Aalto University
School of Economics

Expiration Day Effects of the EURO STOXX 50 Index Futures and Options

Finance

Master's thesis

Markus Joensuu

2010

Department of Accounting and Finance
Aalto University
School of Economics

Aalto University
School of Economics

Expiration Day Effects of the EURO STOXX 50 Index Futures and Options

Master's Thesis
Markus Joensuu
Spring 2010
Finance

Approved in the Department of Accounting and Finance __ / __20__ and awarded the grade

____

Aalto University
School of Economics

Aalto University School of Economics
Master's thesis
Markus Joensuu

ABSTRACT
21.5.2010

EXPIRATION DAY EFFECTS OF THE EURO STOXX 50 INDEX FUTURES AND OPTIONS

PURPOSE OF THE STUDY

The purpose of this thesis is to bring new evidence on index derivatives' expiration day effects in Europe. The study addresses the lacking evidence on the expiration day effects of the EURO STOXX 50 index futures and options, which are among the most traded index derivatives in the world. The thesis studies the abnormal volume, return, volatility and return reversal effects around the monthly options and quarterly futures expiration days. Furthermore, this study examines whether some of the effects are spilled over from the EURO STOXX 50 index to OMXH25 via Nokia, which is a member of both indexes.

DATA

The data used in this study consists of EURO STOXX 50 constituents' daily trading volume and return figures as well as monthly index weights from Datastream. Furthermore, 15 second interval high frequency index price data from STOXX Ltd. is used to compare the intraday volatilities and returns on expiration days to the control group of non-expiration days. The futures expiration day sample includes 40 trading days, the options sample 80 days and the control group 401 days, covering the years 2000-2009. Furthermore, daily high, low, and closing prices, as well as monthly and semiannual weightings and component lists of OMXH25 index constituents are used. This data is from Nasdaq OMX and Datastream.

RESULTS

I find significant expiration day effects around the expiration of EURO STOXX 50 index derivatives. The effects are in general stronger for the expiration of futures than for options. The results show that expiration days are associated with a significantly higher trading volume on the underlying index. This is due to the unwinding of delta positions and to heavy program trading activities on expiration days. Furthermore, a significantly higher intraday volatility around the expiration time at 12:00 CET on expiration days is found. This result is robust also when controlling for sample size differences. Moreover, the intraday returns before expiration are significantly higher and the returns after expiration significantly lower on expiration days. The returns before 12:00 CET tend, on average, to reverse more on expiration days after 12:00 CET than on non-expiration days. The finding regarding reversals suggests that trading is liquidity driven on expiration days and supports theory on the inventory considerations of market makers. Moreover, the systematic direction of the return effect is a sign of potential price manipulation activities and/or on average a significant unwinding of short positions on expiration days. However, no significant evidence of expiration day effects spilling over from the EURO STOXX 50 index to OMXH25 via Nokia is found, at least when studying daily data.

KEYWORDS

Expiration day effects, index arbitrage, program trading, liquidity, return reversals.

Aalto Yliopiston Kauppakorkeakoulu

Aalto Yliopiston Kauppakorkeakoulu TIIVISTELMÄ

Pro Gradu-tutkielma 21.5.2010

Markus Joensuu

EXPIRATION DAY EFFECTS OF THE EURO STOXX 50 INDEX FUTURES AND OPTIONS

TAVOITTEET

Tämän tutkielman tavoitteena on tutkia indeksijohdannaisten erääntymispäiväefektejä Euroopassa. Tutkielma keskittyy EURO STOXX 50 indeksifutuureihin ja -optioihin, jotka kuuluvat maailman eniten kauppaa käytyihin indeksijohdannaisiin. Ensinnäkin, tutkielmassa tarkastellaan indeksin epänormaalia kaupankäyntivolyymiä, tuottoja, volatiliteettiä sekä tuottojen kääntymistä erääntymispäivinä. Lisäksi tutkielmassa tarkastellaan mahdollista erääntymispäiväefektien leviämistä EURO STOXX 50 indeksistä OMXH25 indeksin osakkeisiin Nokian kautta.

AINEISTO

Tutkimuksen aineisto koostuu EURO STOXX 50 indeksin osakkeiden päivittäisistä kaupankäyntivolyymeista, hinnoista sekä osakkeiden indeksipainoista. Tältä osin aineisto on koottu Datastream tietokannasta. Lisäksi tutkielman keskeisenä aineistona käytetään STOXX Ltd:ltä saatuja EURO STOXX 50 indeksin päivänsisäisiä 15 sekunnin välisiä hintoja. Päivänsisäistä dataa käytetään erääntymispäivien (120 päivää) vertaamiseen kontrollityhmään (401 päivää) kattaen vuodet 2000–2009. Lisäksi päivätason tuottoja, päivän ylimpiä, alimpia ja viimeisiä hintoja, sekä puolivuosittaisia indeksipainotuksia käytetään analysoitaessa OMXH25 indeksiä. Tältä osin data on Nasdaq OMX:sta ja Datastreamista.

TULOKSET

Tutkielman tulokset osoittavat ensinnäkin, että EURO STOXX 50 indeksijohdannaisten erääntyminen aiheuttaa merkittävästi korkeampaa kaupankäyntivolyymiä kohde-etuutena olevaan indeksiin tavalliseen päivään verrattuna. Syynä tälle voidaan pitää indeksiarbitraasia sekä delta-positioiden purkua erääntymispäivien yhteydessä. Lisäksi havaitaan, että erääntymispäivien päivänsisäinen volatiliteetti erääntymishetken ympärillä on tavallista merkittävästi korkeampi. Tuotot ennen erääntymishetkeä ovat merkittävästi korkeampia, kuin muina päivinä. Vastaavasti tuotot erääntymishetken jälkeen ovat merkittävästi tavallista alhaisempia. Erääntymishetkeä edeltävät tuotot kääntyvät keskimäärin voimakkaammin erääntymispäivinä erääntymishetken jälkeen, viitaten vahvaan likviditeettijohteiseen kaupankäyntiin erääntymispäivänä. Tuottojen kääntyminen tukee teoriaa markkinatakaajien varastointirooliin liittyvästä tuottovaatimuksesta. Lisäksi tulokset tuottojen systemaattisen suunnan osalta ovat merkki mahdollisesta kurssimanipulaatiosta ja/tai tavallista suurempien lyhyeksi myytyjen positioiden sulkemisista erääntymispäivien yhteydessä.

Toisaalta tutkielman tulokset eivät osoita merkittävää erääntymispäiväefektien tarttumista Nokiasta muuhun OMXH25 indeksiin.

AVAINSANAT

Erääntymispäiväefektit, indeksiarbitraasi, program trading, tuottojen kääntyminen.

Table of Contents

List of Tables

List of Figures

1. Introduction

Since derivative contracts on indexes were introduced in the 1980s, there has been a considerable amount of discussion on whether these instruments have also brought undesirable side effects to the equity markets. Attention has been drawn especially to whether the introduction of index options and futures has changed abnormally the volume, the volatility and the returns on the underlying index. These effects are known in the literature as expiration day effects. Several empirical studies have reported significant volume, price and volatility effects around the expiration of index futures and options. The most common explanations include the unwinding of delta positions as well as index arbitrage, which is executed by arbitrageurs with sophisticated computer algorithms. Given the huge amount of trading in index futures[1], the magnitude of these potential side effects can be large. Also, since index arbitrage is typically executed with expensive technology, the potential benefits are reaped by only a relatively small number of institutional investors, but the side effects suffered by all market participants. Because of this, regulators and derivatives exchanges have also been interested in the expiration day effects. For instance, expiration day settlement procedures have been reviewed in some countries because of these concerns.

The importance of exchange traded derivatives is likely to increase, because of the current regulatory pressure to centralize the trading of over-the-counter (OTC) products to exchanges. Regulators argue that moving the trading of derivatives to centralized exchanges would improve the visibility and hence reduce the systemic risks related to trading of derivatives. This thesis studies some of the adverse effects related to exchange traded derivatives, namely the expiration day effects of the EURO STOXX 50 index futures and options.

1.1. Background and motivation

The importance of expiration day effects on the markets has resulted in a significant amount of interest in the academic world. A number of papers have studied index futures and options

[1] See Appendix 1 for a comparison of index futures and options trading activities around the world.

expiration day effects in several different markets: in the US (e.g. Stoll and Whaley, 1986, 1987, 1991; Hancock, 1993; Chen and Williams, 1994), in Canada (e.g. Chamberlain, Cheung, and Kwan, 1989), in Germany (e.g. Schlag, 1996), in Sweden (Alkebäck and Hagelin, 2004), in Spain (e.g. Corredor, Lechón, Santamaría, 2001), in Hong Kong (e.g. Kan, 2001; Chow, Yung, and Zhang, 2003) and even in Finland (Felixson, 2002). Most studies agree on a significantly higher volume on expiration days, caused by the unwinding of spot positions as well as by price manipulation activities. However, findings on volatility and return effects are mixed. For instance, where Stoll and Whaley (1991) find statistically significantly higher volatility on expiration days, Kan (2001) does not find the same results in the Hong Kong markets. A higher volatility or significantly different returns patterns around the expiration can be expected, if the unwinding activities are strong enough to have a price impact in the underlying market (Stoll and Whaley, 1987). A return reversal, on the other hand, can be justified if the returns right before expiration are the result of heavy liquidity trading instead of informed trading (see e.g. Llorente, Michaely, Saar, and Wang, 2002).

Despite the number of previous studies, not much recent evidence of established and liquid index futures markets exists. Previous European evidence has been brought from markets such as Sweden and Spain (see e.g. Alkebäck and Hagelin, 2004; Corredor et al., 2001; Illueca and Lafuente, 2006), which have relatively small and illiquid futures markets compared to the US, where the most significant effects have been documented. Given that trading volumes around the world have grown not least because of better access to markets as well as advances in technology, index arbitrage activities can be expected to be even more present nowadays than in the 1980s and 1990s, when many of the US studies, for instance, were conducted. Therefore, it is interesting to see, how the current situation looks like in a liquid European market. Since the EURO STOXX 50 index futures are among the most traded index futures in the world, and given that the underlying index is one of the most followed indexes in Europe, it is of interest to study the potential magnitude of the EURO STOXX 50 index futures and options expiration day effects.

Finally, empirical evidence on spilling over of expiration day effects to stocks that are not constituents of the underlying indices is very limited. Thus, as a side study I also examine the potential spilling over of the expiration day effects to the Finnish market. Given that Nokia is part of both the EURO STOXX 50 and OMXH25 indexes, it is likely to co-move with both of them. On expiration days, however, the co-movements could be strong enough to spill over to OMXH25, where Nokia has a very dominant role in terms of turnover.

1.2. Research questions

This thesis studies whether the quarterly expirations of EURO STOXX 50 index futures and the monthly expirations of the options are associated with expiration day effects on the underlying index. The methodology follows mostly studies such as Stoll and Whaley (1986, 1987, and 1991). The following research questions are examined:

- Does the expiration of EURO STOXX 50 index Futures or Options affect the underlying index's volume?
- Does the expiration of EURO STOXX 50 index Futures or Options affect the underlying index's returns?
- Does the expiration of EURO STOXX 50 index Futures or Options affect the underlying index's volatility?
- Are the returns before the expiration of EURO STOXX 50 index Futures or Options reversed after the expiration?

Also, I study whether any potential effect on volume, returns or volatility is spilled over from EURO STOXX 50 to OMXH25 since Nokia is part of both indexes and has a dominant role in the latter. Hence, I try to answer the following question as well:

- Are the expiration day effects spilled over from EURO STOXX 50 to OMX Helsinki 25 via Nokia?

1.3. Contribution to existing literature

This study extends on previous research on expiration day effects in many ways. Firstly, as instruments I study the EURO STOXX 50 index derivatives. This underlying index is an important one for investors since a considerable number of instruments such as exchange traded funds (ETFs) use it as an underlying[2]. Possibly because of this, the futures contract on the index is one of the most traded index futures contract in the world[3], and it is actually surprising that no previous research has been conducted on its potential expiration day effects yet, as far as I know. Also, given that the recent European evidence comes from smaller, local markets (see e.g. Corredor et al., 2001; Felixson, 2002; Alkebäck and Hagelin, 2004; Illueca & Lafuente, 2006) this study brings important evidence on a more liquid, European index derivatives market.

While the effect of index derivatives expiration days on volume is well documented in previous studies, the effects on volatility and intraday returns seem to depend on the market investigated. In this study I use a high frequency dataset consisting of index levels on 15 second intervals. Compared to other studies the dataset is quite unique, since most of other studies using intraday data use minute-per-minute price data. Also, some studies are limited to the use of daily data only (e.g. Vipul, 2005; Alkebäck and Hagelin, 2004). Furthermore, the period under review is January 2000 to December 2009, which is long, compared to previous studies: most of them have samples of only a few years. Consequently, it is possible that with the data set used in this study, more significant results can be found. Finally, the studies on spilling over of the expiration day effects to non-constituent stocks are very limited. Hence, this study sheds light in that area of literature as well.

1.4. Results

Firstly, by using a Wilcoxon rank sum test I find that the expirations of the EURO STOXX 50 index futures and options are associated with a significantly higher volume on the underlying index at the expiration, in line with the majority of previous studies. The results are robust both when comparing detrended trading volumes, and relative trading volumes for all the period under investigation, 2000-2009. This is evidence of heavy program trading and spot positions' unwinding on the expiration days.

[2] The EURO STOXX 50 index is the most widely used regional blue-chip index in Europe according to Deutsche Bank.
[3] See Appendix 2 for a comparison of trading volumes in leading stock index futures.

Secondly, by using an F-test and a Levene's test for equal variances I find that the intraday volatility is significantly higher both on quarterly expiration days of the futures as well as on monthly expiration days of the options. The results for volatility are robust even when using simulated sampling to control for the differences in sample sizes. The volatility effect is likely to be caused by the heavy unwinding of spot positions. Also, it can be related to market manipulation activities on expiration days. Interestingly, the volatility effect is smaller for the sample 2005-2009 than for 2000-2004. An explanation for this is that liquidity has increased during the decade, which has driven the volatility of the index down supporting findings such as in Li and Wu (2006) and Suominen and Rinne (2010).

Thirdly, there is evidence of significant return effects. It appears that the intraday returns before expiration at 12:00 CET on expiration days of the index futures are significantly higher than for the control group of non-expiration days. On the other hand, after expiration the returns are significantly lower on futures' expiration days, suggesting that the abnormal returns are reversed. This is clear evidence of order imbalances around the expiration of the index futures: without any new information, stock prices should reverse back to equilibrium. For the options series, the findings suggest similar return effects, albeit not as significant ones. The question why the returns are higher before the expiration and lower afterwards, on average, cannot be answered properly without analysing detailed order book data. The best explanation is that there is on average a significant unwinding of short positions right before the expiration time. Another explanation for this phenomenon is market manipulation activities as in Aggarwal and Wu (2006), who find that prices tend to increase during the manipulation period and decrease afterwards. The natural asymmetry of liquidity purchases and sales may contribute to this (Allen and Gorton, 1992)

Fourth, I find evidence of significant return reversals. By analysing the reversals with a median test and with an OLS regression model, I find that the returns before the expiration time at 12:00 CET are, on average, reversed in the afternoon, especially during the 15 and 30 minute windows. Also, for index futures the negative returns in the expiration day afternoon tend to continue on the day after the expiration day. The evidence on return reversals supports findings such as in Llorente et al. (2002) and Campbell, Grossman and Wang (1993) suggesting that reversals are likelier to occur when returns are accompanied by high volume and a higher proportion of trading is hedging-based liquidity trading in contrast to informed trading. Thus, the results give support to the inventory considerations of market makers (e.g. Stoll, 1978; Hu and Stoll, 1983; Grossman and Miller, 1988; Andrade et al. 2008), namely that market makers accommodate heavy buying and selling pressure only if they are rewarded for carrying inventory. Finally, market manipulation activities may introduce return reversals as well, as noted in some previous studies (see Aggarwal and Wu, 2006; Comerton-Forde and Putnins, 2007).

Finally, I do not find significant evidence that the expiration day effects would be transferred from Nokia to other OMXH25 index constituents. The OMXH25 index without Nokia tends to have a statistically significantly higher volume on expirations of the EURO STOXX 50 index futures and options, and this effect is stronger for the period 2005-2009. An intuition behind this is that index arbitrageurs trading the OMXH25 index rebalance their portfolios partly according to Nokia's movements as in Hendershott and Seasholes (2008). Another explanation for the higher volume is the potential simultaneous expirations of single stock options of the OMXH25 index constituents. As for the daily volatilities and returns, no statistically significant difference is found, suggesting that no spilling over of volatility or returns from Nokia to other OMXH25 stock occurs. However, the expiration week returns for the OMXH25 index without Nokia tend to be significantly lower on quarterly index futures expirations. Whether this is caused by the EURO STOXX 50 derivatives' expirations or not remains unknown.

1.5. Limitations of the study

The main limitations of the study are related to data. While the data covers 10 years the samples of index futures expiration days (40) and options expiration days (80) are small compared to the control group of non-expiration days (401). However, compared to previous studies the samples of futures and options expirations are relatively large. Also, the significance of the results especially for volume and volatility suggests that they are robust despite small sample sizes. In addition, one would need detailed order book data in order to confirm potential manipulation activities. Moreover, when studying the spill over of the expiration day effects from Nokia to other stocks on the OMXH25 index, I use daily price data instead of intraday high-frequency data. The reason for this is the unavailability of OMXH25 intraday data. Thus, more significant results for return and volatility patterns could possibly be found by using high-frequency data.

1.6. Structure of the study

The rest of the paper is organized as follows: in section 2, I discuss stock index options and futures, as well as delta hedging. Also, I discuss whether the introduction of options and futures as instruments has had an impact on the underlying markets or not. In section 3, I present relevant studies on expiration day effects as well as on the reasons behind them. Also, I discuss studies on trading volume, volatility and return reversals in order to understand better the potential expiration day effects. Moreover, I shed light on studies on co-movements of stocks since they may help explain the rationale behind potential spilling over of the expiration day effects from Nokia to OMXH25. In section 4, I describe the institutional setting and the data: the EURO STOXX 50 index, its futures and its options are presented, as well as the data used in the study. In section 5, I present the methodology used in the empirical part as well as the five hypotheses to be tested in this study. In section 6, I continue by discussing the results of the empirical part, and section 7 concludes the thesis.

2. Stock index futures, stock index options and delta hedging

In this section, stock index options and futures as instruments are presented. I first explain what index futures and options are. Also, I explain what is meant by delta hedging, since it may be one factor behind the expiration day effects studied in this thesis. Finally, I conclude this section with a brief discussion on whether the introduction of options and futures trading has had an impact on the cash market or not.

2.1. Stock index futures and options

Stock index futures contracts were one of the most successful financial innovations of the 1980s (Stoll and Whaley 1997). The first successful index futures contract was the Chicago Mercantile Exchange's S&P 500 futures, which began trading in the US in April 1982. The contract design quickly spread across the world: the Sydney Futures Exchange's Australian All Ordinaries SPI in 1983; London International Financial Futures Exchange's FTSE 100 futures in 1984; the Hong Kong Futures Exchange's Hang Seng Index future in 1986; the MATIF's CAC-40 index futures in 1988; the Osaka Stock Exchange's Nikkei 225 futures in 1988; and DTB's DAX index futures in 1990. Moreover, the European blue chip index EURO STOXX 50 futures contracts started trading at the end of 1999 in Eurex.

An important distinction between a forward and a futures contract is the marking to market of futures: daily profits and losses are marked to market daily. Because of this, the payoffs of a futures position and a forward position differ: on aggregate, though, when the losses and gains are netted in the futures position, the result is and must be the same. As the delivery period of the contract is approached, the futures price converges to the spot price of the underlying asset. When the expiration is reached, the futures price equals or is very close to the spot price. Figure 1 on the next page illustrates the convergence of futures price to spot price (Hull, 2006).

Stock index futures contracts have as an underlying a stock index. They are generally cash settled on the expiration day. The reason is obvious: physical delivery of the underlying index requires having positions in each of the underlying shares, which may be very costly and difficult to arrange in practice. The settlement rules differ from exchange to exchange: some settle at closing prices, some at open prices, some according to the Volume Weighted Average Price (VWAP) of a certain period of time during the day and some at an auction price.

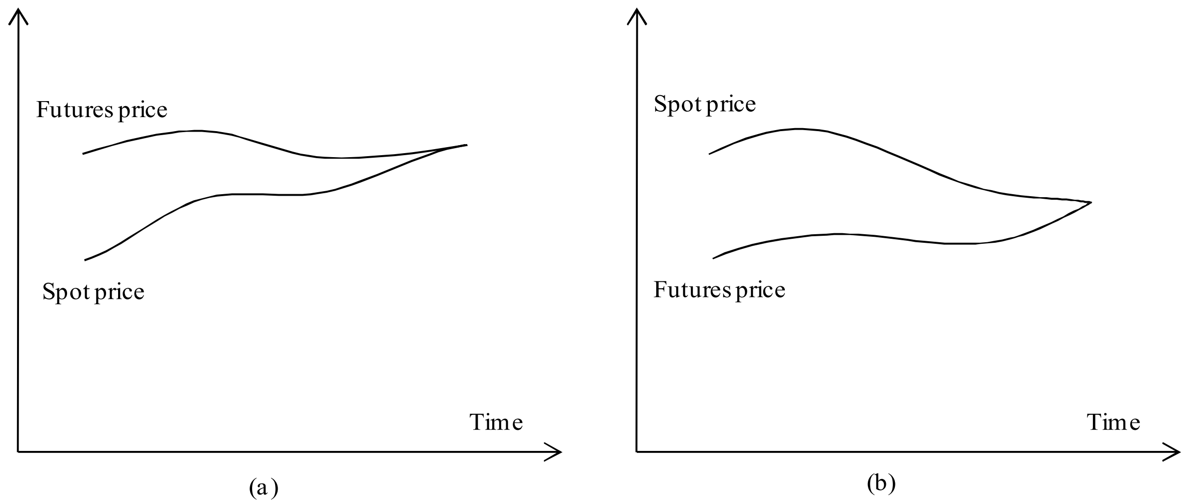

Figure 1: Relationship between futures price and spot price

The figure shows the relationship between futures price and spot price as the maturity is approached. Spot prices and futures prices should converge at delivery time. Case (a) describes situation when the futures price is above the spot price; case (b) when the futures price is below spot price. (Hull, 2006)

Stock index futures are a common way to hedge a stock portfolio's market risk exposures internationally. An asset manager fearing a downturn in the Japanese stock market over the next few weeks can hedge his or her position by selling short Nikkei index futures. The manager can eliminate the risk of a downturn this way more easily and with lower costs than selling a whole portfolio of stocks. Also, it allows the asset manager to maintain exposure on some stocks he or she has picked. Generally speaking, index futures can help reduce costs associated with trading the underlying portfolio of stocks. If q is the dividend yield rate; r the risk-free rate; and T the maturity of the futures contract, Equation 1 provides the futures price F_0 at time 0 as

$$F_0 = S_0 e^{(r-q)T} \tag{1}$$

Stock index options, on the other hand, are options on the stock index. These contracts give the holder the right but not the obligation to buy or sell the index at expiration on a pre-defined price.

These options work exactly as regular stock options, except for the fact that the underlying security is an index, and the option is settled in cash, and not physically. In most of the cases, the contracts are European. However, one exception is the contract on the S&P 100, which is American. Contracts have usually lot sizes of 10, meaning that one contract allows the holder to buy or sell 10 times the index at the strike price. Like futures, index options can reduce trading costs significantly, when taking a position on an underlying index.

2.2. Delta hedging

Delta hedging is relevant to understand in this study, since it is likely to be one explanation behind the expiration day effects. According to Ni, Pearson and Poteshman (2005), the trading of derivatives may increase volatility or introduce price clustering of the underlying assets because of the unwinding of delta positions as well as manipulation. In those cases, stock prices tend to cluster at option strike price levels.

Delta hedging is a form of hedging used by most portfolio managers trading derivatives. Delta hedging is a hedging scheme that is designed to make the price of a portfolio of derivatives insensitive to small changes in the price of the underlying asset. The delta of a derivative is the rate of change of the price of the derivative with the price of the underlying asset. For instance, the delta of a call option can be defined as

$$\delta = \frac{\partial c}{\partial s} \tag{2}$$

where c is the price of the call option and S is the stock price. Hence, a delta-neutral portfolio is a portfolio with a delta of zero, implying that there is no sensitivity to small changes in the price of the underlying asset. (Hull, 2006)

From equation (1) the futures price for a contract on a non-dividend-paying stock is S_0e^{rT}, where T is the time to maturity of the futures contract; and r the risk-free rate. When the stock changes by ΔS, with all else remaining constant, the futures price changes by ΔSe^{rT}. Given that futures are marked to market daily, the holder of a long futures contract makes an almost immediate gain or loss of this amount. The delta of a futures contract is thus e^{rT}, which represents the amount of the underlying one needs to buy or sell in order to set the hedge. Similarly, for a futures contract on an asset providing a dividend yield q, equation (1) implies that the delta is $e^{(r-q)T}$. (Hull, 2006) Portfolio managers trading derivatives and doing delta hedging, who want to close their long (short) positions in derivatives will have to buy (sell) the underlying assets at the same time.

When speaking of index futures and options, the underlying is the index: a portfolio manager trading index options and futures will have to buy or sell the underlying index when closing the position. Since for all index futures and options positions there are always two sides, one could think that there should thus be two opposing hedging positions cancelling each other and thus leaving the spot index volatility and returns unaffected. However, in order to have a perfect hedge, an investor would have to have the whole index represented perfectly in his or her portfolio, which can be costly in practice. Moreover, some investors may take long or short positions in futures without any hedge at all. Also, most portfolio managers merely use index futures or options as hedging instruments to account for a broader market risk. In addition, some investors roll their futures positions at expiration to a future date instead of closing it and liquidating the delta. As a consequence, the hedges are not in practice cancelling out each other, and the unwinding activities can result in volume, volatility and price effects on the markets, if many investors unwind positions at the same time (Stoll and Whaley, 1997).

2.3. Do options and futures trading affect the cash market?

Since the introduction of options and futures, a considerable amount of literature has strived to find whether these instruments affect the cash market returns and volatility. Chan, Chan, and Karolyi (1991) find strong intermarket dependence in the volatility of the S&P 500 stock index and stock index futures markets between 1984 and 1989. Their results showed that price innovations that occur either in the cash or futures markets can be used in predicting the future volatility in the other market. Their finding suggests that there exists strong persistence in the intraday volatility patterns in both markets. The evidence is consistent with the idea that new market information disseminates in both the futures and stock markets and that both markets serve important price discovery roles. Hence, futures trading affects the underlying index, and vice versa. Butterworth (2006) finds, by using both symmetric and asymmetric GARCH[4] techniques for the FTSE Mid 250 futures contract in the UK that the existence of futures trading has significantly altered the structure of spot market volatility. Specifically he finds that while there is evidence of more information flowing into the spot prices following the start of futures trading, the new information is assimilated into prices less rapidly than before, leading to an increase in the persistence of volatility.

Stoll and Whaley (1990b) study the time series properties of 5 minute intraday returns of stock index and index futures. They find that S&P 500 and MM index futures returns lead cash market returns about five minutes on average. The effect appears to be present even if the returns are purged of infrequent trading effects. Chan (1992) finds strong evidence in the US market that futures lead cash prices and weak evidence that cash prices lead futures prices. They also find that when stocks move together, futures lead the cash index to a stronger degree. Harris, Sofianos, and Shapiro (1994) document a correlation between program trading and intraday changes in the S&P 500 Index. It appears that futures prices and to a lesser extent cash prices lead program trades. Moreover, they find that index arbitrage trades are followed by an immediate change in the cash index, which ultimately reverses slightly, which is not the case with non-arbitrage trades.

Edwards (1988) finds no evidence of futures-induced short-run volatility. Conrad (1989), Damodaran and Lim (1988), Detemple and Jorion (1990) and Nabar and Park (1988) find that individual stock volatilities on a daily level have actually reduced after the introduction of stock options, which suggests that derivatives stabilise the underlying market. On the other hand, Harris (1989) finds that S&P 500 volatility has increased after the introduction of index futures and options trading. However, he acknowledges that the increase is economically not significant, and that other factors besides the start of derivatives trading could be responsible for the increase in volatility. Furthermore, Chang, Cheng, and Pinegar (1999) examined whether Nikkei stocks' spot portfolio volatility increased compared with average volatility when Nikkei futures began trading on the Osaka Securities Exchanges. They show that for Nikkei stocks spot portfolio

[4] Generalized Autoregressive Conditional Heteroskedasticity, or GARCH was introduced by Bollerslev (1986). It allows current conditional variance to be a function of past conditional variances.

volatility increased and cross-sectional dispersion decreased. However, they did not find significant shifts in volatility when the same futures began trading on the Singapore International Monetary Exchange (SIMEX). They also find that for non-Nikkei stocks, there was no shift of volatility when the futures began trading on either exchange. Finally, Bollen (1998) studied whether the introduction of options affects the return variance of underlying stocks by using a dataset consisting of the CBOE's history of 1942 option listings on American exchanges from 1973 through 1993. He did not find significantly different variances between a control group of non-optioned stocks and a group of optioned stocks.

These findings suggest that while there is certainly a relationship between futures prices and cash prices, the trading of futures and options as such does not appear to significantly increase the underlying spot volatility.

3. Literature review

In this section, I describe first previous literature on expiration day effects in different markets around the world. Secondly, I discuss the potential sources of expiration day effects: why are expiration days associated with significant shocks in volume, volatility and returns? Thirdly, I discuss relevant studies on the relationship between cash market volume, volatility and price reversals in order to find explanations behind the potential expiration day effects. Finally, I conclude the chapter with a discussion of studies on co-movements of stocks, in order to understand the reason behind the potential spilling over of the expiration day effects from Nokia to OMXH25.

3.1. Previous studies on expiration day effects

Several empirical studies have been conducted to assess the expiration day effects on volume, volatility and price. Most of the studies have found an expiration day volume effect, which refers to an abnormally high volume on and around expiration days (e.g. Stoll and Whaley, 1986, 1987, 1990a; Alkebäck and Hagelin, 2004; Aggarwal, 1988; Schlag, 1996, Pope and Yadav, 1992). This hike in volume is attributable to the unwinding of delta positions at the expiration. Moreover, some studies find abnormally high volatility of the spot index during expiration days (e.g. Stoll & Whaley, 1986, 1987, 1990a; Day and Lewis, 1988; Chamberlain et al. 1989; Bamber and Röder, 1995; Illueca and Lafuente, 2006). On the other hand, a few studies note a tendency for the spot index to fall or rise during expiration days and reverse back the next day of trading, suggesting severe order imbalances during the expiration day. For example Stoll and Whaley (1986, 1987, 1990a) find that the underlying index tends to fall on expiration days and reverse on the subsequent day. The magnitude of the reversal is around 0.4 percent. On the other hand, Chamberlain et al. (1989) find that the cash index tends to go up during the last half-hour of trading and reverse the next day's morning. Indeed, while the volume effect has been mostly acknowledged, the previous results regarding volatility effects and price effects are relatively mixed. In this section, I discuss previous literature on expiration day effects in different markets.

3.1.1. Expiration day effects in the US and Canada

In the US, Stoll and Whaley (1986) study the effect of the last hour of trading on simultaneous expiration days of the S&P 500 futures and S&P 100 options contracts, called the *triple-witching hour*[5]. By using index price intraday data around both the monthly options and the quarterly futures expiration days, they find that there is evidence of clearly higher volume, as well as significantly higher volatility during expiration days than on other days. Also, they find price reversal effects at quarterly expirations of the futures: the spot index tends to fall on quarterly expiration days, and recover the day after. The price effect seems to be solely associated with the quarterly index futures expiration. The price reversal magnitude was around 0.3 to 0.5 percent of the closing index value on expiration depending on the method of calculating the reversal. In Stoll and Whaley (1987), the magnitude of the price effect is documented as 0.4 percent for index futures expirations. Moreover, Stoll and Whaley (1990a) examined the effects of program trading on individual stocks around index futures expiration days, when heavy program trading is expected. They find that expiration days are associated with an almost three times higher cross-sectional variance of stock returns than non-expiration days. Also, they find that S&P 500 stocks exhibit an average common reversal of 0.24 percent. However, it appears that stocks not on the S&P 500 index also exhibit some price reversals the Monday after the expiration day, suggesting "spilling over" of expiration day effects to non-constituent stocks. The magnitude of this common reversal is 0.066 percent. More specifically, they find that the S&P 500 index tends to decline in price the last half hour of Friday and to bounce the following day. However, not all stocks decline; some experience substantial price increases, while others decline by more than the index (Stoll and Whaley, 1990a).

Day and Lewis (1988) find a similar volatility effect than Stoll and Whaley (1986) around expiration days for the years 1983-1986 in a study conducted in the US. They estimate the implied volatilities for each option expiration series using a generalized least squares procedure and examine the volatility of the stock market around the quarterly expirations of stock index futures and the non-quarterly expirations of stock index options. They find that option prices show increases in the volatility of the underlying stock indexes at both quarterly and non-

[5] Triple-witching hour is defined in the literature as the last hour of the stock market trading session on the third Friday of every March, June, September and December. Those days are the expiration of three kinds of securities: index futures, index options and regular stock options.

quarterly expiration days. Moreover, they show that there are significant and positive abnormal returns for call options on the S&P 100 and Major Market Indexes (MMI) on the day before both quarterly and non-quarterly expirations, which is consistent with an unexpected increase in market volatility around expiration days (Day and Lewis, 1988). Aggarwal (1988) find similar effects for the period 1981-1987. Moreover, Ni et al. (2005) find that stocks having options contracts listed on a derivatives exchange had a greater propensity to cluster around strike prices on option expiration days than on other trading days. They suggest that delta-hedge rebalancing by investors with net purchased option positions and stock price manipulation may be the reasons for this.

In order to mitigate the problem regarding occasional abnormal underlying stock price movements during the triple witching hour, the Chicago Mercantile Exchange (CME), the New York Stock Exchange (NYSE) as well as the New York Futures Exchange (NYFE) changed the settlement time of the S&P 500 and NYSE index futures from the closing to the opening in June 1987. The options expiration times remained untouched, however. This change became then a popular research area in the US. For instance, Stoll and Whaley (1991) analyse volatility and volume effects on quarterly and monthly expiration days in the two and a half year period before and after this settlement procedure amendment. They find that the expiration day effects on volume, volatility, and price reversals had only shifted from the close to the opening. Herbst & Maberly (1990) find similar results. Also, Chen and Williams (1994) report that after the change in expiration timing, the volume on expiration days is actually higher. Lee and Mathur (1999), on the other hand, find that the change in the settlement procedure had successfully reduced volatility on both the NYSE and S&P 500 stock index markets.

Chamberlain et al. (1989) study the expiration day effect in Canada, for the TSE 300 Index covering the period November 1985 through May 1987. They consider the time-ordered records of the Toronto Stock Exchange (TSE) 300 during the last half-hour of trading on expiration and non-expiration days. They also find evidence of unusual price behaviour: the rate of return during the last half-hour of trading is significantly higher and more volatile on days on which index options and futures expired than on other Fridays. Moreover, the expiration returns also tend to reverse during the following trading day. Surprisingly, they cannot reject the hypothesis that the trading volume on expiration days equals the trading volume on non-expiration days. They believe that the local market's lack of depth and breadth might limit index arbitrageurs' activities, which would make the significant expiration-day price effects consistent with the absence of a corresponding change in trading volume.

3.1.2. Evidence on expiration day effects from Europe

Pope and Yadav (1992) find evidence of higher trading volume five days leading to stock option expiration time as well as a downward price pressure immediately prior to option expirations in UK. The magnitude of the price effect is approximately -0.5 percent. However, they do not find changes in returns volatility. Bamberg and Röder (1995) find that on expiration days of both DAX options and DAX futures contracts in Germany the intraday volatility of the index increases. Also, Schlag (1996) finds a significant increase in trading volume both on quarterly expiration days of DAX futures and monthly options expirations: the total daily trading volume on quarterly expirations is more than triple the volume on non-expiration days. He also finds some evidence of price effects on futures' expiration days: open-to-close returns tend to be higher on expiration days than on non-expiration days. The effect is not statistically significant, however, and is not observable to the same extent for all underlying stocks.

Alkebäck and Hagelin (2004) examine index futures and options expiration day effects in Sweden between 1988 and 1998 by using daily price data for the OMX index. They conclude that while there appears to be significantly higher volumes on the cash market on expiration days, no evidence suggesting price distortions is found. As an explanation they propose the longer settlement period of the Swedish market compared to that of the Canadian, German and the US markets where price distortions have been documented. Indeed, in Sweden the settlement price of the OMX index derivatives is set to the volume weighted average price (VWAP) of the last trading day. Hence, index arbitrageurs are forced to liquidate their positions in the spot index smoothly, throughout the trading day, reducing order imbalances that may otherwise result in sharp price movements (Alkebäck and Hagelin, 2004). Compared to the US, where the settlement is merely the opening price, the Swedish system should smoothen price manipulations, they argue. Another explanation for their results may also be the fact that OMX index futures expire each month, whereas US index futures expire only quarterly. Indeed, according to Swidler et al.

(1994), fewer expiration months lead to a concentration of unwinding activity and may exacerbate expiration effects.

In Finland, Felixson (2002) studies the expiration day effect and price manipulation on the underlying shares of the FOX-index (nowadays known as the OMXH25 index) for index futures and option expiration days between October 1995 and mid 1999 by using data consisting of all trade lot trades. The expiration day price for the FOX index was back then calculated as the daily VWAP, like in Sweden. He finds no significant evidence of volume, volatility or price reversal effects. However, he notices that some indication of manipulation could be found in cases when there is a large quantity of outstanding futures contracts or at/in the money option contracts, or there exists shares with high index weights but fairly low trading volumes. Also, Felixson suggests that in addition to the different settlement procedure, the specialist trading system in the US could explain part of the differences between the findings.

Corredor et al. (2001) examine the expiration day effects in the Spanish market during the period January 1992 through December 1995 by using daily data. They find abnormally high volume during days before the expiration. Also, they document a downward pressure on prices on days prior to expiration days. However, the price effect is not significant. Illueca and Lafuente (2006) examine the volatility and volume effects for the Spanish Ibex 35 and S&P 500 stock indexes on expiration days. They use 15 minute price data to investigate volatility effects around the settlement trading interval. They find a significant increase of spot trading activity at expiration on the Ibex 35, as well as a significant jump in conditional realized volatility. Interestingly, for S&P 500 they do not find such a hike in volatility at expirations.

3.1.3. Expiration day effects in Asian and Australian markets

In Asia, Bacha and Vila (1994) examine the Nikkei 225 with its futures traded on the Singapore International Monetary Exchange (SIMEX), Osaka Securities Exchange (OSE) and CME by using daily data covering November 1985 – August 1991. They find that futures expiration on all three types of futures contracts does not cause higher cash market volatility than ordinary non-expiration days. Stoll and Whaley (1997) examine the expiration day effect at Sydney Futures Exchange's All Ordinaries Share Price Index futures for the period January 1993 – June 1996 and find abnormally high trading volume near the close on expiration days, but no significant price movements compared to other, non-expiration days. However, they find that the overall average variance of returns on expiration days is nearly twice the overall variance on non-expiration days, and out of fourteen days studied, the difference is statistically significant on eight days. When analysing the variance of five-minute returns in the last two hours of trading, the difference is statistically significant in nine out of fourteen days (Stoll and Whaley, 1997).

In Hong Kong, Chow et al. (2003) use 5-minute price data from the period of 1990-1999 to examine the expiration day effects of the HSI futures and options. They find evidence of negative price effects and higher return volatility on the index. However, they do not find any abnormal trading volume nor return reversals after the expiration. In another study in Hong Kong, Kan (2001) uses minute-by-minute data for the period 1989 – 1992 and finds that the intraday price volatility of the HSI on expiration days is insignificantly different from that of non-expiration days, suggesting no order imbalances owing to the unwinding activities. As for the expiration day price reversal effects, he finds no significant price reversals during the last 15-minute or the last 30 minute intervals on the expiration days. Kan suggests several plausible reasons why the expiration-day effect of index futures trading does not seem to exist in some Asian markets unlike in the US. For instance, short-selling restrictions in the Japanese, Australian and Hong Kong markets may dilute index arbitrageurs' unwinding effect on the underlying spot market. Also, there is no specialist trading system like in the US in use, no computerized trading during the sampling period, and the region has, according to him, distinct macroeconomic factors, which may contribute to the difference in results.

In India, Vipul (2005) studies the expiration day effects on the Nifty Index for the period 2001-2004 and finds evidence of a higher than normal volume in the cash index on the expiration day for all the shares. More specifically, the volume starts building up before the expiration and continues to the day following it for the high relative derivative volume shares, which he defines as shares having a high notional value of derivatives traded compared to the value of the underlying shares traded. He also finds that the returns the day before expiration days are marginally depressed (-0.07 percent, on average), and that the rate of increase in returns after the expiration day is abnormally high (0.9 percent, on average). This increase is much stronger for the high relative derivative volume shares, and is irrespective of the increase or decrease in the price on the expiration day. However, Vipul (2005) does not find significantly different volatility of the underlying shares on expiration days, by using a volatility estimate based on the maximum and minimum prices of the day. In another study in India, Bhaumik and Bose (2007) examine the expiration day effects at the National Stock Exchange (NSE) for the June 2000 – September 2006 period. First of all, they find a significantly higher volume of trading on expiration days as well as on the respective expiration weeks than on non-expiration days and weeks. Also, they document significantly higher mean returns but significantly lower volatility on expiration days compared to non-expiration days. However, they do not find evidence of price reversals following the expiration day. They argue, however, that the price reversal can possibly take place on the expiration days themselves. Finally, Maniar, Bhatt, and Maniyar (2009) find for the same market that the expiration is associated with a significant increase in volatility. However, it appears that the liquidation activities to do not cause any significant shock to the demand curve and to the prices of the underlying stocks.

3.2. Sources of expiration day effects

According to Stoll and Whaley (1997), expiration-day price effects may arise and depend on a combination of factors including: the existence of index arbitrage opportunities; the cash settlement feature of index options and futures; stock market procedures for accommodating the unwinding of arbitrage positions in the cash index; and manipulation activities. These factors are discussed next.

3.2.1. Existence of index arbitrage opportunities

According to Hull (2006), index arbitrage is a trading activity linking the cash price of an index to the price of futures or other derivatives on that index. A stock index can usually be regarded as a price of an investment asset that pays dividends. From equation (1) in the previous section we have the equilibrium between futures price and spot price:

$$F_0 = S_0 e^{(r-q)T} \qquad (1)$$

where F_0 is the future price; S_0 is the spot price; q is the dividend yield; e is the base of the natural logarithms; r is the risk-free rate; and T is the maturity of the contract[6]. If the actual price is different from this equilibrium, and given that the magnitude of the deviation is higher than transaction costs, there is an arbitrage opportunity. For instance, if F_0 is higher than the right-hand side of the equation, an arbitrageur would make riskless profits by selling the future short and taking a long position on the underlying index. Hence, if the equilibrium does not hold, arbitrageurs will participate in trading, which will consequently affect the volume. Generally, this is done with program trading, which consists of portfolio strategies involving buying or selling a basket of shares in considerable amounts with the help of a computer algorithm. NYSE estimates that program trading accounted approximately 25-33% of the average volume in December 2009[7]. Program trading is done throughout the life of the futures contract. On expiration days, the large order imbalances are usually attributed both to the unwinding of the positions of index arbitrageurs, and to traders seeking to trade at a time of predictable high volume (Barclay, Hendershott, and Jones, 2006). For example, there is evidence that discretionary liquidity trading is concentrated, and that informed traders tend to trade more actively during such periods (Admati and Pfleiderer, 1988).

3.2.2. Cash settlement

According to Stoll and Whaley (1997), another reason behind expiration day effects is related to the fact that index futures are cash settled at expiration. When a futures contract expires, the instrument settles through cash settlement according to a predetermined level, which may be the closing price, for instance, of the index. While the futures contract expires in cash, the offsetting positions must be liquidated physically, i.e. selling (or buying) the shares at the market prices. Thus, if there are many arbitrageurs liquidating spot portfolio positions at the same time and in the same direction, price effects are possible (Stoll and Whaley, 1997). The problem of expiration day effects would probably disappear if the futures would also be settled physically as Stoll and Whaley (1997) discuss; an arbitrageur who bought (sold short) stock and sold short (bought)

[6] Note that this equilibrium works only with non-commodity futures. With commodity futures, the equation is slightly different, since the convenience yield as well as storage costs of the underlying asset must be taken into account (Hull, 2006).

[7] NYSE defines program trading as portfolio-trading strategies involving the purchase or sale of a basked of at least 15 stocks. NYSE releases weekly program trading data compiled from member firms' executed volumes. Source: http://www.nyse.com/press/12_2009.html, date of retrieval: 10.2.2010.

index futures would simply deliver (take delivery of) the underlying portfolio of stocks against the index futures. However, since such a physical settlement would be technically very difficult and expensive to arrange in practice, the cash settlement procedure is likely to persist despite the fact that it may cause expiration day effects.

3.2.3. Manipulation activities

Manipulation activities may contribute to the expiration day effects as well (Stoll and Whaley, 1997), and they have attracted a relatively great amount of attention in the academic literature. Jarrow (1992) shows that profitable manipulation strategies are possible if there is either a possibility to corner the market or price momentum so that an increase in a stock price caused by the speculator's trade leads to a subsequent increase in prices. In another study, Allen and Gale (1992) show that in a rational expectations framework, it is possible for an uninformed manipulator to make profits even without price momentum provided that investors attach a positive probability to the manipulator being an informed trader. Furthermore, Allen and Gorton (1992) argue that the natural asymmetry between liquidity purchases and liquidity sales can bring an asymmetry in price responses, and hence introduce profitable manipulation activities. They argue that liquidity traders wishing to buy securities can more freely choose the time to buy. In contrast, liquidity traders who, for example, need to sell because of an immediate need for cash, cannot.Thus, if liquidity sales are more likely than liquidity purchases, there is less information in a sale as it is less likely that the trader is informed. As a consequence, the bid price can move less in response to a sale than the ask price in case of a purchase. Thus, the model suggests that a manipulator can repeatedly buy stock, causing a relatively large effect on price, and then sell with relatively little effect (Allen and Gorton, 2002).

Aggarwal and Wu (2006) find in their study on stock market manipulation in the US that the greater number of active information seekers (i.e. arbitrageurs) there are, the higher the manipulators' returns are. Their data from the Securities and Exchange Commission (SEC) enforcement actions show that manipulators are typically plausibly informed parties (i.e insiders, brokers etc). Aggarwal and Wu (2006) show that stock prices tend to rise through the manipulation period and fall after it. Moreover, it appears that manipulation increases volatility and liquidity. They also find that the vast majority of manipulation cases in their sample involve attempts to increase stock prices rather than to decrease them, which is consistent with the idea that short-selling restrictions make it more difficult to manipulate the prices downward (Aggarwal and Wu, 2006). Thus, in the light of these findings, if expiration days are associated with stronger than normal manipulation activities, the returns are likely to be positive through the manipulation period and negative thereafter. This assumption would also support the hypothesis of Allen and Gorton (2002), when it comes to the direction of the returns.

On the other hand, price manipulation can occur due to agency-based reasons as well. For example Hillion and Suominen (2004) develop an agency-based model of price manipulation where a broker manipulates closing prices of stocks to give a better impression of his or her execution quality to the client. They find that the last minute of trading on the Paris Bourse is associated with a significant rise in volatility, volume and bid-ask spreads. They attribute this phenomenon to manipulation activities. In another study, Comerton-Forde and Putnins (2007) find similar evidence that returns spreads and trading activity at the end of the day increase significantly in the presence of manipulation. They also find that the prices tend to revert the following morning. As a consequence, if expiration days are associated with greater manipulation activities than non-expiration days, manipulators may introduce higher volatility and volume as well as price reversals.

If expiration days attract manipulators, manipulation is likely to involve both the derivatives and the spot market. Kumar and Seppi (1992) investigate the susceptibility of futures markets to price manipulation by developing a model where the manipulator takes a position in the futures market and then manipulates the spot price. They show that uninformed investors can earn positive expected profits by manipulating the spot prices this way. Jarrow (1994) shows that in an economy with a stock and a money market account the introduction of a derivative security on the stock generates market manipulation trading strategies that would otherwise not exist. He shows with his model that a manipulator can then front run his or her trades and taking then advantage of any leads or lags in price adjustments across the stock and derivative security markets. Indeed, Felixson (2002) argues that there is likely to be more manipulation on expiration days when the open interest in futures and in the money option contracts is high, and when the underlying shares have a high weight in the index but a low trading volume.

3.2.4. Stock market procedures

Finally, Stoll and Whaley (1997) argue, that the severity of price effects on expiration days depends partly on the stock market procedures for accommodating order imbalances that may arise when arbitrage positions are unwound. If the underlying market is deep and if suppliers of liquidity are quick to respond to selling or buying pressure, the price effects of large arbitrage unwinding will be small. Also, if market mechanisms are not well designed to offset surprise imbalances, the price effects may be strong. For instance, the choice whether the settlement is done by using a single price or an average price, or the choice whether to settle at the opening or at the closing are both procedural issues that may affect the magnitude of the expiration day effects, as argued by Stoll and Whaley (1997). Table 1 below describes the current cash settlement procedures for selected index futures contracts. One can see that many index futures contracts settle at volume-weighted average prices (VWAP).

Table 1: Settlement price computation for a selected number of index futures contracts

The table describes the settlement price computation of a selected number of index futures contracts. Source: CME, SFE, Euronext NYSE Liffe, Eurex, Osaka Securities Exchange and HKFE websites.

Futures contract	Settlement price
S&P 500 (Chicage Mercantile Exchange)	Special Opening Quotation; based on the opening price of each component stock in the index on expiration Friday.
ASX SPI 200 (Sydney Futures Exchange)	Closing value of the underlying on the last day of trading calculated from the closing prices of the component stocks.
FTSE 100 (Euronext NYSE Liffe)	Settled at 10:30 AM according to the average underlying index values between 10:10 AM - 10:30 AM
CAC-40 (Euronext NYSE Liffe)	Settled at 4:00 PM according to the average underlying index values between 3:40 PM - 4:00 PM.
DAX (Eurex)	Settled according to the Xetra intraday auction prices of the respective index component shares.
Nikkei 225 (Osaka Securities Exchange)	Settled at Special Opening Price, computed from the opening prices of the underlying index stocks the day following the last trading day.
HSI (Hong Kong Futures Exchange)	Settled at a price determined by the Clearing House, consisting of the average quotations of the underlying index taken at 5 minute intervals during the last trading day.
DJ EURO STOXX 50 (Eurex)	Settled according to the DJ EURO STOXX 50 Index values calculated between 11:50 and 12:00 CET.

Previous studies find that the choice of settling either at open or at close is in practice irrelevant, when it comes to the magnitude of the effects (see for instance Herbst and Maberly 1990, Stoll and Whaley 1991). With a single price cash settlement the convergence between the futures and the cash prices is ensured, which removes the potential basis risk arising from a possible lack of cash-to-futures convergence at settlement. However, the trade-off is then that the underlying market can be more easily "driven" to a particular level for a short time period by manipulators in the fashion of Kumar and Seppi (1992). Indeed, Alkebäck and Hagelin (2004) argue that the severity of price effects induced by index arbitrage or market manipulation on expiration days depend on the method determining the index derivatives' settlement price. Should the settlement be based on a stock price at a single point in time or a short period of time, there may be a strong concentration of trading resulting in excess volatility if many arbitrageurs liquidate in the same direction. For example, Hillion and Suominen (2004) find in their study that an introduction of a closing auction reduces manipulation activities and brings the closing price closer to the fair value of the asset at close. Similarly one could expect that manipulation activities are less likely to occur if the settlement price is determined according to an average price instead of a single price in time.

Also, it has been argued that the number of futures expirations in a year may affect the severity of the price effects (Swidler, Schwartz, and Kristiansen, 1994); the argument goes that fewer expiration months lead to a concentration of unwinding activity. Moreover, Kan (2001) suggests, that factors such as short-selling restrictions, differences in settlement procedures, presence of a specialist trading system, presence of programme trading activities, as well as distinct macroeconomic factors may contribute to the different results between US studies and Asian studies on expiration day effects.

3.3. Cash market volatility, volume, and price reversals

As noted earlier, volume, volatility, return shocks and return reversals are the most common expiration day effects documented. There has been much academic research on the relationship between volatility and volume (e.g. Karpoff, 1987; Gallant, Rossi, Tauchen, 1992; Lamoureux and Lastrapes, 1990; Andersen, 1996). Also, empirical evidence on return reversals suggest, among other things, that a higher degree of trading based on hedging purposes as well as days with higher trading volume are associated with a higher probability of return reversals on subsequent periods (see e.g. Llorente et al. 2002; Campbell et al. 1993). The argument goes that short-term reversals are the result of market making activities (e.g. Stoll, 1978; Hu and Stoll, 1983; Grossman and Miller, 1988; Andrade et al. 2008). These studies are briefly discussed next.

3.3.1. Studies on the relationship between price volatility and trading volume

The flow of information to the markets is most of the time measured by using both volume and volatility of returns. A number of studies have found a relationship between trading volume and price changes (see e.g. Karpoff, 1987). Moreover, many studies have documented a positive and contemporaneous correlation between price volatility and trading volume (see e.g. Gallant, Rossi, and Tauchen, 1992; Lamoureux and Lastrapes 1990; Andersen, 1996; and Rahman, Lee, and Ang, 2002).

Lamoureux and Lastrapes (1990) provide empirical support for the notion that Autoregressive Conditional Heteroskedasticity (ARCH)[8] in daily stock returns reflects time dependence in the process generating information flow to the market. They show that daily trading volume, used as a proxy for information arrival time, has significant explanatory power regarding the variance of daily returns. Grammatikos and Saunders (1986) use contract disaggregated data on futures prices to show that there exists strong positive contemporaneous correlations between trading volume and price volatility. Other studies have tried to shed more light on this relationship (e.g. Clark, 1973; Epps and Epps, 1976; Copeland 1976; Admati and Pfleiderer, 1988; and Suominen 2001). The central idea behind their contributions is that volume and returns depend jointly on an underlying latent event or information flow variable, associated with the so called Mixture of Distributions Hypothesis (MDH)[9]. MDH suggests that price volatility and trading volume are both subordinated to the same information arrival rate process. Lee and Mathur (1999) study the market microstructure for the MMI, the NYSE, and the S&P 500 futures markets. Their findings are consistent with the MDH, namely that volatility is driven by information arrival. However, further examination of the level of correlations between volatility and tick volume suggests that

[8] ARCH was introduced by Engle (1982).

[9] For more information on the Mixture of Distributions Hypothesis, see Clark (1976) or the extension study by Andersen (1996).

there may be an inverse relationship between correlation and tick volume (Lee and Mathur, 1999). They explain it with differences in opinion and skills as well as asymmetric information: the influx of information creates more noise, which translates then into a smaller correlation between volatility and tick volume. Suominen (2001) studied an asset market where the availability of private information is stochastically changing over time due to changes in the source of uncertainty in the asset returns. Traders estimate the availability of private information by using past periods' trading volume to adjust their behaviour. Under his model, the conditional variance is autocorrelated and mean reverting, and it may either be positively or negatively correlated with expected trading volume (Suominen, 2001).

Li and Wu (2006) use a modified MDH model to examine the relationship between daily information flows, return volatility and bid-ask spreads. When controlling for the effect of information flow, they find that the positive relationship between volatility and volume is primarily driven by the informed component of trading. There appears to be a negative relationship between return volatility and liquidity based trading volume. Also, Suominen and Rinne (2010) confirm that liquidity decreases volatility. These studies support thus the idea that liquidity trading has a positive effect on market depth and as a consequence a negative effect on price volatility.

Furthermore, Admati and Pfleiderer (1988) argue that as long as there is at least one informed trader, the introduction of more informed traders generally intensifies the forces leading to the concentration of trading by discretionary liquidity traders. They define informed traders as traders who trade on the basis of private information not known to all other traders when the trade is done. Liquidity traders, on the other hand, are described as traders who, like flow traders in banks, trade for reasons not related to the future payoffs of financial assets; their need for trading may, for instance, arise from a liquidity need of a client. Given that both types of traders want to trade when the market is thick (i.e. when trading has little effect on prices), Admati and Pfleiderer (1988) conclude that in equilibrium discretionary liquidity trading is typically concentrated, a finding that is confirmed by e.g. Coppejans, Domowitz and Madhavan (2000). Furthermore, Admati and Pfleiderer (1988) show that in equilibrium the trading of discretionary liquidity traders is relatively more concentrated in periods closer to the realization of their demands.

Finally, informed traders tend to trade more actively in periods when liquidity trading is concentrated (Admati and Pfleiderer, 1988). In the light of their findings, assuming that expiration days attract liquidity trading, it is likely to be concentrated. In addition, expiration days are likely to attract trading from informed traders as well.

Hence, given these findings, there is a strong relationship between volatility and volume. Liquidity trading and informed trading tends to be concentrated. However, the relationship between liquidity trading volume and volatility can be negative.

3.3.2. Evidence on the relationship between reversals and liquidity trading

De Bondt and Thaler (1985, 1987) find long-term price reversals in which past long-term losers outperform past long-term winners over the subsequent three to five years. The same long horizon reversal is documented by Lee and Swaminathan (2000). Moreover, they find that high (low) volume winners (losers) experience faster momentum reversals, suggesting a relationship between reversal and volume. In addition to longer horizon reversals, there is also evidence of shorter-term price reversals. Jegadeesh (1990) and Lehmann (1990) find price reversals at monthly and weekly invervals. Conrad, Hameed and Niden (1994) document that on weekly intervals, the price reversal effect is observed only for heavily traded stocks. Suominen and Rinne (2009) study short term return reversals for NYSE and Amex traded stocks over a period covering 1926 to 2009. They find that the most recent daily returns have the largest effect on the expected returns to reversal trades. Also, they show that for liquid stocks return reversals are smaller and more gradual. Harris et al. (1994) show that index arbitrage trades are followed by an immediate change in the cash index, which reverses eventually slightly, which is not the case with non-arbitrage trades. Thus, one could expect higher than normal reversals on expiration days, if index arbitrage activities are assumed to be present.

Llorente et al. (2002) find in their study that the relation of current return, volume and future returns depends on the relative significance of speculative trading versus trading based on hedging purposes. If speculative trading in a stock is low (and hence trading based on hedging purposes high) returns accompanied by high volume tend to reverse in the subsequent period. They find that the larger the firm is in market capitalization, or the smaller the bid-ask spread, the more likely the returns reverse following high-volume days. More specifically, they argue that for stocks with low information asymmetry (like market indexes and big firms), returns following high-volume days exhibit strong reversals. On the other hand, for stocks with low information asymmetry returns exhibit weaker reversals or continuations, consistent with the findings of Antoniewicz (1993) and Stickel and Verrecchia (1994). Furthermore, Campbell et al. (1993) show that the first order daily autocorrelation of stock returns is lower on high-volume days than on low-volume days, both for stock indexes and individual large stocks. The authors propose as an explanation the idea that risk-averse market makers accommodate buying or selling pressure from liquidity or non-informed traders, as in e.g. Stoll (1978), Ho and Stoll (1983), O'Hara and Oldfield (1986) and Grossman and Miller (1988). The argument goes that market makers are essentially risk-averse utility maximizers who are willing to accommodate non-informational buying or selling pressure, but demand a reward in the form of a higher expected stock return.

Furthermore, Hendershott and Seasholes (2007) study daily inventory and asset price dynamics in the US by using 11 years of specialist inventory data. They confirm market making inventory models predictions that market makers' positions are negatively correlated with past price changes and positively correlated with subsequent changes. Also, they find that order imbalances are positively correlated with contemporaneous returns as in Chordia and Subrahmanyam (2004)[10] and Chordia, Roll, and Subrahmanyam (2002). By using returns calculated with quotes, Hendershott and Seasholes (2007) find that a value-weighted portfolio of stocks where the market maker is long outperforms a portfolio where the market maker is short by 10.25 basis points the next day following portfolio formation, 10.15 basis points the second day, and 3.43 basis points at day five. The cumulative return of the long-short portfolio is 41.12 basis points over 10 days. Also, Hendershott and Seasholes (2007) find that order imbalances are negatively correlated with the level of, and changes in inventories, and that these imbalances predict return reversals over the next 5 days. On the other hand, Avramov, Chordia and Goyal (2006) show that, while the presence of negative autocorrelations in individual security returns is evident, it is not possible to profit from this with a high frequency trading strategy because of transaction costs.

---

[10] Chordia and Subrahmanyan (2004) also find that strategies based on taking a position in the direction of the previous day's imbalance yields positive and statistically significant profits.

Andrade et al. (2008) study how risk-averse liquidity providers accommodate non-informational trading imbalances with a multi-asset equilibrium model. They find that an imbalance in one stock also affects prices of other stocks, and the imbalances generate predictable reversals in stock returns. For instance, supposing that there is a non-informational order to buy stock *i* and no orders to trade stock *j*, the risk-averse market maker will become seller of stock *i*. The liquidity provider can then partially offset the position by buying stock *j,* whose cash flows are positively correlated with stock *i*. Their regression model shows that positive trading imbalances in stock *i* are associated with an initial hike in the price and later a reversal. This reversal may be a result of the market makers' charge for bearing price risk.

In the light of these studies, if expiration days are associated with a greater amount of liquidity trading and stronger than average order imbalances to a particular direction, the returns before expiration are likely to reverse subsequently. This hypothesis supports the market makers' inventory considerations discussed for example in Stoll (1978), Ho and Stoll (1983), O'Hara and Oldfield (1986), and Grossman and Miller (1988).

3.4. Studies on co-movements of stocks

In this section, I briefly discuss studies on co-movements of stocks, in order to explain why expiration day effects can potentially spill over from Nokia as a constituent of EURO STOXX 50 to other OMXH25 constituent stocks.

Hendershott and Seasholes (2008) show that after a stock joins the S&P500 Index, the volume of program trading increases. It results in the stock's order imbalances and returns moving more in unison with the order imbalances of other stocks on the S&P500 Index. They show thus that program traders bring in a common component in the returns of an index. Further evidence of this is provided by Froot and Dabora (1999), who study stocks having the same cash flow claims on a company but trading on different exchanges. They find that these twin stocks co-move more with stocks on the exchange they are listed on than with each other. This relates to the findings of Pirinsky and Wang (2006) who demonstrate that when firms change the geographical location of their head office, the returns of their stocks co-move more with other firms headquartered in the new location and less with stocks headquartered in the old location. These findings suggest that being the member of an index which is subject of program trading may cause significant non-informational demand shocks on the stock, and that such a stock is likely to co-move more with other stocks on the index than with stocks outside the index. Hence, in the light of this, Nokia could well transfer some of the potential expiration day effects that arise from the membership of the EURO STOXX 50 index to other OMXH25 constituents.

Moreover, using data from Taiwan Stock Exchange, Andrade et al. (2008) show that stocks belonging to the same industry and having more correlated fundamentals are likely to have stronger cross-stock price pressure. Hence, a demand shock for one stock has an effect on prices of other stocks, which is explained by Andrade et al. (2008) by the hedging desires of liquidity providers since the correlations of the cash flows of the stocks define the relative attractiveness of other stocks as hedging instruments. In another study, Greenwood (2005) studies non-informational trading on Nikkei 225 stocks, by using data from the Nikkei 225 redefinition, during which the constituent stocks experienced significant changes in index investor demand because of an important change in the constituent list. He finds that stocks not affected by demand shocks but being correlated with stocks undergoing changes in demand, tend to experience returns in relation to their role as a hedge in arbitrageurs' portfolios. Harford and Kaul (2005) provide further evidence on this in their study on common effects in order flow[11], returns and trading costs. They show that common effects are strong for order flows and returns for index constituent stocks, but weak for non-index stocks in the S&P500 Index. They argue that the commonality in returns seems to be driven by the common effects in order flow induced by indexing.

Hence, if indexing brings strong enough common effects to Nokia, and if the role of the stock in OMXH25 is important enough, one can expect any return or volatility effects on Nokia to be spilled over to other OMXH25 components.

[11] Harford and Kaul (2005) define order flow as the difference between buy and sell volume or number of transactions. Because it indicates the net direction of trades, it is sometimes referred to as net order flow in the literature.

4. Institutional setting and data

In this section, I firstly present the EURO STOXX 50 futures and options contracts – what they are, how and where they are traded, and what exactly is the underlying index. Secondly, I describe the data used in the study. EURO STOXX 50 futures and options were chosen as the focus of the study, since the futures contract is one of the most traded index futures in the world in terms of volume[12] and yet no previous studies on expiration day effects has been conducted on it, as far as I know. Given the popularity and the liquidity of the index and the futures, one could expect that there is a significant amount of program trading activities which may give stronger results of expiration day effects than studies conducted on less liquid markets.

4.1. EURO STOXX 50 index futures and options

Since the focus of this study is to investigate the expiration day effect resulting from the EURO STOXX 50 futures' and options' expiration, I present the index as well as its futures and options more in detail in this section. Moreover, I describe how the trading of these instruments is done in practice at Eurex.

4.1.1. EURO STOXX 50 index

The EURO STOXX 50 index is part of the STOXX index family and is Europe's leading blue-chip index for the eurozone, providing a blue-chip representation of supersector leaders in the area. It is a capitalization-weighted index and covers 50 stocks from eurozone countries. The index is licensed to several financial institutions to serve as an underlying instrument for a broad range of investment products such as exchange traded funds (ETF), futures and options, and structured products. Currently, it captures approximately 60% of the free float market capitalisation of the EURO STOXX Total Market Index, which in turn covers approximately 95% of the free float market capitalisation of the represented countries[13]. Figure 2 shows the country weightings as well as the supersector weightings of the index as of end of 2009:

[12] See Appendix 2 for a comparison of selected index futures' trading volumes.
[13] Source: EURO STOXX 50 index factsheet.

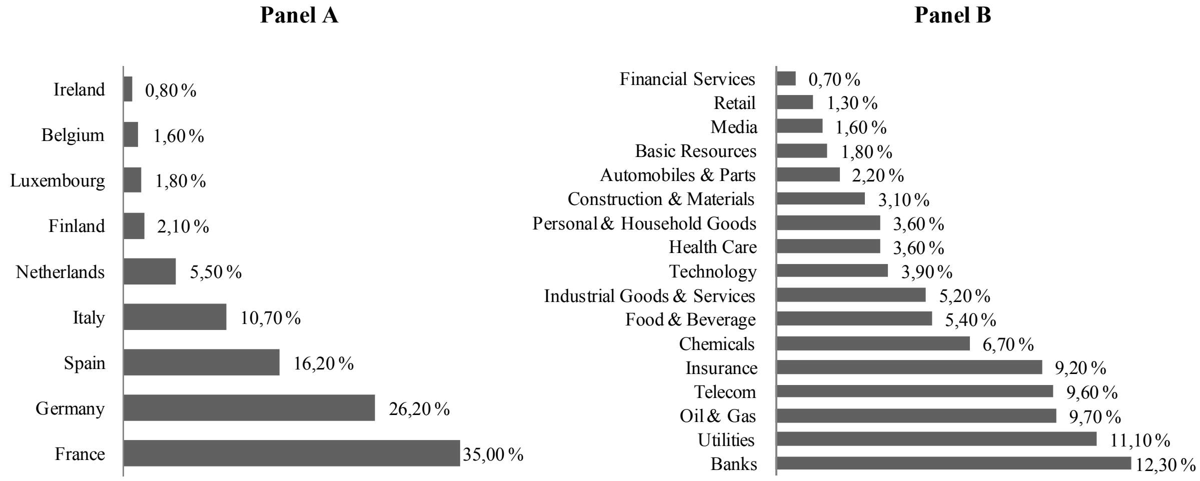

Figure 2: Countries and industries of EURO STOXX 50 index constituents.

The figure describes the country weightings (Panel A) and the supersector weightings (Panel B) of EURO STOXX 50 index on 31.12.2009. The EURO STOXX 50 index is a blue chip capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. The index is reviewed annually, in September. Source: EURO STOXX 50 index factsheet.

One can see that currently there are stocks from 9 different countries. Hence, in order to execute proper programme trading, an investor would need to have direct access to ten different exchanges, which may be expensive and thus not profitable for smaller investors. Appendix 3 lists the index constituents and their weights as of January 12th, 2010.

Table 2 on the next page shows the different instruments that have the index as an underlying (as of December 14, 2009) and their marketplaces. One can see that in addition to the quarterly expiring futures contract (FESX) and the monthly expiring options contract (OESX) there is a significant number of exchange traded funds (ETF) on the market[14].

[14] An exchange traded fund is a passively managed index fund that has shares traded on exchanges, like stocks.

Table 2: Marketplaces of instruments using the EURO STOXX 50 index as underlying

Marketplaces and trading currencies for exchange traded funds, futures and options that use EURO STOXX 50 as an underlying index as of December 14, 2009. The EURO STOXX 50 index is a blue chip capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. Source: EURO STOXX 50 index factsheet.

Instruments	CBOE	NASDAQ OMX U.S.	NYSE Euronext - Arca	Bolsa Mexicana de Valores	Borsa Italiana	Chi-X Europe	Xetra	EUREX	NYSE Euronext	NYSE Liffe	London S.E.	Madrid S.E.	SIX Swiss Exchange	SGX-Singapore Exchange	JSE Limited, Johannesburg
Exchange traded funds															
Acción EURO STOXX 50 ETF												EUR			
CASAM ETF EURO STOXX 50									EUR						
ComStage ETF EURO STOXX 50 TR							EUR						CHF		
db x-trackers EURO STOXX 50 ETF (1C)					EUR		EUR		EUR		GBP		CHF	USD	
db x-trackers EURO STOXX 50 ETF					EUR		EUR		EUR		GBP		CHF		
db x-trackers itrix EURO STOXX 50 ETF															ZAR
EasyETF EURO STOXX 50 (B1)							EUR		EUR						
EasyETF EURO STOXX 50 (A Distr)							EUR		EUR						
EasyETF EURO STOXX 50 (A Cap)									EUR						
ETFlab EURO STOXX 50							EUR								
EURO STOXX 50 Source ETF (A)							EUR								
EURO STOXX 50 Source ETF (B)							EUR								
HSBC EURO STOXX 50 ETF											EUR&GBP				
iShares EURO STOXX 50 (DE)						EUR	EUR		EUR				EUR		
iShares EURO STOXX 50				MXN	EUR	EUR	EUR		EUR		GBP				
Lyxor ETF EURO STOXX 50					EUR		EUR		EUR			EUR	EUR		
SPDR EURO STOXX 50 ETF		USD	USD	MXN											
UBS ETF EURO STOXX 50 I							EUR		EUR						
UBS ETF EURO STOXX 50 / (SM)							EUR								
Futures															
iShares EURO STOXX 50 ETF Fut (EUNF)								EUR							
EURO STOXX 50 Fut (FESX)								EUR							
Options															
iShares EURO STOXX 50 ETF Opt (EUN2)					EUR			EUR							
iShares EURO STOXX 50 ETF Opt										EUR					
Lyxor ETF EURO STOXX 50 ETF Opt										EUR					
SPDR EURO STOXX 50 ETF Opt	USD	USD	USD												
EURO STOXX 50 Opt (OESX)								EUR							
EURO STOXX 50, 1st Friday Weekly Opt (OES1)								EUR							
EURO STOXX 50, 2nd Friday Weekly Opt (OES2)								EUR							
EURO STOXX 50, 4th Friday Weekly Opt (OES4)								EUR							
EURO STOXX 50, 5th Friday Weekly Opt (OES5)								EUR							

4.1.2. EURO STOXX 50 index futures and options

Options and futures on EURO STOXX 50 are traded at Eurex. Eurex is one of the world's largest futures and options exchange, providing electronic access globally. Appendix 1 shows the volumes and notional values traded on selected exchanges. It is considered as one of the three largest derivatives exchanges, along with NYSE Euronext Liffe and Chicago Mercantile Exchange. Also, it is the leading clearing house in Europe. It was established in 1998 with the merger of Deutsche Terminbörse from Germany and SOFFEX from Switzerland.

Eurex operates in three trading phases: pre-trading, trading and post-trading. The Pre-Trading Period begins at 07:30 CET, and allows participants to prepare for the opening of trading: quotes and orders can then be entered, changed or deleted, but no market information such as best bid and ask prices, or offer sizes can be seen. The Opening Period, between the pre-trading and trading phase, consists of several steps taken to uncross the order books and to start the continuous trading phase. Uncrossing is performed through an auction process at the end of which matchable orders are executed. The execution price which results to the maximum executable order volume in the auction becomes the opening price level. Once this netting is done for a product, it automatically enters the Trading Period, which is continuous trading time. During the Trading Period, orders and quotes can be entered, modified and deleted, and orders are immediately matched if possible. Combination quotes and orders can only be entered during the Trading Period. The Trading Period ends with a closing auction. The daily closing price is computed as with the opening price: the daily closing price is the price at which the greatest possible volume can be matched in the respective contract in the auction. The trading ends at 22:00 CET for FESX and 17:30 CET for OESX.

While FESX and OESX have the same underlying, they differ from each other in many ways. Table 3 on the next page summarizes the contract specifications of FESX and OESX. For FESX, the three nearest quarterly months of the March, June, September and December contracts are traded. This means, that in the beginning of January, the contracts of March, June and September are traded. The closest month contract is the one with considerably higher volume and open interest. FESX trades 10 times the value of the underlying index, has a tick value of €10 and is cash settled at T+1, meaning that cash is delivered the next trading day of the settlement. The daily settlement price of FESX is derived from the VWAP of all transactions during the minute before 17:30 CET, provided that more than five trades transacted within this period. The last trading day is the third Friday of each maturity month if this is an exchange day; otherwise the exchange day immediately preceding that day. FESX trading is closed in the maturing futures contract on the last trading day at 12:00 CET. The final settlement price is established as the VWAP of the EURO STOXX 50 index values calculated between 11:50 and 12:00 CET. (Eurex)

Table 3: EURO STOXX 50 index futures and options characteristics

Contract specifications for the index futures contracts (FESX) and options contracts (OESX) on the EURO STOXX 50 index. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. European style refers to a European option, i.e. exercise is possible only at the expiration date. T+1 cash settlement refers to a settlement that is payable in cash the next trading day of the last trading day. Source: Eurex.

	FESX	OESX
Contract Unit	10	10
Minimum Tick Size	1 index points / €10	0.1 index points / €1
Regular Trading Hours	7:50- 22:00 CET	8:50 - 17:30 CET
Contract Months	March, June, September, December	Each month
Strike Prices	-	Strike intervals set at 50 index points
Style	Future	European index option
Exercise	-	On the last trading day, by 21:00 CET
Last Trading Day	Third Friday of the contract month	Third Friday of the contract month
Close of trading on last trading day	12:00 CET	12:00 CET
Settlement	Cash, T+1	Cash, T+1

OESX is also cash settled on a T+1 fashion, trades 10 times the value of the underlying index and has a tick value of €1. It has up to 199 months long of contract series trading: the three nearest successive calendar months, the three following quarterly months of the March, June, September and December cycle thereafter, the four following semi-annual months of the June and December cycle thereafter and the seven following annual months of the December cycle thereafter. OESX is a European-style option, and the last trading day is the final settlement day, which is the third Friday of each expiration month if this is an exchange day; otherwise the exchange day immediately preceding that day. The close of trading in the expiring option series on the last trading day is at 12:00 CET. The daily settlement price is established by the exchange, and it is determined through a modified Black-Scholes model, taking into account dividend expectations, current interest rates as well as other payments if necessary. Finally, the final settlement price is established by the exchange as the VWAP of the underlying index values calculated between 11:50 and 12:00, just like in the case of FESX. (Eurex)

4.2. Data used

High frequency intraday price data for EURO STOXX 50 index is used for the period under study of 2000-2009. The dataset was provided by STOXX Ltd. The index price dataset consists of the index levels every 15 second intervals for each Friday of the period. In most of previous studies using high-frequency data, only minute-per-minute had been available, so it could be that with 15 second interval data one can find more significant results. All in all, the data coverage of 10 years represents 40 quarterly futures expirations and 80 monthly options expirations as well as 401 control group days. There would have been 120 OESX expirations, but the days that coincide with the expiration days of FESX are excluded from the OESX sample. The control group consists of non-expiration Fridays. For all the sample days, data between 9:00 CET - 17:30 CET was available. For some days, there was data for until 17:50 CET, but since regular trading in OESX stops at 17:30 CET, this was chosen as the last observation to be included in the analysis. Also, a few days had a couple of missing data points. In those cases the index level of the preceding 15 second time period was assumed. If a Friday is a holiday, data from the previous day is used – the same procedure is used by Eurex for expiration days that would be otherwise holidays.

Moreover, for the EURO STOXX 50 index daily closing prices, monthly weightings, and daily trading volumes are used in order to compute firstly daily weightings and secondly weighted euro-denominated trading volume figures for the index. The number of expirations analysed is more, on average, than in previous studies[15]. The data has been retrieved from Datastream. The expiration day calendars, on the other hand, are available from Eurex's internet site[16]. If Friday has been a trading holiday, then data for Thursday is used. Finally, daily high, low, and close prices, daily turnover and index weight data is used for the OMXH25 index constituents for the period 2000-2009. These were available from Nasdaq OMX and Datastream.

---

[15] For example, Stoll and Whaley (1990b) analyse data for expirations for 1982-1986. Kan (2001) studies March 1989 to the end of 1992; Chamberlain et al. (1989) study the period Nuvember 1985-May 1987; Vipul (2005) studies the period 2001-2004.

[16] http://www.eurexchange.com, retrieved on February 9th, 2010.

5. Hypotheses and Methodology

In this section, I present the hypotheses for the study as well as the methodology. There are all in all five hypotheses to be tested, which I describe next. After this, I discuss more in detail the methods used in the study.

5.1. Hypotheses

In the light of the studies presented in Section 3, and given that EURO STOXX 50 is one of the most traded index futures in the world (see Appendix 2) one can easily assume that the index is subject to heavy program trading and potentially expiration day effects. Because of the unwinding of positions in the index, a heavier order imbalance is expected on expiration days compared to non-expiration days. Thus, higher volume, higher intraday volatilities and different intraday returns for the expiration days are expected compared to non-expiration days. Furthermore, since the trading is not likely to be information-based, the potential abnormally positive or negative intraday returns should reverse after the expiration.

As a side path of the study I also examine the spilling over of the expiration day effects. If expiration day effects on the EURO STOXX 50 index are found, Nokia is likely to experience significant demand shocks related to non-informational trading. Because of index arbitrage, a significant part of Nokia's trading volume could be attributable to the stock being a hedge in arbitrageurs' portfolios. Moreover, the returns are likely to co-move with other stocks of the EURO STOXX 50. Thus, stocks of the OMXH25 should also be affected, because of the hedge rebalancing of index investors, who trade the OMXH25 index where Nokia has a dominant position when it comes to turnover as described in Appendix 4. Hence, I expect that should there be expiration day effects for Nokia, the effects could "spill over" to other OMXH25 constituents as well.

First of all, in the light of the current literature expiration days are associated with a higher volume of the underlying index because of index arbitrage and spot position unwinding activities. Both discretionary liquidity trading and information-based trading are likely to be concentrated around the expiration, given that both types of traders trade when the market is thick as in Admati and Pfleiderer (1988). Hence, the first hypothesis to be tested is whether EURO STOXX 50 index futures' and options' expirations cause abnormally high volume on the underlying index or not.

Hypothesis 1: *Index futures and options expirations are associated with significantly higher volume on the index compared to non-expiration Fridays.*

Second, it is of interest to find out, whether the intraday returns on expiration days differ from non expiration days. As noted in section 3, according to previous studies some expiration day return effects have been found. Indeed, if the expiration is associated with a heavy order imbalance systematically in one direction, there might be significant effects in the returns. Moreover, if expiration days are associated with higher manipulation activities than non-expiration days, the returns may be different from non-expiration days, as in Aggarwal and Wu (2006). Hence, the second hypothesis is:

Hypothesis 2: *Index futures and options expirations are associated with significantly different returns on the index compared to non-expiration Fridays.*

Third, the volatility effect is tested. As noted before, some studies (see e.g. Stoll and Whaley 1987, 1990, 1997; Hancock 1993; Chow et al. 2003) have found that the volatility of the underlying index at expiration is significantly higher than on non-expiration days. Moreover, if Hypothesis 1 is accepted, implying a significantly higher volume on expiration days, the effect of the volume could be seen in the volatility as noted by some other studies (e.g. Karpoff, 1987). If the expiration day attracts manipulators to the market, it is likely to affect the volatility as in Hillion and Suominen (2004), Aggarwal and Wu (2006) and Comerton-Forde and Putnins (2007). Hence, the third hypothesis to be tested is whether EURO STOXX 50 futures and options expirations cause significantly higher volatility on the underlying index or not:

Hypothesis 3: *Index futures and options expirations are associated with significantly higher volatility of the index compared to non-expiration Fridays.*

Fourth, it is of interest to study whether there is some significant price reversal effects related to the unwinding of positions on the expiration day, as in the case of Stoll and Whaley (1987) and Chamberlain et al. (1989), for example. If expiration days are associated with higher liquidity, the returns are likely to reverse as discussed in Llorente et al. (2002) and Campbell et al. (1993). The argument goes that if expiration days of EURO STOXX 50 index futures and options are associated with higher than normal order imbalances to some direction, market makers may accommodate part of the buying or selling pressure. However, as noted in the literature (e.g. Stoll, 1978; Hu and Stoll, 1983; Grossman and Miller, 1988; Andrade et al. 2008), they do so only if they are rewarded for carrying the inventory risk. Also, reversals can be expected if expiration days attract manipulators, since manipulating activities tend to cause reversals (see e.g. Aggarwal and Wu, 2006; Comerton-Forde and Putnins, 2007). Hence, the fourth hypothesis is:

Hypothesis 4: *The price reversal after 12:00 CET on expiration days is more significant than the reversal on non-expiration Fridays.*

Finally, I test whether some or all of the potential expiration day effects experienced by Nokia as a EURO STOXX 50 index constituent are spilled over to other Finnish stocks on the OMXH25 index, which may be the case if Nokia is dominant enough to lead the co-movements of shares on the OMXH25 index. Moreover, program trading may introduce a common component to the stocks as in Hendershott and Seasholes (2008).

Hypothesis 5: *The expiration day effects on Nokia tend to spill over to other OMXH25 constituent stocks.*

Table 4 on the next page summarizes the hypotheses, and reflects them to findings of previous studies.

Table 4: Summary of hypotheses

The table describes the five hypotheses to be tested in the study, as well as whether findings from previous studies support the hypotheses or not.

Hypothesis		Previous studies
(1)	Index futures and options expirations are associated with significantly higher volume on the index compared to non-expiration Fridays.	Yes
(2)	Index futures and options expirations are associated with significantly different returns on the index compared to non-expiration Fridays.	Yes and no
(3)	Index futures and options expirations are associated with significantly higher volatility on the index compared to non-expiration Fridays.	Yes and no
(4)	The price reversal after 12:00 CET on expiration days is more significant than the reversal on non-expiration Fridays.	Yes and no
(5)	The expiration day effects tend to spill over from Nokia to other OMXH25 stocks.	Yes and no

5.2. Methodology

In this section, I describe the methodological assumptions and choices made in the study. First, I discuss how the volume and return effects are studied. Then I move on to the volatility effect, then to the price reversal effect and finally explain how the potential volume and volatility spillover from Nokia to other OMXH25 stocks is investigated in this study.

5.2.1. Expiration day volume effect

In order to study the volume effect, I compare the volume of the underlying stocks on expiration days to the volume of the same stocks during non-expiration days for three different sample periods (2000-2009; 2000-2004; and 2005-2009) to control for possible market cycles. In this study, volume is defined as euro-denominated turnover. As in some previous studies (see, e.g. Stoll and Whaley 1997), I also study the relative trading volumes for the expiration day instead of absolute volumes only. The relative trading volume of an expiration day is the ratio of trading volume during Friday to the total volume of the week; and the relative trading volume of an expiration week is the ratio of trading volume during the week compared to the trading volume of the month.

In the comparisons, I use the non-parametric Wilcoxon rank sum test, since a *t*-test is not appropriate because it assumes homoskedastic and normally distributed error terms, which is an assumption likely to be violated when analysing financial time series data. The test is used to assess whether two samples are from the same distribution. It assumes that all the observations from both groups are independent of each other and that the measurements are continuous. The null hypothesis is that the distributions of both groups are the same. The calculation of the statistic, usually called U, is done by first ranking all the observations into one ranked series. The ranks from observations which come from sample 1 are then added up. The sum of ranks for sample 2 can be easily computed then. The statistic, U is then computed as:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2} \tag{3}$$

and

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2} \tag{4}$$

where n_1 and n_2 are the sample sizes for samples 1 and 2, respectively; R_1 and R_2 are the sum of the ranks of samples 1 and 2, respectively. The smaller of U_1 and U_2 is then used. U is asymptotically normally distributed, and hence the standardized value is simply computed as:

$$z = \frac{U - m_U}{\sigma_U} \tag{5}$$

where m_U and σ_U represent the mean and the standard deviation of U, respectively. They are computed as:

$$m_U = \frac{n_1 n_2}{2} \tag{6}$$

and

$$\sigma_U = \sqrt{\frac{n_1 n_2(n_1+n_2+1)}{12}} \tag{7}$$

The significance of the test statistic can be then checked in tables of normal distribution. In this study, the abbreviation *W-stat* is used when talking about the test statistic.

I compare three kinds of samples: relative volume of the underlying stocks on the day before expiration (usually a Thursday); relative volume of the underlying stocks during the expiration day (usually a Friday); and the relative volume of the underlying stocks of the expiration week. I compare these values to the respective control group values, which are non-expiration week Thursdays, non-expiration Fridays and non-expiration weeks, respectively. If the expiration day is a Thursday, because of a banking holiday on Friday for instance, the respective preceding trading day is then naturally a Wednesday.

Moreover, in order to analyse more in detail the volume effect I use OLS regression analysis. Equation 8 shows a simple regression model for logarithmic euro-denominated trading volume:

$$VOL_t = \propto + \beta_F FEXP + \beta_O OEXP + \beta_D D + \varepsilon \qquad (8)$$

where VOL_t is the natural logarithm of volume for a time period *t; FEXP* is a dummy variable having a value 1 for quarterly expiration days of FESX and zero otherwise; *OEXP* is a dummy variable having a value of 1 for monthly expiration days of OESX (excluding the days when FESX also expires) and 0 otherwise; and *D* represents the number of trading holidays the week has, in order to control for a higher trading volume resulting of a smaller number of trading days within the week.

However, the weighted trading volume of DJES has not been stable during the 10 years investigated in this study. Figure 3 on the next page depicts the weighted monthly euro-denominated trading volume for the index. One can see, that the years 2000-2005 have experienced a downward trend in the volume, whereas the years between 2005 and 2008 have been years of increased volumes. Finally, the financial crisis has dried liquidity in the markets, the effect of which can be seen in the figure as well for the years 2008-2009.

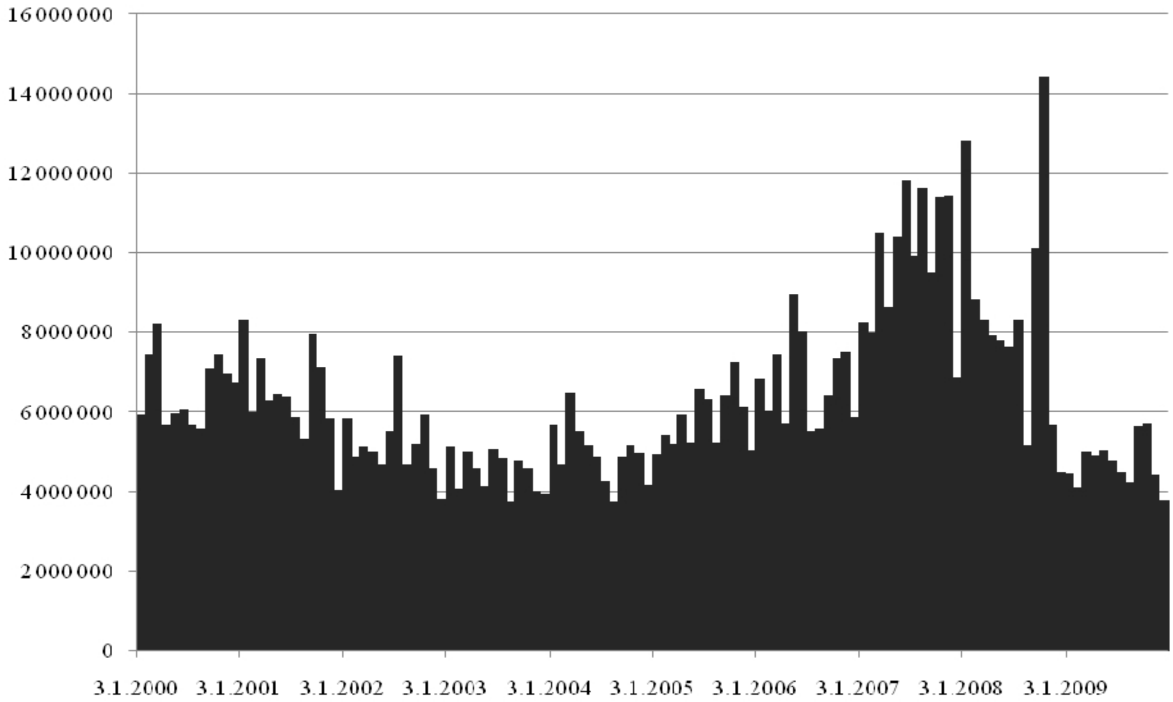

Figure 3: Monthly trading volumes of the EURO STOXX 50 index

The figure describes monthly weighted trading volumes in thousands of euros for the EURO STOXX 50 index, for the period 2000-2009. The EURO STOXX 50 is a blue chip capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. It is reviewed once every year, on September. Source: Datastream, Stoxx Ltd.

In accordance with Chen and Williams (1994), and Alkebäck and Hagelin (2004) I take care of the problem of trend stationarity[17] by regressing the natural logarithm of the trading volume against the time trend as follows:

$$\widehat{VOL_t} = \propto + \beta_1 D_{05-07} t + \beta_2 D_{05-07} t^2 + \beta_3 D_{08} t + \beta_4 D_{08} t^2 + \varepsilon \qquad (9)$$

where $D_{05\text{-}07}$ is a dummy set at 1 for all observations for the years 2005-2007; D_{08} is a dummy set at 1 for all observations after 2007; and t is a variable representing time. The results of the regression are represented in Table 5 below, and one can see that all of the coefficients are significant at the 0.01% significance level.

[17] See e.g. Dougherty (2002).

Table 5: Regression of logarithmic weighted trading volume of EURO STOXX 50 on time trend

The table represents the results of the regression of the natural logarithm of weighted euro-denominated trading volume of the EURO STOXX 50 index on the time trend *t*, which represents the month or day of the observation. The EURO STOXX 50 index is a blue chip capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. Both monthly and daily logarithmic trading volumes are analysed, and the period under review is 2000-2009. $D_{05\text{-}07}$ is a dummy set at 1 for all observations between beginning of 2005 and end of 2007; D_{08} is a dummy set at 1 for all observations after the year 2007. The *t*-statistics are in parentheses, and *** represents statistical significance at the 0.1% level.

$$\widehat{VOL_t} = \propto + \beta_1 D_{05-07}t + \beta_2 D_{05-07}t^2 + \beta_3 D_{08}t + \beta_4 D_{08}t^2 + \varepsilon$$

Model	α	β_1	β_2	β_3	β_4	R^2	*# of obs.*
Monthly	15.502	-0.0134	0.0002	0.0408	-0.0004	0.506	120
	(574.50)***	(-3.70)***	(4.89)***	(6.51)***	(-6.38)***		
Daily	12.411	-0.0005	0.0000	0.0020	0.0000	0.191	2561
	(1156.11)***	(-4.16)***	(5.88)***	(15.78)***	(-15.51)***		

Given the significance of the coefficients, the daily logarithmic trading volume is detrended as follows:

$$\widetilde{VOL_t} = VOL_t - (\beta_1 D_{05-07}t + \beta_2 D_{05-07}t^2 + \beta_3 D_{08}t + \beta_4 D_{08}t^2) \quad (10)$$

An augmented Dickey-Fuller test[18] confirms that the detrended time series are indeed stationary.

5.2.2. Expiration day return effect

As for the returns, I study logarithmic index returns on expiration days on several periods before and after the expiration at 12:00 CET. These returns are then compared to the control group's respective returns. I use the Wilcoxon rank sum test to compare the returns of the samples, because of the unrealistic assumptions of the *t*-test, as discussed previously. Once again, the time periods studied are 2000-2009; 2000-2004; and 2005-2009.

5.2.3. Expiration day volatility effect

When it comes to intraday volatility, I compare four sets of time windows around the expiration: volatility of the underlying index at 11:55-12:05 CET*;* 11:45-12:15 CET; 11:30-12:30 CET; and

[18] The results are reported in Appendix 5.

11:00-13:00 CET. I use an F-test for equality in variances to compare the volatilities of the samples to the control group. Also, since the F-test assumes normally distributed returns, I use the Levene's test[19] as a robustness check, since it does not suffer from such an assumption. The test assesses whether the population variances are equal for two samples. Hence, if the p-value obtained from the test is below the critical level, it is not probable that the differences between the sample variances occur randomly. Given a variable Y with a sample of size N divided into k subgroups, the test statistic, W is computed as:

$$W = \frac{(N-k)}{(k-1)} \frac{\sum_{i=1}^{k} N_i (Z_{i\cdot} - Z_{\cdot\cdot})^2}{\sum_{i=1}^{k} \sum_{j=1}^{N_i} (Z_{ij} - Z_{i\cdot})^2} \tag{11}$$

where W is the Levene's test statistic; k is the number of different subgroup to which the samples belong; N is the total number of samples; N_i is the number of samples in the ith group; Y_{ij} is the value of the jth sample form the ith group. Z_{ij} is usually defined as

$$Z_{ij} = \begin{cases} |Y_{ij} - \bar{Y}_{i\cdot}| \\ |Y_{ij} - \tilde{Y}_{i\cdot}| \end{cases} \tag{12}$$

where $\bar{Y}_{i\cdot}$ is the mean of ith group; and $\tilde{Y}_{i\cdot}$ is the median of ith group. In this case, the mean is used. Finally, $Z_{\cdot\cdot}$ and $Z_{i\cdot}$ are defined as follows:

$$Z_{\cdot\cdot} = \frac{1}{N} \sum_{i=1}^{k} \sum_{j=1}^{N_i} Z_{ij} \tag{13}$$

and

$$Z_{i\cdot} = \frac{1}{N_i} \sum_{j=1}^{N_i} Z_{ij} \tag{14}$$

where $Z_{\cdot\cdot}$ represents the mean of all Z_{ij} and $Z_{i\cdot}$ represents the mean of the Z_{ij} for group i. The Levene's test rejects the hypothesis of equal variances if $W > F(\alpha, k-1, N-k)$, where $F(\alpha, k-1, N-k)$ is

[19] Levene (1960).

the upper critical value of the F-test distribution, with k-1 and N-k degrees of freedom, and α is the significance level chosen.

In this study, the Levene's test statistic is abbreviated as L-stat, to distinguish from the Wilcoxon test statistic. Volatility is defined as the standard deviation of the logarithmic returns. Again, three time periods are studied for both the F-test and the Levene's test: 2000-2009; 2000-2004; and 2005-2009.

5.2.4. Price reversals

For the price reversals, I use the same technique as originally implemented by Stoll and Whaley (1987) but also used by several other previous studies (see e.g. Kan 2001, Felixson 2002, Schlag, 1996). New information should cause permanent price changes in share prices, whereas unwarranted volatility, as Stoll and Whaley (1997) argue, should cause temporary price changes. Stoll and Whaley (1991) use overnight returns from close to open and returns over the first half hour of trading on Friday for expirations at the open. For expirations at close, they use returns for the last half hour of trading on Friday and the overnight returns between Friday close and Monday open. Since in this case the expiration happens at 11:50-12:00 CET, their technique would yield inadequate results, so the time window had to be changed. In this case, the logarithmic index return before the expiration, R_{bt} is defined as the natural logarithm of returns on the index over the last t minutes before the expiration time at 12:00 CET:

$$R_{bt} = \ln\left(\frac{P_e}{P_{e-t}}\right) \tag{15}$$

Where P_e is the index price at expiration, i.e. at 12:00; and P_{e-t} is the index price t minutes prior to expiration. The logarithmic index return after the expiration, R_{at}, is the natural logarithmic returns over the next t minutes:

$$R_{at} = \ln\left(\frac{P_{e+t}}{P_e}\right) \tag{16}$$

Thus, the formula of return reversal *REV* of the index at expiration is:

$$REV_t = \begin{cases} R_{at} \ if \ R_{bt} < 0 \\ -R_{at} \ if \ R_{bt} \geq 0 \end{cases} \tag{17}$$

Hence, generally speaking if t is the time window, the return reversal is positive when $REV_t > 0$ if two consecutive price changes have opposite signs, and negative if two consecutive price changes have the same signs. Therefore, *REV* is the degree to which stock prices reverse after the expiration. Since reversals may occur on non-expiration dates as well, I compare the reversal around expiration to the reversals on non-expiration days with a Wilcoxon rank sum test. I study three time windows: t=15 minutes; t=30 minutes; t=60 minutes; t=3 hours. Also, I try to see if the expiration day returns are reversed the following day (t=1 day).

Also, I analyse the reversals more closely with the following regression:

$$R_{at} = \propto_0 + \beta_R R_{bt} + \beta_F FEXP + \beta_{FR} FEXP\ R_{bt} + \beta_O OEXP + \beta_{OR} OEXP\ R_{bt} + \varepsilon \tag{18}$$

where *FEXP* is a dummy for quarterly expiration days; and *OEXP* is a dummy for the expiration of OESX only. I investigate this in cases when t=30; t=10; and t=1h, again for the three sample periods: 2000-2009; 2000-2004; and 2005-2009.

Finally, with a Wilcoxon rank sum test, I study whether the returns of the expiration day are reversed during the next days after expiration.

5.2.5. Spillover of expiration day effects from Nokia to other OMXH25 constituents

Finally, I compare the expiration day and expiration week volumes and returns of OMXH25 index constituents excluding Nokia to the control group of non-expiration days and non-expiration weeks.

For the volume, I compare the relative volumes of OMXH25 without Nokia on expiration days of FESX and OESX to the control group, similarly as described in the previous section with a

Wilcoxon rank sum test. For returns, I use the same test to compare the cumulative median returns of the OMXH25 without Nokia around OESX and FESX expirations to the control group. Since no intraday data was available, I compare the returns on a daily basis.

As for volatility, I use an extreme value estimator proposed by Parkinson (1980), who showed that estimates based on the difference between high and low prices are good estimators of volatility. Assuming that the asset price follows a geometric Brownian motion without a drift term, his estimator for daily variance of returns can be written as:

$$\widehat{\sigma_p^2} = \frac{1}{4 \ln 2} (\ln H_t - \ln L_t)^2 \tag{19}$$

where H_t is the high and L_t the low price for the security for time t. Thus, according to this estimator, volatility is proportional to the natural logarithm of the daily high minus the natural logarithm of the daily low squared.

Parkinson (1980) shows that this extreme value method provides a better estimator of volatility than an estimator based on closing prices[20]. This method was also used in some previous studies on expiration day effects, for instance by Alkebäck and Hagelin (2004) and Vipul (2005). The control group mean expiration day volatility estimates of the OMXH25 with and without Nokia are compared to the figures for FESX and OESX expiration days. A student's t-test assuming unequal variances is used in the comparisons.

Finally, I regress the OMXH25 (without Nokia) logarithmic volume, logarithmic daily returns and daily volatility estimates on Nokia's respective figures; a dummy for FESX expirations (FEXP); and on a dummy for OESX expirations (OEXP). However, as with the EURO STOXX 50 index, also OMXH25 (without Nokia) has experienced trends in its trading volumes. Figure 4 shows graphically the development of monthly euro-denominated trading volumes.

---

[20] Wiggins (1992) finds the same conclusion.

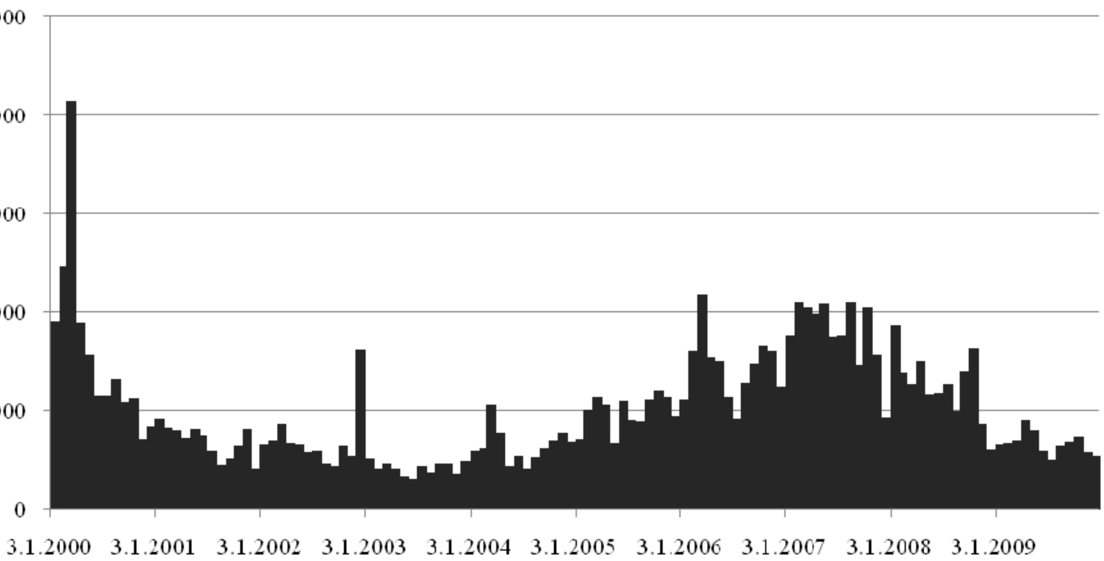

Figure 4: Monthly euro-denominated trading volumes of OMXH 25 excluding Nokia for 2000-2009

The figure describes the monthly weighted trading volumes in thousands of euros for OMXH25 Index without Nokia for the years 2000-2009. The index is a capitalization-weighted stock index having as constituents the 25 most traded shares on the Helsinki Stock Exchange. The index is reviewed twice a year. Source: Datastream, Nasdaq OMX.

Hence, I consider the issue of trend stationarity by regressing the trading volume against the time trend as in section 5.2.1. However, in this case instead of having a dummy $D_{05\text{-}07}$, I use $D_{04\text{-}07}$, since it appears to fit the equation better; the hike in the volume of OMXH25 excluding Nokia appears to grow starting already in early 2004. The results are reported in Table 6 below.

Table 6: Regression of weighted logarithmic OMXH25 volume excluding Nokia on time trend

The table represents the results of the regression of the natural logarithm of weighted euro-denominated trading volume of the OMXH25 Index excluding Nokia on the time trend t, which represents the month or day of the observation. The index is a capitalization-weighted index representing the 25 most traded shares on Nasdaq OMX Helsinki. The index is reviewed twice a year, in August and in February. Both monthly and daily volumes are analysed, and the period under review is 2000-2009. $D_{04\text{-}07}$ is a dummy set at 1 for all observations for the years 2004-2007; D_{08} is a dummy set at 1 for all observations after the year 2007. The t-statistics are in parentheses, and *** represents statistical significance at the 0.1% level.

$$\widehat{VOL_t} = \propto + \beta_1 D_{04-07} t + \beta_2 D_{04-07} t^2 + \beta_3 D_{08} t + \beta_4 D_{08} t^2 + \varepsilon$$

Model	α	β_1	β_2	β_3	β_4	R^2	*# of obs.*
Monthly	12.783	-0.0142	0.0003	0.0514	-0.0005	0.412	120
	(218.61)***	(-2,82)	(4.41)***	(4.22)***	(-4.08)***		
Daily	16.558	-0.001	0.000	0.0025	0.0000	0.326	2510
	(1035.10)***	(-10.69)***	(16.97)***	(15.97)***	(-15.28)***		

Since all the coefficients of the daily model are significant at the 0.1% level, the trend is removed as follows:

$$\widetilde{OMXVOL}_t = OMXVOL_t - (\beta_1 D_{04-07} t + \beta_2 D_{04-07} t^2 + \beta_3 D_{08} t + \beta_4 D_{08} t^2) \quad (20)$$

Once again, an Augmented Dickey Fuller test[21] confirms the stationarity of the detrended volume.

[21] The results of the test are reported in Appendix 5.

6. Empirical results

In this section, I present the empirical results of the study. First, I discuss the results regarding EURO STOXX index derivatives' expiration day effects, after which I move on to the spilling over of the effects to OMXH25. Finally, I summarize the results in section 6.3.

6.1. Volume effect

Table 7 below describes the results of a Wilcoxon rank sum test for medians, where the OESX and FESX expiration days' relative volumes are compared to the control group figures. One can see that both OESX and FESX expirations are associated with a statistically significantly higher relative volume on expiration Fridays than on non-expiration Fridays. For example, the median relative volume on FESX expiration days is 31.2% of the weekly volume in contrast to the control group's 19.9% for the sample 2000-2009. All the results are significant at the 0.1% level of significance.

Table 7: Median relative volumes of the EURO STOXX 50 index around expiration days

The table describes the median relative euro-denominated trading volumes of the EURO STOXX 50 index for three samples, 2000-2009: 2000-2004; and 2005-2009. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. The relative trading volume on Friday or Thursday is the euro-denominated trading volume on that day divided by the respective weekly figure. The relative volume of the week is the weekly euro-denominated trading volume divided by the respective monthly volume. "OESX only" refers to monthly expiration weeks of the EURO STOXX 50 index options, excluding the quarterly expirations of FESX. "FESX" refers to the quarterly expiration days of the EURO STOXX 50 index futures and the control group consists of non-expiration Thursdays, Fridays and weeks. In case of trading holidays, data for the previous day is used. The *W*-stat is the Wilcoxon rank sum test for medians statistic where options (OESX) and futures (FESX) expiration related relative volumes are compared to the control group relative volumes. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*
Control Group									
Thursday	401	0.218		201	0.219		200	0.215	
Friday	401	0.199		201	0.197		200	0.199	
Week	401	0.226		201	0.228		200	0.225	
OESX only									
Thursday	80	0.198	4.74***	40	0.203	2.13*	40	0.192	4.61***
Friday	80	0.250	9.28***	40	0.249	6.10***	40	0.251	7.02***
Week	80	0.247	6.23***	40	0.243	3.48***	40	0.250	5.32***
FESX									
Thursday	40	0.179	7.29***	20	0.184	5.11***	20	0.175	5.17***
Friday	40	0.312	9.28***	20	0.300	6.61***	20	0.325	6.98***
Week	40	0.284	6.23***	20	0.282	5.43***	20	0.286	5.74***

The relative volumes being higher on expiration days (Fridays) means that they tend to be lower on the other days of the week, for example on Thursdays, as can be seen from the table. Moreover, the relative volume of the week is higher on expiration weeks, which further signals that the expirations of FESX and OESX seem to be associated with a significantly higher trading volume.

Table 8 on the next page presents the regression results for absolute euro-denominated volume and detrended absolute volume, for three samples (2000-2009; 2000-2004; 2005-2009). By looking at the results, it is clear that the expiration of FESX, as well as of OESX have a positive effect on the daily trading volumes. The results are significant for FESX for all the samples at the 0.1% level; for OESX the results are significant (0.1%) for the whole sample as well as for the period 2005-2009. Moreover, the expiration of FESX seems to have a positive effect on the week's total volume – however, the test statistics are not significant.

Given these results, expiration days of index futures and options are related with statistically significantly higher volume on the underlying index. This applies for both FESX and OESX, and is robust for all three time samples studied. The most obvious explanation is the huge delta position unwinding as well as index arbitrage activities on the expiration days. Possibly this attracts other traders to the market because of the predictable higher liquidity on the expiration days as argued in the literature (see e.g. Barclay et al. 2006). Also, a concentration of discretionary liquidity trading as well as informed trading as in Admati and Pfleiderer (1988) may contribute to a stronger effect. One can also see that the results for 2000-2004 are not as significant as for 2005-2009, suggesting that the amount of spot position unwinding has increased during time.

Table 8: Regression results for absolute volume and detrended absolute volume

VOL_t represents a regression where the absolute euro-denominated trading volume of a day is regressed on the variables *FEXP*,*OEXP* and *D*. *FEXP* is a dummy having the value of 1 in the case of a quarterly EURO STOXX 50 index Futures (FESX) expiration, and 0 otherwise. *OEXP* is a dummy variable having the value of 1 in the case of monthly EURO STOXX 50 index options (OESX) expirations, excluding days when FESX also expires, and 0 otherwise. *D* represents the number of trading holidays in the week. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone, among others Nokia. For the sample 2000-2009, the number of FESX expiration is 40; the number of OESX expirations 80; and the control group consists of 401 non-expiration days. Three separate regressions are run: one for Thursdays, one for Fridays, and one for weekly volumes. Expiration days are Fridays, unless it is a trading holiday in which case the expiration occurs on the preceding day. If a Friday (Thursday) is a trading holiday, the figure of Thursday (Wednesday) is used. $V\hat{O}L_t$ represents a regression, where the detrended volume is regressed against the same dummies than in the former case. *t*-statistics are in parentheses.* indicates statistical significance at the 5% level; ** indicates significance at the 1% level; and *** indicates significance at the 0.1% level.

$$VOL_t = \propto + \beta_F FEXP + \beta_O OEXP + \beta_D D + \varepsilon$$

Sample years	Day	VOL_t						$V\hat{O}L_t$					
		α	β_F	β_O	β_D	R^2	*# of obs*	α	β_F	β_O	β_D	R^2	*# of obs*
2000-2009													
	Thu	12.59	-0.002	0.041	-0.202	0.032	521	12.49	-0.002	0.048	-0.289	0.084	521
		(636.60)***	(-0.03)	(0.87)	(-3.94)***			(12.49)***	(-0.03)	(1.08)	(-6.68)***		
	Fri	12.51	0.511	0.192	-0.357	0.214	521	12.40	0.515	0.191	-0.370	0.274	521
		(540.71)***	(5.89)***	(3.50)***	(-6.14)***			(623.77)***	(6.91)***	(4.05)***	(-7.40)***		
	Week	62.611	0.662	0.223	-13.15	0.802	521	62.04	0.690	0.267	-13.26	0.900	521
		(543.90)***	(1.53)	(0.82)	(-45.48)***			(795.34)***	(2.36)*	(1.45)	(-67.64)***		
2000-2004													
	Thu	12.48	-0.031	0.063	-0.276	0.075	261	12.48	-0.031	0.063	-0.276	0.075	261
		(479.20)***	(-0.32)	(-1.02)	(-4.39)***			(479.21)***	(-0.03)	(1.02)	(-4.40)***		
	Fri	12.39	0.536	0.160	-0.271	0.210	261	12.39	0.536	0.160	-0.271	0.210	261
		(401.52)***	(4.62)***	(2.19)*	(-3.65)***			(401.54)***	(4.62)***	(2.19)*	(-3.65)***		
	Week	62.03	0.767	0.086	-12.54	0.824	261	62.03	0.767	0.086	-12.54	0.824	261
		(409.71)***	(1.35)	(0.24)	(-34.36)***			(409.71)***	(1.35)	(0.24)	(-34.36)***		
2005-2006													
	Thu	12.70	0.020	0.026	-0.269	0.047	260	12.49	0.029	0.024	-0.306	0.097	260
		(429.24)***	(0.18)	(0.37)	(-3.45)***			(551.42)***	(0.34)	(0.44)	(-5.13)***		
	Fri	12.63	0.495	0.218	-0.451	0.246	260	12.42	0.504	0.216	-0.487	0.370	260
		(390.02)***	(4.09)***	(2.85)**	(-5.29)***			(497.35)***	(5.40)***	(3.65)***	(-7.41)***		
	Week	63.20	0.618	0.326	-13.85	0.804	260	62.20	0.684	0.248	-13.79	0.769	260
		(386.33)***	(1.01)	(0.84)	(-32.16)***			(344.68)***	(1.01)	(0.58)	(-29.03)***		

6.2. Returns effect

Table 9 on the next page describes the summary statistics of a Wilcoxon rank sum test comparing the median logarithmic returns on the index of the control group to the samples representing the expiration of FESX and OESX. One can see, that the expiration of FESX tends to be associated with higher returns before 12:00 CET, except for the period 11:45-12:00. For the whole sample, the period 9:00-12:00 CET experiences statistically significantly higher returns (at the 1% level) than for the control group: the median return around FESX expirations is 0.275 percentage points above that of the control group. This is a moderate difference economically, when assuming a 0.20 % transaction cost. The magnitude of the difference is even stronger for the sample 2005-2009, for which the difference is as much as 0.496 percentage points. Also, the logarithmic returns tend to be lower after the expiration of FESX than for the control group, suggesting an immediate return reversal after the expiration of the futures. Specifically, it appears that the returns right after the expiration, i.e. at 12:00-12:15 CET and at 12:00-13:00 CET, are associated with statistically significantly lower returns compared to the control group of non-expiration days, for all three time periods. For example, for the sample 2000-2009, the median returns on FESX expiration days at 12:00-13:00 CET are approximately 0.257 percentage points below the median returns of the control group for the same period. This finding is significant at the 0.1% level. As for OESX, the results are not as robust: only the sample 2005-2009 shows some significantly higher returns prior to expiration. For example, the median returns on OESX expiration days at 9.00-12:00 CET are 0.136 percentage points above the median returns of the control group in that sample. For the period 2000-2009, the index options expiration days are associated with significantly lower returns (at the 1% level) for 12:00-17:30. For that time window OESX median returns are 0.265 percentage points below the control group. Assuming a 0.20 % transaction cost, the differences are economically small.

Thus, it appears firstly that the returns right before the expiration of FESX and OESX tend to be significantly higher, especially for 2005-2009 than for the control group. Similarly, the returns after expiration tend to be significantly lower. The reason for the return effect could be a higher than normal short position unwinding on expiration days, or market manipulation activities as in Aggarwal and Wu (2006), who report price rises through the manipulation period and prices falling afterwards. The natural asymmetry of liquidity purchases and sales (Allen and Gorton,

1992) may be attracting manipulators to the market. However, to better confirm manipulation activities one would need detailed order book data. The reason why the significance is higher for some time windows for 2005-2009 may be related to the lower volatility in that sample, which is discussed next.

Table 9: Logarithmic intraday returns of around the expiration of FESX and OESX

The table describes the median logarithmic intraday returns (%) of the EURO STOXX 50 index for different time windows around the expiration of the index futures (FESX) and options (OESX). The underlying index is a capitalization-weighted blue-chip index covering the eurozone, and consisting of the 50 supersector leaders of the area. The data used is intraday 15 second interval index price data of the EURO STOXX 50 index for each Friday for 2000-2009, or Thursday if Friday is a trading holiday, obtained from STOXX Ltd. The control group consists of non-expiration days. The whole sample size equals 401 control group days, 40 FESX expiration days, and 80 OESX expiration days when FESX does not also expire. If Friday is a holiday, data for Thursday is used instead. Both FESX and OESX expire on the third Friday of the month at 12:00 CET: the former quarterly and the latter monthly. In addition to the sample covering 2000-2009, also the periods 2000-2004 and 2005-2009 are analysed. *W-stat* represents the test statistic of a Wilcoxon rank sum test for medians. * indicates statistical significance at the 5% level; ** at the 1% level and; *** at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*
9:00-17:30									
Control Group	401	0.060 %		201	0.064 %		200	0.026 %	
FESX	40	0.398 %	1.12	20	0.057 %	0.46	20	0.448 %	2.21 **
OESX only	80	-0.080 %	1.51	40	-0.245 %	2.34 **	40	0.046 %	0.22
9:00-12:00									
Control Group	401	0.061 %		201	0.061 %		200	0.060 %	
FESX	40	0.336 %	2.55 **	20	0.019 %	0.17	20	0.556 %	3.91 ***
OESX only	80	0.152 %	0.59	40	0.031 %	1.16	40	0.196 %	2.21 **
11:00-12:00									
Control Group	401	0.012 %		201	0.066 %		200	-0.009 %	
FESX	40	0.021 %	1.48	20	-0.040 %	0.42	20	0.210 %	2.64 **
OESX only	80	0.082 %	1.39	40	0.062 %	0.18	40	0.113 %	1.98 *
11:45-12.00									
Control Group	401	0.011 %		201	0.009 %		200	0.011 %	
FESX	40	-0.021 %	0.16	20	-0.174 %	1.65	20	0.071 %	1.46
OESX only	80	0.053 %	1.48	40	0.039 %	0.26	40	0.078 %	1.91
12:00-12:15									
Control Group	401	-0.008 %		201	-0.020 %		200	-0.006 %	
FESX	40	-0.142 %	4.24 ***	20	-0.211 %	3.88 ***	20	-0.071 %	2.04 *
OESX only	80	-0.060 %	1.62	40	-0.054 %	0.99	40	-0.062 %	1.35
12:00-13:00									
Control Group	401	-0.009 %		201	0.003 %		200	-0.014 %	
FESX	40	-0.266 %	4.99 ***	20	-0.305 %	3.49 ***	20	-0.242 %	3.76 ***
OESX only	80	-0.062 %	1.24	40	-0.101 %	1.57	40	-0.037 %	0.15
12:00-17:30									
Control Group	401	0.053 %		201	0.060 %		200	0.037 %	
FESX	40	-0.106 %	1.28	20	-0.199 %	1.09	20	-0.084 %	0.77
OESX only	80	-0.212 %	2.81 **	40	-0.161 %	2.10 *	40	0 %	2.10 *

6.3. Volatility effect

Table 10 on the next page describes the results of an F-test for equality of variances comparing the variances of the average logarithmic intraday returns around the expiration of FESX and OESX to the control group. A Levene's test is also computed, reinforcing the results of the F-test: according to it both FESX and OESX expirations are associated with a statistically significant hike in intraday volatility around the expiration time. Indeed, for FESX expiration days the intraday volatility around the expiration is roughly 5–7 times the volatility of non-expiration days for the sample 2000-2009, depending on which time window is compared. As for OESX expirations, the underlying index experiences a roughly 3–4 times higher volatility for the same sample compared to the control group.

However, as the samples used to compute the average logarithmic intraday returns for FESX and OESX are much smaller (40 and 80 days for the period 2000-2009, respectively) than for the control group (401), it is clear that the results can be inflated because of different sample sizes. To see whether the results are robust also when the difference in sample sizes is taken into account, the volatilities for 11:55-12:05, 11:45-12:15, and 11:30-12:30 were compared with means of simulation as in Corredor et al. (2001). A sample of 40 non-expiration days covering 2000-2009 from the control group is randomly picked against FESX and 80 against OESX, and their average 15 second intraday returns for each 15 second time interval are compared with an F-test to FESX and OESX respective average returns. This random sampling is replicated with 500 simulation runs, for all four time windows, for all three samples: 2000-2009; 2000-2004; and 2005-2009. The average simulated F-test statistics' p-values are then gathered as well as the p-values' standard errors. These figures are reported in Table 11. From the table it is clear that the results of Table 10 are robust when taking into account the difference in sample sizes: the expirations of FESX and OESX are associated with a significant jump in intraday volatility around the expiration time at 12:00 CET.

Table 10: Volatility of logarithmic returns around expiration of FESX and OESX vs. control group

The table describes the volatility of the intraday returns of the EURO STOXX 50 index around the quarterly expiration of index futures (FESX) and monthly expiration of index options (OESX). The underlying index is a capitalization-weighted blue-chip index covering the eurozone, and consisting of 50 supersector leaders of the area. The data used is intraday 15 second interval index price data of the EURO STOXX 50 index for each Friday for 2000-2009, or Thursday if Friday is a trading holiday, obtained from STOXX Ltd. The control group consists of non-expiration Fridays. The whole sample size equals 401 control group Fridays, 40 FESX expiration Fridays and 80 OESX only expiration Fridays. If Friday is a holiday, data for Thursday is used instead. σ represents volatility, and is calculated as the standard deviation of average 15 second logarithmic returns for the time window studied. Both FESX and OESX expire on the third Friday of the month at 12:00 CET: the former quarterly and the latter monthly. In addition to the sample covering 2000-2009, also 2000-2004 and 2005-2009 are analysed. *F-stat* refers to the test statistic of an *F*-test for equality of variances; *L-stat* refers to the test statistic of a Levene's test for equality of variances. * indicates statistical significance at the 5% level; ** at the 1% level and; *** at the 0.1% level.

	2000-2009				2000-2004				2005-2009			
	# of days	σ (x 10^3)	*F-stat*	*L-stat*	# of days	σ (x 10^3)	*F-stat*	*L-stat*	# of days	σ (x 10^3)	*F-stat*	*L-stat*
11:00-13:00												
Control Group	401	0.009			401	0.011			401	0.013		
FESX	40	0.043	24.43 ***	280.24 ***	40	0.061	29.66 ***	396.59 ***	40	0.056	18.48 ***	202.31 ***
OESX only	80	0.023	7.25 ***	223.78 ***	80	0.032	7.78 ***	150.57 ***	80	0.040	9.40 ***	178.32 ***
11:30-12:30												
Control Group	401	0.009			401	0.011			401	0.014		
FESX	40	0.051	32.11 ***	130.09 ***	40	0.069	36.30 ***	197.74 ***	40	0.067	23.17 ***	10.75 ***
OESX only	80	0.025	8.01 ***	102.40 ***	80	0.035	9.43 ***	65.58 ***	80	0.045	10.55 ***	80.35 ***
11:45-12:15												
Control Group	401	0.008			401	0.012			401	0.013		
FESX	40	0.062	53.08 ***	85.25 ***	40	0.074	40.54 ***	135.60 ***	40	0.089	46.96 ***	9.06 ***
OESX only	80	0.031	13.08 ***	59.55 ***	80	0.044	13.84 ***	36.58 ***	80	0.057	19.35 ***	46.83 ***
11:55-12:05												
Control Group	401	0.009			401	0.013			401	0.012		
FESX	40	0.060	46.70 ***	64.90 ***	40	0.088	43.96 ***	40.71 ***	40	0.075	41.52 ***	37.66 ***
OESX only	80	0.037	17.72 ***	44.28 ***	80	0.063	22.58 ***	11.81 ***	80	0.059	26.31 ***	33.04 ***

Table 11: Comparison of intraday volatilities with simulated control group sampling

The table describes the mean *p*-values of *F*-tests that were conducted with a simulation of 500 runs where equal sized samples of non-expiration Fridays were picked randomly from the control group to be compared to FESX and OESX. FESX stands for the day of expiration of the EURO STOXX 50 index futures series; OESX stands for the day of expiration of the EURO STOXX 50 index options series. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone. FESX expires quarterly and OESX monthly. Both FESX and OESX expire on the third Friday of the month at 12:00 CET. The whole sample size equals 401 control group days, 40 FESX expiration days and 80 OESX expiration days when FESX does not expire. The data used is intraday 15 second interval index price data of the EURO STOXX 50 index for each Friday for 2000-2009, or Thursday if Friday is a trading holiday, obtained from STOXX Ltd. The intraday volatilities of average 15-second logarithmic returns for 11:55-12:05 CET; 11:45-12:15 CET; and 11:30-12:30 CET of the randomly picked control group sample (CTRL) are compared with *F*-tests for equality of variances to the respective intraday returns of FESX and OESX samples. Control group sample sizes of 40 are used for FESX and 80 for OESX for the period 2000-2009; and similarly 20 and 40 for the periods 2000-2004 and 2005-2009. The mean of the *F*-tests' *p*-values as well as the standard errors are reported in the table. * indicates statistical significance at the 5% level; ** at the 1% level and; *** at the 0.1% level.

	2000-2009		2000-2004		2005-2009	
	FESX	*OESX*	*FESX*	*OESX*	*FESX*	*OESX*
11:55-12:05						
Mean *p*-value of *F*-test vs. CTRL	<0.001***	<0.001***	<0.001***	<0.001***	0.054	0.003**
Standard error of *p*-value estimate	0.0001	0.0000	0.0001	0.0000	0.0070	0.0006
11:45-12:15						
Mean *p*-value of *F*-test vs. CTRL	<0.001***	<0.001***	<0.001***	<0.001***	0.003**	<0.001***
Standard error of *p*-value estimate	0.00001	0.00000	0.00000	0.00004	0.00082	0.00015
11:30-12:30						
Mean *p*-value of *F*-test vs. CTRL	<0.001***	0.008**	<0.001***	<0.001***	0.047*	0.033*
Standard error of *p*-value estimate	0.0000	0.0000	0.0000	0.0005	0.0078	0.0058

To summarize, the expiration of both OESX and FESX increases the underlying index's volatility significantly right around the expiration time, also when controlling for sample size differences. The reason for this is likely to be a higher than normal order imbalance and possibly market manipulation activities, which are documented to increase volatility (see e.g. Hillion and Suominen, 2001; Aggarwal and Wu, 2006). It appears, however, that the intraday volatility is lower for the sample 2005-2009 than 2000-2004. It could be that the proportion of liquidity trading on expiration days has increased for the sample 2005-2009 compared to 2000-2004, reducing volatility. This would support findings such as in Li and Wu (2006) and Suominen and Rinne (2010), namely that liquidity trading dampens volatility. Similarly, the reduced intraday volatility in turn would then be the reason why some of the differences in intraday returns for the sample 2005-2009 are more significant than for 2000-2004. In the light of these findings, we can easily accept the hypothesis of a higher expiration day intraday volatility for the EURO STOXX 50 index on the expiration days of FESX and OESX.

6.4. Price reversal effect

Table 12 below describes the summary statistics of a Wilcoxon rank sum test comparing the return reversal effects. Five reversal periods are studied as pointed out in section 5: for the time windows 11:45-12:15; 11:30-12:30; 11:00-13:00; 9:00-15:00; and the return reversal for the day following an expiration day.

Table 12: Results of a Wilcoxon rank sum test for return reversals

The table describes the results of a Wilcoxon rank sum test comparing the median logarithmic return reversals of the control group versus the expiration days of EURO STOXX 50 index futures (FESX) and options (OESX). The underlying index is a capitalization-weighted blue-chip index covering the eurozone, and consisting of 50 supersector leaders of the area. The data used is intraday 15 second interval index price data of the EURO STOXX 50 index for each Friday for 2000-2009, or Thursday if Friday is a trading holiday, obtained from STOXX Ltd. The control group consists of non-expiration Fridays. If Friday is a holiday, data for Thursday is used instead. The whole sample size equals 401 control group days, 40 FESX expiration days and 80 OESX expiration days when FESX does not expire. If Friday is a holiday, data for Thursday is used instead. Both FESX and OESX expire on the third Friday of the month at 12:00 CET: the former quarterly and the latter monthly. The reversal REV_t for the time window t is calculated as follows:

$$REV_t = \begin{cases} R_{at} \; if \; R_{bt} < 0 \\ -R_{at} \; if \; R_{bt} \geq 0 \end{cases}$$

where R_{at} is the return after expiration for the time period t; R_{bt} is the return before expiration for the time period t. *W-stat* is the test statistic of a Wilcoxon rank sum test for comparing the medians of *FESX* and O*ESX* to the control group. * indicates statistical significance at the 5% level; ** at the 1% level and; *** at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of days	*Median*	*W-stat*	*# of days*	*Median*	*W-stat*	*# of days*	*Median*	*W-stat*
A REV $_{15min}$									
Control Group	401	0.001 %		201	0.001 %		200	0.002 %	
FESX	40	0.004 %	0.40	20	0.004 %	0.39	20	0.006 %	0.25
OESX	80	0.063 %	3.05 ***	40	0.066 %	1.63	40	0.063 %	2.83 ***
B REV $_{30min}$									
Control Group	401	-0.076 %		201	-0.146 %		200	-0.027 %	
FESX	40	0.069 %	0.79	20	0.054 %	0.65	20	0.087 %	0.44
OESX	80	0.064 %	2.29 **	40	0.070 %	1.98 *	40	0.064 %	1.25
C REV $_{1h}$									
Control Group	401	0.010 %		201	0.009 %		200	0.013 %	
FESX	40	0.029 %	0.45	20	0.029 %	0.31	20	0.043 %	0.27
OESX	80	0.021 %	0.46	40	0.003 %	0.36	40	0.037 %	0.43
D REV $_{3h}$									
Control Group	401	0.003 %		201	-0.022 %		200	0.041 %	
FESX	40	0.128 %	1.35	20	0.149 %	1.84	20	0.046 %	0.09
OESX	80	0.024 %	1.01	40	0.008 %	0.73	40	0.029 %	0.67
E REV $_{1d}$									
Control Group	401	-0.001 %		201	0.013 %		200	-0.026 %	
FESX	40	0.397 %	0.17	20	-0.400 %	0.30	20	0.554 %	2.37 **
OESX	80	-0.198 %	0.93	40	-0.382 %	1.77	40	0.130 %	0.58

The reversal coefficients are positive for most of FESX and OESX expirations, suggesting that the returns reverse in the short term. However, only a few of the statistics are statistically significant. Surprisingly, OESX seems to have more significant reversal figures: for instance, the 15 minute reversal associated with the expiration of OESX only is significant at the 0.1% level of significance for the whole sample 2000-2009 as well as for the sample 2005-2009. Also, the 30 minute reversals for 2000-2009 and 2000-2004 around OESX expirations are significant at the 1% level and 5% level, respectively. For FESX, it appears that only the daily returns' reversals for the sample 2005-2009 are statistically significant.

The reversals are studied from another perspective in the fashion of Felixson (2002) in Table 13 on the next page, where intraday logarithmic returns of the index for time window *t* after expiration are regressed on the returns for the same time window before the expiration; dummy variables representing the expirations of FESX and OESX only; the product of these with the returns before the expiration; as well as the logarithmic trading volume of the index on the day. The regression is run by omitting some variables, and from four different models the one presented in Table 13 yielded the highest explanatory power and most significant coefficients, when excluding trading volume as an explanatory variable. It appears that on expiration days of FESX, the returns after the expiration at 12:00 CET are significantly lower given the negative value of β_F for all three time windows studied which is in line with the results described earlier when comparing returns in section 6.2. The similar seems to be true for OESX – however the coefficients are not statistically significant.

Furthermore, the product of FESX and OESX dummies with β_R has opposite coefficients than β_R for the 15 minute window. This suggests that the returns indeed reverse more, on average, on expiration days. For FESX, the magnitude of the reversal is 23% of the returns before expiration, for the 15 minute window, which is significant at the 1% level of significance for the sample 2000-2009. For OESX, the magnitude of the reversal for the same sample for the 15 minute and 30 minute reversals appears to be as much as 62% and 18%, respectively, of the returns before expiration, while the significance levels are 0.1% and 5%, respectively. Hence, it appears that the reversals on an intraday basis are stronger for OESX expirations, the reason for which can be the fact that OESX has a double sample size compared to FESX.

Table 13: Regression of returns after expiration to returns before expiration

The table describes the regression coefficients of a regression where the intraday logarithmic returns of the EURO STOXX 50 index after expiration (R_{at}) is regressed on the returns before expiration (R_{bt}), a dummy representing the quarterly expiration of the EURO STOXX 50 index futures (*FESX*), a dummy representing the monthly expiration of the EURO STOXX 50 index options (*OESX*) and the product of these to R_{bt}. The time windows studied are *t*=15min; *t*=30min; and *t*=1h. Three samples are studied: 2000-2009; 2000-2004; and 2005-2009. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone. The data used is intraday 15 second interval index price data for each Friday for 2000-2009, or Thursday if Friday is a trading holiday. The data is obtained from STOXX Ltd. The control group consists of non-expiration Fridays. If Friday is a holiday, data for Thursday is used instead. The whole sample size equals 401 control group days, 40 FESX expiration days, and 80 OESX expiration days when FESX does not expire. If Friday is a holiday, data for Thursday is used instead. Both FESX and OESX expire on the third Friday of the maturity month at 12:00 CET. The *t*-statistics are in parentheses. * indicates statistical significance at the 5% level; ** at the 1% level and; *** at the 0.1% level.

$$R_{at} = \propto_0 + \beta_R R_{bt} + \beta_F FEXP + \beta_{FR} FEXP\, R_{bt} + \beta_O OEXP + \beta_{OR} OEXP\, R_{bt} + \varepsilon$$

Panel A: 2000-2009

	α	β_R	β_F	β_O	β_{FR}	β_{OR}	R^2	# of obs
t=15 min	-0.0001	0.2220	-0.0013	0.0000	-0.2257	-0.6203	0.12	521
	(-1.54)	(3.73)***	(-4.24)***	(-0.21)	(-2.61)**	(-7.15)***		
t=30 min	-0.0001	-0.0039	-0.0021	-0.0003	0.1661	-0.1828	0.07	521
	(-0.73)	(-0.08)	(-5.38)***	(-1.31)	(-1.93)	(-2.21)*		
t=1h	0.0000	-0.1443	-0.0006	0.0004	0.0985	0.0980	0.08	521
	(-0.19)	(-3.24)**	(-4.34)***	(-0.24)	(2.12)*	(-2.10)*		

Panel B: 2000-2004

	α	β_R	β_F	β_O	β_{FR}	β_{OR}	R^2	# of obs
t=15 min	-0.0002	0.2009	-0.0020	0.0002	-0.2779	-0.6290	0.14	521
	(-1.38)	(2.65)**	(-4.68)***	(-0.71)	(-2.69)**	(-4.39)***		
t=30 min	-0.0001	0.2523	-0.0029	-0.0006	-0.1134	-0.4759	0.09	521
	(-0.25)	(2.54)**	(-3.81)***	(-1.13)	(-0.77)	(-2.28)*		
t=1h	0.0000	0.0915	-0.0028	-0.0006	-0.0620	-0.2458	0.06	521
	(-0.08)	(-1.41)	(-3.63)***	(-0.98)	(-0.53)	(-1.52)		

Panel C: 2005-2009

	α	β_R	β_F	β_O	β_{FR}	β_{OR}	R^2	# of obs
t=15 min	-0.0001	0.2542	-0.0008	0.0001	-0.1376	-0.6430	0.13	521
	(-0.82)	(2.68)**	(-1.66)	(-0.42)	(-0.75)	(-5.34)***		
t=30 min	-0.0002	-0.5166	-0.0013	-0.0001	0.6596	0.3364	0.20	521
	(-0.91)	(-7.53)***	(-1.87)	(-0.19)	(3.19)**	(3.04)**		
t=1h	-0.0002	-0.3660	-0.0021	0.0008	0.5492	-0.0809	0.21	521
	(-1.01)	(-6.25)***	(-2.50)*	(-1.54)	(2.71)**	(-0.69)		

Finally, it is of interest to compare the cumulative returns of FESX, OESX and the control group before and after the expiration day. Figure 5 below depicts the cumulative median returns of an investment of €1 two days before expiration for the control group of non-expiration days, FESX expiration days, and OESX expiration days. Moreover, Appendix 6 describes the results of a Wilcoxon rank sum test where the median daily returns around FESX and OESX expiration days are compared to the control group, in order to assess the reliability of Figure 5. From the figure one can see that the positive returns on the expiration day of FESX tend to be reversed the subsequent day. This difference has a Wilcoxon rank sum test *p*-value of 9.6% for the whole sample and 5.4% for the sample 2000-2004, compared to the control group. For OESX, the return pattern is completely different: the returns are negative until the third day after expiration, after which they bounce. Indeed, the median 3rd day return is statistically significantly lower than the for the control group only for the subsample 2000-2004, having a Wilcoxon rank sum test *p*-value of 0.02%.

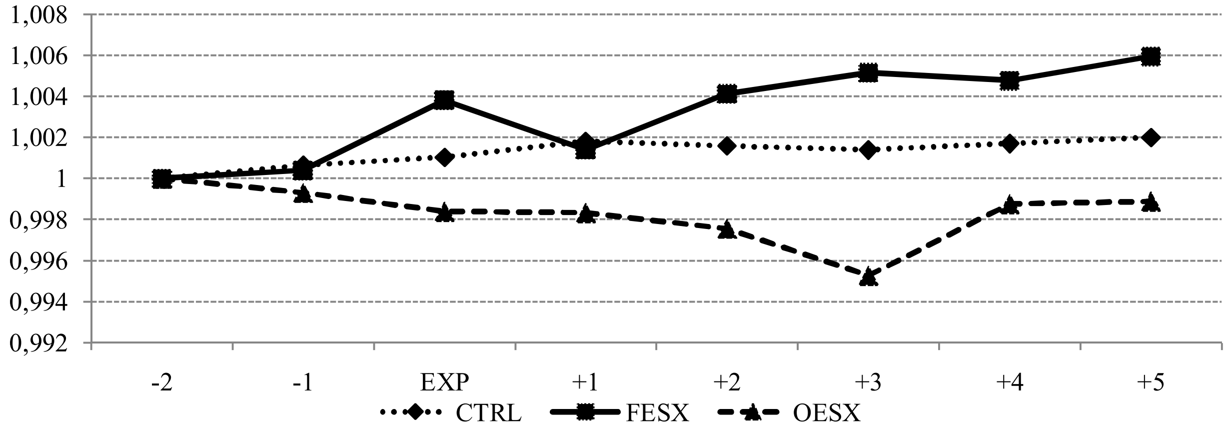

Figure 5: Cumulative median logarithmic returns before and after the expiration of FESX and OESX

The figure describes the development of the value of €1 invested two days before the expiration date, on Wednesday in the EURO STOXX 50 index. The returns used in computing the figure are median daily logarithmic returns for three types of Fridays for 2000-2009: CTRL refers to the control group of non-expiration Fridays (401observations), FESX to the sample of quarterly expiration days of EURO STOXX 50 index futures (40 observations), and OESX to the monthly expirations of the Index Options (80 observations), excluding days when FESX also expires. If Friday has been a trading holiday, return figures of Thursday are used instead. The EURO STOXX 50 index is a capitalization-weighted index consisting of 50 supersector leaders of the eurozone. Both FESX and OESX expire on the third Friday of the maturity month at 12:00 CET.

The difference between FESX and OESX is interesting. From the figure, it appears that part of the expiration day returns of FESX are reversed on the subsequent day. For OESX, it seems that the returns experience some continuation instead of reversal for the following three days, after which they bounce. Obviously one has to be careful in interpreting these results because of the mixed results between the year samples and the potential window-dressing activities of portfolio managers at the end of the month, which can at least partly explain the strange return pattern on the week after expiration. Despite the relatively low statistical significance, Figure 5 still gives some support for expiration related returns reversing the following day, when it comes to FESX.

To summarize, I find evidence of significant intraday return reversals on expiration days. A return reversal can be justified if the returns right before expiration are the result of heavy liquidity trading instead of informed trading as argued by Llorente et al. (2002). Both information-based trading and discretionary liquidity trading are likely to be concentrated (Admati and Pfleiderer, 1988). Thus, my findings support the inventory consideration of market makers discussed in section 3.3. Market makers accommodate heavy buying or selling pressure only if they can expect a positive return (e.g. Stoll, 1978; Hu and Stoll, 1983; Grossman and Miller, 1988; Campbell et al. 1983; Andrade et al. 2008). Hence, if expiration days are associated with significant order imbalances to one direction before the expiration time, the returns are likely to reverse afterwards. Finally, the reversals can also result from manipulation activities, as in Comerton-Forde and Putnins (2007) or Aggarwal and Wu (2006). For example, Aggarwal and Wu (2006) show that stock prices tend to rise through manipulation periods and fall after it, which is exactly the return pattern observed here. Obviously in order to confirm this one would need detailed order book data.

6.5. Spilling over of expiration day effects from Nokia to other OMXH25 shares

In this section I discuss whether there is evidence of expiration day effects spilling over from Nokia to other OMXH25 constituent shares. Since Nokia is part of both the EURO STOXX 50 index and the OMXH25 index, it could be that part of the expiration day effects related to FESX and OESX expirations are spilled over to OMXH25. This assumption is plausible if Nokia co-moves strongly enough with EURO STOXX 50 on expiration days.

6.5.1. Volume

Table 14 on the next page shows the results of a Wilcoxon rank sum test for medians, where the relative volumes of the OMXH25 index without Nokia around OESX and FESX expirations are compared to the control group. It appears that the expiration days of OESX and FESX are associated with a significantly higher relative volume on the OMXH25 index excluding Nokia compared to the control group. For the whole sample, about 24.4% of weekly turnover on expiration weeks of FESX occur on the expiration day, on average. The similar figure for non-expiration days is 20.1%.

Table 14: Median relative trading volumes of OMXH25 index without Nokia

The table presents the median relative euro-denominated trading volumes of OMXH25 index without Nokia for three samples, 2000-2009; 2000-2004; 2005-2009. The index is a capitalization-weighted index representing the 25 most traded shares on Nasdaq OMX Helsinki. The index is reviewed twice a year, in August and in February. In this case, Nokia's volume is removed from the OMXH25 figure. The relative trading volume on Friday or Thursday is the portion of the euro-denominated trading volume on that day divided by the respective weekly figure. The relative volume of the week is the weekly euro-denominated trading volume divided by the respective monthly volume. "OESX only" refers to monthly expirations of the EURO STOXX 50 index options excluding the days when the futures expire, "FESX" to quarterly expiration days of the EURO STOXX 50 index futures and the control group consists of non-expiration Thursdays, Fridays and weeks. If a Friday (Thursday) is a trading holiday, the figure of Thursday (Wednesday) is used. Both OESX and FESX expire on the third Friday of their maturity month, or the previous day if Friday is a holiday. The *W-stat* is the Wilcoxon rank sum test statistic where index Options (OESX) and Futures (FESX) expiration related median relative volumes are compared to the control group median relative volumes. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*	# of obs.	Median	*W-stat*
Control Group									
Thursday	401	0.219		201	0.221		200	0.218	
Friday	401	0.201		201	0.208		200	0.197	
Week	401	0.227		201	0.231		200	0.225	
OESX									
Thursday	80	0.213	1.47	40	0.218	0.44	40	0.211	1.65
Friday	80	0.221	2.93**	40	0.210	0.36	40	0.233	4.03***
Week	80	0.233	1.96*	40	0.224	0.01	40	0.236	3.08**
FESX									
Thursday	40	0.217	0.39	20	0.220	0.17	20	0.214	0.81
Friday	40	0.244	4.68***	20	0.239	1.83	20	0.245	4.98***
Week	40	0.256	2.93**	20	0.247	1.11	20	0.260	3.18**

The *W*-stats are not statistically significant for the period 2000-2004, whereas for 2005-2009 the statistics are significant at the 1% level for the expiration week and at the 0.1% level for the expiration day, both for FESX and OESX. As for expiration week Thursdays, there is some evidence of a lower relative volume for the samples 2000-2009 and 2005-2009. Obviously this increase in volumes on expiration days is not necessarily only related to the expiration of FESX, but can also be related to the expiration of OMXH25 constituents' options on the same day. Nevertheless, one can see that the difference between the monthly (OESX) and quarterly (FESX) expiration days is high, suggesting that there seems to be some effect related to the expiration of FESX. The explanation for this is that the index arbitrageurs trading the OMXH25 index must rebalance their portfolios when highly weighted stocks such as Nokia experience volatile price development, which could hence bring the whole index volume up.

6.5.2. Volatility

The average Parkinson high-low volatility estimates of the control group for the OMXH25 index and the OMXH25 index without Nokia are compared to the figures of FESX and OESX for 2000-2009 with a student's *t*-test. The results are presented in Table 15 below. One can see that the estimates of daily volatilities of FESX and OESX are not significantly higher than for the control group for OMXH25 Index with and without Nokia. Thus, in the light of these findings, the volatility of Nokia does not seem to transfer to the OMXH25 index around the expiration of FESX and OESX, at least based on expiration day volatility estimates. However, an analysis of high frequency intraday data would be required in order to capture the potential volatility effect better. Due to unavailability of such data, a detailed analysis was not possible.

Table 15: Expiration day volatility estimates of OMXH25 with and without Nokia 2000-2009

The table represents the volatility estimates of the OMXH25 for the control group of non-expiration Fridays (401 days), as well as for the expiration of FESX (40 days) and OESX (80 days), the EURO STOXX 50 index futures and options series, respectively. FESX and OESX are index derivatives having as an underlying the EURO STOXX 50 index, a capitalization-weighted index consisting of 50 supersector leaders of the eurozone. FESX expires quarterly, and OESX monthly, on the third Friday of the month. Here OESX observations consist of days when OESX only expires, without FESX. If a Friday is a holiday, the expiration occurs on the previous day. Thus, for the control group the same is assumed. The volatility estimate figures for the index excluding Nokia are computed as well (OMXH25 w/o Nokia). The volatility estimate is computed according to the High-Low method of Parkinson (1980). The *t*-stat represents the results of a student's *t*-test for means assuming unequal variances. The period under review is 2000-2009. OMXH25 is a capitalization-weighted index consisting of the 25 most traded shares in the Helsinki Stock Exchange. The index is reviewed twice a year; in February and in November. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	OMXH25			OMXH25 w/o Nokia		
	# of obs	Mean	*t*-stat	# of obs	Mean	*t*-stat
Control Group	401	0.000179		401	0.000639	
FESX	40	0.000248	0.86	40	0.000686	0.37
OESX	80	0.000183	0.11	80	0.000648	0.10

6.5.3. Returns

Table 16 below compares the cumulative median returns of the OMXH25 Index without Nokia around OESX and FESX expirations to the control group with a Wilcoxon rank sum test.

Table 16: Cumulative returns on the OMXH25 Index without Nokia

The table describes the results of a Wilcoxon rank sum test of medians for the logarithmic returns and median logarithmic cumulative returns of the OMXH25 Index without Nokia around the expiration of the index futures (FESX) and options (OESX) of EURO STOXX 50 compared to the control group of non-expiration days (CTRL). OMXH25 Index is a capitalization weighted index consisting of the 25 most traded shares on the Helsinki Stock Exchange, including Nokia. In this case, Nokia is removed from the index. EURO STOXX 50 index is a capitalization-weighted blue-chip index covering the eurozone, consisting of the 50 supersector leaders of the area, including Nokia. FESX expires quarterly and OESX monthly, on the third Friday of the expiration month (or Thursday if Friday is a trading holiday). Hence, the control group consists of non-expiration Fridays or Thursdays if the Friday is a trading holiday. OESX consists of monthly expirations of the options, excluding days when FESX also expires. *p*-value of *W*-test refers to the *p*-value of the Wilcoxon rank sum test of medians comparing FESX and OESX to CTRL. The numbers in brackets tell the time window for the cumulative returns, 0 being the expiration day. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of obs	Median	*p*-value of *W*-test	# of obs	Median	*p*-value of *W*-test	# of obs	Median	*p*-value of *W*-test
CTRL									
Exp week	401	0.278 %		201	-0.011 %		200	0.547 %	
Thursday [-1]	401	-0.019 %		201	-0.214 %		200	0.135 %	
Friday [0]	401	0.166 %		201	0.247 %		200	0.100 %	
Fri-Mon [0,1]	401	0.166 %		201	0.316 %		200	0.241 %	
Fri-Wed [0,3]	401	0.339 %		201	0.264 %		200	0.453 %	
Fri-Fri [0,5]	401	0.150 %		201	0.011 %		200	0.312 %	
FESX									
Exp week	40	-0.551 %	0.048*	20	-2.174 %	0.010**	20	-0.057 %	>0.20
Thursday [-1]	40	-0.136 %	>0.20	20	-0.409 %	>0.20	20	-0.001 %	>0.20
Friday [0]	40	-0.230 %	0.102	20	-0.608 %	0.005**	20	0.284 %	>0.20
Fri-Mon [0,1]	40	0.097 %	>0.20	20	-0.678 %	0.009**	20	0.818 %	0.123
Fri-Wed [0,3]	40	0.126 %	>0.20	20	-0.681 %	0.011*	20	0.746 %	0.091
Fri-Fri [0,5]	40	0.570 %	>0.20	20	-0.104 %	>0.20	20	1.188 %	0.125
OESX									
Exp week	80	0.899 %	>0.20	40	0.804 %	>0.20	40	0.921 %	>0.20
Thursday [-1]	80	0.149 %	>0.20	40	0.158 %	0.131	40	0.113 %	>0.20
Friday [0]	80	0.149 %	>0.20	40	0.021 %	0.134	40	0.322 %	>0.20
Fri-Mon [0,1]	80	0.204 %	>0.20	40	-0.264 %	0.019*	40	0.798 %	0.092
Fri-Wed [0,3]	80	0.233 %	>0.20	40	-0.778 %	0.021*	40	0.899 %	>0.20
Fri-Fri [0,5]	80	0.698 %	0.049*	40	0.498 %	>0.20	40	0.769 %	0.077

One can see, that the expiration weeks of FESX tend to be associated with statistically significantly lower returns for the OMXH25 excluding Nokia, for the sample 2000-2009 (at the 5% level) and for 2000-2004 (at the 1% level). Also, the expiration of FESX tends to be associated with significantly lower cumulative returns compared to the control group for the first three days following expiration days for the sample 2000-2004. Similar results can be seen for OESX. While it could be that the relationship between Nokia and OMXH25 constituents was stronger in 2000-2004, this result must be interpreted with care since it does not hold for 2005-2009 nor does it hold for the whole sample. Moreover, for the sample 2000-2009 the expirations of OESX are associated with significantly higher median cumulative five-day returns after the expiration. This may be related to end of month window dressing activities of portfolio managers mentioned earlier, and hence is likely not to be related to the expiration day itself.

6.5.4. Summary of spilling over of expiration day effects

Table 17 below represents the results of a series of regressions where 1) the detrended logarithmic volume, 2) the logarithmic returns and 3) the Parkinson (1980) High-Low volatility estimates of the OMXH25 index without Nokia are regressed on the respective figures of Nokia (NOK); a dummy variable for FESX expirations (FESX); and a dummy variable for OESX expirations (OESX).

Table 17: Spilling over of effects from Nokia to other OMXH25 constituents

The table describes the results of regressions where (1) the detrended volume, (2) the logarithmic returns and (3) the estimated volatility of OMXH25 index without Nokia are regressed on Nokia's daily figures (NOK), a dummy having the value 1 on expiration days of the EURO STOXX 50 index futures and 0 otherwise (FESX), and on a dummy having the value 1 on expiration days of the EURO STOXX 50 index options, excluding days when FESX also expires, and 0 otherwise (OESX). The sample includes all the Fridays of 2000-2009 or Thursdays if Friday is not a trading day. VOLUME here is the detrended euro-denominated trading volume; LOGRETURNS are the natural logarithmic daily returns; and VOLATILITY is the Parkinson (1980) High-Low volatility estimate. OMXH25 is a capitalization-weighted blue-chip index consisting of the 25 most traded stocks on the Helsinki Stock Exchange. In this analysis, Nokia is removed from the index in order to capture the potential spilling over of the expiration day effects better. EURO STOXX 50 index is a blue-chip index consisting of the 50 supersector leaders of the eurozone. FESX expires quarterly and OESX monthly. * indicates statistical significance at the 5% level; ** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	NOK	FESX	OESX	R^2	# of obs
(1) VOLUME					
coefficient	0.3374	0.1983	-0.0366	0.131	521
p-value of *t*-stat	<0.001***	0.018*	>0.20		
(2) LOGRETURNS					
coeff	0.2969	-0.0011	-0.0005	0.384	521
p-value of *t*-stat	<0.001***	>0.20	>0.20		
(3) VOLATILITY					
coeff	0.4195	0.0000	0.0001	0.225	521
p-value of *t*-stat	<0.001***	>0.20	>0.20		

One can see that the figures of Nokia tend to have a positive relationship with the figures of OMXH25 without Nokia since all NOK coefficients are significant at the 0.01% level. As for the expirations of FESX and OESX, it appears that only the expirations of FESX are associated with a statistically significantly higher volume on expiration days, at the 5% level of significance.

Thus, it appears that the only expiration day effect to be potentially transferred to OMXH25 via Nokia is the volume effect related to FESX expirations.

To summarize, there is weak evidence, at best, of expiration day effects spilling over from Nokia to other OMXH25 constituents. When it comes to volume, the OMXH25 Index without Nokia has significantly higher volumes on expiration days of FESX or OESX, suggesting that there might be some spilling over of trading volume to other constituents. The reason for this could be attributable to program trading activities on OMXH25 as in Hendershott and Seasholes (2008). When Nokia, as a major component of the index, faces buying or selling pressure, the rebalancing trading activities could result in higher turnover of other constituents as well. However, the findings of the regression (1) in Table 17 suggest that only the expirations of FESX tend to cause a higher volume on OMXH25 excluding Nokia. Secondly, the volatility estimates for OMXH25 without Nokia are not significantly higher on expiration days, at least based on daily data. With intraday data different findings could be found, however. Finally, expiration weeks of FESX are associated with statistically significantly lower logarithmic returns for 2000-2009 (5% level) and 2000-2004 (1% level) for OMXH25 without Nokia. In addition, expiration days of FESX and OESX for 2000-2004 tend both to be associated with significantly lower cumulative median returns for the days following expiration. This evidence cannot be found on the whole sample of 2000-2009, and hence the results must be interpreted with care. Also, the evidence of Table 17 does not suggest any spilling over of return effects from Nokia to the rest of OMXH25. In the light of these findings, one cannot make a strong argument for the spilling over of expiration day effects from Nokia to other OMXH25 constituents, at least when it comes to return or volatility effects.

6.6. Summary of empirical results

Table 18 on the next page shows a summary of the five hypotheses that are tested in this study and compares them to the empirical evidence that is found. The main findings are briefly summarized next.

Table 18: Findings versus hypotheses

The table presents the hypotheses of the study and compares them to the main empirical findings. The percentages in brackets refer to statistical significance levels. FESX refers to the expiration of the EURO STOXX 50 index futures series, and OESX to the expiration of the EURO STOXX 50 index options series. EURO STOXX 50 index is a capitalization-weighted blue-chip index covering the eurozone, consisting of the 50 supersector leaders of the area, including Nokia. *F*-test refers to an *F*-test for equal variances. OLS refers to Ordinary Least Squares regression. Wilcoxon rank sum test is used to compare volumes, detrended volumes, and returns. OMXH25 Index is a capitalization weighted index consisting of the 25 most traded shares on the Helsinki Stock Exchange, including Nokia. The data used in the tests consists of intraday 15 second time interval index price data for the EURO STOXX 50 index for 2000-2009 for each Friday (or Thursday if Friday is a trading holiday). The expirations of FESX (40 days) and OESX (80 days) are compared to the control group (401 days). For OMXH25 daily level price and turnover data is used. Source of data: Stoxx Ltd., Datastream, Nasdaq OMX.

Hypothesis	Empirical evidence
(1) Index futures and options expirations are associated with significantly higher volume on the index compared to non-expiration Fridays.	**Strong evidence** (0.1%), robust when volumes detrended and time frames altered.
(2) Index futures and options expirations are associated with significantly different returns on the index compared to non-expiration Fridays.	**Strong evidence**. For the whole sample, returns before expiration higher at the 1% level (FESX); after expiration lower returns at the 1% level (OESX) and 0.1% (FESX).
(3) Index futures and options expirations are associated with significantly higher volatility on the index compared to non-expiration Fridays.	**Strong evidence**. (0.1%) for both FESX and OESX at expiration +/- 30min, 15min and 5min time windows. Results significant both with *F*-test and Levene's test. *F*-stats robust when accounting for sample size differences.
(4) The price reversal after 12:00 CET on expiration days is more significant than the reversal on non-expiration Fridays.	**Moderate evidence**. OESX expiration +/- 15min and 30 min higher return reversals for the whole sample (0.1%), FESX expiration +1day higher reversals for 2005-2009 (1%). OLS regressions show that FESX expirations also associated with significant return reversals for the expiration +/- 15min window.
(5) The expiration day effects tend to spill over from Nokia to other OMXH25 stocks.	**Weak/No evidence**. Volume of OMXH25 without Nokia significantly higher on expiration days of FESX (0.1%) and OESX (1%) for 2000-2009 and 2005-2009, but only the expiration of FESX appear to explain a spillover from Nokia to the rest of OMXH25. Expiration week cumulative returns for FESX expirations significantly lower. Expiration days tend to be followed by significantly negative cumulative returns for FESX and OESX for 2000-2004. However, no evidence of spilling over of return and volatility effects from Nokia to rest of OMXH25 is found.

6.6.1. Expiration day effects of EURO STOXX 50 index derivatives

In line with previous studies on expiration day effects, the expiration of the EURO STOXX 50 index futures and options are increasing significantly the volume of the underlying index on the expiration day and the expiration week. Moreover, when analysing the detrended volume it appears that the effect is stronger for more recent years (2005-2009). Hence, we can easily accept

Hypothesis 1: index futures and options expirations are associated with a significantly higher volume on the underlying index compared to non-expiration days.

Secondly, at the expiration of FESX, the logarithmic returns on the index tend to be higher before the expiration and lower after the expiration compared to the control group. For OESX similar results are found, but the statistical significance is lower. This is clear evidence of heavy order imbalances around the expiration of FESX and OESX. The systematic direction of the imbalance may be related either to an average short position unwinding or even to market manipulation activities, possibly related to the natural asymmetry of liquidity purchases and sales (Aggarwal and Wu, 2006; Allen and Gorton, 1992). However, in order to be able to better confirm manipulation, one would need high frequency order book data for the stocks and the index derivatives to analyse the order imbalances more in detail. Also, for 2005-2009 some of effects for OESX and FESX tend to be statistically more significant, the reason for which may be the lower volatility of that sample. Given these findings, we can accept Hypothesis 2.

Thirdly, the intraday volatilities around the expirations of FESX and OESX are significantly higher than for the control group according to an *F*-test and a Levene's test for equal variances. The results appear to be robust when taking into account the differences in sample sizes by using simulated sampling. The intraday volatility appears to be lower for the sample 2005-2009, probably because of increased liquidity trading. Hence, Hypothesis 3 can be accepted: expiration days are associated with a significantly higher volatility on the underlying index.

Fourth, there is evidence of expiration day returns reversing. For FESX, there is evidence of the 3 hour returns before expiration to be reversed during the 3 hours after expiration. According to median reversal tests, the only significant evidence exists for the reversals occurring the day after FESX expiration, in the sample 2005-2009: the expiration day returns tend to be reversed the following day. For OESX, the evidence is significant (at the 0.1% level) for 15 minute as well as 30 minute time window reversals. However, when using OLS regression analysis, I find stronger evidence of the reversals. FESX coefficients are significant especially for the 15 minute and 1 hour windows for the sample 2000-2009. Once again, for OESX the coefficients are more significant, which may be related to a higher sample size. Assuming that liquidity trading on expiration days is higher and more concentrated than average and given that expiration days are associated with higher trading volumes, reversals can be justified with the inventory concerns of market makers, who accommodate order imbalances (Admati and Pfleiderer, 1988; Grossman and Miller, 1988; Campbell et al. 1993; Llorente et al. 2002). Given these findings, we can accept Hypothesis 4: returns tend to reverse more, on average, on expiration days than on non-expiration days.

6.6.2. Spillover of expiration day effects from Nokia to other OMXH25 constituents

As for the spilling over of the expiration day effects from Nokia to other OMXH25 Index constituents, weak evidence is found. It appears that the expiration of FESX may cause a significant spilling over of the volume effect from Nokia to other OMXH25 constituents. Obviously part of the volume effect can be attributed to OMXH25 constituents' options expiration, which may occur on the same day. Volatility and returns, however, do not appear to spill over, and as a consequence we reject Hypothesis 5.

7. Conclusion

Expiration day effects of index derivatives have attracted attention both from regulators and the academic world. Stoll and Whaley (1986) were among the first to find that the expiration of S&P 500 index futures brings undesirable side effects to the underlying index, namely significant shocks in volume, volatility and prices. The explanation behind such findings is that delta positions unwinding and index arbitrage activities are heavier on expiration days than normally. As a consequence, a strong order imbalance occurs in the underlying index around the expiration time, potentially affecting the returns and volatilities significantly.

In this thesis I study the expiration day effects of the EURO STOXX 50 index futures (FESX) and options (OESX), which are one of the most traded index derivatives in the world. I use a unique high frequency 15 second interval dataset including all expiration days, and non-expiration Fridays for the years 2000-2009. I analyse whether expiration days of FESX or OESX are associated with significantly different volume, volatility, returns, and return reversals compared to non-expiration days. Also, I examine whether these effects are transferred from Nokia to other OMXH25 Index constituents, since Nokia is part of both indexes.

Firstly, I find that the expiration days and expiration weeks of FESX and OESX are associated with a significantly higher trading volume on the underlying index. For example, the expiration days of FESX and OESX account for 31% and 25%, respectively, of the week's total trading volume. For the control group of non-expiration Fridays, the similar median figure is slightly below 20% for the sample 2000-2009. The results are robust when analyzing detrended volumes as well. The best explanation for the volume effect is index arbitrage activities and the huge amount of delta unwinding on the expiration days, increasing the amount of non-informative trading.

Secondly, I find that the intraday volatility of the underlying index experiences a significant jump on expiration days of FESX and OESX. I use simulated sampling to control for the differences in sample sizes, and I find that the results are robust even then. FESX tends to have a 5-7 times higher volatility and OESX a 3-4 times higher volatility right around the expiration time of 12:00

CET on expiration days compared to the control group for the sample 2000-2009. This is clear evidence of significant order imbalances on expiration days.

Thirdly, I find that the underlying index experiences a significant shock in returns around the expiration of FESX and OESX, which further supports the idea of order imbalances close to the expiration. Both FESX and OESX expirations are associated with higher returns just before the expiration time of 12:00 CET and lower returns thereafter according to a Wilcoxon rank sum test. For example, on the expiration days of FESX the median returns for the period 9:00-12:00 CET are significantly higher at the 1% level of significance, and the returns for 12:00-13:00 CET significantly lower at the 0.1% level compared to the control group of non-expiration Fridays. The results for OESX are similar, but less significant.

Fourth, I find that the returns on expiration days tend to reverse right after the expiration time of 12:00 CET on average more than on non-expiration days. By using both a median test for median reversals and OLS regressions, I find that especially when analyzing the 15 minute returns before and after the expiration time, there is evidence of significant reversals. More specifically, it appears that on average 23% of the 15 minute returns before the expiration of FESX are reversed 15 minutes after the expiration. For OESX the proportion of the prior expiration returns that are reversed appears to be as much as 62%. In addition, there is evidence that part of the FESX expiration day returns are reversed the day after expiration.

Fifth, no significant spilling over of expiration day effects from Nokia to other components of the OMXH25 index is found. Evidence that the expiration of FESX may cause a significant spilling over of trading volume from Nokia to other OMXH25 constituents is seen. However, part of the volume effect can be attributed to OMXH25 constituents' options expirations, which may occur on the same day. Hence, in the light of this study, the expiration day effects do not appear to spill over from the underlying index to non-constituent stocks, at least when analysing daily data.

This study gives support to findings (e.g. Stoll and Whaley, 1986, 1987, 1990a; Day & Lewis, 1988; Aggarwal, 1988; Chamberlain et al., 1989; Bamberg and Röder, 1995; Illueca and Lafuente, 2006) suggesting that significant expiration day effects on underlying index volume, returns and volatility exist. Spot position unwinding as well as index arbitrage are the most common explanations for the effects. The reason for the direction of the return effect in this case can be a higher than normal short position unwinding on expiration days, or market manipulation activities as in Aggarwal and Wu (2006), who report price rises through the manipulation period and prices falling afterwards. The natural asymmetry of liquidity purchases and sales may contribute to this (Allen and Gorton, 1992). However, further evidence on order book data is required in order to confirm manipulation. Nevertheless, assuming that expiration days attract liquidity traders, both liquidity trading and information-based trading is likely to be concentrated (Admati and Pfleiderer, 1988). Liquidity trading, on the other hand, increases the magnitude of reversals (Llorente et al. 2002; Campbell et al. 1993). Thus, my findings support the inventory concerns of market makers (see e.g. Stoll 1978; Hu and Stoll, 1983; Grossman and Miller, 1988; Andrade et al. 2008). Market makers accommodate heavy order imbalances only if they are compensated for carrying inventory. The results of this study are important, considering that, to my knowledge, no previous empirical studies on the expiration day effects of index futures and options of the EURO STOXX 50 index have been conducted yet.

While the volume effect is widely acknowledged in the literature, previous findings on price and volatility effects are mixed. The reason why the findings in this thesis appear to be more significant than in some other studies may be related to 1) a longer sample; 2) higher frequency intraday data; 3) differences in settlement procedures; and 4) the popularity of EURO STOXX 50 index derivatives. Firstly, the sample 2000-2009 is relatively long compared to most expiration day effect studies where shorter samples are used. This may cause the findings to be more significant than in studies that used only a few years of data. Secondly, most of studies that used intraday price data had minute-per-minute data in use, while in this study 15 second interval data is used, which may increase the significance of the findings. Thirdly, the settlement procedures of FESX and OESX may differ significantly from other similar instruments elsewhere. Both FESX and OESX expire according to the Volume Weighted Average Price (VWAP) of ten minutes before the expiration time at 12:00 CET. In some markets the VWAP of the whole day is in use, while in other markets the opening or the closing prices are used. Thus, my findings raise the question whether a 10 minute VWAP settlement is long enough. Also, in some markets both the futures and options expire monthly, while in this case FESX expires quarterly. One could possibly expect lower expiration day effects if the expiration frequency would be higher as argued by Swidler et al. (1994). Fourth, EURO STOXX 50 is one of the most followed and traded indexes in Europe. Also, it has one of the most traded index futures and options in the world. Potentially because of this, the amount of spot position unwinding on expiration days, index arbitrage and even manipulation activities are greater than in smaller and less liquid markets where less significant results are found (e.g. Sweden, Spain or India).

While numerous studies on expiration day effects already exist, there are still gaps to be filled. When it comes to the EURO STOXX 50 index derivatives expiration day effects, it would be of interest to study further the direction of the price effect and the reversals. One would probably need detailed order book data both for the futures and the spot market in order to find strong evidence on manipulation activities. Also, the role of liquidity in the price effect needs further investigation. Secondly, the usage of intraday price data to study the spilling over of the expiration day effects would probably bring stronger evidence of whether part of the effects are spilled over to stocks that are not part of the underlying index or not. Generally speaking, further recent evidence on expiration day effects as well as on other possible issues related to exchange traded derivatives would be interesting to have, because of the recent developments in the regulatory field. Regulators are striving to centralize the trading of simpler OTC derivatives to centralized exchanges. Hence, trading of OTC products will possibly diminish, relatively speaking, while exchange traded instruments (such as FESX and OESX) are likely to experience an increase in popularity. Such a development will probably increase the visibility of the derivatives' markets, which can be seen as a good thing. However, increased trading in exchange traded products can cause more positions to expire at the same time. Hence, the centralization of derivatives trading can possibly aggravate side effects such as the ones examined in this study.

8. References

Aggarwal, R. 1988. Stock index futures and cash market volatility. *Review of Futures Markets,* Vol. 7, pp. 290-299.

Aggarwal, R, Wu, G. 2006. Stock Market Manipulations. *Journal of Business,* Vol. 79, No. 4, pp. 1915-1953.

Admati, A.R., Pfleiderer, P. 1988. A theory of intraday patterns: Volume and Price Variability. *The Review of Financial Studies*, Vol. 1, No. 1 (Spring, 1988), pp. 3-40.

Alkebäck, P., Hagelin, N. 2004. Expiration day effects of index futures and options: evidence from a market with a long settlement period. *Applied Financial Economics,* Vol. 14, No. 6, 15 March 2004 , pp. 385-396.

Allen, F., Gale, D. 1992. Stock price manipulation. *Review of Financial Studies,* Vol. 5, pp. 503-529.

Allen, F., Gorton, G. 1992. Stock price manipulation, market microstructure and asymmetric information. *European Economic Review*, Vol. 36, pp. 624-630.

Andersen, T.G. 1996. Return volatility and trading volume: an information flow interpretation of stochastic volatility. *The Journal of Finance*. Vol. 51, No. 1, March 1996, pp. 169-204.

Andrade, S.C., Chang, C., Seasholes, M.S. 2008. Trading imbalances, predictable reversals, and cross-stock price pressure. *Journal of Financial Economics*. Vol. 88, Issue 2, May 2008, pp. 406-423.

Antoniewicz, R.L. 1993. Relative volume and subsequent stock price movements. Working Paper. Board of Governors of the Federal Reserve System.

Avramov, D., Chordia, T., Goyal, A. 2006. Liquidity and autocorrelations in individual stock returns. *The Journal of Finance,* Vol. 61, No. 5, pp. 2365-2394.

Barclay, M.J., Hendershott, T., Jones, C.M. 2006. Order consolidation, price efficiency and extreme liquidity shocks. *Journal of Financial and Quantitative Analysis*. Vol. 43, No. 1, March 2008, pp. 93-122.

Bhaumik, S., Bose, S. 2007. Impact of derivatives trading on emerging capital markets: a note on expiration day effects in India. William Davidson institute Working Paper Number 863 March 2007.

Bollen, N.P.P. 1998. A note on the impact of options on stock return volatility. *Journal of Banking & Finance*, 22, pp. 1181-1191.

Bollerslev, T. 1986. Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, Vol. 31, pp. 307-327.

Butterworth, D. 2000. The impact of futures trading on underlying stock index volatility: the case of the FTSE Mid 250 contract. *Applied Economics Letters*, 2000, Vol. 7, pp. 439-442.

Campbell, J.Y., Grossman, S.J., Wang, J. 1993. Trading volume and serial correlation in stock returns. *The Quarterly Journal of Economics,* Vol. 108, No. 4 (Nov., 1993), pp. 905-939.

Chamberlain, T. W., Cheung, C.S., Kwan, C.C.Y., 1989. Expiration-day effects of index futures and options: some Canadian evidence. *Financial Analysts Journal*, Sep-Oct 1989, pp. 67-71.

Chang, E.C., Cheng, J.W., Pinegar, J.M. 1999. Does futures trading increase stock market volatility? The case of the Nikkei stock index futures markets. *Journal of Banking & Finance*, Vol. 23, pp. 727-753.

Chan, K. 1992. A further analysis of the lead-lag relationship between the cash market and stock index futures market. *The Review of Financial Studies,* Vol. 5, No. 1, pp. 123-152.

Chan, K., Chan, K.C., Karolyi, G.A. 1991. Intraday volatility in the stock index and stock index futures markets. *The Review of Financial Studies*, Vol. 4, No. 4 (1991), pp. 657-684.

Chen, C., Williams, C., 1994. Triple-Witching Hour, the change in expiration timing, and stock market reaction. *The Journal of Futures Markets*, May 1994, Vol. 14, No. 3, pp. 275-292.

Chordia, T., Subrahmanyam, A. 2004. Order imbalance and individual stock returns: theory and evidence. *Journal of Financial Economics*, 72 (2004), pp. 485-518.

Chordia, T., Roll, R., Subrahmanyam, A. 2002. Order imbalance, liquidity, and market returns. *Journal of Financial Economics*, Vol. 65, pp. 111-130.

Chow, Y-F., Yung, H.H.M., Zhang, H. 2003. Expiration day effects: the case of Hong Kong. *Journal of Futures Markets*, Vol. 23, No. 1, pp. 67-86.

Clark, P.K. 1973. A subordinated stochastic process model with finite variance for speculative prices. *Econometrica*, Vol. 41, No. 1 (Jan. 1973), pp. 135-155.

Comerton-Forde, C., Putnins, T.J. 2007. Measuring closing price manipulation. Working paper. Discipline of Finance, Faculty of Economics and Business, University of Sydney, NSW 2006, Australia. Forthcoming in *Journal of Financial Intermediation.*

Conrad, J. 1989. The price effect of option introduction. *The Journal of Finance*, Vol. 44, pp. 487-498.

Conrad, J.S., Hameed, A., Niden, C. 1994. Volume and autocovariances in short-horizon individual security returns. *The Journal of Finance*, Vol. 49, No. 4, September 1994, pp. 1305-1329.

Copeland, T.E. 1976. A model of asset trading under the assumption of sequential information arrival. *The Journal of Finance*. Vol. 31, No. 4, September 1976, pp. 1149-1168.

Corredor, P., Lechón, P., Santamaría, R. 2001. Option-expiration effects in small markets: the Spanish stock exchange. *The Journal of Futures Markets*, Vol. 21 (2001), No. 10, pp. 905-928.

Damodaran, A., Lim, J. 1988. The effects of options listing on the underlying stocks' return processes. *Journal of Banking and Finance,* Vol. 15, Issue 3, pp. 647-664.

Day, T.E., Lewis, C.M. 1988. The behaviour of the volatility implicit in the prices of stock index options. *Journal of Financial Economics*, vol. 22 (1988), pp. 103-122.

De Bondt, W.F.M., Thaler, R. 1985. Does the stock market overreact? *The Journal of Finance*, Vol. 40, No. 3, July 1985, pp. 793-805.

De Bondt, W.F.M., Thaler, R.H. 1987. Further Evidence on Investor Overreaction and Stock Market Seasonality. *The Journal of Finance,* Vol. 42, No. 3, July 1987, pp. 557-581.

Detemple, J., Jorion, 1990. Option listing and stock returns: an empirical analysis. *Journal of Banking and Finance*, Vol. 14, Issue 4, pp. 781-801.

Dougherty, C. 2002. *Introduction to Econometrics*. 2nd Edition. Oxford University Press. pp. 383-386.

Edwards, F.R. 1988. Does futures trading increase stock market volatility? *Financial Analysts Journal*, Vol. 44, No. 1, pp. 63-69.

Engle, R.F. 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica*, Vol. 50, No. 4 (Jul., 1982), pp. 987-1007.

Epps, T.W., Epps, M.L. 1976. The stochastic dependence of security price changes and transaction volumes: implications for the Mixture of Distributions Hypothesis. *Econometrica*, Vol. 44, No. 2 (Mar., 1976), pp. 305–321.

Felixson, K. 2002. The expiration day effect of index options and index futures on the underlying shares. Swedish School of Economics and Business Administration Working Papers. 473.

Felixson, K., Pelli, A. 1999. Day end returns – stock price manipulation. *Journal of Multinational Financial Management*. Vol. 9, pp. 95-127.

Froot, K.A., Dabora, E.M. 1999. How are Stock Prices Affected By the Location of Trade? *Journal of Financial Economics*, Vol. 53, pp. 189-216.

Gallant, A.R., Rossi, P.E., Tauchen, G. 1992. Stock prices and volume. *The Review of Financial Studies*, Vol. 5, No. 2, pp. 199-242.

Grammatikos, T., Saunders, A. Futures price variability: a test of maturity and volume effects, *The Journal of Business*, Vol. 59, No. 2, Part 1 (Apr., 1986), pp. 319-330.

Grossman, S.J., Miller, M.H. 1988. Liquidity and market structure. *The Journal of Finance,* Vol. 43, No. 3, Papers and Proceedings of the Forty-Seventh Annual Meeting of the American Finance Association, Chicago, Illinois, December 28-30, 1987 (Jul., 1988), pp. 617-633.

Harford, J., Aditya, K. 2005. Correlated order flow: pervasiveness, sources and pricing effects. *Journal of Financial and Quantitative Analysis*, 40, pp. 29-55.

Harris, L., Sofianos, G., Shapiro, J.E. 1994. Program trading and intraday volatility. *The Review of Financial Studies*, Vol. 7, No. 4 (Winter, 1994), pp. 653 – 685.

Hendershott, T., Seasholes, M.S. 2007. Market maker inventories and stock prices. *American Economic Review*, Papers and Proceedings 97, pp. 210-214.

Herbst, A.F., Maberly, E.D. 1990. Stock index futures, expiration day volatility, and the "special" Friday opening: a note. *Journal of Futures Markets*, Vol. 10, No. 3, pp. 323-325.

Herbst, A.F., Maberly, E.D. 1991. An Alternative Methodology for Measuring Expiration Day Price Effects at Friday's Close: The Expected Price Reversal – A Note. *The Journal of Futures Markets*, Vol. 11, No. 6, pp. 751-754.

Hillion, P., Suominen, M. 2004. The manipulation of closing prices. *Journal of Financial Markets*, Vol. 7, pp. 351-375.

Hull, J.C., 2006. *Options, Futures and Other Derivatives*. Pearson Prentice Hall 6th Edition.

Illueca, M., Lafuente, J.A., 2006. New evidence on expiration-day effects using realized volatility: an intraday analysis for the Spanish stock exchange. *Journal of Futures Markets*, 26, pp. 923-938.

Hancock, G.D. 1993. Whatever happened to the triple witching hour? *Financial Analysts Journal,* 43:3, pp. 66-72.

Harris, L. 1989. S&P 500 cash stock price volatilities. *The Journal of Finance,* Vol. 44, No. 5, pp. 1155-1175.

Ho, T.S.Y., Stoll, H.R. 1983. The dynamics of dealer markets under competition. *The Journal of Finance,* Vol. 38, No. 4, pp. 1053-1074.

Jegadeesh, N. 1990. Evidence of predictable behaviour of security returns. *The Journal of Finance,* Vol. 45, pp. 881-898.

Jegadeesh, N., Titman, S. 2001. Profitability of momentum strategies: an evaluation of alternative explanations. *The Journal of Finance*, Vol. 56, No. 2, April 2001, pp. 699-720.

Jegadeesh, N., Titman, S. 1993. Returns to buying winners and selling losers: implications for stock market efficiency. *The Journal of Finance,* Vol. 48, No. 1, March 1993, pp. 62-91.

Kan, A.C.N. 2001. Expiration-day effect: evidence from high-frequency data in the Hong Kong stock market. *Applied Financial Economics*, 2001, 11, pp. 107-118.

Karpoff, J.M. 1987. The relation between price changes and trading volume: a survey. *Journal of Financial and Quantitative Analysis*. Vol. 22, No. 1, March 1987, pp. 109-126.

Kumar, P., Seppi, D.J. 1992. Futures manipulation with “cash settlement”. *The Journal of Finance,* Vol. 47, No. 4, September 1992.

Lamoureux, C.G., Lastrapes, W.D. 1990. Heteroskedasticity in stock return data: volume versus GARCH Effects. *The Journal of Finance*. Vol. 45, No. 1. March 1990, pp. 221-229.

Lee, C.I., Mathur, I. 1999. The influence of information arrival on market microstructure: evidence form three related markets. *The Financial Review*, 34, pp. 1-26.

Lee, C.M.C., Swaminathan, B. 2000. Price momentum and trading volume. *The Journal of Finance*, Vol. 55, No. 5, Oct. 2000, pp. 2017-2069.

Lee, B-S, Rui, O.M., 2001. Empirical identification of non-informational trades using trading volume data. *Review of Quantitative Finance and Accounting*. Vol 17., No.4, December 2001. pp. 327-350.

Lehmann, B. 1990. Fads, martingales and market efficiency. *Quarterly Journal of Economics,* Vol. 105, pp. 1-28.

Levene, H. 1960. Robust tests for equality of variances. In: Olkin, I. et al. *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling.* Stanford University Press. pp. 278-292.

Li, J., Wu, C. 2006. Daily return volatility, bid-ask spreads, and information flow: analyzing the information content of volume. *The Journal of Business*. Vol. 79, no. 5, pp. 2697-2739.

Llorente, G., Michaely, R., Saar, G., Wang, J. 2002. Dynamic volume-return relation of individual Stocks. *The Review of Financial Studies*, Fall 2002, Vol. 15, No. 4, pp. 1005-1047.

Maniar, H.M, Bhatt, R., Maniyar, D.M. 2009. Expiration hour effect of futures and options markets on stock market – a case study on NSE (National Stock Exchange of India). *International Review of Economics and Finance*. Vol. 18, pp. 381-391.

Nabar, P., Park, S.Y. 1988. Options trading and stock price volatility. Working Paper 460, Leonard N. Stern School of Business, New York University.

Ni., S.X., Pearson, N.D., Poteshman, M.A. 2005. Stock price clustering on option expiration dates. *Journal of Financial Economics*. Vol. 78, pp. 49-87.

O'Hara, M., Oldfield, G.S. 1986. The microeconomics of market making. *The Journal of Financial and Quantitative Analysis*, Vol. 21, No. 4 (Dec., 1986), pp. 361-376.

Pirinsky, C., Wang, Q. 2006. Does corporate headquarters location matter for stock returns? *The Journal of Finance,* Vol. 61, No. 1, pp. 1991-2015.

Rahman, S., Lee, C-F., Ang, K.P. 2002. Intraday return volatility process: evidence from NASDAQ stocks. *Review of Quantitative Finance and Accounting*. Vol. 19, pp. 155-180.

Röder, K. 1996. Intraday-volatilität und expiration-day-effekte bei DAX, IBIS-DAX und DAX Future. *Finanzmarkt und Portfolio Management*, Vol. 10, No. 4, pp. 463-477.

Schlag, C. 1996. Expiration day effects of stock index derivatives in Germany. *European Financial Management*, Vol. 1., No. 1, pp. 69-95.

Stickel, S.E, Verrecchia, R.E. 1994. Evidence that volume sustains price changes. *Financial Analyst Journal ,* November-December, pp. 57-67.

Stoll, H.R. 1978. The supply of dealer Services in securities markets. *Journal of Finance*, Vol. 33, No. 4 (Sep., 1978), pp. 1133-1151.

Stoll, H.R., Whaley, R.E. 1986. Expiration day effects of index options and futures. *Monograph Series in Finance and Economics*, Monograph 1986-3.

Stoll, H.R., Whaley, R.E. 1987. Program trading and expiration-day effects. *Financial Analysts Journal*, March-April 1987. pp. 16-28.

Stoll, H.R., Whaley, R.E., 1990a. Program trading and individual stock returns: ingredients of the Triple-Witching brew. *The Journal of Business*, Vol. 63, No.1, Part 2: A conference in honor of Merton H. Miller's contributions to Finance and Economics (Jan. 1990), pp. S165 – S192.

Stoll, H.R., Whaley, R.E. 1990b. The dynamics of stock index and stock index futures returns. *The Journal of Financial and Quantitative Analysis*. Vol. 25, No. 4 (Dec., 1990), pp. 441 – 468.

Stoll, H.R., Whaley, R.E., 1991. Expiration-day effects: what has changed? *Financial Analysts Journal*. Jan-Feb 1991, pp. 58-72.

Stoll, H.R., Whaley, R.E. 1997. Expiration-day effects of all ordinaries share price index futures: empirical evidence and alternative settlement procedures. *Australian Journal of Management*, Vol. 22, No. 2, Dec 1997.

Suominen, M. 2001. Trading volume and information revelation in stock markets. *Journal of Financial and Quantitative Analysis*, Vol. 36, No. 4 (Dec 2001), pp. 545-565.

Suominen, M., Rinne, K. 2009. A structural model of short-term reversals. Working paper. Helsinki School of Economics.

Suominen, M., Rinne, K. 2010. Short-term reversals, returns to liquidity provision and the costs of immediacy. Working paper, Helsinki School of Economics.

Swidler, S., Schwartz, L., Kristiansen, R. 1994. Option expiration day effects in small markets: evidence from the Oslo Stock Exchange. *Journal of Financial Engineering*, Vol. 3, No. 2, June 1994, pp. 177-195.

Vipul, 2005. Futures and options expiration-day effects: the Indian evidence. *The Journal of Futures Markets*, Vol. 25, No. 11, 1045-1065.

Online sources

CME Group. Volume reports for CME and CBOT products. Date of retrieval 11.2.2010.
http://www.cmegroup.com/market-data/volume-open-interest/

Deutsche Bank. db x-trackers EURO STOXX 50 ETF description. Date of retrieval 18.2.2010.
http://www.dbxtrackers.com/EN/showpage.asp?pageid=143&pketf=4&stinvestortyp=instinv

EUREX. Date of retrieval 9.2.2010
http://www.eurexchange.com

New York Stock Exchange weekly program-trading data reports. Date of retrieval 10.2.2010.
http://www.nyse.com/press/12_2009.html

NYSE Euronext, Euronext.liffe monthly and annual statistics. Date of retrieval 11.2.2010.
http://www.euronext.com/editorial/wide/editorial-7341-EN.html

Stoxx Ltd. EURO STOXX 50 index factsheet. Date of retrieval 10.2.2010.
http://www.stoxx.com/indices/factsheets/coverage.html

World Federation of Stock Exchanges. Date of retrieval 9.2.2010.
http://www.world-exchanges.org/statistics

9. Appendices

Appendix 1: Index options and futures trading activities around the world

The table describes the amount of index options and index futures contracts traded as well as the notional values of the contracts in millions of USD for a selected number of exchanges for 2007 and 2008. Source: World Federation of Stock Exchanges

	Index Options				Index Futures			
	Contracts traded		Notional value (mUSD)		Contracts traded		Notional value (mUSD)	
	2008	2007	2008	2007	2008	2007	2008	2007
Australian SE	3 309 609	2 936 632	165 273	242 079	20 378 735	16 631 555	2 024 335	2 145 401
Chicago Board Options Exchange (CBOE)	233 465 008	207 092 336	25 019 595	26 915 279	N/A	N/A	N/A	N/A
CME Group	44 210 472	41 123 839	7 253 585	9 025 696	898 277 566	675 179 528	54 640 635	49 957 818
Eurex	514 894 678	352 971 005	24 343 878	19 753 764	511 748 879	400 538 510	33 043 374	33 425 517
Hong Kong Exchanges	5 592 128	9 279 120	437 915	2 809 299	44 436 944	32 339 682	2 889 780	4 334 968
NASDAQ OMX Nordic Exchange	19 654 145	19 715 474	27 186	37 485	39 307 915	31 609 779	N/A	N/A
National Stock Exchange of India	150 916 778	52 707 150	688 462	312 131	202 390 223	138 794 235	915 040	821 724
NYSE Liffe (European markets)	66 932 112	63 106 661	5 343 877	5 969 181	106 099 614	93 284 741	8 823 669	9 844 295
Osaka SE	32 126 060	29 181 598	N/A	N/A	131 028 334	79 291 064	5 312 981	5 029 481
Tokyo Stock Exchange Group	62 045	19 555	7 682	2 644	19 178 901	16 578 731	2 103 026	2 328 663

Appendix 2: Comparison of selected index futures' volumes and turnovers

The table compares the contract volumes as well as the turnovers of a selection of index futures. The turnover figures are in euros except for FTSE 100, for which the turnover is expressed in GBP. The USD-denominated turnover of the S&P 500 or Nasdaq 100 were not available. Sources: Eurex; CME Group; and Euronext.liffe.

Instrument	Code	Contracts traded Jan10	Turnover Jan10	Contracts traded Jan09	Turnover Jan09
DAX Futures	FDAX	3 125 677	455 240 345 400	3 283 863	368 699 649 175
DJ EURO STOXX 50 Index Futures	FESX	26 558 769	768 462 495 280	26 226 173	606 674 419 260
MINI S&P 500	ES	40 765 093	N/A	45 814 102	N/A
S&P 500	SP	403 627	N/A	674 413	N/A
E-MINI NASDAQ 100	NQ	6 711 669	N/A	5 713 178	N/A
CAC 40	FCE	3 152 817	123 850 838 496	3 294 611	101 220 299 125
FTSE 100 Index*	Z	2 446 539	149 469 523 160	2 834 276	131 598 738 281
OMX-Helsinki 25 Futures	FFOX	12 323	249 775 079	363	5 534 128

Appendix 3: EURO STOXX 50 index composition list

The table shows the composition list of EURO STOXX 50 index as of January 12th, 2010 close. The index is a capitalization-weighted blue-chip index covering the eurozone, and consisting of the 50 supersector leaders of the area. Market Cap Meur is the market capitalization in millions of euros. The weight represents the weight of the stock on the index at the time of close on January 12th, 2010. Source: Stoxx Ltd.

	Country	Exchange	Name	Market cap mEUR	Weight (%)	Industry
1	FR	EURONEXT (FR)	TOTAL	99 859.16	6.13	Oil & Gas
2	ES	SIBE	BCO SANTANDER	95 869.15	5.89	Financials
3	ES	SIBE	TELEFONICA	75 921.52	4.66	Telecommunications
4	FR	EURONEXT (FR)	SANOFI-AVENTIS	59 473.51	3.65	Health Care
5	DE	XETRA (DE)	E.ON	57 768.87	3.55	Utilities
6	FR	EURONEXT (FR)	BNP PARIBAS	57 658.65	3.54	Financials
7	DE	XETRA (DE)	SIEMENS	54 144.42	3.33	Industrials
8	ES	SIBE	BCO BILBAO VIZCAYA ARGENTAR	48 929.74	3.01	Financials
9	IT	Milan	ENI	44 326.49	2.72	Oil & Gas
10	DE	XETRA (DE)	BAYER	44 076.32	2.71	Basic Materials
11	IT	Milan	UNICREDIT	41 957.40	2.58	Financials
12	FR	EURONEXT (FR)	GDF SUEZ	40 279.93	2.47	Utilities
13	DE	XETRA (DE)	ALLIANZ	39 187.08	2.41	Financials
14	DE	XETRA (DE)	BASF	38 584.66	2.37	Basic Materials
15	FR	EURONEXT (FR)	GRP SOCIETE GENERALE	38 225.76	2.35	Financials
16	NL	EURONEXT (NL)	UNILEVER NV	34 054.16	2.09	Consumer Goods
17	FI	OMX (FI)	NOKIA	33 741.99	2.07	Technology
18	FR	EURONEXT (FR)	FRANCE TELECOM	33 670.13	2.07	Telecommunications
19	DE	XETRA (DE)	DAIMLER	32 340.83	1.99	Consumer Goods
20	DE	XETRA (DE)	DEUTSCHE BANK	31 787.98	1.95	Financials
21	DE	XETRA (DE)	SAP	30 555.10	1.88	Technology
22	FR	EURONEXT (FR)	AXA	30 522.69	1.88	Financials
23	IT	Milan	INTESA SANPAOLO	30 330.62	1.86	Financials
24	DE	XETRA (DE)	DEUTSCHE TELEKOM	30 090.10	1.85	Telecommunications
25	LU	EURONEXT (NL)	ARCELORMITTAL	29 749.35	1.83	Basic Materials
26	NL	EURONEXT (NL)	ING GRP	28 763.07	1.77	Financials
27	DE	XETRA (DE)	RWE	28 158.67	1.73	Utilities
28	IT	Milan	ENEL	26 574.92	1.63	Utilities
29	FR	EURONEXT (FR)	DANONE	26 248.08	1.61	Consumer Goods
30	ES	SIBE	IBERDROLA	26 112.14	1.60	Utilities
31	FR	EURONEXT (FR)	VIVENDI	25 241.59	1.55	Consumer Services
32	IT	Milan	ASSICURAZIONI GENERALI	25 091.55	1.54	Financials
33	BE	EURONEXT (BE)	ANHEUSER-BUSCH INBEV	24 277.38	1.49	Consumer Goods
34	FR	EURONEXT (FR)	AIR LIQUIDE	21 506.26	1.32	Basic Materials
35	DE	XETRA (DE)	MUENCHENER RUECK	21 427.95	1.32	Financials
36	FR	EURONEXT (FR)	VINCI	20 933.23	1.29	Industrials
37	FR	EURONEXT (FR)	SCHNEIDER ELECTRIC	20 809.01	1.28	Industrials
38	FR	EURONEXT (FR)	CARREFOUR SUPERMARCHE	20 606.47	1.27	Consumer Services
39	FR	EURONEXT (FR)	LVMH MOET HENNESSY	20 441.44	1.26	Consumer Goods
40	NL	EURONEXT (NL)	PHILIPS ELECTRONICS	20 289.37	1.25	Consumer Goods
41	FR	EURONEXT (FR)	L'OREAL	18 474.04	1.13	Consumer Goods
42	FR	EURONEXT (FR)	SAINT GOBAIN	15 722.33	0.97	Industrials
43	ES	SIBE	REPSOL YPF	14 770.20	0.91	Oil & Gas
44	FR	EURONEXT (FR)	CREDIT AGRICOLE	13 647.87	0.84	Financials
45	IE	XETRA (IE)	CRH	12 826.02	0.79	Industrials
46	DE	XETRA (DE)	DEUTSCHE BOERSE	10 725.00	0.66	Financials
47	IT	Milan	TELECOM ITALIA	10 723.85	0.66	Telecommunications
48	FR	EURONEXT (FR)	ALSTOM	10 535.32	0.65	Industrials
49	NL	EURONEXT (NL)	AEGON	7 656.07	0.47	Financials
50	DE	XETRA (DE)	VOLKSWAGEN	3 157.18	0.19	Consumer Goods

Appendix 4: OMXH25 constituent list as of 21.1.2010

OMXH25 Index specifications, as of 21st of January, 2010. OMXH25 is a capitalization weighted index, having review dates twice a year, in February and in August. It consists of the 25 shares listed in Helsinki having the highest median daily turnover in euros. The index has a cap limit of 10%. Market values are presented in billions of euros. (Source: NASDAQ OMX)

	Base Value	Closing Price	Total Index Shares	Turnover	Total Market Value (Bn)	Divisor
OMX Helsinki 25	500.00	2059.64	5 814 434 426	486 540 639	67.63	32 836 478

Company Name	Security Symbol	Closing Price	Shares	Turnover	Market Value (Bn)	Weight
Nokia Corporation	NOK1V	9.16	703 394 048	148 893 567	6.44	9.527 %
Stora Enso Oyj R	STERV	4.56	570 904 776	42 340 123	2.60	3.847 %
Fortum Corporation	FUM1V	18.68	379 466 671	30 239 965	7.09	10.481 %
Sampo Plc A	SAMAS	17.75	371 472 014	30 206 838	6.59	9.749 %
UPM-Kymmene Corporation	UPM1V	8.10	519 970 088	28 453 414	4.21	6.228 %
KONE Corporation	KNEBV	28.86	190 452 333	23 847 860	5.50	8.127 %
Konecranes Plc	KCR1V	21.73	61 849 720	23 624 171	1.34	1.987 %
Wärtsilä Corporation	WRT1V	33.18	81 774 264	22 512 246	2.71	4.012 %
Nordea Bank AB (publ) FDR	NDA1V	6.92	437 133 186	16 807 225	3.02	4.473 %
Metso Corporation	MEO1V	25.22	126 059 327	15 632 009	3.18	4.701 %
Outokumpu Oyj	OUT1V	13.47	125 563 669	15 049 791	1.69	2.501 %
Rautaruukki Corporation	RTRKS	16.35	84 628 725	12 218 401	1.38	2.046 %
Nokian Tyres Plc	NRE1V	18.19	124 848 890	11 783 222	2.27	3.358 %
Neste Oil Corporation	NES1V	0.00	127 945 439	9 896 537	1.60	2.359 %
Orion Corporation B	ORNBV	16.00	89 817 160	7 850 315	1.44	2.125 %
TeliaSonera AB	TLS1V	0.00	884 001 519	7 031 993	4.32	6.393 %
Cargotec Oyj	CGCBV	21.05	35 896 082	6 767 541	0.76	1.117 %
Elisa Corporation	ELI1V	16.00	138 987 957	6 343 417	2.22	3.288 %
Pohjola Bank A	POH1S	7.33	183 248 669	5 815 054	1.34	1.986 %
Outotec Oyj	OTE1V	25.57	42 000 000	5 518 308	1.07	1.588 %
YIT Corporation	YTY1V	16.01	112 723 422	4 774 455	1.80	2.668 %
Tieto Corporation	TIE1V	16.54	67 841 172	3 735 234	1.12	1.659 %
Kesko Corporation B	KESBV	23.43	66 476 241	3 557 921	1.56	2.303 %
Sanoma Corporation	SAA1V	15.83	99 513 298	3 294 736	1.58	2.329 %
Talvivaara Mining Company Plc	TLV1V	4.12	188 465 756	2 389 928	0.78	1.148 %

Appendix 5: Augmented Dickey-Fuller test for detrended trading volumes

The table describes the results of an Augmented Dickey-Fuller Test where the stationarity of the detrended euro-denominated trading volume of EURO STOXX 50 index and OMXH25 index is analysed. EURO STOXX 50 is a capitalization-weighted blue-chip index covering the eurozone, and consisting of 50 supersector leaders of the area. The index is reviewed once a year, in September. OMXH25 is a capitalization weighted index, having review dates twice a year, in February and in August. It consists of the 25 shares listed in Helsinki having the highest median daily turnover in euros. The index has a cap limit of 10%. The period under review is 2000-2009. ADJ statistics refers to the test statistic; Sign. refers to the statistical significance; DW stat refers to the Durbin Watson test for autocorrelation statistic. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	ADF statistic	Sign.	DW stat	R^2	Lag length	# of obs after adjustments
EURO STOXX 50	-13.34	***	1.984	0.36	4	2556
OMXH25	-9.300	***	1.999	0.31	4	2505

Appendix 6: Median logarithmic returns of the EURO STOXX 50 index around expiration days

The table describes the results of a Wilcoxon rank sum test of medians for the logarithmic returns of the EURO STOXX 50 index around the expiration of the index futures (FESX) and expiration of options (OESX) compared to the control group of non-expiration days (CTRL). FESX expires quarterly and OESX monthly, on the third Friday of the expiration month (or Thursday if Friday is a trading holiday). Hence, the control group consists of non-expiration Fridays or Thursdays if the Friday is a trading holiday. The OESX sample excludes days when FESX also expires.The sample covers the years 2000-2009. The EURO STOXX 50 index is a capitalization-weighted blue-chip index covering the eurozone, and consisting of the 50 supersector leaders of the area. Exp week refers to expiration week, and Exp day to expiration day. *p*-value of *W*-test refers to the *p*-value of the Wilcoxon rank sum test of medians comparing FESX and OESX to CTRL. * indicates statistical significance at the 5% level;** indicates significance at the 1% level; *** indicates significance at the 0.1% level.

	2000-2009			2000-2004			2005-2009		
	# of obs	Median	*p* -value of *W* -test	# of obs	Median	*p* -value of *W* -test	# of obs	Median	*p* -value of *W* -test
CTRL									
Week	401	0.190 %		201	-0.005 %		200	0.237 %	
Exp day -1	401	0.065 %		201	0.240 %		200	-0.038 %	
Exp day	401	0.039 %		201	0.031 %		200	0.043 %	
Exp day +1	401	0.078 %		201	0.078 %		200	0.078 %	
Exp day +2	401	-0.022 %		201	-0.039 %		200	-0.012 %	
Exp day +3	401	-0.020 %		201	-0.147 %		200	0.176 %	
Exp day +4	401	0.032 %		201	0.093 %		200	-0.016 %	
Exp day +5	401	0.029 %		201	-0.096 %		200	0.102 %	
FESX									
Week	40	0.102 %	>0.20	20	-0.502 %	>0.20	20	0.600 %	>0.20
Exp day -1	40	0.039 %	>0.20	20	-0.823 %	0.060	20	0.282 %	0.184
Exp day	40	0.342 %	>0.20	20	0.096 %	>0.20	20	0.429 %	>0.20
Exp day +1	40	-0.240 %	0.096	20	-0.431 %	0.054	20	-0.191 %	>0.20
Exp day +2	40	0.270 %	>0,20	20	0.369 %	0.120	20	0.212 %	>0.20
Exp day +3	40	0.103 %	>0.20	20	-0.517 %	>0.20	20	0.402 %	0.178
Exp day +4	40	-0.040 %	>0.20	20	-0.109 %	>0.20	20	-0.020 %	>0.20
Exp day +5	40	0.118 %	>0.20	20	0.192 %	0,030*	20	-0.214 %	0.183
OESX									
Week	80	0.057 %	>0.20	40	0.187 %	>0.20	40	-0.021 %	>0.20
Exp day -1	80	-0.070 %	>0.20	40	0.027 %	>0.20	40	-0.091 %	>0.20
Exp day	80	-0.091 %	>0.20	40	-0.276 %	0,037*	40	0.181 %	>0.20
Exp day +1	80	-0.006 %	>0.20	40	-0.006 %	>0.20	40	0.021 %	>0.20
Exp day +2	80	-0.059 %	>0.20	40	-0.086 %	>0.20	40	-0.025 %	>0.20
Exp day +3	80	-0.229 %	0.108	40	-0.461 %	0,019*	40	-0.050 %	>0.20
Exp day +4	80	0.351 %	0.059	40	0.796 %	0.008**	40	-0.075 %	>0.20
Exp day +5	80	0.012 %	>0.20	40	0.012 %	>0.20	40	0.039 %	>0.20