev	4.33%	1.44%
Tuesday	Return	0.98%	0.65%
	Std.dev	0.74%	0.58%
Wednesday	Return	-0.77%	-1.56%
	Std.dev	NA	NA
Thursday	Return	-0.70%	-0.37%
	Std.dev	0.95%	0.39%
Friday	Return	-0.03%	0.20%
	Std.dev	0.69%	0.26%

Table 39: Holidays OMXS30

Table 39, presents the average returns and volatilities for intraday and interday trading, when it is the first day after a holiday. In the same way as at OSEBX, the tests suffer from having few observations and therefore we cannot calculate the volatility and t-stat for Wednesdays.

Tuesdays is the only intraday that yield a positive return, and also the only one that is significant at a 5% level. The t-values and close-to-close returns are presented in appendix VII. The interday return is positive for three out of five days. As both the intraday and interday returns indicate opposite explanations, there seems to be no specific “closed-market” or holiday effect at S30, which is consistent with the findings at OSEBX.

7.2.2 Weekend effect

In this section, we exclude the holidays from the calculations. By omitting the holidays, we are able to test both the weekend effect and whether there are differences in returns between the trading days during a week.

Weekend effect when holidays are omitted					
		Before adjusting		After adjusting	
		Intraday	Interday	Intraday	Interday
Monday	**Return**	1.17%	0.94%	1.17%	0.94%
	Std.dev	5.84%	3.67%	**9.87%**	**2.25%**
Tuesday	**Return**	-0.51%	0.61%	-0.51%	0.61%
	Std.dev	6.71%	2.23%	**11.35%**	**2.77%**
Wednesday	**Return**	0.11%	1.15%	0.11%	1.15%
	Std.dev	6.55%	2.53%	**11.07%**	**3.13%**
Thursday	**Return**	-0.58%	2.66%	-0.58%	2.66%
	Std.dev	6.57%	3.19%	**11.10%**	**3.95%**
Friday	**Return**	0.62%	3.16%	0.62%	3.16%
	Std.dev	6.05%	2.57%	**10.23%**	**3.19%**

Table 40: Weekend effect when holidays are omitted. OMXS30

In table 40, we omit holidays, and calculate the volatility before and after adjusting for time. After omitting the holidays, the intraday return on Mondays is now positive compared to the first analysis, where the holidays were included. In other words, the reason for the negative intraday returns was the negative intraday return after a holiday. When omitting holidays, the volatility on Mondays is also reduced. This indicates that the Mondays intraday return has the best risk-reward return, when comparing to the other weekdays.

After omitting holidays, the interday returns decrease for all days, besides Wednesdays and Thursdays which increase. This is a result of omitting the negative holiday returns on these specific days. The t-values and close-to-close returns are presented in appendix VII.

Compared to OSEBX, S30 does not confirm French's findings. When omitting the holidays, the weekend effect on the close-to-close returns are positive. We observe a positive interday weekend return which is consistent with Cooper et al., (2008) findings.

At last, we adjust the volatility in the same way as we did for OSEBX. The intraday volatility is adjusted by using 0.35 days, while the interday volatility is adjusted using 0.65 days. The interday weekend volatility is adjusted using 2.65 days.

After adjusting the volatility for time, all of the volatilities, beside weekend interday, are increased. Before adjusting, the interday volatility after weekends was larger compared to other days, which favor the calendar time hypothesis. However, after the adjustment the volatility is lower compared to the other days' volatilities, which is not consistent with the hypothesis. The intraday volatility is higher than the interday volatility, which is in line with the findings at OSEBX. Thus, we cannot state that there are any differences regarding the time adjusted volatility at S30 compared to OSEBX.

7.3 OMXC20CAP - Copenhagen

The third and last of the Scandinavian indices is C20CAP, which we conduct the tests on.

All			
		Intraday	**Interday**
Monday	**Return**	-0.05%	3.47%
	Std.dev	6.72%	4.67%
Tuesday	**Return**	-0.31%	4.05%
	Std.dev	6.74%	2.57%
Wednesday	**Return**	0.25%	5.18%
	Std.dev	6.46%	2.39%
Thursday	**Return**	-3.06%	5.44%
	Std.dev	6.14%	3.27%
Friday	**Return**	-2.43%	4.97%
	Std.dev	6.48%	3.06%

Table 41: Days OMXC20CAP

Table 41, presents the average intraday and interday returns and volatilities for each trading day. The close-to-close returns and t-values are presented in appendix VII. C20CAP has a positive Friday close to Monday close, which stand out compared to OSEBX and S30. The reason for this is the large interday return over the weekend. The intraday return on Mondays is negative but close to zero, and therefore it does not account for a large part in the close-to-close return. Besides Mondays, all of the interday returns are statistically significant different from zero on a 5% level.

The Wednesdays interday return yield the second highest return and the lowest volatility, making it an obvious choice for an investor to exploit. For the rest of the days during the week, we observe large differences in the intraday returns between the first three trading days compared to the last two trading days. The interday returns are in general larger at C20CAP compared to the other indices.

7.3.1 Holiday effect

We continue the analysis by filtering the data in order to investigate the holiday effect at C20CAP. The data is sorted in the same way as earlier.

Holidays			
		Intraday	Interday
Monday	Return	-1.21%	0.88%
	Std.dev	1.02%	0.91%
Tuesday	Return	0.90%	0.78%
	Std.dev	0.89%	0.79%
Wednesday	Return	NA	NA
	Std.dev	NA	NA
Thursday	Return	-0.63%	-0.08%
	Std.dev	1.21%	0.65%
Friday	Return	0.16%	0.87%
	Std.dev	0.34%	0.27%

Table 42: Holidays OMXC20CAP

From table 42, we observe that, at the day after a holiday, there are both positive and negative intraday returns. We do not have any data for Wednesdays, simply because Wednesday has never been the first trading day after a holiday in the data set. The interday return during a holiday is positive for three out of four days, which indicates that there may be a positive "closed-market" or holiday effect at C20CAP. This is also strengthened by the fact that the positive interday returns are significant at a 5% level, while the negative observation on Thursdays is not significant. We should be aware of the limitation to make any conclusions due to the low number of observations. The close-to-close returns and t-values are presented in appendix VII.

7.3.2 Weekend effect

The last step in the analysis is to omit the holidays to test the weekend effect and check for differences between the individual trading days.

Weekend effect when holidays are omitted					
		Before adjusting		After adjusting	
		Intraday	Interday	Intraday	Interday
Monday	**Return**	1.15%	2.58%	1.15%	2.58%
	Std.dev	6.62%	4.57%	**11.52%**	**2.80%**
Tuesday	**Return**	-1.22%	3.27%	-1.22%	3.27%
	Std.dev	6.66%	2.42%	**11.60%**	**2.96%**
Wednesday	**Return**	0.25%	5.18%	0.25%	5.18%
	Std.dev	6.46%	2.39%	**11.24%**	**2.92%**
Thursday	**Return**	-2.75%	5.48%	-2.75%	5.48%
	Std.dev	6.09%	3.25%	**10.61%**	**3.97%**
Friday	**Return**	-2.56%	4.31%	-2.56%	4.31%
	Std.dev	6.47%	2.97%	**11.26%**	**3.63%**

Table 43: Weekend effect when holidays are omitted. OMXC20CAP

In table 43, we omit holidays and calculate the volatility before and after adjusting for time. After omitting the holidays from the data set there are some interesting observations. As previously illustrated, it was a negative intraday return on Mondays after a holiday. When we omit this, the negative intraday return we had in the beginning of the analysis turns positive. This is the same for Thursdays, where there is an increase in the intraday return. In the same way, Tuesdays and Fridays average intraday returns decrease when omitting the positive intraday return after a holiday. The returns for Wednesdays are unchanged, since we do not have any observations following a holiday.

The interday returns change after omitting the holidays. The returns are reduced for Mondays, Tuesdays and Fridays, due to the positive interday returns on these days, while Thursdays return increase. The Wednesday interday return still yields the second highest return, but now at the second lowest volatility. It is, however, still statistically significant at a 5% level. The close-to-close returns and t-values are presented in appendix VII.

After omitting the holiday, we find contradicting evidence against French's (1980) research as the close-to-close return over a weekend is positive. The interday weekend return is positive, which is in line with the previous findings at the Scandinavian indices and the research by Cooper et al., (2008).

At last, we adjust the volatilities in the same way as earlier. The intraday volatilities are adjusted with 0.33 days, while the interday volatilities are adjusted using 0.67 days. The interday weekend volatility is adjusted using 2.67. As a result of these adjustments, the intraday volatilities are increased. The weekend interday volatility is decreased, while the interday volatilities for the rest of the days are increased.

The intraday volatility is higher than the interday volatility, which is in line with the findings at OSEBX and S30. This is not consistent with either the calendar time hypothesis or the trading time hypothesis. The interday volatility after weekends is lower compared to the other interday volatilities, which is not consistent with Fama's (1965) research. Therefore, we cannot state that are any differences regarding the time adjusted volatilities at C20CAP compared to OSEBX and S30.

7.4 Comparing the indices

On all three indices, there was a positive interday return after a weekend when we omit the holidays from the data set. This is consistent with Cooper et al., (2008) research, and therefore it seems like it exists a weekend effect on the indices. These findings are, however, not statistically significant at a 5% level, which limit the ability to draw conclusions.

When analyzing the Friday close to Monday close, there was negative returns at OSEBX. On both S30 and C20CAP, it was positive close-to-close return during a weekend, which contradicts French's (1980) findings. There are no evidences for a holiday effect on either of the indices, as whether the return is positive or negative depends on what day the first day after the holiday is.

Overall, there are no evidences for the calendar time or trading time hypothesis at either of the Scandinavian indices. By replicating Fama's (1965) and Clark's (1973) approach, we find no proportional relationship between time and volatility or volatility equal to zero during non-trading hours. Therefore, it seems to be unequal volatilities for different times during a day.

Throughout the analysis, we reveal that certain days yielded either negative or positive returns which are statistically significant on 5% level. These are market abnormalities, which indicate that investors may profit on this information. When investors have the possibility to systematically profit on such information, it indicates market inefficiency.

C20CAP stand out, since most of the findings regarding interday returns are statistically significant. We do not believe that the differences between the indices are directly related to whether the exchange is owned by Nasdaq or not, as we would expect to observe larger similarities between S30 and C20CAP.

However, a logical reason for the significant results at C20CAP, is due to the exceptional increase the index had during the four-year period and as a result of when these returns are generated. As illustrated in section 5.4.3 and figure 18, the interday returns are skewed towards right because of the positive development on the exchange. Thus, when returns are in general positive and large, the t-tests yield a larger t-value and we can with better certainty draw conclusions regarding the data set.

A reason for not observing the same at S30, may be that we observe lower average values for the interday returns. When the average value is closer to zero, the t-test will yield a lower t-value and we cannot draw any conclusions regarding the data set.

Using the same reasoning at OSEBX, we observe that the intraday returns are positively skewed as well. However, the difference compared to the interday returns at C20CAP, is that the variance for the intraday returns at OSEBX is much higher. Therefore, the t-test will yield a lower t-value and we cannot draw any conclusions regarding the data set.

It may seem that C20CAP is inefficient, since traders may be able to exploit the abnormalities in the market. However, we have not incorporated the effect of transaction costs. By systematically trading on the interday returns, it is possible to obtain positive returns. In chapter 10, we include brokerage fees, and investigate whether this hold in a real world setting.

OSEBX appears to be the most efficient index in Scandinavia, since it is not possible to obtain a profit by systematically following a specific trading strategy regarding intraday and interday returns. A reason for us drawing this conclusion, is a result of that most of the returns are generated during the intraday trading. As we observed and discussed, the volatility of the returns is higher during the intraday. Therefore, when most of the returns are generated during this high volatility period, the findings are not significant and the market may be efficient. After discovering different volatilities for each day, we continue with an analysis of how these findings might affect option pricing.

8 Pricing of options

8.1 Motivation

After splitting the intraday and interday returns into specific days, we observed that there exists various volatility between different days and hours during a day. For instance, the volatility during non-trading hours in a weekend is lower than the volatility during non-trading hours in a weekday. We use these findings to investigate how this will affect the option prices at Oslo Stock Exchange. In this section, we discuss the problem statement below.

- What are the implications of varying volatility during a day for pricing options?

The volatility is interesting for an investor, as it is both a benchmark for the risk in the investment, but it is also a key factor when pricing options. An option is a frequently traded financial instrument, which enables the investor to both profit and hedge his or her positions in the financial market. In theory, we commonly use constant volatility when calculating the price of an option. The constant volatility, also called the theoretical volatility, is the daily changes in the underlying over the past period, and is regularly annualized in order to ease the complexity of the calculations. The annualized theoretical volatility is then adjusted for the number of days until maturity of the option when calculating the price. Therefore, it does not account for volatility differences throughout the different days and time periods. This may lead to over- or underpriced options, since we assume a constant volatility when, in reality, it may be different.

Currently, at Oslo Stock Exchange, the available listed options have monthly, quarterly, semiannually or annually maturity. It is possible to trade weekly options at Stockholm Stock Exchange, which is the only stock exchange in Scandinavia that offer options with short maturity, where the main index is the underlying asset (Weekly Options, n.d.). However, it is increasing interest for options with short maturity and we believe that this will be traded at the stock exchanges in Oslo and Copenhagen in the future.

Although there are limited listed options at Oslo Stock Exchange, it is possible to trade options in the Over-the-Counter (OTC) market. The advantage of such options is that it is possible to tailor the option in order to meet any needs. This means, that if an investor wishes to hedge or position himself over a weekend, overnight during a weekday, etc. it is possible to obtain such a position even though that specific listed option does not exist. A prerequisite for this, is that the investor finds a counterparty that is willing to sell or buy the opposite. In order words, someone who bet against you. From monthly statistics provided by Oslo Stock Exchange, we observe an active OTC market. In February 2017, there was sold and bought 285,000 put and call options in this OTC market. The observed traded options had different maturities which proves the initial thought, that it is possible to trade options at different maturities even though they are not listed.

At Oslo Stock Exchange, there is no listed options where OSEBX is the underlying. However, it is possible to take a position in the OBX index, which is the index with the 25 most liquid companies. By considering different volatility for day to day, we compare this to the theoretical volatility. We create tailor-made options, and the important part is how this affect the option price. The findings illustrate how an investor could take a position in the OBX index, which is very similar to OSEBX as described in section 4.2.

In addition to different volatility, we vary the time to maturity to illustrate the development of the option price. In the end, we compare the findings with listed options traded at Oslo Stock Exchange. In order to compare the options, we calculate the implied volatility of the listed option and compare this with the constructed OTC option with the same strike price, underlying price and maturity. Although the underlying of these options is OBX, we use the variances from OSEBX since we have these calculations from earlier. The variances between these indices do not differ in a reasonable amount.

8.2 Practical implications

An important aspect in this chapter, is to define how the volatilities are calculated. There are two ways, the first include the different volatilities we calculated earlier, called the observed historical volatility. The second method assumes constant volatility for each day, and this is the method that follows the calendar time hypothesis, where it assumes a proportional relationship between variance and time. This is called theoretical volatility throughout the thesis.

The volatility that considers various observed volatility for each day, is calculated by summarize the variance for each day/period for the whole time-span for each option.

$$\sigma_T^2 = \sum_{t=1}^{T} \sigma_t^2$$

T is the time to maturity and t is all days and weekends that is included. If the time-span for an option is Monday to Monday, the volatility for Mondays is included twice. The estimated variance is then squared such that we can use the formula below, to annualize the volatility.

$$\sigma_{T,annualized} = \sigma_T \sqrt{\frac{365}{Calendar\ days_T}}$$

Where $Calendar\ days_T$ refers to the number of days until maturity. The fraction is an annualizing factor which is the number of intervals per year. For instance, Friday close to Monday open represents 2.69 days, which is the denominator in this fraction. We have included 365 days, and not the number of average trading days per annum, since the variance for these options are based on the whole week and not only the variance in the trading hours.

The volatility that ignores different day-to-day variances is estimated by calculating the total variance for a whole week by the formula below.

$$\sigma_{week}^2 = \sum_{t=1}^{T} \sigma_t^2$$

Where t refers to all trading days included nights and weekends. Thereafter, we calculate the volatility that ignores differences for each day before we change this to standard deviation and annualize this. The two formulas we use are illustrated below.

$$\sigma_T^{2*} = \sigma_{week}^2 * \frac{Calendar\ days_T}{7}$$

$$\sigma_{T,annualized}^* = \sigma_T^* \sqrt{\frac{365}{Calendar\ days_T}}$$

The first formula is dividing the total variance, for the whole week, into the respective trading days. Before annualizing the variance, we take the square root of this, to get standard deviation. The second formula is annualizing the volatility by using the same squared root fraction as earlier.

8.3 Findings

Estimated volatility						
	Hours	**Days**	**Variance**	**Variance***	**Std.dev yearly**	**Std.dev yearly***
Friday-Monday (close-open)	64.58	2.69	0.000%	0.020%	0.31%	16.47%
Monday (open-close)	7.42	0.31	0.011%	0.002%	35.48%	16.47%
Mondag-Tuesday (close-open)	16.58	0.69	0.000%	0.005%	0.78%	16.47%
Tuesday (open-close)	7.42	0.31	0.010%	0.002%	34.66%	16.47%
Tuesday-Wednesday (close-open)	16.58	0.69	0.000%	0.005%	0.85%	16.47%
Wednesday (open-close)	7.42	0.31	0.010%	0.002%	34.34%	16.47%
Wednesday-Thursday (close-open)	16.58	0.69	0.000%	0.005%	0.74%	16.47%
Thursday (open-close)	7.42	0.31	0.011%	0.002%	36.83%	16.47%
Thursday-Friday (close-open)	16.58	0.69	0.000%	0.005%	0.94%	16.47%
Friday (open-close)	7.42	0.31	0.010%	0.002%	33.84%	16.47%
Total	**168**	**7**	**0.052%**	**0.052%**	**16.47%**	**16.47%**

Table 44: Estimated Volatility

Table 44 presents the historical volatility. The volatility is separated between the calendar time hypothesis, which is denoted as variance* and standard deviation yearly*, and the observed historical volatility in the market, which are denoted as variance and standard deviation yearly. The estimated volatilities based on the calendar time hypothesis, which we call theoretical volatility, do not include different volatilities for each day, but these are calculated based on the number of trading days for the whole period. The annualized standard deviation will be the same for each period, since this is based on the same variance but distributed differently to each trading period.

The theoretical volatility is overestimating the standard deviation for the weekend (Friday close – Monday open) and overnight, while it underestimates the intraday variance, compared to what we observed in the market. The observed historical volatility, that includes various variance from time to time, have large variation in the variance. We observe that the annualized standard deviation goes from a minimum of 0.31% to the maximum of 36.83%. The theoretical standard deviation is 16.47% in the weekend, while the observed standard deviation for the weekend was only 0.31%.

If an option has time to maturity over the weekend, the option will be overpriced if it is assumed that the volatility over the weekend is the same as the volatility for trading days. To repeat ourselves, a higher expected volatility increases the option price.

In appendix VII, we divide different options into two groups depending on maturity. In group 1, we calculate option prices on Friday close, where the options expire on Monday opening, for different time to maturities. The calculations reveal large price differences between options calculated using the theoretical volatility or the observed historical volatility. By using the theoretical volatility, the price for put and call options are overestimated compared to the prices calculated using the observed historical volatility. This is a result of the weekend effect, where the observed historical volatility is much lower than what the calendar time hypothesis predicts. The results illustrate that the largest differences are for the options with the shortest time to maturity. Once we increase the time to maturity, the volatilities converge and the price differences decrease. The reason for this is due to the low volatility during weekends is evened out by the higher volatility during the week. Therefore, by increasing time to maturity the volatility converges towards the calendar time volatility.

In group 2, we calculate option prices on Monday open, where the options expire on Friday close, for different time to maturities. The calculations reveal that the options calculated using the theoretical volatility are underestimated, since the observed historical volatility during the week is higher. In the same way as in group 1, the price differences decrease due to converging volatilities when increasing the time to maturity. The reason for this, is because of the high volatility during the weeks is evened out by the low volatility in the weekends.

This indicates that the volatility-factor in option pricing is a possible risk. Most investors are risk-averse, and the findings from this option analysis indicate that an investor has to consider the implied volatility of the option prices in the market. An investor might discover that the option is either under- or overpriced. Thus, this highlights the importance of breaking down the option prices to discover which volatilities that are used to determine the prices in the option market.

So far in this chapter, we have used tailor-made options to describe how different volatility throughout the week is affecting the option prices. In the following section we use an option that is traded at Oslo Stock Exchange to make it more relevant for business practitioners, and discuss if the market considers the observed lower volatility during weekends.

8.4 The impact of varying volatility on option pricing in the Easter period

In this section, we compare the findings with a listed option at Oslo Stock Exchange. The option is an index option where OBX is the underlying. The option had maturity right after the Easter holiday. Thus, after a long period of non-trading at the exchange. By using this option and the specified time period, we illustrate the effect of lower observed volatility during the closed-market period.

It is important to bear in mind the findings from earlier, that the observed historical volatility is lower during non-trading hours than during trading hours. Thus, if we use the observed historical volatility to calculate the option prices, these prices are lower compared to the prices based on the theoretical volatility. Lastly, these calculated prices are compared to the observed bid-ask prices, to determine whether there is any evidence of potential mispricing in the market.

This section is based on the Easter break, since this holiday stretches over 5 days with a closed market. After this holiday, there are 8.41 days until the OBX options mature, which was the 20th of April. We use the closing price of the underlying at 12th of April, which was the Wednesday before Oslo Stock Exchange closed because of Easter holiday. The price of the underlying was 626.32. To compare the theoretical prices to the observed, we use the following strike prices; 620, 630 and 640. The volatility is calculated as we describe in section 8.3.

In the tables below, we compare the calculated Black-Scholes-Merton (BSM) prices to the observed bid and ask prices. The bid price is the price we are able to sell an option for, while the ask price is the price we have to pay to buy the option. This bid-ask spread is the difference between the highest price that a buyer is willing to pay for the option and the lowest price that a seller is willing to accept in order to sell it (Brealey et al., 2011).

Listed options do often have a large spread between bid and ask. This spread might be caused by a low liquidity. Less liquidity in the market leads to a higher spread, as it is harder to find a match between investors that want to buy and investors that want to sell the option. The real value of an option is often in the middle between the bid and the ask price, since neither part will buy, or sell, for more or less than necessary. Thus, we use the average of the bid-ask spread as the fair market price when we calculate the implied volatility (Brealey et al., 2011).

Revealing differences between the market prices and the calculated prices for different options do not lead to an arbitrage opportunity for the investors. Even though we find that options might be mispriced in the market, we are not able to profit on this directly. In order to obtain an arbitrage opportunity, we must have the possibility to buy or sell an option and instantly trade to a more favorable price, which we do not have. When pricing an option, the time until expiration and volatility determines the probability of a profitable move, and we know that if the underlying is highly volatile, we reasonably expect a greater degree of price movement before expiration.

Call prices		**Wednesday close 12.04.17 to Thursday close 20.04.17**							
Time to maturity				8.14					
Observed volatility				11.92%					
Theoretical volatility*				16.47%					
		Our Prices	**Strike**	**Observed prices**		**Profit?**	**Average**	**Difference**
Delta ca. -	Call	2.95	630	Bid	2.70	No	3.08	**-0.25**
50% ATM	Call*	4.60		Ask	3.45	No		**0.50**
Delta ca. -	Call	0.64	640	Bid	0.45	No	0.73	**-0.19**
25% OTM	Call*	1.67		Ask	1.00	No		**0.36**
Delta ca. -	Call	8.46	620	Bid	7.90	No	8.33	**-0.56**
75% ITM	Call*	9.95		Ask	8.75	No		**0.29**

Table 45: Results Call options

The call prices in the market are not in line with the calculated call prices. Call* is based on the theoretical volatility, whereas Call is based on the observed historical volatility. This potential mispricing may be due to the expected volatility, also called implied volatility, that the market prices into the options. In general, a lower option price implies that the market expects a lower volatility and vice versa. The reason for this is that it is less likely for the option to be profitable when there is a lower volatility. Thus, investors are less willing to buy the option, which in turn lead to a lower price.

From the call prices highlighted in table 45, the calculated option prices for the ATM and OTM options are less than the average bid-ask prices. The calculated price for the ITM option is, however, higher than the average bid-ask price. Therefore, it seems that the market expects a higher volatility in the underlying for the ATM and OTM option, compared to what the observed historical volatility model does. The market expects, in contrast, a lower volatility for the ITM option. However, due to the bid-ask spread we are not able to either buy or sell these options to benefit directly from this potential mispricing. If we wanted to sell these different call options, we would receive 0.25, 0.19 and 0.56 NOK less than the prices calculated in our model. If we wanted to buy these call options, we would pay an extra 0.50, 0.36 and 0.29 NOK compared to the prices calculated in our model. If we compare the prices in the market with the calculated prices using the theoretical volatility, we observe that the market expects a lower volatility than the theoretical model.

Put prices		Wednesday close 12.04.17 to Thursday close 20.04.17						
Time to maturity			8.14					
Observed volatility			11.92%					
Theoretical volatility*			16.47%					
		Our Prices	**Strike**	**Observed prices**		**Profit?**	**Average**	**Difference**
Delta ca. - 50% ATM	Put	6.39	630	Bid	7.30	Yes	7.78	**0.91**
	Put*	8.03		Ask	8.25	No		**1.86**
Delta ca. - 25% OTM	Put	1.90	620	Bid	3.00	Yes	3.33	**1.10**
	Put*	3.39		Ask	3.65	No		**1.75**
Delta ca. - 75% ITM	Put	14.08	640	Bid	14.75	Yes	15.50	**0.67**
	Put*	15.11		Ask	16.25	No		**2.17**

Table 46: Results Put options

In table 46, we compare the put prices with the calculated prices. In the same way as with the call prices, it seems that the market expects a higher volatility in the underlying of the option, compared to the observed historical volatility. By comparing the calculated prices with the bid and ask prices, it is not beneficial to buy these put options. We would pay 1.86, 1.75 and 2.17 NOK extra compared to what we calculated in the model. However, it is possible to sell the put options, and we are able to trade on this potential mispricing. We are able to sell the put options at the bid price, and receive 0.91, 1.10 and 0.67 NOK more than what the model estimates.

As previously mentioned, this difference between the market price and the calculated price is not an arbitrage opportunity since we are not able to buy at a lower price than the sell price. We are, however, able to sell options where the market expects that the probability of the option being profitable is higher than what our model predicts. Higher volatility results in a higher option price as it is more likely to move in a favorable direction for the buyer. The investors believe that the underlying will vary to a greater degree, compared to the observed volatility. They believe, in other words, that the option is more likely to be profitable, compared to what we expect. Therefore, they are willing to pay a higher price. Thus, we are able to sell an option to a price where the probability of the option being executed is lower than what the market price reflects.

If we compare the market prices with the prices calculated using the theoretical volatility, the market expects a lower volatility for the ATM and OTM options, while expecting a higher volatility for the ITM option.

The implication of these findings is that an investor may be able to sell more put options according to his or her own risk preferences. If the put option is executed, then the investor that sells the put, is obligated to buy the underlying to the strike price. Since the observed volatility is lower than the market estimates, it is less likely that the option will be executed. Therefore, a lower probability of a favorable move for the buyer of the option means that the investor could be willing to sell a higher amount of put options as the seller receives a premium for each option, and it is less likely that he or she is obligated to buy the underlying at the strike price.

As discussed above, the put prices seem to be overpriced compared to the calculations. The reason is that the market incorporates a higher volatility. The implied volatility from the call prices indicates that the market incorporates the lower volatility due to a holiday. This might be a sign of market efficiency. However, the put prices indicate the opposite. In theory, the implied volatility for call and put options should be the same (Brealey et al., 2011).

There are two possible explanations for why the implied volatility differs between the call and put prices. Either the model is not right or the data are not right. We know that the observed prices are correct, whereas the model is the most accurate we can use. The model is, however, a theoretical framework, and we know that theoretical models do not always fit the real word. If there are for instance, restrictions or limitations of short sales of the underlying, dividends or other cost of carrying involved, or lastly, not unlimited liquidity, then this might be some explanations of why the implied volatility differs.

There are no limitations to short the OBX index, since this index is very liquid, and there are no dividends or cost of carrying connected to this underlying asset. Thus, the most likely explanation for the difference in implied volatility, is the lack of liquidity in the put options. At the time we retrieved the data, there was considerable higher volume in the call options than in the put options. This observation strengthens the thought about lack of liquidity in the put options. Low liquidity indicates higher risk since buyers and sellers are not able to find each other in a timely manner. If this occurs, either the buyer or the seller, have to increase or decrease the price in order to close the trade. As a result of this, investors generally demand a higher return for increased liquidity risk, called liquidity premium.

There are two possible reasons for the mispricing in the observed put options. The first reason might be that the market has not incorporated the historical observed lower volatility in the put options. This gives the investor a possibility to benefit from the mispricing, as the market overestimates the probability for the option to be profitable. This might be evidence for an inefficient option market. The second reason is the lack of liquidity in the put options market. The market price of the put options is higher due to the risk of not finding a buyer or a seller, in a timely manner.

In addition, we investigate whether the pattern, higher implied volatility in put options than call options, are transferable to a larger data set. We observe a number of options with approximately 1, 2, 3 and 5 months to maturity. These observations are collected at different times of the day for different days, within the months, April and May.

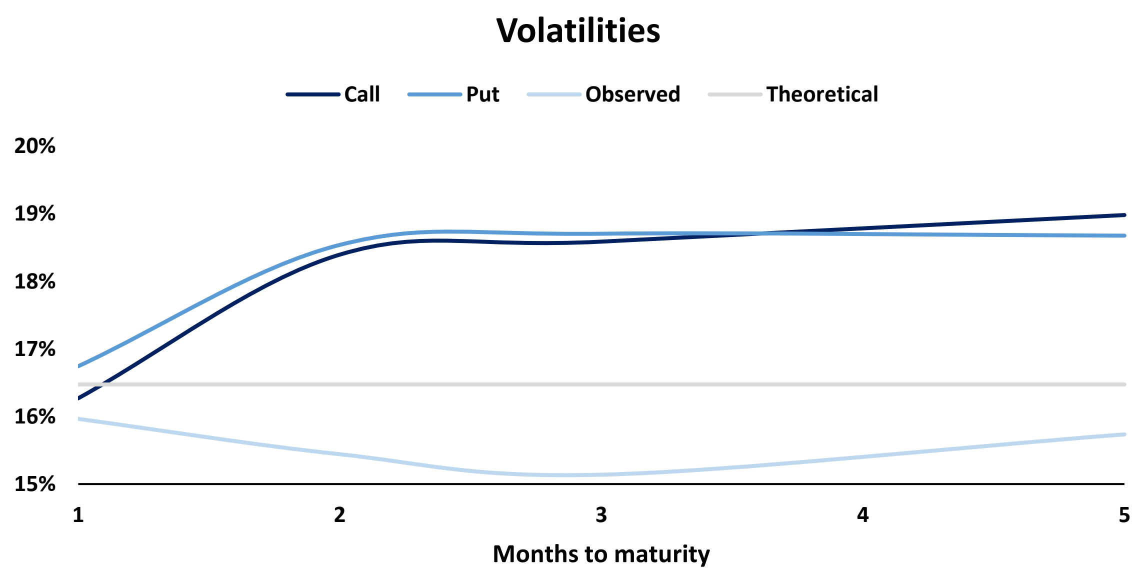


Figure 25: Different volatilities

Figure 25 illustrates how the average implied volatilities differs with different maturities. The numbers to this figure are presented in appendix VIII. In contrast to the Easter options, the implied volatilities for the put and call options are relative identical. However, there are large differences between the implied volatilities compared to the observed historical volatilities and the theoretical volatilities. These large differences indicate that it is possible to observe mispriced options, since the market expects a higher volatility than the historical observed volatility. These findings strengthen the result regarding the potential mispricing of the Easter option, but we should be aware that the market may add a liquidity premium resulting in a higher implied volatility.

The implication of varying volatilities during a day is that options might be mispriced in the market. This results in a possibility for an investor to exploit, as he or she is able to trade options where the market overestimates the probability of the options to be profitable. In addition, we observed a historical lower volatility compared to the theoretical volatility and the implied volatilities. In other words, the market does not incorporate a varying volatility throughout the day.

9 Trading

Throughout the thesis, we highlighted that the stock indices in Scandinavia differs regarding when the returns are generated throughout a day. To illustrate how these differences might be used by an investor, we construct two different trading strategies. We should be aware that it exists institutional traders which use High-Frequency-Trading (HFT) to discover and exploit mispricing in the market. The introduction of HFT in the market has led to increased liquidity as such systems may generate a large number of trades during a millisecond throughout the trading day (High Frequency Trading Explained Simply, 2014). What differ between such systems and regular investors, is that they are able to react instantly and that they usually do not pay any brokerage fee for each trade. Companies and funds that use HFT systems have in general a lower brokerage fee due to the high number of transactions. They have often a direct agreement with the stock exchange, and do not have to deal with a brokerage firm We do not discuss the implication of the findings for such systems, since we do not have the necessary information for discussing this widely. We present the strategies below and discuss the findings in light of market efficiency and the implications for an investor.

9.1 Strategy 1

The returns at OSEBX are mainly driven by the intraday trading, while the returns at C20CAP are generated during the interday. To exploit these differences, we construct a trading strategy where you simply invest in OSEBX intraday and C20CAP interday on the most profitable days during the week. In other words, you invest in OSEBX at the beginning of the trading day on each Tuesday, Wednesday, Thursday and Friday, and sell at the close of these trading days. The proceedings are then invested at C20CAP the same day and held overnight, and this is sold once the exchange opens the day after. We call this strategy, "Strategy 1".

When investigating the strategy, we make some assumptions. First, we are not including different exchange rates between each country. Thus, the invested capital included the gain, or loss, from Oslo throughout the intraday, is placed with the same amount in Copenhagen. Second, this strategy does not include the weekend and Monday intraday return. Therefore, an investor could invest the capital, at Friday close, in the bank to a risk-free rate and hold it until Monday close. These days with additional interest are not included. However, with the historical low risk-free rates in these countries, this would probably not change the result of these strategies with any significant amount. In both strategies the initial investment is 1,000,000 NOK.

Figure 26: Strategy 1 without brokerage fee vs OMXC20CAP & OSEBX

Figure 26 illustrates the development if the brokerage fee is not included. The differences in the return between the trading strategy and by simply investing in either of the indices are illustrated in the figure. Without the brokerage fee, the historical total return was 122.47% throughout the four-year period, resulting in an average yearly return of 22.13% by following the strategy. This illustrates that the trading strategy would have outperformed both indices. Next, we discuss and illustrate how the results differs if we include brokerage fee.

The strategy leads to a large amount of trades during a month. Due to the high number of trades, an investor is able to obtain the best brokerage fee at Nordnet as discussed in section 4.4.

Figure 27: Strategy 1 with brokerage fee vs OMXC20CAP & OSEBX

The value of the portfolios from investing 1,000,000 NOK in either strategy 1, C20CAP or OSEBX are illustrated in figure 27. By following strategy 1 and pay the brokerage fee of 0.035%, there was a historical total return of 24.11% over a four-year period which results in an average yearly return of 5.55%. In comparison, if we invested 1,000,000 NOK at C20CAP or OSEBX, and paid the brokerage fee, both when buying and selling, it was a historical total return of 64.21% at C20CAP resulting in a yearly return of 13.20%, and a total return of 35.49% at OSEBX resulting in a yearly return of 7.89%. These findings illustrate that although a trading strategy is profitable when only considering the returns, it is not outperforming the indices when the brokerage fees are incorporated.

Figure 27 clarifies the effect of brokerage fee on the trading strategy. Once we implement a strategy which demands several trades during a day, the fee "eat" a lot of the potential profit. We should, however, be aware that institutional traders may pay a lower brokerage fee than a normal investor. If the brokerage fee is below 0.002%, this trading strategy would yield the same return as the C20CAP. This could be relevant for investors that use HFT-systems, but we do not know whether this is above or below the normal fee for such an investor. It is difficult for us to know how much the institutional traders pay in brokerage fee since they trade directly at the stock exchanges.

In strategy 1 we combine the significant interday returns at C20CAP, with the insignificant intraday returns at OSEBX. By combining these observations, we cannot say anything about whether this trading strategy is statistically significant. However, we use these findings in order to discuss evidence of market efficiency.

In the first case, strategy 1 outperforms the market on a four-year perspective. However, in this case the brokerage fees are not included. Due to the high frequency of trading, this strategy did not outperform the market when including the brokerage fees. As a result of the findings, the first thought was that since this strategy outperformed the market, there was evidence of market inefficiency. In contrast to the potential evidence of market inefficiency, we get opposite results when including brokerage fees.

Even though it first seems like that investors may systematically benefit from strictly trading during specific trading hours, this is not the case in the real world. Therefore, these findings support the financial theory of market efficiency in the Scandinavian stock indices.

9.2 Strategy 2

In addition to the previous strategy, we examine another trading strategy. In this strategy we use the significant interday returns at C20CAP. Thus, invest in the index on Tuesday, Wednesday, Thursday and Friday when the exchange closes, and sell in the morning when the exchange opens for each respective day. In this case, the number of trades is halved which reduce the brokerage fee. This is called, “Strategy 2”. The second assumption in strategy 1, is also relevant for this strategy.

Without brokerage fee, the historical total return for this strategy was 77.88% throughout the four years, resulting in a yearly return of 15.49%. This is illustrated in appendix IX. The strategy yielded a higher return than simply investing in C20CAP and holding it for four years, as this yielded a total return of 65.40% and a yearly return of 13.41%. These returns differ from the average returns we calculated in chapter 5, since these returns include the specific gain or loss through each day.

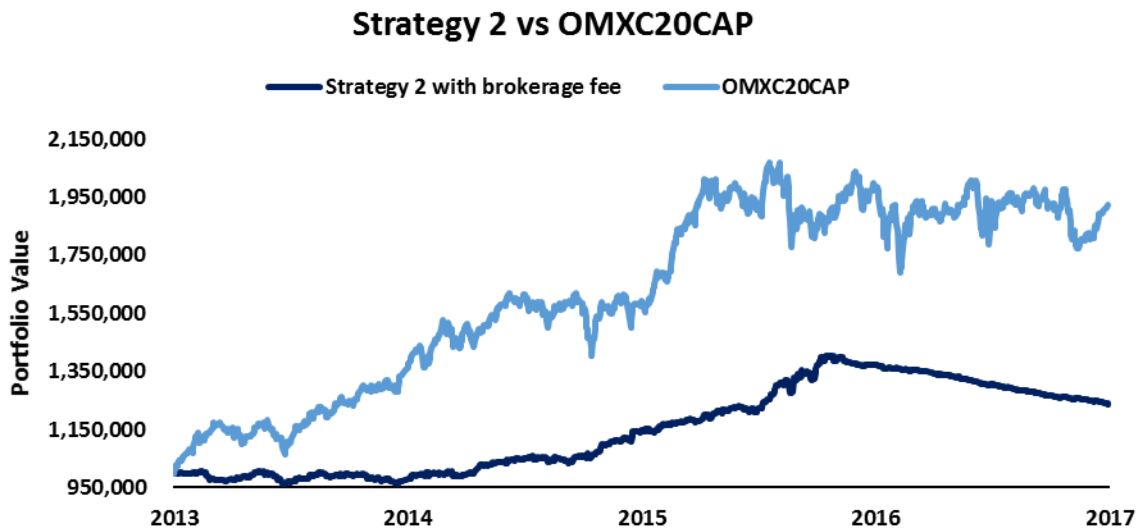


Figure 28: Strategy 2 vs OMXC20CAP

The value of the portfolios including brokerage fees are illustrated in figure 28. When accounting for the brokerage fee of 0.035%, the strategy yields a total return of 21.38% and a yearly return of 4.96%. Investing only in the index yields a total return of 65.33% and a yearly return of 13.39%. Thus, as illustrated in the figure, the index clearly outperform strategy 2 due to the brokerage fees. What in the beginning seemed like a highly profitable strategy, is simply not possible in the real world as it involves a high frequency of trading which results in high costs.

This strategy seemed to support that C20CAP was inefficient, and that investors could systematically obtain positive returns based on public available information, but in a real world context this was not the case. By including the brokerage fee, we observe that even though the interday returns are significant and positive, it is not possible to exploit using the proposed strategy.

9.3 Discussion

In this chapter, we examined two strategies we thought would outperform the market, in order to discuss market efficiency in the three indices. By including two different strategies, we illustrated how the frequency of trading and the brokerage fees affect the value of a portfolio. At first, it was evidence of inefficiency due to high returns and portfolios that outperformed the indices using the findings. However, by incorporating brokerage fees, this was not possible in a real world setting. Although the brokerage fee appears to be very low, this was clearly enough to make the strategies unprofitable, when comparing to investing in one of the indices.

It was not possible to obtain a profit using a systematic approach to the trading when the brokerage fees were incorporated. This is consistent with the theory presented by Fama (1970), where the stock returns follow a random walk. Fama (1970) states that all private and public information is incorporated in the stock price, but we have no basis to claim that all investors are aware of these significant differences in the markets. The findings, when incorporating brokerage fees, might support the theory about the financial markets being efficient and, therefore, an investor is not able to earn abnormal profits using a systematic approach.

10 Conclusion

The main purpose of the thesis is to elaborate whether it exist differences in intraday and interday returns between the three main Scandinavian stock indices. This is discussed in light of the efficient market theory and the implications in terms of structural differences. We investigated the indices OSEBX, S30 and C20CAP at the respective stock exchanges, Oslo, Stockholm and Copenhagen.

The main findings from the analysis are the large differences between the indices at Oslo Stock Exchange and the two Nasdaq-owned exchanges; Stockholm and Copenhagen. Most of the return at OSEBX is generated during the trading hours, with a minimal movement and variation during the non-trading hours. Unlike Oslo, the main indices in Stockholm and Copenhagen generate most of the return during the non-trading hours.

The differences in the duty of disclosure might be a plausible explanation for the findings, since the interpretation of the rules at Oslo Stock Exchange give the firms the option to delay stock exchange announcements to the trading opening hours. This might in turn lead to low activity during non-trading hours and, therefore, generate small variations between the closing price and the opening price the following day.

The differences may also be explained by the composition of the three indices. OSEBX consist of 62 firms, where the top 5 companies make up for roughly 60% of the total market capitalization. By decomposing the index, and comparing different segments and portfolios with the equivalents on the two other indices, the intraday and interday returns are behaving in the same way. OSEBX is heavily exposed to the oil and salmon price. These segments offer some explanations for the differing results, since they are consistent with the original findings at the index. The oil-exposed firms yielded a higher intraday return and a lower interday return compared to the index. The firms exposed to salmon prices yielded both a high and positive intraday and interday return.

Another plausible explanation might be the importance of the first trade of the day. If the first trade is in one of the smallest companies at OSEBX, it will hardly affect the opening price, due to the low weighting at the index. S30 and C20CAP are, however, not dominated by a few large companies, and the weighting of each company is more evenly distributed. Therefore, a move in either of the firms will have a larger affection on the price at S30 and C20CAP.

In addition to comparing the average returns, we investigated whether there is evidence of seasonality at the three indices. The indices at the Nasdaq-owned exchanges have an equal pattern regarding which months that are performing best and worst. Compared to these indices, OSEBX yielded different results. We investigated the January effect, but this month did not outperform the other months on neither index. This might indicate that the indices are efficient. In addition, we examined the trading strategy, “Sell in May, go away”. This strategy outperformed the market on all indices, after adjusting for brokerage fees. Hence, there is evidence that the Scandinavian indices might not be efficient.

On all three indices there is a positive interday return after a weekend when omitting the holidays, which is consistent with previous research. These findings are, however, not statistically significant. Further, we did not find evidence for the calendar time or trading time hypothesis. In other words, there exist varying volatility between trading hours and the different days throughout a week. Additional, some weekdays provide positive returns and these are statistically significant. This means that it exists market abnormalities, when we do not consider the brokerage fees. By only considering these results, OSEBX appears to be the most efficient index in Scandinavia. However, the reason for not finding significant results at OSBEX, might not be due to efficiency. Other factors such as structural differences, composition of the index, and the low number of observations might affect the findings.

As a result of the findings in previous sections, where we found that the volatility differs within a day, we used options to illustrate the implications of this. There are large differences between the observed historical volatility and the theoretical volatility. Due to the large differences, we highlighted whether the options were over- or underpriced compared to the observed historical volatility. In the end of this chapter, we used a listed option at Oslo Stock Exchange to find whether the market incorporate the observed historical volatility or the theoretical volatility. OBX put options were overpriced compared to the model, which gives an investor the opportunity to sell puts at a higher price than the fair value estimated by the model. By comparing the model to several options in the market, we found that the market incorporate a higher implied volatility compared to the model. This strengthen the initial thought; that the market does not consider varying volatilities throughout the day.

After finding significant and insignificant results throughout the analysis, we constructed two different trading strategies. Both strategies yielded a return which beat the market throughout the four-year period. However, when we implemented a brokerage fee, the strategies were beat by the market. This is simply because the strategies demanded a high frequency of trading, and therefore the brokerage fee reduced the profit. The results of the strategies argued that there might be evidence of market inefficiency at the indices. However, by implementing brokerage fee, the markets appeared to be efficient as it is not possible to exploit the difference between the trading days in order to obtain a profit.

Throughout the thesis, we found significant differences between the three main Scandinavian indices. These findings might be due to the different composition at the indices, where different segments and industries yielded different intraday and interday returns, which may explain the overall returns at the indices. Further, there are significant differences between weekends and individual days at the three indices. These findings indicated that the markets might be inefficient, but once these were applied in a real-world setting our presumptions were rejected. As a result, the findings indicate the indices are efficient, even though there are large differences between the distribution of returns at the indices.

Figure List

Table List

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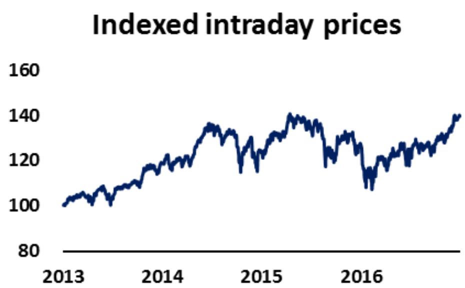
Data Sources

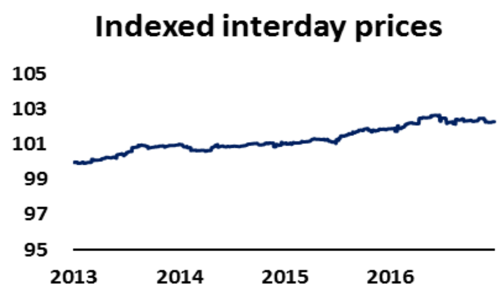
Bloomberg Terminal

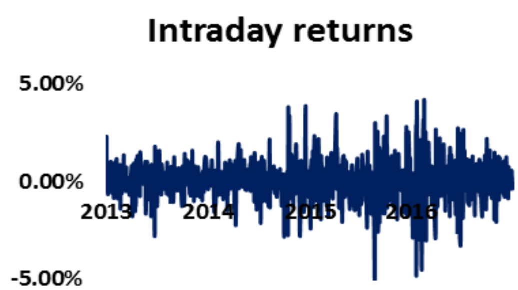
Oslo Børs

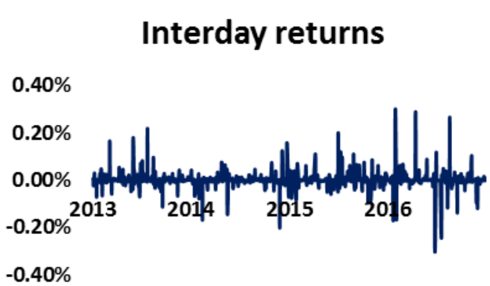
Appendix

I. Stationarity OSEBX

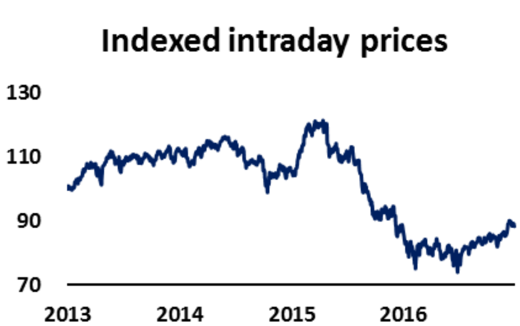


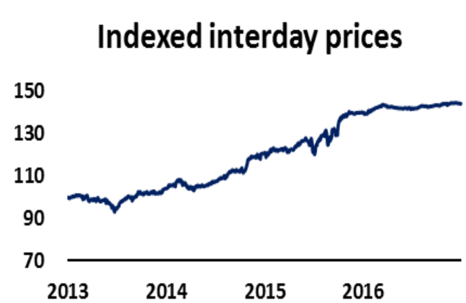


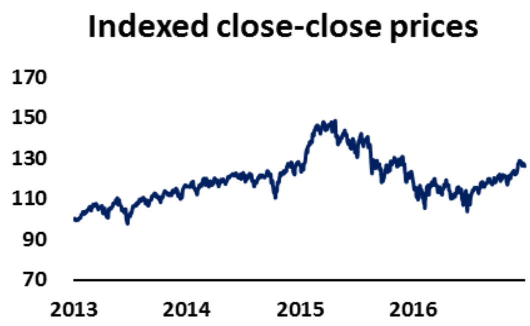


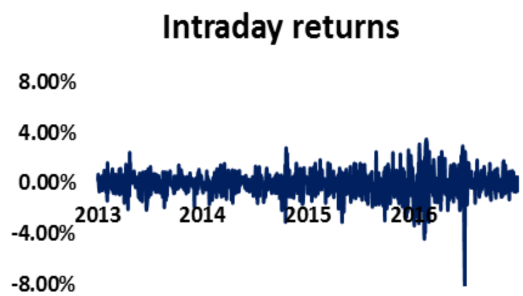


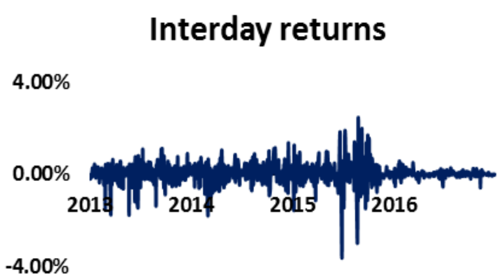
II. Stationarity OMXS30

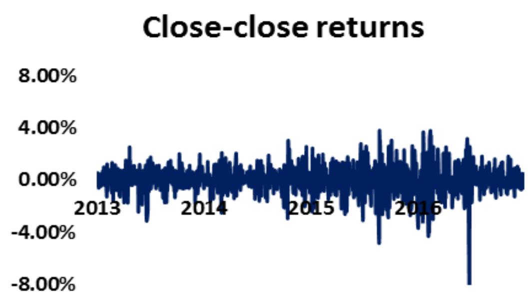




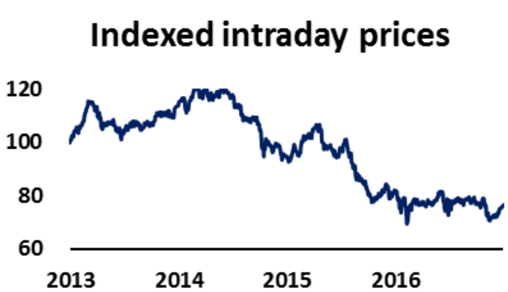


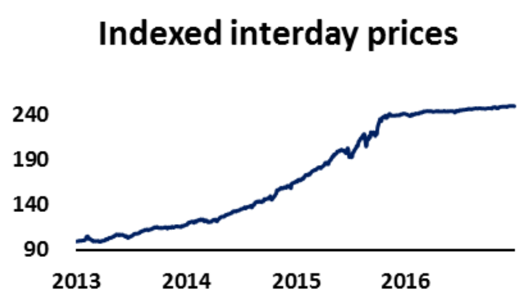


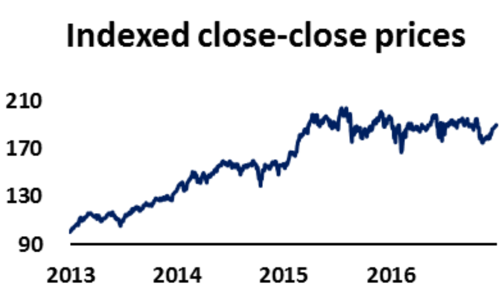


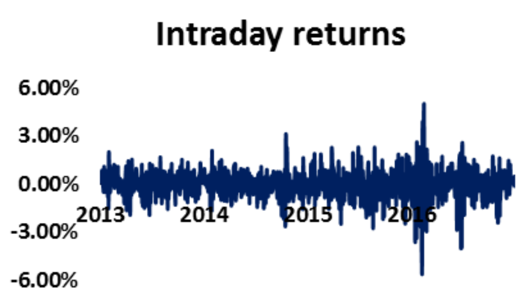


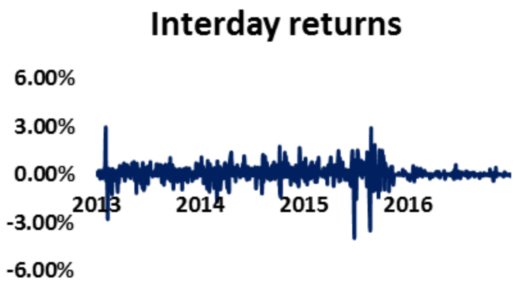
III. Stationarity OMXC20CAP

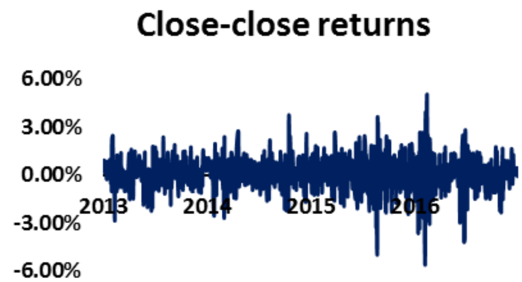




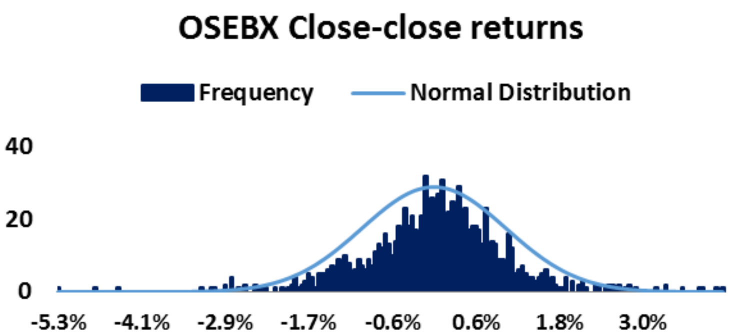


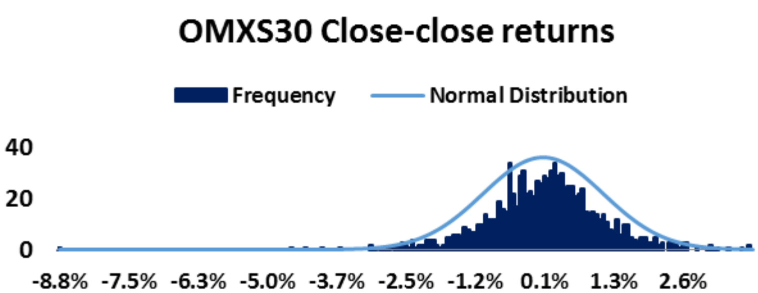


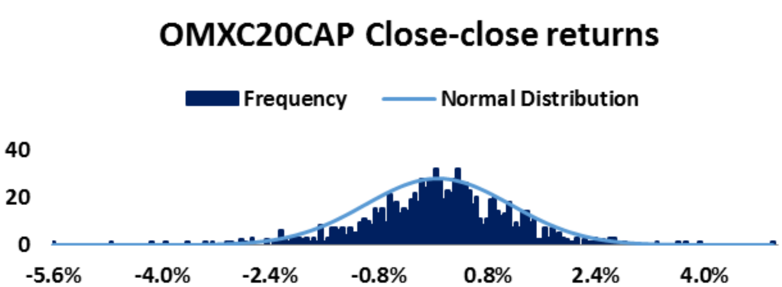




IV. Robustness







V. Decomposing the indices

Composition of OSEBX Big 5			
	Intraday	Interday	Close-close
Statoil ASA (44%)			
Average	-0.53%	3.28%	2.75%
Std.dev	22.12%	16.37%	27.65%
DNB ASA (20%)			
Average	-2.55%	17.01%	14.46%
Std.dev	21.75%	13.57%	26.11%
Telenor ASA (19%)			
Average	-6.86%	10.10%	3.24%
Std.dev	18.49%	13.16%	22.36%
Norsk Hydro ASA (9%)			
Average	-13.42%	22.33%	8.91%
Std.dev	23.86%	15.21%	27.48%
Yara International ASA (8%)			
Average	-12.47%	17.61%	5.14%
Std.dev	20.75%	14.16%	25.01%

Composition of OSEBX Big 5 - oil excluded			
	Intraday	Interday	Close-close
DNB ASA (32%)			
Average	-2.55%	17.01%	14.46%
Std.dev	21.75%	13.57%	26.11%
Telenor ASA (29%)			
Average	-6.86%	10.10%	3.24%
Std.dev	18.49%	13.16%	22.36%
Norsk Hydro ASA (15%)			
Average	-13.42%	22.33%	8.91%
Std.dev	23.86%	15.21%	27.48%
Yara International ASA (13%)			
Average	-12.47%	17.61%	5.14%
Std.dev	20.75%	14.16%	25.01%
Orkla ASA (6%)			
Average	-7.08%	18.42%	11.34%
Std.dev	16.57%	10.53%	20.22%

Composition of OMXS30 Big 5			
	Intraday	Interday	Close-close
Nordea Bank AB (28%)			
Average	-2.87%	15.11%	12.25%
Std.dev	19.60%	12.84%	24.06%
Hennes & Mauritz AB (23%)			
Average	-14.87%	18.18%	3.31%
Std.dev	16.54%	12.90%	21.33%
Swedbank AB (17%)			
Average	-2.79%	16.69%	13.91%
Std.dev	17.81%	12.98%	23.20%
Atlas Copco AB (17%)			
Average	-2.14%	13.21%	11.07%
Std.dev	23.08%	11.97%	26.07%
Svenska Handelsbanken AB (16%)			
Average	3.29%	9.17%	12.68%
Std.dev	18.52%	12.86%	22.99%

Composition of OMXC20CAP Big 5			
	Intraday	Interday	Close-close
Novo Nordisk A/S (46%)			
Average	-21.04%	-10.97%	-32.01%
Std.dev	21.45%	82.65%	84.50%
Danske Bank A/S (22%)			
Average	0.76%	19.39%	20.16%
Std.dev	19.74%	14.13%	23.94%
A.P. Møller-Mærsk A A/S (11%)			
Average	-37.30%	4.24%	-33.06%
Std.dev	25.97%	81.39%	86.23%
A.P. Møller-Mærsk B A/S (11%)			
Average	-27.57%	-5.67%	-33.24%
Std.dev	24.74%	81.57%	86.10%
Vestas Wind systems A/S (11%)			
Average	-17.11%	83.80%	66.69%
Std.dev	36.28%	24.94%	43.01%

Composition of OSEBX Big 10							
	Intraday	Interday	Close-close		Intraday	Interday	Close-close
Statoil ASA (35%)				Orkla ASA (6%)			
Average	-0.53%	3.28%	2.75%	Average	-7.08%	18.42%	11.34%
Std.dev	22.12%	16.37%	27.65%	Std.dev	16.57%	10.53%	20.22%
DNB ASA (16%)				Gjensidige Forsikring ASA (5%)			
Average	-2.55%	17.01%	14.46%	Average	4.72%	8.07%	12.79%
Std.dev	21.75%	13.57%	26.11%	Std.dev	17.27%	13.50%	21.42%
Telenor ASA (15%)				Marine Harvest ASA (5%)			
Average	-6.86%	10.10%	3.24%	Average	13.76%	71.32%	85.08%
Std.dev	18.49%	13.16%	22.36%	Std.dev	22.18%	116.19%	118.61%
Norsk Hydro ASA (7%)				Subsea 7 ASA (3%)			
Average	-13.42%	22.33%	8.91%	Average	-27.68%	22.22%	-5.46%
Std.dev	23.86%	15.21%	27.48%	Std.dev	34.23%	21.87%	38.87%
Yara International ASA (6%)				Aker ASA (2%)			
Average	-12.47%	17.61%	5.14%	Average	3.33%	6.44%	9.77%
Std.dev	20.75%	14.16%	25.01%	Std.dev	27.13%	15.58%	28.73%

Banks OSEBX				Banks OMXS30			
	Intraday	Interday	Close-close		Intraday	Interday	Close-close
DNB ASA (71%)				Nordea Bank AB (46%)			
Average	-2.55%	17.01%	14.46%	Average	-2.87%	15.11%	12.25%
Std.dev	21.75%	13.57%	26.11%	Std.dev	19.60%	12.84%	24.06%
Gjensidige Forsikring ASA (21%)				Swedbank AB (28%)			
Average	4.72%	8.07%	12.79%	Average	-2.79%	16.69%	13.91%
Std.dev	17.27%	13.50%	21.42%	Std.dev	17.81%	12.98%	23.20%
Storebrand ASA (8%)				Svenska Handelsbanken AB (26%)			
Average	-11.97%	24.52%	12.55%	Average	3.29%	9.17%	12.68%
Std.dev	27.64%	18.79%	33.63%	Std.dev	18.52%	12.86%	22.99%

Banks OMXC20CAP			
	Intraday	Interday	Close-close
Danske Bank A/S (88%)			
Average	0.76%	19.39%	20.16%
Std.dev	19.74%	14.13%	23.94%
Jyske Bank A/S (12%)			
Average	25.08%	-6.78%	18.30%
Std.dev	20.86%	13.77%	24.54%

OSEBX Oil: After oil price drop			
	Intraday	Interday	Close-Close
Average	-13.97%	9.57%	-4.40%
Std.dev	23.76%	16.94%	29.95%
OSEBX Oil: Before oil price drop			
	Intraday	Interday	Close-Close
Average	7.65%	1.20%	8.85%
Std.dev	11.69%	8.08%	13.53%

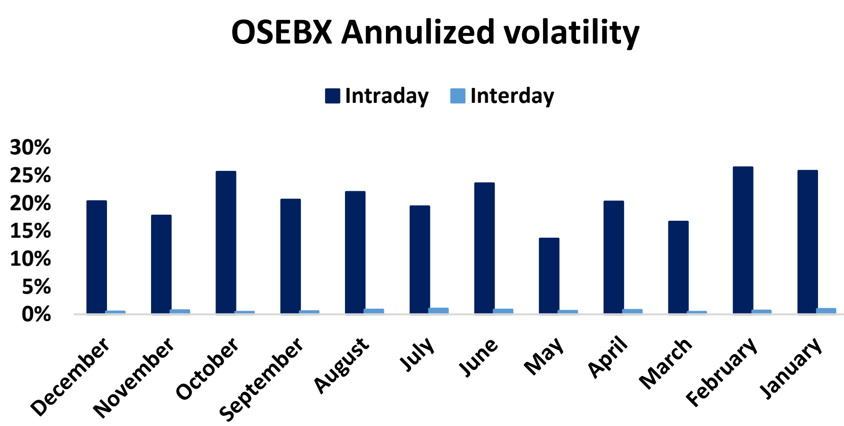
Oil related firms at OSEBX			
	Intraday	Interday	Close-close
Statoil ASA (83%)			
Average	-0.53%	3.28%	2.75%
Std.dev	22.12%	16.37%	27.65%
Subsea 7 (7%)			
Average	-27.68%	22.22%	-5.46%
Std.dev	34.23%	21.87%	38.87%
TGS-NOPEC Geophysical Company ASA (3%)			
Average	-19.26%	19.68%	0.42%
Std.dev	32.07%	21.00%	37.95%
Aker Solutions ASA (2%)			
Average	-41.75%	48.24%	6.49%
Std.dev	41.44%	54.31%	66.74%
Seadrill Limited (1%)			
Average	-70.50%	22.51%	-47.99%
Std.dev	51.61%	45.13%	71.45%
DNO ASA (1%)			
Average	-58.01%	54.83%	-3.18%
Std.dev	44.16%	28.59%	51.66%
Petroleum Geo-Services ASA (1%)			
Average	-75.63%	45.35%	-30.29%
Std.dev	49.02%	28.26%	55.16%

Composition of OSEBX Seafood			
	Intraday	Interday	Close-close
Marine Harvest ASA (50%)			
Average	13.76%	71.32%	85.08%
Std.dev	22.18%	116.19%	118.61%
Lerøy Seafood Group ASA (20%)			
Average	16.93%	15.03%	31.96%
Std.dev	26.81%	15.16%	29.01%
SalMar ASA (18%)			
Average	6.10%	37.02%	43.12%
Std.dev	27.72%	15.08%	30.81%
Bakkafrost ASA (12%)			
Average	18.23%	25.03%	43.26%
Std.dev	27.03%	14.33%	29.73%

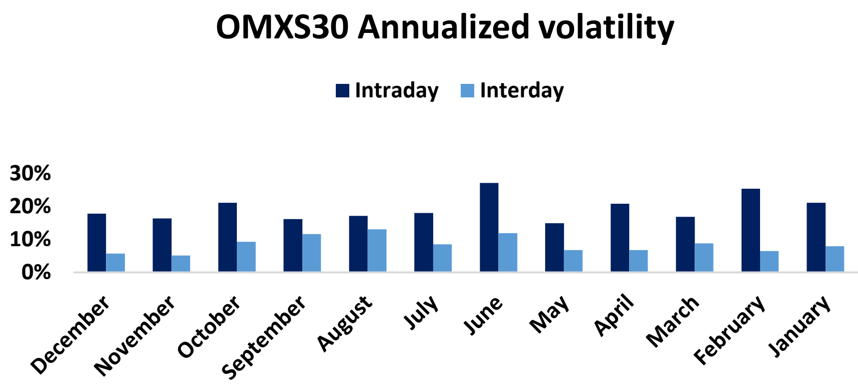
VI. Seasonality

OSBEX Monthly Seasonality												
Intraday												
	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.
Return	0.047%	0.045%	0.111%	-0.007%	-0.079%	0.080%	-0.088%	0.124%	0.150%	0.024%	0.129%	-0.059%
Std.dev	1.045%	0.847%	1.154%	0.949%	1.012%	0.864%	1.122%	0.716%	1.013%	0.814%	1.307%	1.231%
Interday												
Return	0.003%	-0.001%	0.000%	0.000%	0.006%	0.006%	-0.004%	0.004%	0.010%	0.003%	0.000%	0.000%
Std.dev	0.026%	0.035%	0.020%	0.025%	0.038%	0.046%	0.041%	0.032%	0.038%	0.023%	0.032%	0.045%
Close-to-close												
Return	0.050%	0.044%	0.112%	-0.007%	-0.073%	0.086%	-0.091%	0.128%	0.160%	0.027%	0.129%	-0.059%
Std.dev	1.048%	0.858%	1.158%	0.955%	1.020%	0.871%	1.143%	0.722%	1.029%	0.819%	1.320%	1.232%

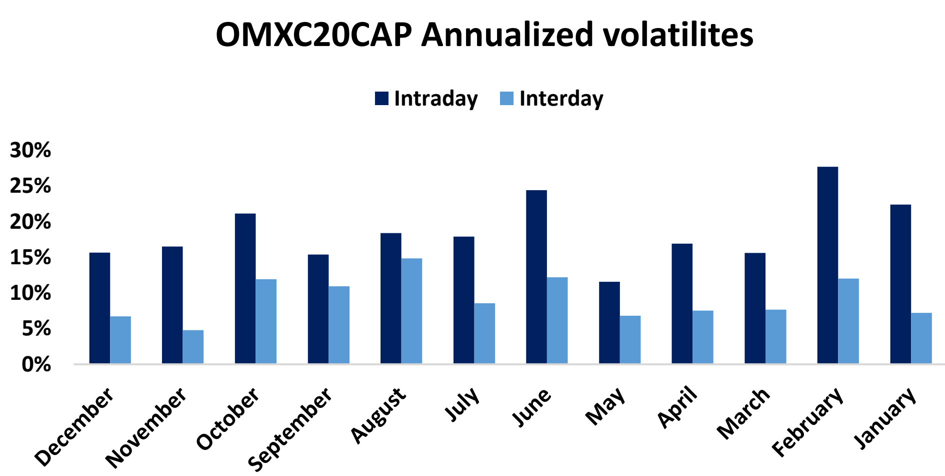
Average monthly volume at OSEBX												
Months	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.
Volume (in millions)	3,524	3,510	3,494	2,844	2,748	2,677	3,173	3,384	3,437	3,460	3,915	3,591



OMXS30 Monthly Seasonality												
Intraday												
	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.
Return	-0.067%	0.097%	-0.020%	-0.075%	-0.087%	0.035%	-0.141%	0.051%	-0.051%	0.019%	0.177%	-0.037%
Std.dev	0.912%	0.776%	0.947%	0.744%	0.789%	0.800%	1.386%	0.733%	1.012%	0.803%	1.250%	1.040%
Interday												
Return	0.048%	0.022%	0.118%	0.080%	0.017%	0.148%	-0.079%	0.020%	0.015%	-0.043%	0.017%	0.061%
Std.dev	0.291%	0.242%	0.415%	0.532%	0.599%	0.379%	0.607%	0.334%	0.332%	0.421%	0.318%	0.391%
Close-to-close												
Return	-0.019%	0.120%	0.098%	0.004%	-0.070%	0.184%	-0.219%	0.071%	-0.037%	-0.024%	0.195%	0.024%
Std.dev	1.037%	0.786%	1.045%	1.000%	1.166%	0.965%	1.594%	0.842%	1.074%	0.936%	1.330%	1.205%



OMXC20CAP Monthly Seasonality												
Intraday												
	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.
Return	-0.004%	0.018%	-0.070%	-0.090%	-0.151%	-0.026%	-0.129%	0.071%	-0.139%	-0.003%	0.235%	0.036%
Std.dev	0.802%	0.787%	0.950%	0.708%	0.847%	0.795%	1.206%	0.618%	0.867%	0.763%	1.367%	1.055%
Interday												
Return	0.071%	0.068%	0.135%	0.104%	0.091%	0.179%	-0.024%	0.134%	0.151%	0.031%	0.058%	0.106%
Std.dev	0.345%	0.228%	0.537%	0.503%	0.682%	0.381%	0.603%	0.362%	0.385%	0.373%	0.594%	0.340%
Close-to-close												
Return	0.067%	0.086%	0.066%	0.014%	-0.060%	0.153%	-0.153%	0.205%	0.013%	0.028%	0.292%	0.141%
Std.dev	0.927%	0.802%	1.087%	0.942%	1.263%	0.913%	1.316%	0.728%	0.996%	0.938%	1.493%	1.134%



VII. Weekend and Holiday effect

OSEBX - All		Intraday	Interday	Close-close
Monday	Return	-3.02%	0.04%	-2.99%
	Std.dev	7.28%	0.19%	7.34%
	T-stat	-0.83	0.40	-0.81
Tuesday	Return	3.26%	0.06%	3.32%
	Std.dev	7.22%	0.24%	7.29%
	T-stat	0.90	0.49	0.91
Wednesday	Return	5.58%	0.22%	5.81%
	Std.dev	7.12%	0.26%	7.18%
	T-stat	1.57	1.71	1.62
Thursday	Return	0.76%	0.16%	0.92%
	Std.dev	7.48%	0.22%	7.52%
	T-stat	0.20	1.39	0.24
Friday	Return	3.06%	0.09%	3.15%
	Std.dev	6.96%	0.29%	7.03%
	T-stat	0.88	0.62	0.90

OSEBX - Holidays		Intraday	Interday	Close-close
Monday	Return	-0.36%	-0.02%	-0.38%
	Std.dev	1.40%	0.04%	1.40%
	T-stat	-0.45	-0.69	-0.47
Tuesday	Return	0.91%	0.03%	0.94%
	Std.dev	2.73%	0.06%	2.77%
	T-stat	0.67	1.08	0.68
Wednesday	Return	1.34%	0.00%	1.34%
	Std.dev	NA	NA	NA
	T-stat	NA	NA	NA
Thursday	Return	-0.57%	0.01%	-0.56%
	Std.dev	0.24%	0.05%	0.29%
	T-stat	-3.31	0.32	-2.73
Friday	Return	0.45%	0.02%	0.47%
	Std.dev	0.76%	0.02%	0.77%
	T-stat	1.20	1.44	1.23

OSEBX - Holidays omitted & before adjusted for time		Intraday	Interday	Close-close
Monday	Return	-2.75%	0.05%	-2.70%
	Std.dev	7.20%	0.18%	7.26%
	T-stat	-0.76	0.55	-0.74
Tuesday	Return	2.35%	0.03%	2.38%
	Std.dev	6.73%	0.24%	6.79%
	T-stat	0.70	0.25	0.70
Wednesday	Return	5.25%	0.22%	5.47%
	Std.dev	7.09%	0.26%	7.16%
	T-stat	1.48	1.71	1.53
Thursday	Return	1.05%	0.15%	1.20%
	Std.dev	7.47%	0.22%	7.51%
	T-stat	0.28	1.35	0.32
Friday	Return	2.61%	0.07%	2.68%
	Std.dev	6.92%	0.29%	6.99%
	T-stat	0.75	0.51	0.77

OSEBX - Holidays omitted & After adjusted for time		Intraday	Interday	Close-close
Monday	Return	-2.75%	0.05%	-2.70%
	Std.dev	12.94%	0.11%	4.19%
	T-stat	-0.76	0.55	-0.74
Tuesday	Return	2.35%	0.03%	2.38%
	Std.dev	12.08%	0.28%	6.79%
	T-stat	0.70	0.25	0.70
Wednesday	Return	5.25%	0.22%	5.47%
	Std.dev	12.74%	0.32%	7.16%
	T-stat	1.48	1.71	1.53
Thursday	Return	1.05%	0.15%	1.20%
	Std.dev	13.42%	0.27%	7.51%
	T-stat	0.28	1.35	0.32
Friday	Return	2.61%	0.07%	2.68%
	Std.dev	12.43%	0.35%	6.99%
	T-stat	0.75	0.51	0.77

OMXS30 - All		Intraday	Interday	Close-close
Monday	Return	-1.82%	1.38%	-0.44%
	Std.dev	7.40%	3.92%	8.89%
	T-stat	-0.49	0.70	-0.10
Tuesday	Return	0.48%	1.26%	1.74%
	Std.dev	6.79%	2.34%	7.63%
	T-stat	0.14	1.08	0.46
Wednesday	Return	-0.09%	0.76%	0.67%
	Std.dev	6.56%	2.65%	7.44%
	T-stat	-0.03	0.57	0.18
Thursday	Return	-1.11%	2.38%	1.27%
	Std.dev	6.63%	3.22%	7.72%
	T-stat	-0.33	1.48	0.33
Friday	Return	0.57%	3.55%	4.12%
	Std.dev	6.12%	2.60%	7.08%
	T-stat	0.19	2.73	1.16

OMXS30 - Holidays		Intraday	Interday	Close-close
Monday	Return	-2.98%	0.44%	-2.54%
	Std.dev	4.33%	1.44%	5.19%
	T-stat	-1.38	0.61	-0.98
Tuesday	Return	0.98%	0.65%	1.63%
	Std.dev	0.74%	0.58%	0.98%
	T-stat	2.65	2.23	3.34
Wednesday	Return	-0.77%	-1.56%	-2.33%
	Std.dev	NA	NA	NA
	T-stat	NA	NA	NA
Thursday	Return	-0.70%	-0.37%	-1.07%
	Std.dev	0.95%	0.39%	0.97%
	T-stat	-1.28	-1.64	-1.91
Friday	Return	-0.03%	0.20%	0.17%
	Std.dev	0.69%	0.26%	0.63%
	T-stat	-0.11	2.12	0.77

OMXS30 - Holidays omitted & Before adjusted for time				
		Intraday	Interday	Close-close
Monday	Return	1.17%	0.94%	2.10%
	Std.dev	5.84%	3.67%	7.21%
	T-stat	0.40	0.51	0.58
Tuesday	Return	-0.51%	0.61%	0.11%
	Std.dev	6.71%	2.23%	7.48%
	T-stat	-0.15	0.55	0.03
Wednesday	Return	0.11%	1.15%	1.26%
	Std.dev	6.55%	2.53%	7.35%
	T-stat	0.03	0.91	0.34
Thursday	Return	-0.58%	2.66%	2.07%
	Std.dev	6.57%	3.19%	7.63%
	T-stat	-0.18	1.67	0.54
Friday	Return	0.62%	3.16%	3.78%
	Std.dev	6.05%	2.57%	7.03%
	T-stat	0.21	2.46	1.08

OMXS30 - Holidays omitted & After adjusted for time				
		Intraday	Interday	Close-close
Monday	Return	1.17%	0.94%	2.10%
	Std.dev	9.87%	2.25%	4.16%
	T-stat	0.40	0.51	0.58
Tuesday	Return	-0.51%	0.61%	0.11%
	Std.dev	11.35%	2.77%	7.48%
	T-stat	-0.15	0.55	0.03
Wednesday	Return	0.11%	1.15%	1.26%
	Std.dev	11.07%	3.13%	7.35%
	T-stat	0.03	0.91	0.34
Thursday	Return	-0.58%	2.66%	2.07%
	Std.dev	11.10%	3.95%	7.63%
	T-stat	-0.18	1.67	0.54
Friday	Return	0.62%	3.16%	3.78%
	Std.dev	10.23%	3.19%	7.03%
	T-stat	0.21	2.46	1.08

OMXC20CAP - All				
		Intraday	Interday	Close-close
Monday	Return	-0.05%	3.47%	3.41%
	Std.dev	6.72%	4.67%	8.23%
	T-stat	-0.02	1.49	0.83
Tuesday	Return	-0.31%	4.05%	3.74%
	Std.dev	6.74%	2.57%	7.51%
	T-stat	-0.09	3.16	1.00
Wednesday	Return	0.25%	5.18%	5.43%
	Std.dev	6.46%	2.39%	7.27%
	T-stat	0.08	4.33	1.49
Thursday	Return	-3.06%	5.44%	2.38%
	Std.dev	6.14%	3.27%	7.08%
	T-stat	-1.00	3.33	0.67
Friday	Return	-2.43%	4.97%	2.53%
	Std.dev	6.48%	3.06%	7.62%
	T-stat	-0.75	3.25	0.66

OMXC20CAP - Holidays				
		Intraday	Interday	Close-close
Monday	Return	-1.21%	0.88%	-0.32%
	Std.dev	1.02%	0.91%	1.56%
	T-stat	-2.37	1.94	-0.41
Tuesday	Return	0.90%	0.78%	1.68%
	Std.dev	0.89%	0.79%	1.42%
	T-stat	2.01	1.97	2.37
Wednesday	Return	NA	NA	NA
	Std.dev	NA	NA	NA
	T-stat	NA	NA	NA
Thursday	Return	-0.63%	-0.08%	-0.70%
	Std.dev	1.21%	0.65%	1.87%
	T-stat	-0.73	-0.17	-0.53
Friday	Return	0.16%	0.87%	1.03%
	Std.dev	0.34%	0.27%	0.07%
	T-stat	0.82	5.50	26.17

OMXC20CAP - Holidays omitted & Before adjusted for time				
		Intraday	Interday	Close-close
Monday	Return	1.15%	2.58%	3.74%
	Std.dev	6.62%	4.57%	8.09%
	T-stat	0.35	1.13	0.92
Tuesday	Return	-1.22%	3.27%	2.06%
	Std.dev	6.66%	2.42%	7.32%
	T-stat	-0.37	2.70	0.56
Wednesday	Return	0.25%	5.18%	5.43%
	Std.dev	6.46%	2.39%	7.27%
	T-stat	0.08	4.33	1.49
Thursday	Return	-2.75%	5.48%	2.73%
	Std.dev	6.09%	3.25%	7.00%
	T-stat	-0.90	3.37	0.78
Friday	Return	-2.56%	4.31%	1.76%
	Std.dev	6.47%	2.97%	7.57%
	T-stat	-0.79	2.90	0.46

OMXC20CAP - Holidays omitted & After adjusted for time				
		Intraday	Interday	Close-close
Monday	Return	1.15%	2.58%	3.74%
	Std.dev	11.52%	2.80%	4.67%
	T-stat	0.35	1.13	0.92
Tuesday	Return	-1.22%	3.27%	2.06%
	Std.dev	11.60%	2.96%	7.32%
	T-stat	-0.37	2.70	0.56
Wednesday	Return	0.25%	5.18%	5.43%
	Std.dev	11.24%	2.92%	7.27%
	T-stat	0.08	4.33	1.49
Thursday	Return	-2.75%	5.48%	2.73%
	Std.dev	10.61%	3.97%	7.00%
	T-stat	-0.90	3.37	0.78
Friday	Return	-2.56%	4.31%	1.76%
	Std.dev	11.26%	3.63%	7.57%
	T-stat	-0.79	2.90	0.46

VIII. Pricing of options

Group 1		Group 2	
Maturity	**Days**	**Maturity**	**Days**
Friday close to Monday open	2.69	Monday open to Friday close	4.31
Friday close to 2. Monday open	9.69	Monday open to 2. Friday close	11.31
Friday close to 6. Monday open	37.69	Monday open to 6. Friday close	39.31
Friday close to 12. Monday open	79.69	Monday open to 12. Friday close	81.31

The strike prices change as a result of different deltas. The formulas for delta call and delta put is presented below.

$$Delta\ call = N(d_1)$$

$$Delta\ put = N(d_1) - 1$$

Group 1		Friday close to Monday open		Friday close to 2. Monday open		Friday close to 6. Monday open		Friday close to 12. Monday	
Time to maturity		2.69		9.69		37.69		79.69	
Observed volatility		0.31%		14.00%		15.88%		16.19%	
Theoretical volatility*		16.47%		16.47%		16.47%		16.47%	
		Price	**Strike**	**Price**	**Strike**	**Price**	**Strike**	**Price**	**Strike**
Delta ca. 50% ATM	Call	0.12	600.00	5.63	600.00	12.88	600.00	19.52	600.00
	Call*	3.43		6.60		13.34		19.84	
Delta ca. 25% OTM	Call	0.00	605.92	1.63	611.54	4.26	624.05	6.38	636.87
	Call*	1.25		2.37		4.62		6.63	
Delta ca. 75% ITM	Call	5.65	594.45	12.24	589.79	24.69	581.13	35.49	574.19
	Call*	6.92		12.98		25.06		35.74	
Delta ca. - 50% ATM	Put	0.03	600.00	5.29	600.00	11.53	600.00	16.68	600.00
	Put*	3.34		6.25		11.99		16.99	
Delta ca. - 25% OTM	Put	-	594.45	1.70	589.79	4.52	581.13	6.95	574.19
	Put*	1.27		2.44		4.88		7.20	
Delta ca. - 75% ITM	Put	5.83	605.92	12.82	611.54	26.90	624.05	40.23	636.87
	Put*	7.08		13.55		27.27		40.48	
Differences									
		%		%		%		%	
50% Delta Call		**2693%**		17.10%		3.57%		1.60%	
25% Delta Call		NA		45.10%		8.54%		**3.90%**	
75% Delta Call		22.52%		6.04%		1.48%		0.70%	
-50% Delta Put		**12439%**		18.22%		3.98%		1.87%	
-25% Delta Put		NA		43.56%		8.07%		**3.59%**	
-75% Delta Put		21.52%		5.75%		1.35%		0.62%	

Group 2		Monday open to Friday close		Monday open to 2.Friday close		Monday open to 6. Friday close		Monday open to 12. Friday close	
Time to maturity		4.31		11.31		39.31		81.31	
Observed volatility		21.00%		18.33%		17.03%		16.74%	
Theoretical volatility*		16.47%		16.47%		16.47%		16.47%	
		Price	**Strike**	**Price**	**Strike**	**Price**	**Strike**	**Price**	**Strike**
Delta ca.	Call	5.54	600.00	7.92	600.00	14.07	600.00	20.35	600.00
50% ATM	Call*	4.36		7.14		13.64		20.05	
Delta ca.	Call	2.57	607.54	3.20	612.51	5.07	624.62	6.94	637.30
25% OTM	Call*	1.59		2.56		4.72		6.70	
Delta ca.	Call	9.70	593.05	14.64	589.03	25.93	580.76	36.33	573.97
75% ITM	Call*	8.72		14.00		25.59		36.08	
Delta ca. -	Put	5.38	600.00	7.52	600.00	12.67	600.00	17.45	600.00
50% ATM	Put*	4.21		6.74		12.23		17.15	
Delta ca. -	Put	2.60	593.05	3.27	589.03	5.33	580.76	7.52	573.97
25% OTM	Put*	1.62		2.64		4.98		7.27	
Delta ca. -	Put	9.96	607.54	15.29	612.51	28.23	624.62	41.16	637.30
75% ITM	Put*	8.97		14.66		27.88		40.91	
Differences									
		%		**%**		**%**		**%**	
50% Delta Call		-21.23%		-9.86%		-3.09%		-1.49%	
25% Delta Call		**-38.30%**		-19.94%		-6.90%		**-3.52%**	
75% Delta Call		-10.13%		-4.35%		-1.35%		-0.67%	
-50% Delta Put		-21.84%		-10.39%		-3.43%		-1.74%	
-25% Delta Put		**-37.81%**		-19.46%		-6.56%		**-3.25%**	
-75% Delta Put		-9.89%		-4.17%		-1.24%		-0.59%	

Implied volatility	1 month	2 months	3 months	5 months
Average* Call	**16.3%**	**18.4%**	**18.6%**	**19.0%**
Average* Put	**16.7%**	**18.5%**	**18.7%**	**18.7%**
Observed	16.0%	15.4%	15.1%	15.7%
Theoretical	16.5%	16.5%	16.5%	16.5%

Average* = Average implied volatility

IX. Trading – Strategy 2