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The Informational Role of Implied Volatility

Examining the relation between implied volatility and S&P 100 returns around FOMC announcements

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ABSTRACT:

Volatility has been a widely discussed subject in financial research and many papers consider it synonymous with the risk of an investment. However, further research has revealed that besides exhibiting the level of risk, volatility has more wide-ranging implications. Empirical evidence indicates that the forward-looking measures of volatility may have informational value over future equity returns.

This thesis studies the relation between implied volatility and equity returns around FOMC interest rate announcements. The main purpose of this thesis is to examine whether FOMC announcements increase the level of information that implied volatility contains about future stock returns. The research framework is motivated by the findings of Du, Fung & Loveland (2018) about the increased return predictability in the banking sector. This thesis contributes to the existing literature by examining the information content of implied volatility in a market-wide context.

By using daily observations from 1995 to 2008, multivariate regressions are run in an attempt to explain stock returns by lagged changes in implied volatility and binary variables that identify FOMC announcement days. The possible impact of FOMC announcements on return predictability associated with implied volatility is studied by augmenting the model with an interaction variable. For further examination, daily changes in implied volatility are divided into quartiles so that it is possible to examine whether the magnitude of change in implied volatility impacts return predictability. Additionally, the sample period is divided into two subsamples so that any timely differences can be perceived. Finally, similar regressions are applied to the days surrounding the actual announcement days.

The results of this thesis suggest that stock returns are positively associated with not only the lagged changes in implied volatility but also FOMC announcements in general. These findings are consistent with the previous studies. Regarding the hypothesized increase in return predictability, significant results are attained for certain subsamples and days following the FOMC announcements. Even though these results do not directly suggest that the findings of Du et al. (2018) apply in a market-wide context, this thesis provides qualified evidence that FOMC announcements have a positive influence on the predicting power of implied volatility. Therefore, this thesis motivates to examine the information content of implied volatility in future research as well.

KEYWORDS: Implied volatility, FOMC, Monetary policy, VXO

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Abbreviations

ATM	At-the-Money
CAPM	Capital Asset Pricing Model
CBOE	Chicago Board Options Exchange
DDM	Dividend Discount Model
ECB	European Central Bank
EMH	Efficient Market Hypothesis
FED	Federal Reserve System
FOMC	Federal Open Market Committee
FRED	Federal Reserve Bank of St. Louis
FTO	Fine-Tuning Operation
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
ITM	In-the-Money
LTRO	Longer-Term Operation
MRO	Main Financing Operation
OEX	S&P 100 Index
OTM	Out-of-the-money
SEP	Summary of Economic Projections
SML	Security Market Line
SPX	S&P 500 Index
VIX	CBOE S&P 500 Volatility Index
VXO	CBOE S&P 100 Volatility Index

1 Introduction

Estimating the influence of uncertainty on asset returns has arguably been the very crux of investor behavior. Regardless of the model used in pricing assets or forecasting their returns, the financial risk appears to equal uncertainty. Theoretically speaking, this uncertainty means volatility, which is widely considered to equal the dispersion of a data set relative to its mean – that is, standard deviation.

Volatility can be examined either as a derivation from a chosen time series, or as an implicit prediction of future uncertainty: this thesis treats the latter. On a global basis, the volatility indices of Chicago Board Options Exchange (CBOE) are considered as the most apposite measures of implied volatility. The main CBOE indices, usually referred to as VIX and VXO, are indicators destined to gauge the expected volatility of the US stock market. The negative correlation between the stock market and these indices has been empirically established (Whaley, 2000; Carr & Wu, 2006). Furthermore, the existing literature indicates how the implied volatility of an index option reflects information about its price risk. Although neither VIX nor VXO is an investable instrument, their feasibility as indicators for equity return fluctuation has been widely acknowledged. (Giot, 2005; Carr & Wu, 2006; Banerjee, Doran & Peterson, 2007.)

Previous studies find evidence of equity return predictability through implied volatility around events that incorporate idiosyncratic information important solely to certain stocks. However, only few papers have studied the information that implied volatility indices contain in an event-specific environment where information is relevant to all market participants. Thus, this thesis examines the informational role of market-wide volatility around macroeconomic news announcements, namely the interest rate decisions of the Federal Open Market Committee (FOMC). This is done by regressing post-announcement stock returns on pre-announcement changes in implied volatility.

1.1 Previous literature

The core purpose of implied volatility indices is to reflect market expectations on future fluctuation in asset prices. As mentioned earlier, the CBOE has two main indices that are considered as benchmarks for equity market volatility. The initially formed volatility index, which is nowadays called VXO, is computed by utilizing option prices on the S&P 100 (OEX) index. VXO rests strongly upon the Black-Scholes option pricing model, which will be separately treated in section 2.1.

In 2003, the CBOE decided to alter their volatility index and back-calculate its values to 1990 based on the historical option prices. Furthermore, the CBOE began disseminating prices for another volatility index, VIX. The new volatility index VIX is based on the prices of S&P 500 (SPX) index options and does not rely on any specific pricing model. Carr and Wu (2006), among others, report very strong positive correlation between the two indices. One can therefore conclude that both VIX and VXO represent the overall stock market volatility. Moreover, any character of VIX is ought to be present in VXO and vice versa. Should there be any exception to these conclusions, each index will be treated individually. This paper studies the information contained in VXO, which is why section 2.3 provides a more profound treatment over the characteristics of VXO.

Previous studies imply the mean-reverting nature of implied volatility. According to Whaley (2009) and Banerjee et al. (2007), volatility is not expected to move parallel with the stock market but to revert to its mean, VIX for example doing so in around 44 days. Furthermore, extensive evidence indicates how the behavior of volatility is asymmetric; volatility indices tend to react drastically (tepidly) to negative (positive) surprises in equity returns (Whaley, 2000; Giot, 2005). With reference to this thesis, the above findings are important. Before examining what kind of information does implied volatility include about future price movement, it is beneficial to understand the way implied volatility reacts to new price information in the first place.

The existing literature documents a significant relationship between market uncertainty and FOMC announcements. Nikkinen and Sahlström (2004) report a decrease in implied volatility on the day of the announcement, which is later supported by, for example, Chen and Clements (2007). However, there are partly dissenting views on the roles of monetary policy surprises and mean reversion in the behavior of implied volatility around FOMC announcements (Vähämaa & Äijö, 2011; Chen, Krieger & Mauck, 2012). Chapter 5 examines these papers, among others, in further detail.

When studying the informative nature of implied volatility around macroeconomic news announcements, theoretical framework tends to rest upon two well-established principles. First, it is expected that the options market, from which the data is being collected to compute implied volatility, contains more information than its underlying stocks (Cremers & Weinbaum, 2010). Second, the options trading volume is assumed to cluster around occasions that involve imperfect information and moral hazard (Cao & Ou-Yang, 2009). The above-mentioned findings endorse the idea of implied volatility containing heralds of future stock price movement upon macroeconomic news announcements.

Apart from the computed indices, the informational role of volatility can also be inspected through volatility spreads (defined as the weighted difference in implied volatilities between call and put options with same maturity and exercise price) on individual stocks. Du, Fung & Loveland (2018) utilize this procedure while examining the predictability of stock returns within the banking sector. By regressing future bank stock returns on the implied volatility spreads preceding the FOMC meetings, Du et al. (2018) discover significant predictability compared to days when no meetings are being held. Furthermore, their findings are on par with the observations of Easley, O’Hara & Srinivas (1998) on the causal relationship between information asymmetry and option price deviation from put-call parity. However, Du et al. (2018) focus mainly on the banking sector and thus leave room for further examination in a market-wide context.

1.2 Purpose of the study and research framework

Previous research emphasizes the role of the options market as a venue for informed trading. For an investor willing to take a stand on future price movement, options appear attractive due to their mitigated short-sale limitations and hence higher leverage opportunities. Motivated by the findings of the information value contained in the options market, this paper examines the kind of information that implied volatility contains around FOMC announcements. More accurately, this thesis studies whether VXO incorporates more information about future S&P 100 returns around FOMC announcements than it usually does. This study is motivated by, for example, Du et al. (2018) and their findings on significant return predictability within the banking sector.

To examine whether the occurrence of a FOMC meeting has an impact on the predicting power of VXO over future OEX returns, the following hypothesis is formed:

> *H0*: Stock return predictability related to implied volatility does not increase around FOMC meeting days.

This thesis attempts to reject *H0* by examining whether return predictability is significantly greater on FOMC meeting days compared regular trading days. More specifically, this is done by regressing OEX returns on the preceding changes in implied volatility and then examining whether the occurrence of a FOMC meeting affects this relationship. Rejecting *H0* would support the assumption that index options and their implied volatilities are more informative around FOMC meetings than they usually are, justifying the following hypothesis:

> *H1*: Stock return predictability related to implied volatility increases around FOMC meeting days.

This study contributes to the existing literature by studying the event-specific relationship of implied volatility and stock returns in a market-wide context.

The sample period for this thesis covers data from 1995–2008. Following Du et al. (2018), there are two main reasons why the sample period is terminated at the end of 2008. First, due to the prevailing market circumstances at the time, the Federal Reserve started quantitative easing and thereby urged the FOMC to make no changes to the federal fund rate between 2008–2015. Second and consequently, the Federal Reserve faced a zero lower bound created by the near-zero target range for the federal fund rate. As a result, the Federal Reserve began to target their monetary actions at the long end of the yield curve, which is why market participants had no reasonable expectations for federal fund rate to change during the period.

The chosen sample period is also a reason why this thesis examines the relationship between VXO and OEX instead of VIX and SPX. As mentioned earlier, it was not until 2003 that the CBOE started computing the new VIX. Therefore, the new VIX is unsuitable for a thesis that covers data between 1995–2008. Furthermore, the prevailing consensus states that it is the large firms with substantial amount of debt and high dividend payout ratios that are more sensitive to interest rates. As the companies included in the S&P 100 tend to be the largest and most established companies in the US market, it is reasonable to use S&P 100 data in an event-specific study that considers the interest rate decisions of the FOMC.

This thesis is structured as follows. The following chapter covers implied volatility and its relationship with the stock market. After that, chapter 3 discusses the way monetary policy actions impact interest rates and hence asset prices. Theoretical diagnosis is concluded by chapter 4 that briefly treats the concept of market efficiency. Chapter 5 emphasizes the extant literature and treats papers relevant to the chosen subject. After chapter 6 that presents the framework for empirical analysis, chapter 7 exhibits the results of this paper. Finally, chapter 8 concludes.

2 Volatility

Measuring the uncertainty associated with future stock price movement is a widely embraced way of examining future risk. However, as this uncertainty occurs at some point in the future, one must naturally treat it in a forward-looking and subjective manner. Therefore, the problem of flawlessly forecasting the fluctuation of stock prices is yet to be solved.

Regarding the existent literature, it was initially assumed that stock returns are lognormally distributed with stationary variances, hence one could derive accurate estimates of future prices from historical stock returns. However, it quickly became to common knowledge that empirically assembled return distributions differ significantly from the lognormal ones (Officer, 1973). Still, even though there is no model that can predict the future, the market has absorbed a few methods for assessing future returns.

One established approach is to compute implicit predictions of future volatility from realized standard deviations. These implied volatilities represent the expected deviation in the price of an underlying asset. Prior to more profound treatment of the characteristics of implied volatility, the following section examines the Black-Scholes option theory, which is widely recognized as the underlying theory of implied volatilities.

2.1 The Black-Scholes option theory

Since the early 1970s, the Black-Scholes option theory has arguably been one of the most established ways of pricing options and thus assessing their implied volatilities. Having been augmented by Merton (1973), the Black-Scholes theory has acted as an underlying theory for further development within the derivatives market (Cuthbertson & Nitzsche, 2001). The Black-Scholes theory derives option prices from a differential equation, which rests upon the following assumptions (Hull, 2006):

1. Market participants have access to a riskless asset with a constant rate of return, namely the risk-free interest rate.
2. The price of a stock follows a geometric Brownian Motion with constant expected return and volatility.
3. During the validity of a given derivate instrument, its underlying stock does not pay out dividends.
4. There are no arbitrage opportunities.
5. The market is frictionless in a way that the transactions do not incur any fees or costs.
6. Market participants can borrow and lend cash at the riskless rate.
7. It is possible for market participants to short sell stocks.

Owing to the assumptions mentioned above, one can presume that the return of a portfolio including a derivative and a stock equals to the risk-free interest rate. This risk-free portfolio can be composed because the values of both assets in the portfolio are driven by the same factor – future fluctuation in the price of a stock. Given any short-term time period, the prices of the two assets correlate negatively and thus any gain (loss) in one instrument is compensated by an equivalent loss (gain) in another one.

The assumption of a stochastic process, namely the geometric Brownian Motion, is essential when examining the differential equation behind the Black-Scholes theory. Equation (1) exhibits that the change in the price of a stock ΔS relative to its current price S follows the standardized normal distribution Φ (0,1) with an average of $\mu\Delta t$ and a standard deviation of $\sigma\sqrt{\Delta t}$:

$$\frac{\Delta S}{S} \sim \phi(\mu\Delta t, \sigma\sqrt{\Delta t}). \tag{1}$$

Equation (1) is consistent with the findings of Itô (1944) about the stochastic component (the Wiener process) being the same for both assets in the abovementioned risk-free portfolio. Therefore, one can conclude that the return of a stock during a time period Δt

is a sum of two parts: expected return $\mu\Delta t$ (drift rate) and the stochastic component $\sigma S\Delta z$ (variance rate):

$$\Delta S = \mu S\Delta t + \sigma S\Delta z. \tag{2}$$

Considering equation (2) and the Black-Scholes assumption about no arbitrage opportunities, the total return of a portfolio must equal[1] the risk-free interest rate *r*. In line with this perception, the Black-Scholes differential equation describes the price of an option *V* as a function of stock *S* and time *t*:

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0. \tag{3}$$

The key finding of this equation (3) is that one can fully hedge the option position by selling or buying the underlying stock. Moreover, equation (3) denotes that there is only one appropriate price for the call (put) option *c* (*p*), which can be calculated with the formula introduced by Black and Merton (1973):

$$c = S_0 N(d_1) - Xe^{-rT} N(d_2) \text{ and} \tag{4}$$

$$p = Xe^{-rT} N(-d_2) - S_0 N(-d_1)\text{, where} \tag{5}$$

$$d_1 = [ln\frac{S_0}{X} + \left(r + \frac{\sigma^2}{2}\right)T]\frac{1}{\sigma\sqrt{T}} \text{ and}$$

$$d_2 = d_1 - \sigma\sqrt{T}.$$

In these equations: S_0 is the current price of the underlying asset, *X* is the exercise price of the option, *T* is the date of expiration and function *N(x)* represents the cumulative

[1] If the total return of a portfolio exceeds the risk-free interest rate, investors could make riskless profit by borrowing cash to buy the portfolio. Conversely, should the portfolio return be less than the risk-free rate, arbitrage could be achieved by short selling the portfolio and simultaneously buying the risk-free asset.

distribution function for a normal distribution. In other words, *N(x)* is the probability for a Φ (0,1) distributed variable to be less than *x*, which in this formula refers to d_1 and d_2.

Besides solving the partial differential equation introduced in equation (3), the Black-Scholes pricing methods can be derived by utilizing the argument of risk neutrality. As each variable in equation (3) is independent from investor's risk appetite, the option values computed with the Black-Scholes formula equal to the actual option values in the markets. This idea of risk neutrality has simplified the pricing of derivatives in the financial markets (Cox & Ross, 1976). For example, under the assumption of risk neutrality, the present value for the expected return *E* for a European[2] put option is

$$p = e^{-rT}E, \text{ where} \tag{6}$$

$$E = [\max(S_T - X, 0)].$$

Regarding call options, one can apply the Black-Scholes method also to American options as long as they do not pay out dividends. Furthermore, it is possible to extend the Black-Scholes method to account for dividends by deducting the present value of future dividends from the price of an underlying stock. However, in this case the option must be European. Next, this thesis discusses the further characteristics of implied volatility.

2.2 Implied volatility

Regarding volatility as a term, it can be considered as a theoretical concept with multiple interpretations. As Black and Scholes (1973) indicate, one can treat volatility as a variable that follows the stochastic process and thus fits into partial differential equations. However, this idea is not flawless as more recent literature implies that despite constant maturity, volatility can vary depending on the current price and the exercise price of an

[2] Contrary to American options, the execution of a European option is limited to its maturity.

option (Rubinstein, 1985). This has led to a situation where alternative models have been discovered by, for example, altering the Black-Scholes model so that volatility correlates with the price of the underlying asset (Heston, 1993).

It is also possible to gauge volatility through GARCH[3] models that treat volatility as a variable that may correlate with other factors in the pricing model. As the commonly utilized models of (ordinary) least squares call for the given data set to fulfil the conditions of homoskedasticity[4], GARCH models account for the varying error terms and compute individual estimates of the variances of each error term. GARCH models are particularly suitable for assessing volatility in a time series analysis. (Engle & Patton, 2001; Woolridge, 2013.)

As discussed earlier, computing implicit predictions of future volatility from realized standard deviations is one established way of measuring future risk. Implied volatility is a measure of future price movement, which is computed from the current price of an option. One can therefore conclude that implied volatility is directly dependent on the assumptions used in the chosen option pricing model. Looking at the equations in section 2.1, this conclusion holds up also with the Black-Scholes pricing model. Following the stochastic process addressed by Itô (1944), volatility can be defined as a standard deviation of return provided that the return is calculated in a continuous manner. Furthermore, owing to the geometric Brownian Motion documented in equation (1), volatility is expected to relatively increase over time.

However, it is essential to understand that the difference between implied and realized volatilities occurs whenever the market expects that future price movement will differ from historical patterns. Therefore, implied volatility shall not be considered as an explanatory factor of actual volatility. Furthermore, one cannot derive a function from

[3] Generalized Autoregressive Conditional Heteroscedasticity.
[4] If a data set is homoscedastic, the anticipated values of its error terms must always equal. If otherwise, the data set is considered heteroskedastic (Woolridge, 2013).

the Black-Scholes model that directly computes the value of implied volatility. In fact, implied volatility is the only variable in the model that cannot be directly observed. In other words, implied volatility is the value of volatility variable in the pricing model that leads to an option price that is in line with market expectations. (Hull, 2006.)

Further examination of the Black-Scholes model and its idea of implied volatility shows that the implied volatilities of options with similar underlying assets and exercise prices are expected to be equal. This is, however, not the case as more recent literature indicates significant relationships between the three factors (Rubinstein, 1994; Dumas, Fleming & Whaley, 1998).

Moreover, the Black-Scholes model presumes that the price of an underlying asset develops steadily with no discrete jumps at random times. However, when comparing the theoretical Black-Scholes prices to actual market prices, it is discovered that the model underestimates the probability of an out-of-the-money[5] (OTM) option to turn in-the-money (ITM) during its maturity. Then again, when the Black-Scholes model is utilized for options that are at-the-money (ATM), the computed prices concur with the actual market prices. (Rubinstein, 1985; Cuthbertson & Nitzsche, 2001.)

To conclude, it has been discovered that the Black-Scholes model is inefficient in pricing options that are trading far from their exercise prices. However, when assessing the future volatility of an option during its maturity, implied volatility is still considered as a usable estimate. As the existing literature treats volatility as a variable rather than a constant, a rational investor should price options with a model that takes the stochastic nature of volatility into account. Regarding the predictive nature of implied volatility, empirical evidence verifies the correlation between implied and actual volatilities. More specifically, Latane and Rendleman (1976) suggest that despite the existence of factors affecting all options in a similar way, the implied volatilities computed with the Black-Scholes model are correlated with actual standard deviations. However, as no model can

[5] A call (put) option is OTM if its strike price is more (less) than the current spot price and ITM, if vice versa.

fully predict the future, testing the prediction power of implied volatility is simultaneously testing of the current level of efficiency in the options markets. As this paper examines the informative nature of implied volatility, understanding the three levels of market efficiency is important. Thus, Chapter 4 concludes the theoretical part by briefly treating the observations of Fama (1970), among others.

2.3 The original volatility index VXO

The CBOE Volatility Index was originally drawn up to reflect investor's expectations on short-term volatility. VXO is based on OEX options and aims to equal the average of the Black-Scholes implied volatilities on eight near-the-money options at the two closest maturities. In case the nearest maturity is no more than eight days, the next two maturities are utilized instead. At each maturity, the computation formula takes two call and two put options at strike prices that straddle the spot level. Next, the VXO computation formula averages the implied volatilities of both call and put options at each strike price, so that the spot implied volatilities can be interpolated. These implied volatilities are then further interpolated along the maturity dimension to create a 22-trading-day volatility, which eventually constitutes VXO.

Besides VXO, the CBOE maintains another implied volatility index VIX. Although the two indices differ in terms of computation, they have relatively similar characteristics. Moreover, it has been discovered that the two indices correlate positively and thus run almost parallel with each other. Carr and Wu (2006) compare the two indices and report the summarizing statistics and daily differences in table (1). Furthermore, table (1) presents the corresponding 30-day realized volatilities for both indices; *RVol(SPX)* for VIX and *RVol(OEX)* for VXO.

Table 1. VIX, VXO and realized volatilities from January 1990 to August 2005 (Carr & Wu, 2006).

	VIX	RVol(SPX)	VXO	Rvol(OEX)	VIX	RVol(SPX)	VXO	Rvol(OEX)
	Levels				Daily Differences			
Mean	19.46	14.64	20.39	15.30	-0.00	-0.00	-0.00	-0.00
Stdev	6.37	6.82	7.29	7.29	1.01	0.82	1.16	0.86
Skewness	0.78	1.46	0.95	1.43	0.68	0.87	0.68	0.69
Kurtosis	0.78	2.64	0.76	2.38	10.24	36.61	13.71	33.06

Table (1) indicates that the realized sample mean of OEX exceeds the mean of SPX. Moreover, the sample mean of VXO is greater than the mean of VIX. This is mostly due to the trading-day conversion included in VXO computation. This conversion is related to the Black-Scholes model and will be discussed in section 2.4. Both implied and realized volatilities in table (1) incorporate modest positive skewness[6] and excess kurtosis[7], which is significantly greater for daily differences. The excess kurtosis may be related to discontinuous movements in index return volatility. These jumps in asset returns are examined by, for example, Eraker, Johannes & Polson (2003). Carr and Wu (2006) also report the t-statistics for the differences between indices and their respective realized volatilities. Between VIX and RVol(SPX), the t-statistic implies high significance at 14.09. The same statistic between VXO and RVol(OEX) is 6.72, which is highly significant as well.

Furthermore, Carr and Wu (2006) document the cross-correlation between not only VIX and VXO but also their subsequent 30-day volatilities. As can be seen in table (2), both indices are strongly correlated with the realized volatilities of their underlying indices. On the other hand, the correlation coefficients of realized volatilities get close to zero when examined on a daily level.

[6] The mean of positively skewed data will be greater than the median.
[7] Positive kurtosis means that the distribution of a data set has fatter tails than a normal distribution. In other words, the probability largely positive or negative results is higher.

Table 2. Correlation between VIX, VXO and their corresponding 30-day volatilities (Carr & Wu, 2006).

	VIX	RVol(SPX)	VXO	RVol(OEX)	VIX	RVol(SPX)	VXO	RVol(OEX)
	Levels				Daily Differences			
VIX	1.00	0.76	0.98	0.76	1.00	-0.04	0.86	-0.04
Rvol(SPX)	0.76	1.00	0.78	0.99	-0.04	1.00	-0.06	0.98
VXO	0.98	0.78	1.00	0.78	0.86	-0.06	1.00	-0.05
Rvol(OEX)	0.76	0.99	0.78	1.00	-0.04	0.98	-0.05	1.00

In table (2), another matter worth noticing is the high correlation between the two volatility indices. VIX and VXO are positively correlated in both levels (0.98) and daily differences (0.86). Considering this and the previously established negative correlation between the implied volatility and the stock market, one can conclude that both VIX and VXO proxy the overall stock market volatility. For this thesis, this observation is important. Owing to the robust analogy between the two volatility indices, one can conclude that a given character of VIX may also be present in VXO and vice versa. Should there be a reason to depart from this conclusion, each index will be treated individually.

As mentioned previously, the negative correlation between the stock market and volatility indices has been widely recognized. Dash and Moran (2005) study the correlation more in detail and establish the following: a major part of historical spikes in volatility can be explained by simultaneous bearish states within the stock market. This kind of negative correlation is depicted in figure (1) that follows the development of VXO and OEX from November 1995 to November 2019.

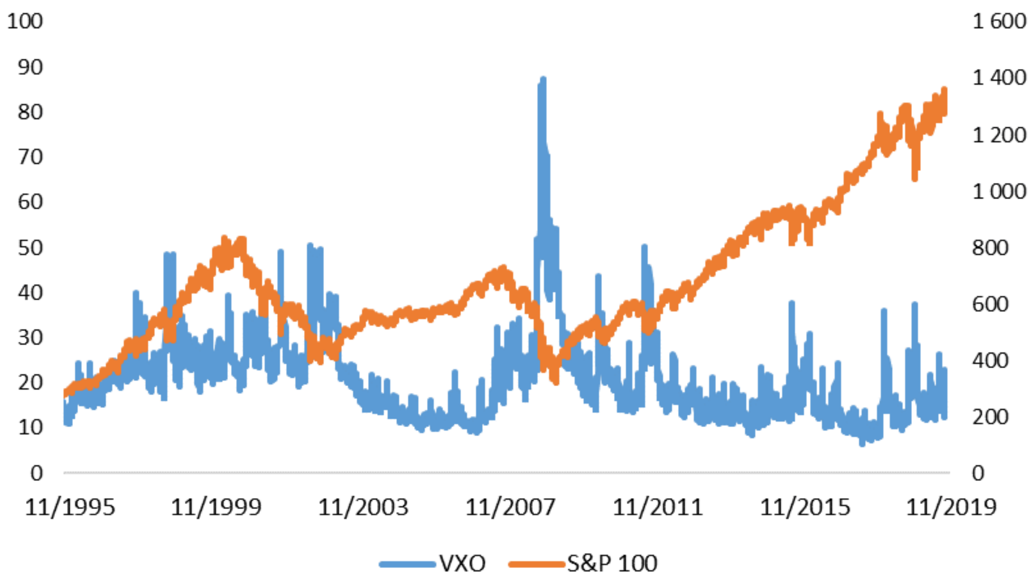

Figure 1. The negative relation between VXO and S&P 100, 1995–2019.

Besides the negatively correlating relationship, figure (1) illustrates its asymmetry; the correlation appears to be most robust when OEX is performing badly. Given this asymmetry, one could argue that instead of eagerness, VXO is a more accurate measure of general uncertainty among market participants. This finding is important when examining the informational role of volatility around events relevant to all market participants, such as the meetings of the FOMC.

3 Monetary policy

This chapter grounds the empirical part of this paper by examining the relationship between central bank monetary policy and the economy. Monetary policy decisions affect the economy in a relatively similar manner regardless of the market in question. Therefore, when discussing the common tools and schemes of monetary policy, this thesis considers the European Central Bank (ECB) as well. However, as the research question centers around the information role of implied volatility in the US market, most emphasis is put on the Federal Reserve and the monetary activities of the FOMC.

Monetary policy is what the central banks do to control the amount money and credit in the market. The goal of monetary policy is to enhance employment rates, stabilize prices and thus support enduring economic growth. These objectives are commonly conveyed as macroeconomic variables (Bernanke & Kuttner, 2005). However, the best possible impact on these variables is usually achieved through indirect methods. That is because the most extreme methods, namely the interest rate changes, have an impact only on the financial markets. Thus, central banks aim to achieve their monetary goals by altering economic behavior through indirect methods. (Bernanke & Kuttner, 2005, ECB, 2011a.)

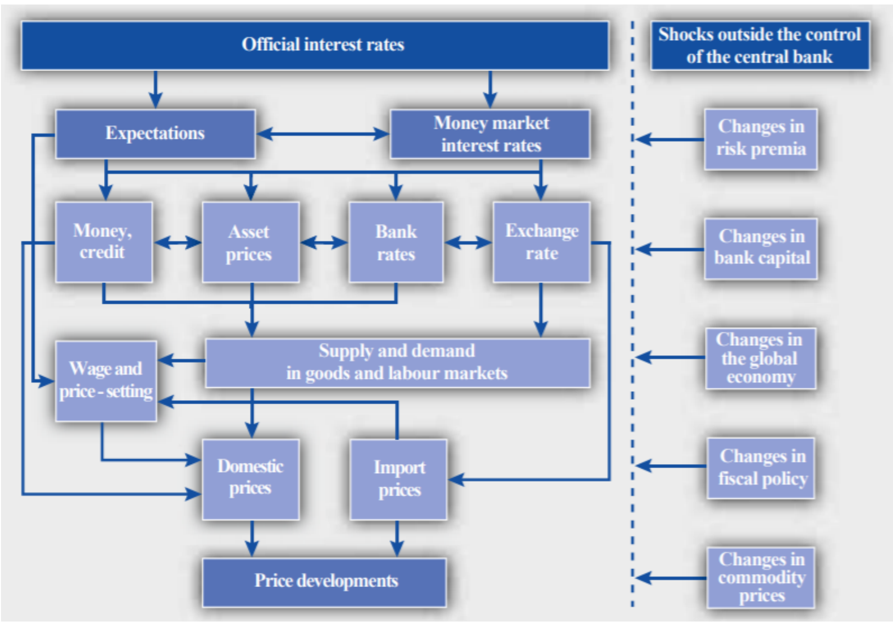

Figure 2. An illustration of the transmission mechanism from interest rates to prices (ECB, 2011a).

In figure (2), the European Central Bank describes how interest rates affect asset prices through several transmission channels. Different impulses can be signaled through various individual links that may have separate effects on future price development. Policymakers must therefore acknowledge the entire transmission chain when making single decisions. Moreover, exogenous shocks described in figure (2) are also factors that should be avoided or at least considered prior to making monetary policy decisions. (ECB, 2011a.)

The description of transmission channel described in figure (2) is relevant to not only ECB but also other central banks. When a change in the official interest rate occurs, central banks alter their own operations. These operations usually refer to transactions where the central bank borrows money to other banks. The demand for additional funds from the central bank implies that either the public demand for a given currency has increased or the borrowing bank requires money to fulfil interbank liabilities or minimum reserve requirements[8]. However, there are some central banks, for example those in Australia, Canada and Sweden, that do not apply to the minimum reserve requirements. (ECB, 2011a.)

Given the central bank controlling the interest rates on these transactions and thereby regulating the cost of liquidity, the banking sector is forced to pass on these costs to their end customers. Therefore, a change in money market[9] rate is commonly followed by a change in the rates set by the banking sector on loans and deposits. Short-term interest rates may also vary due to the expected changes in the money market rates. Then again, rates for longer maturities are usually not affected as they rely on more longer-term trends, such as economic growth and inflation.

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[8] Reserve requirements are the portions of deposits that banks are obliged to either maintain themselves or deposit at their designated central bank.

[9] Money market is a marketplace that consists of financial institutions that either borrow or lend money with a maturity of less than a year.

These changes in short-term rates are anticipated to have an influence also on the behavior of banks' end customers. For example, an increase in short-term interest rates is ceteris paribus anticipated to hold back the common interest of financing consumption or investments with borrowed money. Furthermore, this increase in rates should be followed by a similar increase in savings rate and thus encourage consumers to save their income. Following these changes in willingness to consume or invest, the relationship between domestic supply and demand becomes relevant. For example, should demand exceed supply, an upswing in prices is anticipated to occur. Moreover, a change in either supply or demand will in the long run have an influence on the labor market as well. (ECB, 2011a.)

Besides interest rate changes and minimum reserve requirements, central banks can also influence the supply of bank reserves through open market operations that are synonymous with buying and selling of government securities. ECB (2011a) has categorized[10] these operations into main financing operations (MROs), longer-term operations (LTROs), fine-tuning operations (FTOs) and structural operations. ECB considers MROs as the most effective liquidity-providing reverse transactions owing to their one-week maturities and frequencies.

On the other hand, central banks tend to implement LTROs with three-month (one-month) maturity (frequency) when counterparties need refinancing for a longer time period. Finally, FTOs and structural operations are used to guide interest rates, dodge liquidity shocks and alter the structure of the financial system. Both FTOs and structural operations are based on the current liquidity situation, which is why they are mostly non-standardized. (ECB, 2011a; ECB, 2011b.)

Rate changes, reserve requirements and open market operations are all utilized also by the central bank of the United States, The Federal Reserve System (FED). However, prior to examining the monetary actions of the FED, one should treat a section from ECB's

[10] The categorization is performed based on the type, maturity and frequency of the transaction.

policy that is not similarly present in the US. That section involves standing facilities, which are to stabilize overnight liquidity and reflect the current status of the monetary policy. As stated by ECB (2011a), standing facilities inject or absorb liquidity with an overnight maturity on the initiative of counterparties.

Counterparties have access to two kinds of facilities, namely the marginal lending facility and the deposit facility. The former has a function of obtaining central bank liquidity against the eligible assets, whereas the latter is used to make overnight deposits with the central bank. Given normal market conditions, it is not of banks' interest to use these facilities as their rate is not favourable compared to market rates. However, ECB (2011a) has compiled data about the daily usage of standing facilities from January 1999 to August 2008, available in figure (3).

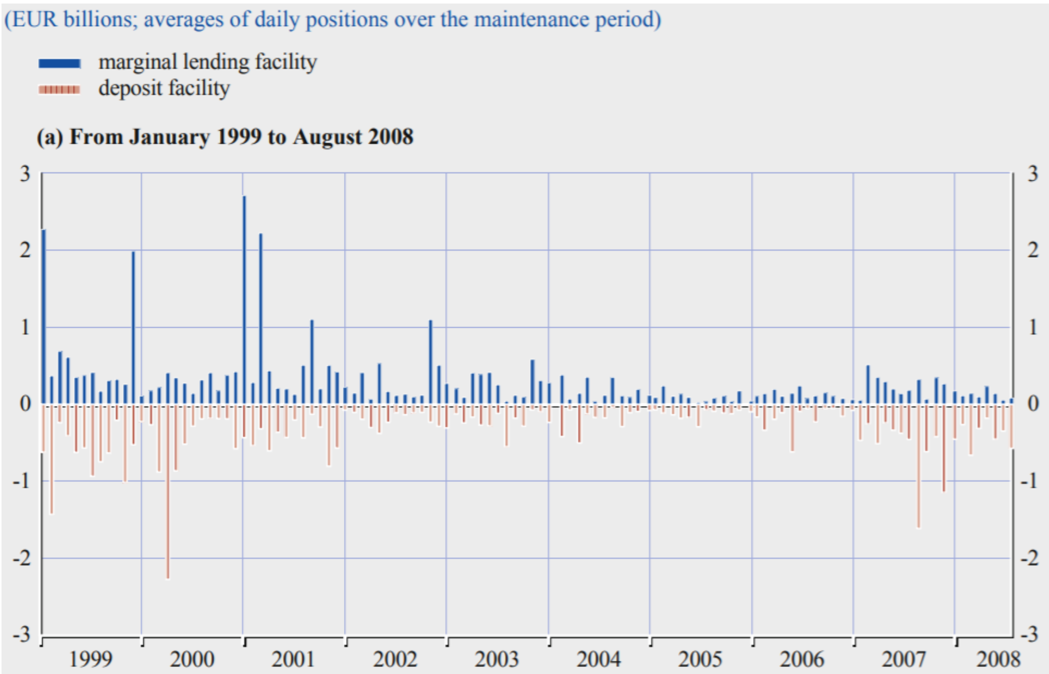

Figure 3. Daily positions in the ECB standing facilities, from 1999 to 2008 (ECB, 2011a).

Figure (3) verifies ECB's observations about the redundancy[11] of standing facilities around normal market conditions. However, whenever the banking sector faces

[11] During the chosen time period, the use of both facilities breached €1 billion only during turbulent market conditions.

exceptional market conditions, the role of standing facilities as a controller of liquidity becomes more evident. This is because during financial turmoil, banks prefer to deposit their assets at the central bank rather than lending them to other market participants (ECB, 2011b).

Understanding the behavior of standing facilities is useful for not only this thesis but for all other papers examining the relationship between implied volatility and equity returns around FOMC announcements. As standing facilities become relevant in turbulent market conditions, one may hypothesize that an increase in their utilization rate would lead to an upswing in implied volatility. This increase in implied volatility would consequently cause the stock market to decline given their negatively correlating relationship. Moreover, looking at the historical meetings of the FOMC, emergency meetings have for the most part occurred right around the turbulent market conditions. Therefore, there is arguably interaction between implied volatility, stock returns and the utilization rate of standing facilities. However, a more thorough conclusion- would require further examination of the timing of these effects, especially during financial turmoil.

3.1 The Federal Reserve and the FOMC

Having discussed the general tools and schemes of global monetary policy, this section narrows the scope of examination and focuses on the FED and the interest rate decisions of the FOMC. The Federal Reserve System, created in 1915 by the Congress, is a central banking system of the United States. The FED (2016) divides itself into three salient units; a central governing Board, a decentralized operating structure of 12 Reserve Banks, and the FOMC.

The Board of Governors is the governing unit of the FED. It involves seven members, namely the governors, who are appointed by the president and later verified by the senate. Besides promoting the public interest and formulating monetary policy, it is on

Board's responsibility to monitor the operations of the 12 Reserve Banks. Then again, the Reserve Banks implement the FED strategy by, for example, overseeing the state member banks and lending money to depository institutions to ensure local liquidity. Third unit, the FOMC, will be separately treated later.

It has been perceived that inflation, labor situation and long-term rates fluctuate over time in response to economic shocks. Moreover, the influence of monetary policy actions on economic activity and price development tends to occur with a lag. Therefore, the decisions of the FOMC should be in line with not only the FED's long-term objectives but also its medium-term market outlook. (FED, 2016.)

Following the Federal Reserve Act, the FED should strive for bolstering economic growth through maximum employment, stable prices and moderate long-term interest rates. The FED's main tool for this is to control the federal funds interest rate, which refers to the interest rate that banks charge other banks for lending them money from their reserve balances on an overnight basis. (FED, 2016.)

The federal funds rate is mostly driven by open market operations, and it can therefore be used as an indicator of the credit availability in the economy. Furthermore, any change in the federal funds rate is commonly reflected in various other economical rates, such as short-term interest rates and foreign exchange rates. The target levels for the federal funds rate have been historically published by the FOMC. Next, this thesis will treat the FOMC and its role in the US monetary policy.

Third unit of the FED, the Federal Open Market Committee, is to codify the nation's monetary policy. This is synonymous with decisions regarding not only the open market operations, but also the size and nature of the FED asset holdings. The FOMC involves 12 voting members, 7 of whom are members of the board. The main duty of the FOMC is to control the federal funds rate through open market operations. The FOMC treats these macroeconomic matters on a scheduled basis, having a regular meeting eight times a year. In each meeting, the FOMC outlines its policy for the upcoming period before the next scheduled meeting. Under extraordinary conditions, such as turmoil in the financial markets, the FOMC may be gathered for an unscheduled meeting. (FED 2016.)

The FED (2016) has guided the FOMC that during each meeting, the following questions should be considered:

1. How is the US economy likely to evolve in the near and medium term?
2. What is the appropriate monetary policy setting to help move the economy over the medium term to the FOMC's goals of 2 percent inflation and maximum employment?
3. How can the FOMC effectively communicate its expectations for the economy and its policy decisions to the public?

The FOMC strives for answering these questions through the following decision-making process. Prior to each meeting, the staff of the Federal Reserve Banks collect and gather information about the present state of the economy, which is then compiled into an overall summary, the so-called Beige Book[12]. Based on this summary and the economic forecasts provided by the Board of Governors, the FOMC participants formulate their initial opinions on the economic outlook. At the time of the FOMC meeting, a voting about future interest rates and other monetary actions is preceded by a presentation made by the Federal Reserve Bank of New York. This presentation acts as a directive for the FOMC regarding the long-term objectives and short-term operating guidelines. (FED 2016.)

As per the initial Federal Reserve Act, the main tool for FED to put monetary policy into action is the open market operations. However, with reference to the subject of this thesis, the examination will from now on center around the FOMC's decisions about

[12] The Beige Book is released to the public a week before the FOMC meeting.

changes in the federal funds target rate. As mentioned, the FED charges interest on credit they provide to banks and depositary institutions. This credit is provided through three different discount window programs: primary credit, secondary credit and seasonal credit. The FED has defined separate discount rates for each program. (FED, 2016.)

The primary credit program involves short-term credit, which is directed to depositary institutions with satisfactory financial profile. The price for this kind of credit is expected to be above the present market rates. Should there be a financial institution that does not fulfil the requirements of the primary credit program, it can procure short-term credit from the secondary credit program, which is usually more expensive than the primary one. Finally, the seasonal credit program exists to provide liquidity for institutions that are small and have seasonal need for credit. The rate for this program equals the average of the market rates selected by the FED. (FED, 2016.)

3.2 Interest rates and monetary policy

When examining the market interest rates, it is important to distinguish the different components of nominal interest rate r_n, which is the rate presented in the FOMC announcements. Allen, Brealey & Myers (2011) describe r_n as a product of real interest rate r_r and expected inflation i:

$$1 + r_n = (1 + r_r)(1 + i). \tag{7}$$

Considering equation (7), a change in the anticipated level of inflation should be proportionally reflected in the nominal interest rate, hence the real interest rate that consumers require is not affected by inflation. Bain and Howells (2005) take similar approach in equation (8) by assuming that besides r_r and the inflation premium π, the nominal rate r_n is driven by liquidity premium l and risk premium ρ:

$$r_n = r_r + \pi + l + \rho. \tag{8}$$

In equation (8), π reflects the compensation related to the anticipated price increase during maturity, while *l* originates from the difference between short-term and long-term interest rates. As lenders prefer the shortest possible maturity, they require compensation for any longer time periods. Thus, given no risk and constant prices, lenders that give up their possibility to spend require compensation amounting at least to the real interest rate *rr*. This kind of behavior is the reason behind the term structure of interest rates. (Bain & Howells, 2005; Allen et al., 2011.)

As examined earlier, the central banks have an essential role in steering interest rates. Now that both the common tools of monetary policy and the structure of nominal interest rates have been presented, this thesis further examines the existing literature about interest rates and the underlying monetary policy.

The study published by Lee (2006) observes the significant influence of the central bank monetary policy actions on interest rates. More accurately, the standard deviation of short-term interest rates appears to strongly response to the unexpected changes in the fed funds target rate. Also, the existing literature covers the relationship between the FED rate decisions and banks' reserve-demand behavior. In 1994, the FED started to announce target rate changes that were implemented through the scheduled FOMC meetings. The idea of this change was to reduce uncertainty around the FED's policy and thus decrease market volatility. The results confirm that since 1994, the target rate changes have been followed by lower interest rate volatility than before the policy change. (Bartolini, Bertola & Pratti, 2002.)

Motivated by the term structure of interest rates shown in equation (8), Balduzzi, Bertola & Foresi (1997) study whether the term structure is affected by the FED's decisions about the short-term target rate. By establishing a model that accounts for the discrete changes in target rates when studying the behavior of the term structure, Balduzzi et al. (1997) discover that it is the expectations of changes in the target rate that drive the spreads between short-term rates and the overnight FED funds rate.

To conclude, empirical evidence indicates how the impact of the central bank policy on market rates is not constant but varies with the expectations of future policy rates. Given the fact that this paper studies the relationship between the pre-FOMC implied volatilities and post-FOMC equity returns, the findings mentioned above are not essential. It is, however, useful to fully understand the process described in figure (2): what is the complete impact of the central bank rate decisions on market interest rates and eventually, asset prices.

3.3 The influence of interest rates on stock prices

As an extension for the previous chapter, this section investigates whether interest rates have any role in asset price valuation and stock pricing. The modern financial literature presents multiple different models for stock pricing. However, as this thesis focuses on the relationship between the stock prices and the pre-meeting volatilities, it is not meaningful to go through each model. Thus, to present a brief overview of the factors possibly affecting stock pricing, only few models relevant to this context are being presented.

One of the most well-known models is arguably the capital asset pricing model (CAPM), introduced by Sharpe (1964). The model is based on the idea of an asset having an expected rate of return $E(r_i)$, which is derived as follows:

$$E(r_i) = r_f + \beta_i(E(r_m) - r_f). \tag{9}$$

Consistent with other asset pricing models, CAPM is centered around the risk-free rate of return r_f. Considering equation (7), the risk-free rate of return is the sole variable that is directly dependent on the federal funds target rate. The other component in equation (9) is the market risk premium $E(r_m) - r_f$, which equals the return investors require on top of the risk-free rate when optimizing their risk-reward ratios. In other words, the market risk premium is the return of a portfolio that is subject to systematic risk only. As each asset is exposed to different amount of market risk, CAPM multiplies the market risk premium by β_i, which is the beta of the asset in question.

As per CAPM, an asset is priced correctly if its return positions the asset on the security market line[13]. When considering dividends *D*, an equilibrium occurs if the CAPM-implied $E(r_i)$ equals with the actual rate of return r_a:

$$r_a = \frac{D}{P+g}. \tag{10}$$

In equation (10), dividends are divided by the sum of the market price of the asset *P* and the earnings growth rate *g* (Bain & Howells 2005). Another pricing model driven by dividends is the dividend discount model (DDM) that treats the true price of stock *V* as a sum of the present values of its expected future dividends:

$$V = \sum \frac{D_t}{(1+k)^t}. \tag{11}$$

In equation (11), variable *k* is important as it describes the correct discount rate for the given level of risk. Equation (11) depicts the basic model, which has been later altered to account for various other factors, such as constant dividend growth (Bodie, Kane & Marcus, 2014). However, these applications are sidelined with reference to the subject of this thesis.

Should an investor plan to sell a stock after a certain holding period, dividends may also be used to determine the anticipated selling price of the stock in question. In other words, the total return of a stock can be considered as a sum of two parts: the difference between the purchase price and the expected selling price, and the present values of the expected dividends from that holding period. (Bodie et al., 2014.)

[13] Security market line (SML) is a visualization of CAPM, plotting different levels of systematic risk against the expected return of the market portfolio.

Following Bernanke and Kuttner (2005), there are three scenarios where stock prices may be affected by the unexpected federal funds rate changes: the expected excess return for the given stock increases, the expected amount of future dividends decreases, or the expected real interest rates used to discount future dividends increase. However, Bernanke and Kuttner (2005) discover that the direct effect of real interest rates on stock prices is slender, whereas changes in excess returns or future dividends may have a significant impact on stock prices.

These results, however, consider only the direct effects of interest rates on stock prices. Chen, Mohan & Steiner (1999) report significant results when studying the reaction of equity returns to changes in discount rates. As can be seen, the prevalent asset valuation methods tend to rely on expectations about future cash flows and discount rates. That being stated, one should consider whether these expectations are legitimate and how can one justify them. Therefore, the following chapter will treat these topics when briefly examining market's capability to absorb new information.

4 Market efficiency

Allocating the ownership of the capital stock of the economy has been adopted as the primary role of capital markets. Therefore, a well-functioning market should be able to give accurate signals for resource allocation. In other words, within an ideal market, participants can allocate their wealth between different asset classes under the assumptions that their prices incorporate and reflect all information available at that moment. This principle was first introduced by Fama (1970), who states that a market in which asset prices always incorporate all available information is called efficient.

Given all available information and an assumption of asset prices being immediately bid to fair levels, one can conclude that asset prices change solely when new information is injected into the market. This new information must, by definition, be unpredictable as any predictable information would be reflected in current asset prices. Furthermore, as asset prices are expected to be influenced by this information, the future development of these asset cannot be predicted. This is the underlying argument of a theory by which asset prices ought to follow *a random walk*.

In their pioneering study, Kendall and Bradford (1953) attempt to forecast the stock market price behavior by utilizing the systematic components of stock market time series. However, their main finding is that forecasting is possible only when market-exterior information is involved. Authors refer to the concept of random walk by stating that when it comes to forecasting future stock prices, time series analysis as a method is as accurate as drawing lots.

Should stock prices be determined rationally and with full access to all existing information, new information is the sole factor that drives stock prices that consequently follow random walk. If the price changes could be predicted, meaning that there exists information not yet incorporated in prices, market would be considered inefficient. Therefore, the notion of stock prices incorporating all available information is referred to as the efficient market hypothesis (EMH). (Bodie et al., 2014.)

The EMH is a striking application of the theory of rational expectations, which was initially presented by Muth (1961). This theory treats the various economic situations in which the outcome fully or partially depends on what involved parties anticipate to happen in the future. With reference to future stock prices, investors strive for accurate forecasts by rummaging various sources of information, such as past price fluctuation and any patterns in it. At the time of an investment decision, investors go long (short) in stocks they believe to generate return higher (lower) than their respective averages. By doing so, investors bid up (drive down) the prices of the stocks they decided to buy (sell). The prices continue to change until each stock has equal risk-adjusted expected returns, that is the moment when market prices fully reflect investors' beliefs on future price movement. Thus, all remaining factors that drive stock prices cannot be predicted, meaning that the prices ought to follow a random walk. It is important to notice that regardless of the form in question, the EMH asserts that prices should reflect only information that is available at the time. Whenever new information is injected to the market, stock prices are anticipated to change relative to that new information only.

4.1 Three forms of market efficiency

There exists a wide consensus among finance literature regarding the three forms of market efficiency. As per Fama (1970), the level of market efficiency can be distinguished by the degree of information incorporated in asset prices. Should the prices reflect only the kind of information that can be derived from existing trading data, the market is said to function under the weak-form hypothesis. This information can be, for instance, historical price patterns or trading volumes. Under the weak-form hypothesis, current prices fully reflect the historical information, hence investors cannot generate alpha by utilizing existing data in predicting future prices. (Fama, 1970; Bodie et al., 2014.)

The semi strong-form hypothesis states that in addition to past price information, the price of a stock should reflect all other public information related to the firm in question. The information referred in this context may include fundamental data on the firm's production line, management, balance sheet composition, intellectual property or earnings forecasts. Therefore, any news on a certain company should not influence its stock price as it already reflects all publicly available information.

Fundamental analysis of publicly available firm-specific information is a widely established method of security analysis. Therefore, the semi-strong form hypothesis, which assumes that all public information is already impounded into stock prices, has been under criticism. By investigating the relation between unexpected earnings announcements and abnormal stock returns, Rendleman, Jones & Latané (1982) report findings against semi-strong form hypothesis. However, most of the existing literature supports the hypothesis. even if a firm-specific occasion results in stock price changes, the market adjusts to new information so rapidly that fundamental analysis does not generate abnormal returns.

The strong-form hypothesis is arguably the strictest of the three as it states that all information, whether it is available for public or insiders only, is incorporated in stock prices. As per the hypothesis, this insider information is not beneficial in predicting future price movement. Referring to the studies mentioned earlier, there is evidence that stock prices may not reflect all available firm-specific information. A widely referenced study by Jaffe (1974) documents that significant profits can be generated by trading on information that is not publicly available. Even though such insider trading is illegal, it illustrates the possibility of making a profit on information asymmetry. There is, however, strong evidence on market’s ability to almost fulfill the requirements of the strong-form hypothesis (see e.g. Jensen, 1969).

4.2 Efficient markets and monetary policy

Following the EMH, market participants are expected to respond only to announcements involving previously unknown information. Therefore, it is only the unexpected part of information that may shift prices. When it comes to monetary policy actions, there exists a market consensus on their disposition and magnitude. At the time of a monetary policy announcement, actions that are in line with market consensus have no impact on stock prices. Then again, any deviation from this consensus is considered surprising and hence affects stock prices. The bigger the surprise, the bigger the adjustment in stock prices. Naturally, the direction of this adjustment depends on the prevailing market expectations. (Bernanke & Kuttner, 2005.)

The EMH can be applied also to stock options as options follow same principles with their underlying assets. For option market to be efficient, the pricing models should be appropriate, and each option should have an implied volatility that accurately describes their yet-to-be realized volatilities. In other words, implied volatility should fully reflect all information available at the time. However, Ederington and Guan (2005) document that the ability of an option to reflect available information and thus comply with the EMH is driven by its exercise price and moneyness.

The existing literature has also alluded to market efficiency when examining what kind of an impact does the FED policy have on the stock market. It is embraced that the stock market tends to react positively on expansionary monetary policy actions. More specifically, it has been discovered that the federal funds rate is negatively correlated with following stock returns (Ang & Bekaert, 2007). Maio (2014) rests his work on this idea and utilizes the information associated with the federal funds rate when constructing dynamic trading strategies. In practice, these strategies increase the weight of riskier assets whenever the federal funds rate declines. Maio (2014) reports that these strategies generate significant returns and outperform the traditional buy-hold strategies that use leverage. Moreover, Maio (2014) exhibits that when it comes to predictors that are used in active trading strategies, the federal funds rate outperforms other alternatives. These findings further support the notion that FOMC announcements incorporate new information and thereby have an influence on the stock market.

Considering this thesis, which studies whether pre-announcement changes in implied volatility contain any information about post-announcement stock returns, understanding the concept of efficient markets is important. If markets were efficient, any historical data such as changes in implied volatility should not be useful in predicting future stock returns. Moreover, given efficient markets, the information content of these changes should be the same whether there is a monetary policy announcement or not.

5 Literature review

A comprehensive treatment of the chosen subject is possible only after the theoretical diagnosis. Thus, this chapter focuses solely on extant literature and approaches the matter inversely by first discussing the relationship between equity returns and FOMC announcements. Then, the behavior of implied volatility around FOMC announcements is inspected. Finally, the literature about the informational role of implied volatility around FOMC announcements is taken under examination.

5.1 The relation between FOMC announcements and the stock market

The existing literature documents how equity market reacts to FOMC announcements in a way that cannot be explained by standard asset pricing theory. Lucca and Moench (2015) report that since the 1980s, US equities have generated large excess returns in the 24 hours before scheduled FOMC announcements. It is discovered that these returns do not revert in following trading days and thereby compose a major part of the realized excess stock returns. However, Lucca and Moench (2015) note that there is a puzzle as these returns cannot be fully explained with factors such as undiversifiable risk, information leakage, liquidity or volatility.

Thereafter, the pre-FOMC announcement drift has been under further research. Boguth, Gregoire & Martineau (2019) examine if the way the FOMC communicates has any impact on these returns. In 2011, the FOMC implemented its new communication policy by which it is to hold a press conference after every other scheduled meeting. Boguth et al. (2019) document that the pre-FOMC drift stems from the announcements that are accompanied with these press conferences. Later, Gilbert, Kurov & Wolfe (2020) support these findings by extending the sample to 2019 and exhibiting that the pre-FOMC drift disappears when no press conferences are being held. Furthermore, Gilbert et al. (2020) document that since 2016, the pre-FOMC drift has weakened also in announcements that are accompanied with press conferences. Finally, Ben Dor and Rosa (2019) report that the pre-FOMC drift is limited to equity markets only. Even though these findings about pre-FOMC equity returns are important for this thesis, some remarks shall be made. First, it is worth noticing that this thesis covers data between 1995–2008, that is time before the new communication policy of the FOMC. Second, this thesis considers stock returns that are captured on the announcement days (or surrounding days) instead of the preceding 24 hours.

When discussing the impact of prevailing monetary policy circumstances on equity market, a paper worth considering is the one published by Gu, Kurov & Wolfe (2018). They study the behavior of stock returns following FOMC announcements, especially the ones that are accompanied by the release of the Summary of Economic Projections (SEP). In 2007, the FOMC started to publish projections for major three economic indicators after every other FOMC meeting. This publication is referred to as the SEP report, and Gu et al. (2018) examine whether its presence has an impact on the following stock returns. Figure (4) depicts their main findings: whenever FOMC announcements are accompanied with the SEP report, the subsequent equity returns are more positive.

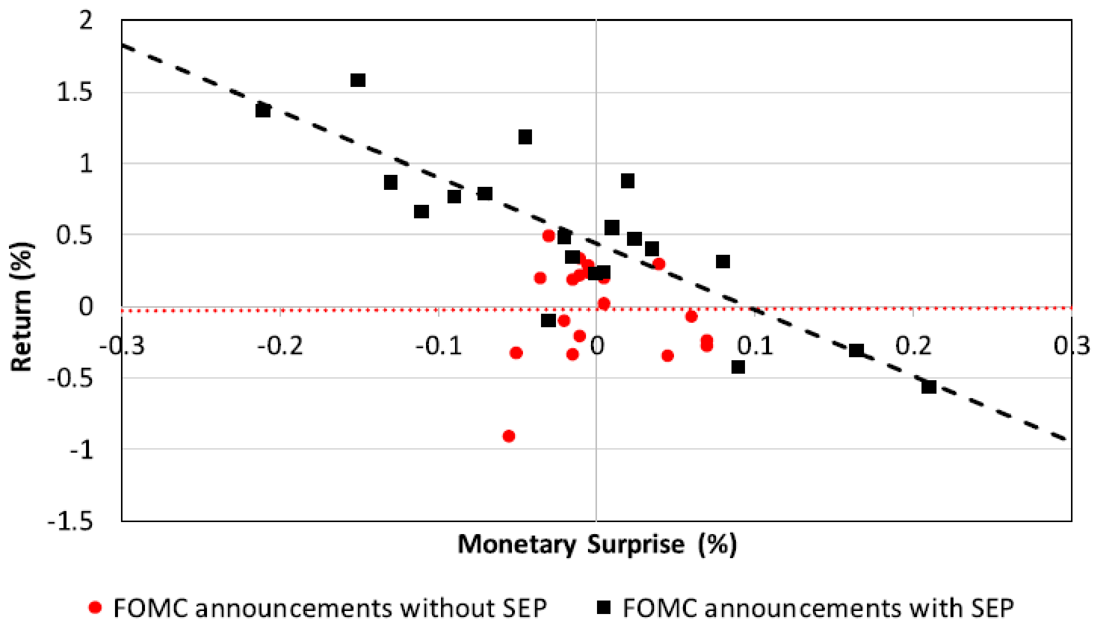

Figure 4. Monetary surprises and post-announcement stock returns (Gu et al., 2018).

Even though Gu et al. (2018) sideline the role of implied volatility and study purely the behavior of stock returns amid FOMC announcements, the information contained in figure (4) is relevant to this thesis. Figure (4) confirms that stocks tend to generate positive returns after FOMC announcements. Given the negative correlation between stock returns and implied volatility, these returns should be accompanied with a decrease in implied volatility. In addition, figure (4) illustrates how stocks generate most return when monetary information is considered negatively surprising.

Existing literature has been focusing mainly on the linkage between macroeconomic announcements and the equity pricing process, leaving room for studies related to implied volatility. Motivated by this literature gap, Nikkinen and Sahlström (2004) study the impact of scheduled FOMC meetings on stock market uncertainty, measured by the old S&P 100 VIX. By regressing changes in implied volatility on dummy variables identifying the FOMC announcement time frames[14], they find that implied volatility increases (decreases) prior to (on the day of) the scheduled announcement. Furthermore, contrary to other macroeconomic news releases, FOMC announcements are not preceded by sudden jumps in implied volatility. By supporting the existence of the tripartite relationship between implied volatility, FOMC announcements and stock market behavior, these results are relevant to this thesis.

Chen and Clements (2007) base their study upon the findings of Nikkinen and Sahlström (2004) and examine the behavior of VIX around FOMC announcements. However, the two studies report partly differing results. While both studies document a decrease in implied volatility on the FOMC announcement day, contradiction occurs in the pre-FOMC behavior of implied volatility. Nikkinen and Sahlström (2004) report an increase in VIX prior to the announcement whereas Chen and Clements (2007) do not support this notion. This is due to the mean-reverting nature of VIX, meaning that the return on VIX is seen to be dependent on its current level.

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[14] Not only the announcement days but also the surrounding days (t-1 and t+1).

Later, Vähämaa and Äijö (2011) extend the findings of Chen and Clements (2007) by regressing daily VIX changes on various FOMC variables and thus establishing the bearing of the FED's policy decisions on market uncertainty. At the time publication, their study had novelty value in three different aspects. First, they examined the influence of monetary policy shocks on stock market uncertainty by separating surprising decisions from all FOMC decisions. This separation was done by utilizing the daily changes in fed funds futures contracts. Second, they presumed that scheduled and unscheduled meetings have different effects on market uncertainty, which is why they divided all FOMC meetings into two subsamples. Finally, motivated by previous studies, their examination accounted for the potential cyclical variation in the relationship between policy decisions and implied volatility. (Vähämaa & Äijö, 2011.)

Vähämaa and Äijö (2011) document how implied volatility is affected by monetary policy decisions. Furthermore, they agree with Nikkinen and Sahlström (2004) and Chen and Clements (2007) about the post-FOMC decrease in implied volatility. However, due to the separation of policy shocks into positive and negative surprises, they perceive how implied volatility is mostly driven by negative[15] surprises that are to reduce general uncertainty. Moreover, the results of Vähämaa and Äijö (2011) suggest that it is not only scheduled but also unscheduled meetings that have an impact on implied volatility.

The link between scheduled FOMC meetings and implied volatility has also been studied by Chen et al. (2012). Their first results confirm the findings of Nikkinen and Sahlström (2004), Chen and Clements (2007) and Vähämaa and Äijö (2011) about the significant decrease (-2.74% on average) in implied volatility on scheduled FOMC meeting dates. Therefore, one can conclude that by declaring scheduled interest rate decisions, the FOMC notably unloads the prevailing market uncertainty. However, Chen et al. (2012) counter the existing findings in two ways. First, they suggest that the decrease in VIX is present for the full sample and thus does not depend on the prevailing monetary policy

[15] Vähämaa and Äijö (2011) considered target rate surprise to be negative, if the rate increase (cut) was smaller (greater) than expected.

stance. Second, Chen et al. (2012) differ by not recognizing the influence of policy surprises on implied volatility. In other words, Chen et al. (2012) reckon VIX as a proxy that captures pure uncertainty rather than information. This perception about the insignificant role of policy surprises on decrease in implied volatility is indirectly countered by Gu et al. (2018), as depicted in figure (4).

It is also Gospodinov and Jamali (2012) that study the way implied volatility reacts to FOMC announcements. By separating the expected and surprise elements of each FOMC announcement, Gospodinov and Jamali (2012) report that implied volatility does not respond to the expected component of a target rate change. On the other hand, the impact of the surprise component on implied volatility is reported to be positive and significant. This observation is inconsistent with other presented papers that report a decrease in implied volatility following FOMC announcements.

The mechanisms through which the release of macroeconomic news affect financial markets have also been studied by Chan and Gray (2018). Besides other announcements, Chan and Gray (2018) examine FOMC meetings and document negative jumps in implied volatility following the announcements. This is consistent with the notion that option prices contain heightened volatility prior to a forthcoming announcement. In addition, Chan and Gray (2018) exhibit that the magnitude of these jumps is a function of the surprise element in the announcement, as earlier suggested by Vähämaa and Äijö (2011). This finding contrasts the conclusions made by Chen et al. (2012).

These findings on post-FOMC stock returns and implied volatility are important when inverting the angle of approach and studying whether pre-FOMC implied volatility incorporates event-specific information about future stock returns. Should implied volatility react in a systematic manner surrounding macroeconomic news announcements, one could expect that given the negative correlation between implied volatility and stock returns, this pattern could provide some information on the subsequent equity returns as well.

5.2 The information content of option trading

The influence of the options market on the way stocks react to new information has been thoroughly investigated. Initial studies put emphasis on options listing status, and the informational linkage between options trading volume and equity markets became prevalent shortly after. Easley et al. (1998) discover that owing to a pooling equilibrium scenario, traders with superior information may perform their transactions in the options market and hence turn them informative for the future movement of stock prices. However, associating options trading volume with informed trading often calls for high-frequency options data and may thereby lead to proprietary limitations (Cao, Chen & Griffin, 2005; Pan & Poteshman, 2006).

Acknowledging these limitations, Lei, Wang & Yan (in press) shift focus from options trading volume to option pricing effects. More accurately, Lei et al. (in press) employ the spread between call and put implied volatilities to study the implication of options trading on the way stocks response to earnings announcements. By dividing each month into six five-day intervals, Lei et al. (in press) report a gradual increase in implied volatility spreads when approaching the earnings announcement. Furthermore, they suggest that cumulative abnormal implied volatility spreads have predicting power over subsequent stock returns amid earnings announcements. These findings together with other related papers (see e.g. Jin, Livnat & Zhang, 2012; Atilgan, 2014) endorse the idea of informed traders steering the options market prior to earnings announcements.

In addition to earnings announcements, the informational role of implied volatility has also been studied prior to other firm-specific events such as corporate share repurchase announcements. Using a sample of 2256 share repurchase announcements between 1996–2012, Hao (2016) studies the development of implied volatility spreads before their respective announcements and discovers abnormally large spreads immediately prior to announcements. Furthermore, Hao (2016) reports that these volatility spreads have informational value over stock returns on the announcement days. Similar results have been obtained also for other firm-specific occasions such as mergers and acquisitions (Chan, Ge & Lin, 2015) and stock splits (Ghargori, Maberly & Nguyen, 2017). Again, these findings support the notion that implied volatility contains information about future equity returns, at least on a firm-specific level.

As previous studies report evidence of equity return predictability from the options market around firm-specific events, Du et al. (2018) examine whether this perception holds also around a macro-level event such as FOMC announcement. However, due to the differences in sensitivity to interest rate across industries, their paper focuses solely on stock returns of the banking sector[16]. Therefore, also the measure of implied volatility is adjusted to depict only the banking sector by focusing on implied volatility spreads. These spreads are defined as the weighted difference in implied volatilities between call and put options with equal maturities and exercise prices. Finally, Du et al. (2018) examine whether the return predictability is greater around FOMC announcements that are surprising. This is done by utilizing federal funds futures and the related approach initially presented by Kuttner (2001) and later employed by Bernile, Hu & Tang (2016).

Du et al. (2018) exhibit significant returns when constructing a hedge portfolio based on the implied volatility spreads preceding the FOMC announcements. For the full sample, risk-adjusted return for the hedge portfolio is 28.6 basis points (bps). In addition, their results indicate the positive relation between return predictability and the magnitude of surprise in macroeconomic announcement. For the hedge portfolio constructed from surprise rate changes, the risk-adjusted return is 112.1 bps. To conclude, Du et al. (2018) document that compared to days without FOMC announcements, implied volatility predicts stock returns to a greater degree when there is an announcement by the FOMC. Furthermore, they report that this predictability is driven by the announcements that are considered surprising. This is consistent with the findings of Bernile et al. (2016).

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[16] Du et al. (2018) reckon firms within the banking sector to be sensitive to interest rates given notable differences in the maturity composition of their balance sheets.

It is important to distinguish the differences between the papers published by Du et al. (2018) and Lucca and Moench (2015). Lucca and Moench (2015) document significant pre-FOMC returns and suggest that these unconditional excess returns are not directly associated with the actual decisions of the FOMC. Then again, Du et al. (2018) measure the effect of the actual policy decision and focus on the realized returns captured during the announcement, that is before and after the actual announcement. Furthermore, Du et al. (2018) exhibit information revelation in the options market on the day before the announcement, meaning that the options market would predict stock returns the FOMC decision.

Even though the findings of Du et al. (2018) are based solely on the implied volatility spreads of options associated with banking sector, one can, by implication, utilize them in a market-wide environment. Option trading around FOMC meetings has predicting power not just for bank stocks, but for each stock that is sensitive to interest rates. Thus, this thesis studies whether implied volatility can predict equity returns also when both variables are detached from the banking sector and examined in a market-wide context.

6 Data and methodology

As outlined in section 1.2, this thesis studies whether implied volatility contains more information about future stock returns around FOMC interest rate announcements than it usually does. The empirical examination is grounded by this chapter, which presents the data and methodology used. Section 6.1 exhibits the collected data set and its characteristics. Thereafter, section 6.2 presents the empirical methodology and treats the chosen research hypotheses.

6.1 Data description

This thesis puts most emphasis on stock returns and changes in implied volatility, hence the data set contains daily values of the two market-wide indices, VXO and OEX. These indices measure implied volatility and equity returns, respectively. The data set also accounts for the event study-like environment by not only containing changes in the fed funds target rate, but also distinguishing the three-day windows around FOMC announcements. Finally, the changes in implied volatility are divided into quartiles and treated in separate subgroups, that is the three-day windows around FOMC announcements.

The data is collected from Refinitiv, a database formerly provided by Thomson Reuters yet later renamed as the Blackstone Group LP acquired majority of the Thomson Reuters Financial & Risk data business. With reference to the monetary policy data, the development of the fed funds target rate is provided by Refinitiv as well. The FOMC meeting calendar, especially the meeting days when no target rate changes were made, is collected from a database maintained by the Research division of the Federal Reserve Bank of St. Louis (FRED).

As justified in section 1.2, the sample period covers data from 1995–2008 for two reasons. First, due to the aftermath of the financial crisis, the Federal Reserve made no changes to its target rate between 2008–2015. Second and consequently, there were no reasonable expectations for target rate to change during that period, and thus the FOMC announcements after 2008 are not comparable with the ones preceding the period of quantitative easing. Regarding the chosen sample period, there are nine daily observations that are omitted as their respective 3-day time windows overlap each other. Furthermore, as this thesis considers changes in VXO as a lagged variable, the first pair of observations is omitted from the empirical examination. Besides these notices, there are no other limitations regarding the collected data set. Table (3) presents the descriptive statistics for VXO, OEX and their respective daily changes.

Table 3. Descriptive statistics of VXO and OEX from January 1995 to December 2008. All changes are of logarithmic nature. These statistics include all daily observations from the sample period. Out of the total 3653 daily observations, nine are omitted as their three-day time windows around FOMC meetings overlap each other. Out of the 3643 changes, 3642 are taken into empirical examination.

Statistics	**Level**		**Change**	
Index	VXO	OEX	VXO	OEX
Number of observations	3 644	3 644	3 643	3 643
Mean	21.85	539.41	0.03 %	0.02 %
Median	21.34	560.90	0.00 %	0.02 %
Minimum	9.05	214.20	-35.52 %	-9.19 %
Maximum	87.24	832.65	53.23 %	10.66 %
Standard deviation	9.44	139.39	6.30 %	1.25 %

The data sample consists of 3644 daily observations of VXO and OEX between January 1. 1995 and December 31. 2008. Table (3) exhibits that for both indices, the average daily change is close to zero. Furthermore, table (3) reports how the absolute value of maximum daily change in volatility (53.23 %) is greater than the respective minimum value (35.52 %). This finding supports the results of Giot (2005) about the asymmetric characteristics of volatility. Table (3) also confirms that daily changes in implied volatility are more drastic than the daily returns of the stock market. This is widely acknowledged in existing literature and is caused by the fact implied volatility measures uncertainty.

Figure (5) displays the development of the FED funds rate during the sample period 1995-2008. The sample period incorporates 132 FOMC meetings and 53 rate changes in total, of which 25 (28) are positive (negative). Thus, 79 meetings result in no changes to FED funds rate.

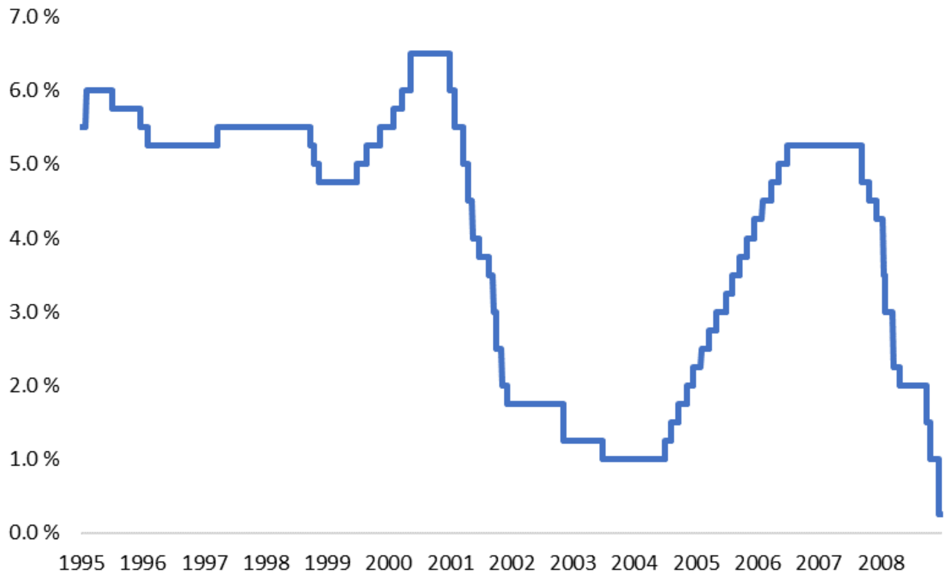

Figure 5. The development of the FED funds target rate during the sample period 1995–2008.

The FED funds rate varies significantly during the sample period. Between 1995 and 1998, the FED funds rate fluctuates around 5 % without any notable trends in its development. In 1999, the target rate increases gradually since the US economy is performing well. Regarding this sample period, the FED funds rate peaks at 6.5 % in May 2000. The US economy enters recession shortly after, which is why the FOMC starts to aggressively lower the target rate. Between June 2004 and June 2006, the FOMC executes a full cycle of rate increases from 1.00 % to 5.25 %. The target rate stands at 5.25 % for over 12 months, until the FOMC starts executing rate cuts in 2007. Between September 2007 and December 2008, the FOMC combats recession by conducting easing monetary policy, that is decreasing the FED funds rate from 5.25 % to 0.25 %.

The FED funds rate is further examined in figure (6) by plotting the nominal rate changes against the daily OEX returns of the FOMC meeting days. During the sample period 1995-

2008, there are only few spikes in daily OEX returns on the FOMC meeting days. A thing worth noticing is that most of these spikes occurs at the time of recession (either 2001 or 2008) and are preceded by rate cuts. Regarding this thesis, it is of great interest to examine whether these rate cuts and their following stock returns could have been foreseen by utilizing the preceding changes in implied volatility.

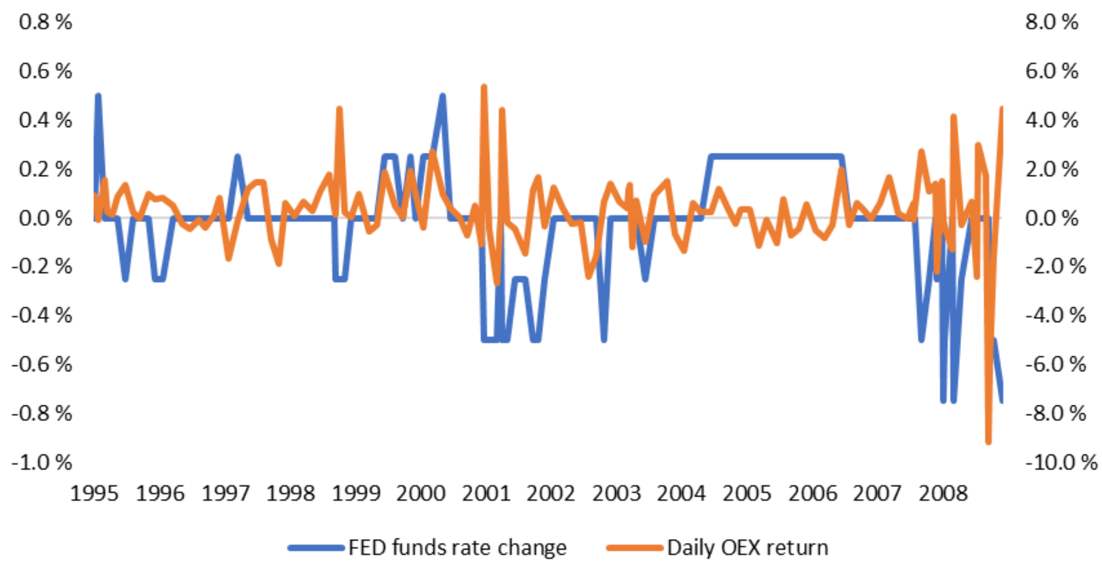

Figure 6. Changes in the FED funds rate plotted against the same day OEX returns, 1995–2008.

The final figure that treats the FED funds rate data is Figure (7), which represents the distribution of different FED funds rate changes and their respective same day OEX average returns. During the sample period, the most extreme rate cuts (-0.75 %) are followed by a same day return of 2.88 % on average. Other rate cuts (-0.5 % and -0.25 %) yield smaller yet still positive returns (0.39 % and 0.25 % respectively). A bit surprisingly, also the returns following rate increases (0.25 % and 0.5 %) are slightly positive (0.31 % and 0.47 % respectively). Given no rate changes, OEX yields a minor daily return of 0.16 % on average. To conclude, the stock market tends to react positively on new information stemming from FOMC meetings. Moreover, changes in the FED funds rate appear to be negatively correlated with the same day OEX returns. In other words, big rate cuts tends to generate the best average stock returns. These findings are on par with Du et al. (2018) that focused mostly on the banking sector.

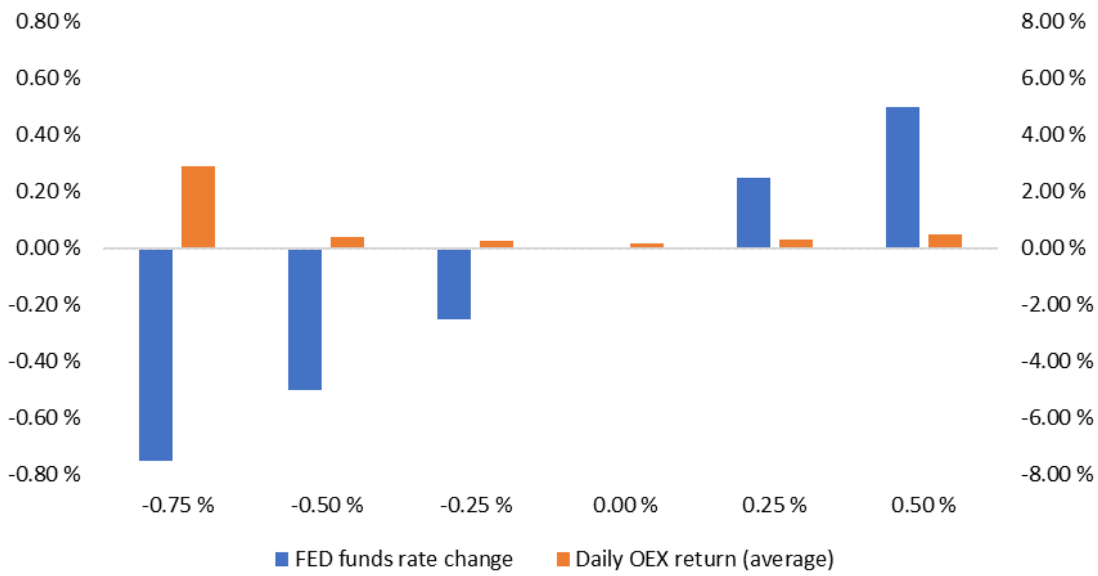

Figure 7. Distribution of the FED funds rate changes and daily OEX returns, 1995–2008.

As mentioned, the sample period includes a total of 132 FOMC meetings. Motivated by previous studies, this thesis divides the meetings into two categories. The first category incorporates all scheduled FOMC meetings. By standard, the FOMC has meetings eight times a year. The second category includes the unscheduled meetings, that is the conference calls. Table (4) presents descriptive statistics related to FOMC meetings.

Table 4. Descriptive statistics of FOMC meeting days, 1995–2008. The average OEX return is computed by taking an arithmetic mean of daily logarithmic returns. (Un)scheduled meetings are the ones (not) held according to the meeting calendar. Non-meeting days incorporate all days when no FOMC meetings were being held.

	Scheduled	Unscheduled
Panel A: All meetings		
Number of observations	111	21
Average OEX daily return	0.31 %	0.15 %
Panel B: Meetings 1995-2001		
Number of observations	56	8
Average OEX daily return	0.27 %	2.17 %
Panel C: Meetings 2002-2008		
Number of observations	55	13
Average OEX daily return	0.35 %	-1.10 %
Panel D: Non-meeting days		
Number of observations	3 510	3 510
Average OEX daily return	0.01 %	0.01 %

Out of the 132 total meetings, 111 are organized according to schedule. By dividing the sample period into two halves, one can verify that these scheduled meetings are evenly distributed across the 14-year period. For both subsamples (Panel B and Panel C), the average daily stock return is about the same (0.27 % and 0.35 % respectively). By nature, the average daily return for all scheduled meetings (0.31 %) is nearly the same as well. Differences occur when examining the unscheduled meetings. These 21 meetings are not evenly distributed across the sample period as they are not tied to the FOMC meeting calendar. Moreover, contrary to the scheduled meetings, table (4) reports how the average OEX return following unscheduled meetings varies notably between the subsamples. For the first (last) seven years of the sample period, the average daily OEX return is 2.17 % (-1.10 %). It is worth noticing that none of the 21 unscheduled meetings involve rate increase, whereas rate cut is present in five of the observations. Finally, table (4) reports the days without FOMC meetings in Panel D. By nature, the number of observations (3512) without FOMC meeting represents most of the entire population.

6.2 The impact of FOMC events on return predictability

The methodology of this study is motivated by the empirical framework implemented by Du et al. (2018). Furthermore, this study rests upon the idea of VXO reflecting investors' beliefs on future price development and general uncertainty. By extracting individual three-day samples around each FOMC meeting, this thesis examines whether recent changes in implied volatility can predict future stock returns. The general framework is presented in figure (8) that demonstrates the three-day window around the day of FOMC announcement, appointed as *t*.

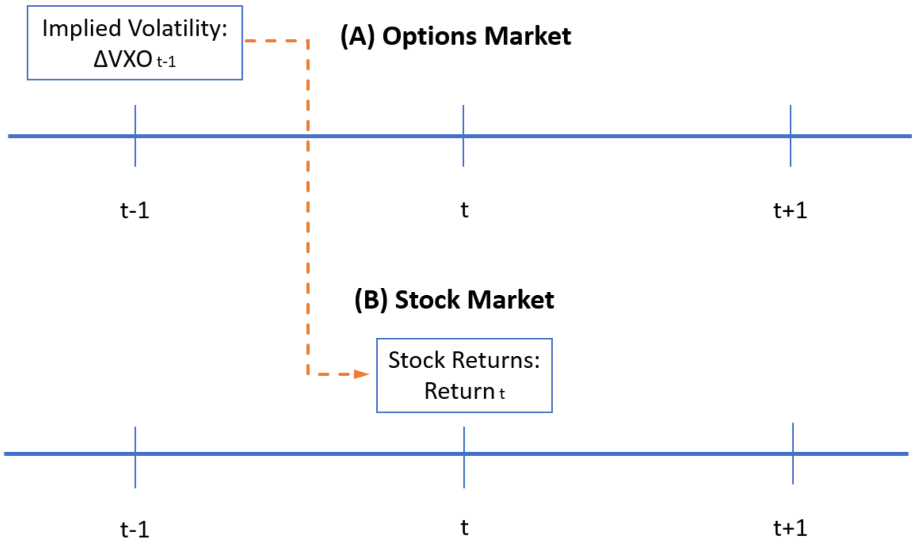

Figure 8. The generic framework for empirical analysis.

As figure (8) illustrates, the main purpose of this thesis is to model a relation between changes in the level of uncertainty and subsequent stock returns. The change in the level of uncertainty is measured by calculating daily changes in VXO a day before each FOMC meeting (t-1), whereas the daily returns of OEX are used to capture the following stock market reaction. As presented in section 1.2, the hypotheses of this thesis are formed as follows:

> *H0*: Stock return predictability related to implied volatility does not increase around FOMC meeting days.

This study attempts to reject H_0 and thus support the following alternative hypothesis about the impact of FOMC meetings on stock return predictability:

> *H1*: Stock return predictability related to implied volatility increases around FOMC meeting days.

In practice, the empirical research is conducted by regressing day *t* equity returns on preceding *t-1* changes in implied volatility. After the VXO variable is lagged, a dummy variable is added into the regression to indicate days when FOMC announcements are made. Thus, main analysis is conducted by utilizing the following formula:

$$Return_t = \alpha + \beta(\Delta\text{VXO}_{t-1}) + \delta_1(D_{FOMC}) + \delta_2(D_{VXO\ x\ FOMC}) + \varepsilon_{t+n}, \qquad (12)$$

where

$Return_t$ = logarithmic daily return of OEX,

α = intercept term,

ΔVXO_{t-1} = logarithmic daily change in VXO,

D_{FOMC} = value 1 for FOMC announcement dates, 0 otherwise,

$D_{VXO\ x\ FOMC}$ = interaction variable between lagged volatility and FOMC meetings,

ε_{t+n} = residual return not reflected in implied volatility.

Most emphasis is put on the examination of δ_2 as its positive significance would provide support against H_0. Contrary to the study conducted by Du et al. (2018), this thesis follows Chen et al. (2012) and assumes the behavior of implied volatility is independent from the content of the meeting. Therefore, the models do not include variables that measure the level of surprise in each meeting.

Besides the main regression in equation (12), this paper carries over the 3-day time window by one day and regresses *t+1* OEX returns on day *t* changes in implied volatility. That is because the existing literature documents habitual decrease in implied volatility on FOMC announcement dates as well as negative correlation between implied volatility and stock returns.

Motivated by previous studies, the empirical analysis accounts also for the two kinds of FOMC meetings and examines whether the predicting power of implied volatility is different around FOMC meetings that are not held according to the initial schedule. As mentioned, the initial meeting schedule of the FOMC incorporates eight meetings a year. Thus, each meeting outside this schedule is considered unscheduled. The possible difference in scheduled and unscheduled meetings is examined by performing another regression that designates two dummy variables, together with their respective interaction variables, to indicate the two kinds of meetings. This method results in a following formula:

$$Return_t = \alpha + \beta(\Delta \text{VXO}_{t-1}) + \delta_1(D_s) + \delta_2(D_{us}) + \delta_3(D_{VXO\ x\ S}) + \delta_4(D_{VXO\ x\ US}) + \varepsilon_{t+n}, \quad (13)$$

where

D_S = value 1 for scheduled meetings, 0 otherwise,

D_{US} = value 1 for unscheduled meetings, 0 otherwise,

$D_{VXO\ x\ S}$ = interaction variable between lagged volatility and scheduled meetings,

$D_{VXO\ x\ US}$ = interaction variable between lagged volatility and unscheduled meetings.

In each model, the non-meeting days are considered as the reference group as there is no dummy variable that explicitly represents them. Finally, the main regression presented in equation (12) is altered so that instead of the FOMC meeting days, the dummy variable accounts for all days within the 3-day time windows (from *t-1* to *t+1*):

$$Return_t = \alpha + \beta(\Delta \text{VXO}_{t-1}) + \delta_1(D_{3-DAY}) + \delta_2(D_{VXO\ x\ 3-DAY}) + \varepsilon_{t+n}, \quad (14)$$

where

$D_{3\text{-}DAY}$ = value 1 for days within the 3-day time windows, 0 otherwise,

$D_{VXO\ x\ 3\text{-}DAY}$ = interaction variable between lagged volatility and three-day time windows.

These regressions are applied to the sample of 3642 daily observations. As mentioned, it is of main interest to study the significance of the chosen interaction variables. For further examination, this thesis divides daily changes in implied volatility into quartiles. Following this classification, same regressions are applied to four subgroups to examine whether the magnitude of the preceding change in volatility correlates with the degree of return predictability. Finally, the sample period is chronologically divided into two seven-year subsamples so that any timely differences can be perceived.

Table (5) compiles the descriptive statistics for daily changes in implied volatility. Panel A exhibits the full sample of 3642 observations and illustrates how the daily changes in VXO are moderate, only 3 bps on average. Furthermore, Panel A presents the descriptive statistics for the full sample quartiles. Quartile 1 contains days with big declines in implied volatility, whereas quartile 4 consists of days with sharp daily increases. Quartile 2 (3) is the quartile right below (above) the full sample median. In quartile 4, the average change (7.81 %) is more positive than the average change is negative for quartile 1 (-7.26 %). For quartiles 2 and 3, the average daily changes are -1.71 % and 1.27 % respectively.

Table 5. Daily changes in implied volatility between 1995–2008. Average change is computed by taking an arithmetic mean of daily logarithmic changes. Panel A presents all observations that are considered in empirical examination. Panel B consists of same observations, yet it categorizes them into the three-day windows and non-meeting days.

	Average	Median	Std. dev.	N
Panel A: Full sample				
All observations	0.03 %	0.00 %	6.30 %	3 642
Quartiles:				
(1)	-7.26 %	-6.12 %	3.90 %	910
(2)	-1.71 %	-1.70 %	1.02 %	911
(3)	1.27 %	1.15 %	0.99 %	911
(4)	7.81 %	6.35 %	4.82 %	910
Panel B: Categorized observations				
FOMC meeting days	-2.27 %	-1.91 %	6.69 %	132
Days before FOMC meetings	0.29 %	0.45 %	6.35 %	132
Days after FOMC meetings	-0.59 %	-1.37 %	6.73 %	132
Days outside FOMC meetings	0.13 %	0.00 %	6.24 %	3 246

Panel B in table (5) highlights differences between the categorized observations. Between 1995-2008, the average (median) daily decrease in VXO is -2.27 % (-1.91 %) on FOMC meeting days. The decrease in implied volatility is not bounded by the meeting days as the average daily change for the days following FOMC meetings is also negative (-59 bps). Then again, implied volatility tends to increase by 29 bps on days before FOMC meetings. On days when no FOMC meetings are being held, VXO faces modest increase of 13 bps on average.

One may find resemblance when reflecting these findings on the existing literature. Following Chen et al. (2012), implied volatility can be perceived as a proxy for uncertainty, and hence the increase in VXO prior to FOMC meetings could be justified. Also, the documented decrease in implied volatility on FOMC meeting days is consistent with prior findings (Nikkinen & Sahlström 2004; Chen & Clements 2007; Vähämaa & Äijö 2011). Before treating the main research problem, that is the impact of FOMC meetings on return predictability, this paper briefly verifies the decrease in implied volatility on FOMC meeting days. This is done by using a plain model where daily changes in VXO are regressed on a dummy that indicates the FOMC meeting days:

$$\Delta \mathrm{VXO}_t = \alpha + \delta(D_{FOMC}) + \varepsilon_{t+n}, \tag{15}$$

where

D_{FOMC} = value 1 for FOMC announcement dates, 0 otherwise.

The next chapter will present the empirical results of this paper. In practice, the main area of interest is to study whether the change in VXO prior to FOMC announcements contains more information about future stock returns than the change that is captured before non-meeting days.

7 Empirical results

This chapter will discuss the results of the empirical analysis conducted to examine the predictability of stock returns through implied volatility around FOMC announcements. Diverging from existing literature, research problem is treated in a market-wide context. The chosen methodologies rest upon previous related studies and the empirical framework presented in chapter 6.

As discussed in section 1.2, the existing research studying the information contained in implied volatility is mostly based on two principles. First, option prices are expected to incorporate information not yet reflected in underlying stock prices (Cremers & Weinbaum 2010). Second, the option trading volumes are believed to cluster around occasions involving asymmetric information, as exhibited by Cao and Ou-Yang (2009). Given these presumptions, the following results are expected to extend the analysis of Du et al. (2018) by providing empirical evidence to support the predicting power of implied volatility around FOMC announcements. Furthermore, due to the nature of these regressions, the results are expected to be on par with Du et al. (2018) regarding the modest coefficients of determination.

The following tables present the results formed by utilizing the Ordinary Least Squares (OLS) method. Each table consists of three panels: Panel A for full sample and separate panels for subsamples 1995–2001 and 2002–2008, Panel B and Panel C respectively. Before treating the main research problem, the impact of FOMC meetings on implied volatility is briefly documented in table (6). However, most emphasis is put on results related to return predictability around FOMC meetings, that is from table (7) onwards. In each of these tables, results are presented for not only all observations in the group, but also for the quartiles initially presented in Panel A of table (5).

Table 6. The impact of FOMC meetings on implied volatility, 1995–2008. For all intercepts and coefficients, their respective p-values are reported in parentheses below. The significance levels at 1%, 5% and 10% are indicated as ***, ** and * respectively.

	Intercept	δ_{FOMC}	R Square	N
Panel A: Full sample				
	0.001	-0.024 ***	0.005	3 642
	(0.296)	(0.000)		
Panel B: 1995-2001				
	0.001	-0.030 ***	0.009	1 819
	(0.404)	(0.000)		
Panel C: 2002-2008				
	0.001	-0.018 **	0.003	1 823
	(0.512)	(0.026)		

As expected, the results reported in table (6) confirm the significant decrease in implied volatility on FOMC meeting days. For the full sample of 3642 daily observations, the coefficient estimate for dummy variable indicating FOMC meetings is negative at -0.024 and significant at the 1 % level. In other words, the occurrence of a FOMC meeting leads to a 2.4 % same day decrease in VXO. The coefficient estimates remain significant for both subsamples as well. Panel B indicates that between 1995–2001, FOMC meetings result in a VXO decrease of -3.0 %, significant at the 1 % level. For another subsample, the documented decrease is -1.8 %, significant at the 5 % level. In general, the results in table (6) are similar across the sample and one can thereby conclude that uncertainty generally decreases after FOMC meetings. Again, these results are reported just to ground the main analysis of this paper and to further authenticate the previous findings on this matter (Nikkinen & Sahlström 2004; Chen & Clements 2007; Vähämaa & Äijö 2011).

Regarding the chosen research problem, table (7) is of great interest as it presents the results of the regression in which daily OEX returns are explained by not only the lagged changes in VXO, but also the dummy variables indicating the FOMC meeting days.

Table 7. OEX returns explained by changes in VXO on FOMC meeting days, 1995–2008. For all intercepts and coefficients, their respective p-values are reported in parentheses below. The significance levels at 1%, 5% and 10% are indicated as ***, ** and * respectively.

	Quartiles				All
	(1)	(2)	(3)	(4)	
Panel A: Full sample					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.619)
$\beta_{VXO\ t-1}$	0.005	-0.001	-0.002	-0.019 ***	0.010 ***
	(0.355)	(0.700)	(0.661)	(0.006)	(0.002)
δ_{FOMC}	0.003	0.001	0.000	-0.006 **	0.003 **
	(0.138)	(0.444)	(0.767)	(0.018)	(0.013)
$\delta_{VXO\ x\ FOMC}$	0.018	0.017	-0.024	-0.027	-0.005
	(0.517)	(0.307)	(0.439)	(0.403)	(0.754)
R Square	0.005	0.002	0.001	0.017	0.004
Number of observations	910	911	911	910	3 642
Panel B: 1995-2001					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.129)
$\beta_{VXO\ t-1}$	0.004	-0.016 ***	-0.004	-0.036 ***	0.000
	(0.589)	(0.007)	(0.416)	(0.000)	(0.937)
δ_{FOMC}	0.002	0.001	0.001	0.002	0.005 ***
	(0.311)	(0.478)	(0.468)	(0.751)	(0.001)
$\delta_{VXO\ x\ FOMC}$	0.035	0.049	-0.084	0.209	0.076 **
	(0.296)	(0.138)	(0.336)	(0.195)	(0.012)
R Square	0.007	0.019	0.005	0.037	0.009
Number of observations	439	462	468	450	1 819
Panel C: 2002-2008					
Intercept	0.011 ***	0.002 ***	-0.001 ***	-0.012 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.510)
$\beta_{VXO\ t-1}$	0.006	0.009 *	0.001	-0.005	0.019 ***
	(0.453)	(0.074)	(0.847)	(0.632)	(0.000)
δ_{FOMC}	0.003	0.001	-0.002	-0.007 *	0.001
	(0.261)	(0.728)	(0.310)	(0.053)	(0.501)
$\delta_{VXO\ x\ FOMC}$	0.000	0.002	-0.024	-0.040	-0.038 *
	(0.997)	(0.932)	(0.466)	(0.281)	(0.084)
R Square	0.004	0.008	0.003	0.016	0.009
Number of observations	471	449	443	460	1 823

In table (7), Panel A exhibits the full sample results. Regarding all observations, the coefficient estimate for previous-day changes in VXO is positive (0.010) and significant at the 1 % level. Thus, holding other factors fixed, any changes in VXO are positively and significantly associated with the following day OEX returns. Also, the FOMC dummy variable is positive (0.003) and significant at the 5 % level, implying positive yet modest influence on subsequent stock returns. However, the interaction dummy between VXO changes and FOMC meetings is insignificant and thereby supports *H0*. These results suggest that even though stock returns are positively affected by FOMC meetings and lagged changes in implied volatility, their predictability through VXO does not necessarily increase around FOMC meetings.

However, the subsamples reported in Panel B and Panel C document slightly differing results. Between 1995–2001, the coefficient estimate for FOMC meeting variable is highly significant, implying positive impact on same day stock returns. Moreover, also the interaction dummy is positive and significant at the 5 % level. The estimate for lagged changes in VXO fails to be significant. These results in Panel B indicate that even though the predicting power of implied volatility cannot be verified for the full subsample, it significantly increases on FOMC meeting days between 1995–2001.

Panel C exhibits the results for the latter subsample 2002–2008. Contrary to Panel B, the lagged VXO variable is positive and significant, thereby suggesting that the full sample significance in lagged VXO is driven by the last seven years. The interaction dummy is significant as well, although negative and thus implying a decrease in stock return predictability on FOMC meeting days. The FOMC meeting dummy is insignificant between 2002–2008. This variability brings on challenges in making flawless conclusions about the results.

Regarding the intercept term for all observations, the expected mean return is zero when all independent variables have zero values. Following the negative correlation between implied volatility and the stock market, mean return is positive (negative) when implied volatility decreases (increases). Table (7) also presents the regression results for different quartiles of daily changes in VXO. As mentioned, quartile 1 contains days with big declines in implied volatility, whereas quartile 4 consists of days with sharp daily increases. The interaction variable is insignificant regardless of the chosen quartile.

The VXO coefficient turns from positive to negative when moving from big daily declines to sharp increases. Examining quartile 4, this coefficient is negative and highly significant for both the full sample and the subsample 1995–2001. This finding is in line with previous studies about the negative correlation between stock returns and implied volatility. Furthermore, table (7) implies that regarding quartile 4, the FOMC meeting variable is negative and significant at the 5 % (10 %) for the full sample (subsample 2002–2008). These results suggest that a big increase in implied volatility affects stock returns more negatively on FOMC meeting days than on regular trading days.

Following the presented methodology, similar regression is performed with an altered dummy variable that indicates the days after FOMC meetings instead of the actual meeting days. Still, the generic framework of regressing daily stock returns on the preceding changes in implied volatility remains the same. The *t+1* dummy is motivated by Du et al. (2018) and results in table (6), both reporting significant decrease in VXO on FOMC meeting days. The results for t+1 regression are presented in table (8).

Table (8) exhibits that considering all observations and full sample period, the FOMC *t+1* meeting dummy and the interaction variable both have positive and significant effect on stock returns, indicating that return predictability is higher on days after FOMC meetings than on non-meeting days (reference group). This perception is supported by positive estimate for the lagged changes in implied volatility, significant at the 5 % level.

The relations presented above are arguably driven by the subsample 2002-2008: the respective coefficient estimates in Panel C are even more positive while maintaining high significance. For the first subsample 1995–2001, each coefficient estimate fails to be significant. Nevertheless, contrary to results documented in table (7), these results support *H1* by implying that stock return predictability through VXO increases on days following the FOMC meetings. Furthermore, these observations verify that stock returns are positively affected by not only days following the FOMC meetings, but also the lagged changes in implied volatility. This finding is in line with the ones reported in table (7).

Table 8. OEX returns explained by changes in VXO on days following the meetings, 1995–2008. P-values are reported in parentheses. The significance levels at 1%, 5% and 10% are indicated as ***, ** and * respectively.

	Quartiles				All
	(1)	(2)	(3)	(4)	
Panel A: Full sample					
Intercept	0.011 ***	0.002 ***	-0.001 ***	-0.012 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.542)
$\beta_{VXO\ t-1}$	0.002	-0.001	-0.003	-0.022 ***	0.008 **
	(0.745)	(0.835)	(0.460)	(0.001)	(0.013)
$\delta_{FOMC\ t+1}$	0.003 *	0.003 **	0.000	-0.002	0.003 ***
	(0.060)	(0.029)	(0.743)	(0.432)	(0.004)
$\delta_{VXO\ x\ FOMC\ t+1}$	0.096 ***	0.015	0.021	0.017	0.054 ***
	(0.000)	(0.480)	(0.284)	(0.608)	(0.001)
R Square	0.019	0.005	0.002	0.012	0.007
Number of observations	910	911	911	910	3 642
Panel B: 1995-2001					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.010 ***	0.001 *
	(0.000)	(0.000)	(0.001)	(0.000)	(0.057)
$\beta_{VXO\ t-1}$	0.004	-0.016 ***	-0.004	-0.035 ***	0.002
	(0.576)	(0.008)	(0.429)	(0.000)	(0.748)
$\delta_{FOMC\ t+1}$	0.002	0.002	-0.001	-0.005	0.002
	(0.617)	(0.158)	(0.775)	(0.250)	(0.291)
$\delta_{VXO\ x\ FOMC\ t+1}$	0.094	0.036	-0.024	-0.006	0.009
	(0.194)	(0.176)	(0.619)	(0.897)	(0.765)
R Square	0.006	0.020	0.002	0.034	0.001
Number of observations	439	462	468	450	1 819
Panel C: 2002-2008					
Intercept	0.011 ***	0.002 ***	-0.002 ***	-0.013 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.391)
$\beta_{VXO\ t-1}$	0.000	0.009 *	-0.001	-0.012	0.014 ***
	(0.982)	(0.055)	(0.789)	(0.247)	(0.004)
$\delta_{FOMC\ t+1}$	0.005 *	0.003	0.000	0.000	0.004 **
	(0.067)	(0.104)	(0.889)	(0.982)	(0.026)
$\delta_{VXO\ x\ FOMC\ t+1}$	0.092 ***	-0.007	0.033	0.029	0.069 ***
	(0.002)	(0.838)	(0.140)	(0.518)	(0.001)
R Square	0.028	0.014	0.005	0.003	0.015
Number of observations	471	449	443	460	1 823

Looking at the quartile regressions in table (8), one may find similarities to the results in table (7) as most of the coefficient estimates are insignificant. Regarding the full sample results in Panel A, lagged VXO variable is significant for quartile 4 only. Again, this illustrates that sheer increases in implied volatility often lead to negative stock returns. On the contrary, the dummy variable indicating days after the FOMC meetings is positive and significant only for quartiles 1 and 2, that is when implied volatility decreases.

It is not only the FOMC dummy variable but also the interaction variable that appears to be driven by big declines in implied volatility – quartile 1 is the only quartile with a significant full sample estimate, and that is the case for the subsample 2002–2008 as well. In addition to this observation, no major remarks arise from the quartile results in table (8). As anticipated, all quartile intercepts are significant implying the expected OEX development excluding all other variables.

Motivated by the significant findings[17] of Du et al. (2018), this thesis considers both scheduled and unscheduled FOMC meetings. This regression follows equation (13) and its results are reported in table (9). Similar to the results presented earlier, the full sample impact of lagged VXO changes on daily OEX returns is positive and highly significant. The full sample coefficient of dummy variable that indicates scheduled FOMC meetings is positive and significant as well, suggesting more positive OEX returns on days with scheduled FOMC meetings compared to days when no meetings are being held. For unscheduled meetings, the respective coefficient fails to be significant.

In terms of significance, the full sample results differ when examining the interaction variables in table (9). For unscheduled meetings, the full sample estimate of interaction variable is significant and negative, thereby suggesting a decrease in return predictability on days of unscheduled FOMC meetings. This observation is inconsistent with the full-sample results presented in other tables. The respective coefficient for scheduled meetings fails to be significant. These findings suggest that even though stock returns are positively affected by meetings that are scheduled, the full sample return predictability does not behave in a similar manner when meetings are divided into scheduled and unscheduled.

[17] Utilizing the lagged implied volatility spreads within the banking sector, Du et al. (2018) report significant interaction variables for both scheduled and unscheduled meetings.

Table 9. FOMC meetings divided into scheduled and scheduled, 1995–2008. Blank values denote variables for which the estimate cannot be computed as there are not enough observations in their respective subsamples and quartiles. P-values are reported in parentheses.

	Quartiles				All
	(1)	(2)	(3)	(4)	
Panel A: Full sample					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.619)
$\beta_{VXO\ t-1}$	0.005	-0.001	-0.002	-0.019 ***	0.010 ***
	(0.355)	(0.699)	(0.661)	(0.006)	(0.002)
δ_S	0.001	0.000	0.000	0.000	0.003 ***
	(0.583)	(0.671)	(0.953)	(0.970)	(0.010)
δ_{US}	0.008 **	0.007 *	-0.014 *	-0.019 ***	0.003
	(0.037)	(0.088)	(0.098)	(0.005)	(0.256)
$\delta_{VXO\ x\ S}$	0.009	0.012	-0.027	0.055	0.025
	(0.763)	(0.495)	(0.404)	(0.301)	(0.224)
$\delta_{VXO\ x\ US}$	0.027	0.094 *	-0.227	0.006	-0.081 **
	(0.645)	(0.095)	(0.193)	(0.916)	(0.016)
R Square	0.008	0.005	0.004	0.026	0.006
Number of observations	910	911	911	910	3 642
Panel B: 1995-2001					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.128)
$\beta_{VXO\ t-1}$	0.004	-0.016 ***	-0.004	-0.036 ***	0.000
	(0.582)	(0.007)	(0.415)	(0.000)	(0.937)
δ_S	-0.002	0.001	0.001	0.002	0.002
	(0.325)	(0.531)	(0.467)	(0.748)	(0.122)
δ_{US}	0.015 ***	0.004		0.010	0.019 ***
	(0.001)	(0.769)		(0.353)	(0.000)
$\delta_{VXO\ x\ S}$	0.001	0.052	-0.084	0.209	0.049
	(0.974)	(0.169)	(0.336)	(0.195)	(0.149)
$\delta_{VXO\ x\ US}$	0.102	0.074			0.184 ***
	(0.188)	(0.665)			(0.005)
R Square	0.049	0.019	0.016	0.038	0.020
Number of observations	439	462	468	450	1 819
Panel C: 2002-2008					
Intercept	0.011 ***	0.002 ***	-0.001 ***	-0.012 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.508)
$\beta_{VXO\ t-1}$	0.006	0.009 *	0.001	-0.005	0.019 ***
	(0.454)	(0.073)	(0.847)	(0.628)	(0.000)
δ_S	0.004	0.000	-0.001	0.002	0.004 **
	(0.154)	(0.881)	(0.535)	(0.722)	(0.038)
δ_{US}	-0.002	0.013 **	-0.014	-0.033 ***	-0.007 *
	(0.768)	(0.044)	(0.102)	(0.000)	(0.087)
$\delta_{VXO\ x\ S}$	0.012	-0.006	-0.023	0.025	0.010
	(0.809)	(0.778)	(0.504)	(0.670)	(0.702)
$\delta_{VXO\ x\ US}$	-0.021		-0.230	0.083	-0.098 **
	(0.803)		(0.187)	(0.213)	(0.022)
R Square	0.007	0.017	0.008	0.044	0.018
Number of observations	471	449	443	460	1 823

When examining all observations in two subsamples, the results are relatively similar. The interaction variables that account for unscheduled meetings are significant in both subsamples. However, the coefficient is positive (0.184) between 1995–2001 and negative (-0.098) from 2002 onwards. Contrary to the full sample results, the dummies for unscheduled meeting are significant in both subsamples, but again with differing signs. The modest yet still positive stock returns associated with scheduled FOMC meetings are driven by the latter subsample, as Panel C reports positive and highly significant estimate for scheduled meetings. Moreover, also the positive impact of lagged VXO changes on daily OEX returns appears to occur only in the latter subsample: between 2002–2008, the VXO estimate is positive and significant at the 1 % level, whereas the respective estimate for all observations between 1995–2001 fails to be significant.

Regarding the quartile regressions in table (9), it is worth noticing that the full sample estimate of the dummy indicating unscheduled meetings is significant across all quartiles but fails to reach significance when accounting for all observations. These coefficient estimates behave in a similar manner with the lagged VXO estimates as they again turn from positive to negative when moving from daily declines to increases in implied volatility. However, the full sample VXO estimate is significant only in quartile 4.

As reported in Panel B and Panel C of table (9), the coefficient estimate of scheduled FOMC meetings fails to be significant across all quartiles in both subsamples. On the contrary, some of the quartile estimates that designate unscheduled meetings are significant. Finally, table (10) reports the results of a regression that follows equation (14) by altering dummy variables to indicate the three-day time windows around FOMC announcements.

Table 10. OEX returns explained by changes in VXO on days within the 3-day windows, 1995–2008. The significance levels at 1%, 5% and 10% are indicated as ***, ** and * respectively. P-values are reported in parentheses.

	Quartiles				All
	(1)	(2)	(3)	(4)	
Panel A: Full sample					
Intercept	0.011 ***	0.002 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.893)
$\beta_{VXO\ t-1}$	0.001	-0.001	-0.003	-0.019 ***	0.008 **
	(0.821)	(0.708)	(0.431)	(0.007)	(0.021)
δ_{3-DAY}	0.003 **	0.002 **	0.001	-0.004 ***	0.002 ***
	(0.014)	(0.020)	(0.108)	(0.003)	(0.001)
$\delta_{VXO\ x\ 3-DAY}$	0.036 **	0.010	0.014	-0.023	0.021 **
	(0.016)	(0.399)	(0.285)	(0.274)	(0.036)
R Square	0.015	0.006	0.004	0.020	0.007
Number of observations	910	911	911	910	3 642
Panel B: 1995-2001					
Intercept	0.011 ***	0.003 ***	-0.001 ***	-0.011 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.498)
$\beta_{VXO\ t-1}$	0.004	-0.018 ***	-0.004	-0.036 ***	0.000
	(0.586)	(0.004)	(0.421)	(0.000)	(0.966)
δ_{3-DAY}	0.002	0.002 **	0.002 **	-0.001	0.004 ***
	(0.229)	(0.038)	(0.038)	(0.739)	(0.000)
$\delta_{VXO\ x\ 3-DAY}$	0.016	0.034 *	0.000	0.017	0.028 *
	(0.457)	(0.056)	(0.996)	(0.689)	(0.086)
R Square	0.006	0.028	0.011	0.032	0.011
Number of observations	439	462	468	450	1 819
Panel C: 2002-2008					
Intercept	0.010 ***	0.002 ***	-0.002 ***	-0.012 ***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.441)
$\beta_{VXO\ t-1}$	-0.001	0.010 *	-0.002	-0.004	0.015 ***
	(0.930)	(0.053)	(0.763)	(0.701)	(0.003)
δ_{3-DAY}	0.004 **	0.001	0.000	-0.006 ***	0.001
	(0.035)	(0.262)	(0.972)	(0.004)	(0.430)
$\delta_{VXO\ x\ 3-DAY}$	0.046 **	-0.007	0.017	-0.043 *	0.016
	(0.028)	(0.629)	(0.277)	(0.093)	(0.243)
R Square	0.024	0.011	0.003	0.023	0.008
Number of observations	471	449	443	460	1 823

Results are relatively similar compared to ones reported in tables (7) and (8). For the full sample regression, the impact of lagged VXO changes on stock returns is positive and significant. The coefficient estimate of the three-day dummy is positive and significant as well. Moreover, also the full sample interaction variable is positive and significant, implying higher return predictability around FOMC announcements. This perception is in line with the positive and significant interaction variable reported in Panel A of table

(8). In other words, the increase in return predictability associated with preceding changes in volatility is significant for not only days following the meetings, but also for the full three-day time windows around the meetings. In table (7), which reports the results of the actual meeting days, the respective interaction variable is positive and significant for subsample 1995–2001. However, the full sample variable is negative and fails to be significant.

Panel B in table (10) reports that for all observations between 1995–2001, the three-day dummy variable is slightly positive and highly significant whereas the interaction dummy implies significance at the 10 % level. Regarding the latter subsample reported in Panel C, only the lagged VXO variable is significant when considering all observations. The full sample quartile results in Panel A show that apart from quartile 3, the estimate of the three-day dummy variable remains significant. Furthermore, the three-day estimate turns from positive to negative when moving from quartile 1 to quartile 4, thereby behaving like the actual FOMC meeting dummy in table (7). With reference to the full sample interaction variable, it appears to be driven by sudden decreases in implied volatility as the only quartile with a significant coefficient estimate is quartile 1.

It is interesting to reflect the full sample quartile results against the subsample results presented in Panel B and Panel C. Regarding the three-day dummy variable between 1995–2001, its coefficient estimates are significant for quartiles 2 and 3. On the contrary, the latter subsample 2002–2008 reports significant results for quartiles 1 and 4. Similar to the results presented earlier, the coefficient estimates turn from positive to negative when moving from negative to positive changes in implied volatility.

It is mentioned earlier that the interaction variable would be driven by observations in quartile 1, that is the sharp declines in market uncertainty. However, this appears to be the case only in the full sample regression as the subsample estimates in table (10) imply somewhat differing results: the quartile 1 estimate is significant only in the latter subsample and moreover, there are significant estimates for other quartiles as well.

All in all, the findings about the return predictability associated with implied volatility differ between the implemented models. As hypothesized, it is discovered that return predictability increases around FOMC announcements. However, these kinds of results are attained only when the model considers either the days after the announcements or certain subsamples. Furthermore, the coefficients of determination remain at modest level regardless of the model used. This is consistent with e.g. Du et al. (2018) and is caused by the nature of these regressions. The intercept terms behave in a similar manner across all models: the intercept is zero for all observations, and it turns positive (negative) when implied volatility decreases (increases).

Even though the significance of the chosen variables varies between the models, there are some outlines that apply to each model. Moreover, there arguably is analogy between the results of this paper and the findings presented in earlier research. The following chapter concludes this thesis by discussing the results in further detail and reflecting them against the existing literature.

8 Conclusion

For decades, volatility has been a common subject in financial research. As many financial models consider financial risk to equal volatility, market participants have absorbed volatility as a key measure of uncertainty. However, it has been later discovered that besides designating the computational level of risk, the forward-looking measures of volatility may have informational value over future equity returns (Chen et al., 2012; Du et al., 2018).

Acknowledging the findings mentioned above, this thesis examines whether the information contained in implied volatility increases around FOMC announcements. In practice, this thesis examines whether implied volatility includes more information about future stock returns around FOMC announcements than it usually does. The methods used in this thesis replicate closely the study conducted by Du et al. (2018). However, Du et al. (2018) treat the subject mostly within the banking sector. Therefore, this thesis contributes to the existing literature by examining the chosen subject in a market-wide environment.

Prior to examining the informational role of implied volatility, this thesis verifies the already established decrease in implied volatility on FOMC meeting days. By regressing daily changes in implied volatility on a dummy variable indicating FOMC meeting days, a negative and significant relationship is discovered. The significance of this relationship holds in full sample regression as well as in both subsamples. This is consistent with previous studies (Nikkinen & Sahlström, 2004; Vähämaa & Äijö, 2011; Chen et al., 2012).

After confirming the post-FOMC decrease in implied volatility, the empirical analysis focuses on the relationship between implied volatility and stock returns around FOMC announcements. It is discovered that stock returns are positively affected by lagged changes in implied volatility around FOMC meeting days. Furthermore, the lagged VXO variable appears to be driven by quartile 4 that has negative and highly significant coefficient estimate. This is line with the existing literature about the negative correlation between implied volatility and the stock market (Whaley, 2000; Dash & Moran, 2005; Carr & Wu, 2006). These results are nearly similar in each model deployed in this thesis.

It is also discovered that daily stock returns are positively associated with FOMC meeting days. Apart from the variable that designates the unscheduled meetings (see equation 13), each dummy variable indicating FOMC meetings or their surrounding days is slightly positive and highly significant. Again, one can find similarities when reflecting these findings against the existing literature. Following Chen et al. (2012), implied volatility indices can be considered as proxies for market uncertainty. When implied volatility declines on FOMC meeting days, market uncertainty is perceived to abate. Given the negative correlation between implied volatility and the stock market, stocks may therefore generate higher return on FOMC meeting days than they usually do.

This thesis puts most emphasis on examining the predicting power of implied volatility. The initial results suggest that as the full sample interaction variable is insignificant on FOMC meeting days, stock return predictability associated with implied volatility does not increase around FOMC meetings. On the other hand, the interaction variables turn significant when similar regressions are performed on two subsamples. Furthermore, significant interaction variables are obtained when FOMC meetings are divided into scheduled and unscheduled meetings. However, these interaction variables imply contingency as their sign changes between the subsamples, which is inconsistent with the findings of Du et al. (2018). Therefore, these results alone are inadequate for rejecting *H0*.

However, when deferring the three-day time window by one day, return predictability associated with implied volatility increases significantly. Moreover, it is discovered that this return predictability is driven by the subsample 2002–2008. As the financial markets faced high information asymmetry during that period, these results are consistent with the findings of Cao and Ou-Yang (2009) about the clustering of options trading around events that involve information asymmetry and moral hazard. Similar results about the increase in return predictability can be found when the model is altered to consider all days within the three-day windows instead of single announcement days. These results together provide evidence against *H0*.

To conclude, the results of this thesis have several implications. First, it is verified that implied volatility decreases on FOMC meeting days. Second, the results suggest that stock returns are positively associated with both the lagged changes in implied volatility and FOMC meetings in general. These findings are in line with the previous studies. Regarding the hypothesized increase in return predictability, significant results are attained when the model is altered to take either certain subsamples or days following the FOMC meetings into account. However, as these results are not flawless, one cannot directly apply the findings of Du et al. (2018) to a market-wide context that utilizes indices instead of individual stocks.

There are numerous suggestions for further research. For example, one might attain more immaculate results by sidelining the volatility indices and computing the changes directly from the index options. Furthermore, future research could contrast with Chen et al. (2012) and treat implied volatility as a proxy for sentiment rather than pure uncertainty. In practice, this could mean supplementing the model with additional variables that measure, for example, the level of surprise in each FOMC announcement.

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