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Sindre van Mourik & Anette Hadberg Olsen

Oil price shocks and stock market returns in a net oil exporting economy: An empirical analysis of Norway

University College of Southeast Norway
School of Business and Faculty of Social Sciences
Institute of Business and Management
PO BOX 164 Sentrum
NO-3502 Hønefoss, Norway

http://www.usn.no

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Abstract

We investigate the impact of oil price shocks on the Norwegian stock market returns for the period 1997-2017. We employ different oil price specifications in dynamic VAR models and in alternative models, to examine how the Norwegian stock market responds to oil price shocks, both positive and negative. We pay specific attention to the asymmetry of the stock market responses regarding increase and decreases in oil price. We find that the impact of oil price shocks differs along the different sectors and the benchmark index. In general, our findings indicate that oil price impacts stock market returns in the same month or within one month of the shock. The exception is the Energy sector (OSE10), where the impact is significant in or within 24 months. Further, we find little evidence of any asymmetry between the impact of oil price decrease and increase on the Norwegian stock market.

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1. Introduction

The purpose of this paper is to study the impact oil price shocks have on stock market returns in a net oil exporting economy, and to establish if positive and negative shocks have a different impact. The stock market is represented in this paper by the Norwegian stock market, more specifically Oslo Stock Exchange (OSE). This paper follows the spirit of previous work, where four research papers are used as basis for different oil price specifications, which act as proxies for oil price shocks. The use of extensive methods and models from previous literature is an important part of generalizing and enhancing the findings in this paper. This paper goes beyond, and contributes to the existing literature of oil prices and stock market in the following ways: First, we examine the relationships between oil price shocks and sector stock returns, and the benchmark index return. Secondly, we address the asymmetric pattern of the sector stock returns and benchmark index returns with respect to positive and negative oil price changes.

In recent years, oil price has been highly volatile compared to previous years. Oil is one of the most important commodities in the world, if not the most important (Mintec, 2016). This makes it relevant and important to examine the impact oil price shocks have on stock market returns. The importance of oil price on the world economy should not be downplayed. Adelman (1993, p. 537) states that *"Oil is so significant in the international economy that forecasts of economic growth are routinely qualified with the caveat: 'Provided there is no oil shock'"*. While numerous papers have studied the relationship between oil price and economic activity, relatively few studies have assessed the related question of the effect oil price has on the stock market. The common approach in the literature regarding oil price and stock market returns, is using aggregated indexes like benchmark indexes and all shares indexes. Previous literature presents a relationship between stock markets and oil price that is intricate, where findings vary among time periods and methods used.

In this thesis, we take a somewhat different approach and examine how sector returns and benchmark index returns respond to oil price shocks. We include sector indexes in this paper since the benchmark index or an aggregate index may mask the heterogeneous response of the different sectors or hide sector effects (Arouri et al, 2011 and Faff & Brailsford, 1999). A Vector Autoregression (VAR) model is conducted with linear and non-linear oil price specifications. In general, our results from the impulse response show that oil price shocks have a statistically significant impact on the stock returns, in the same month or within one month after the shocks. The Energy sector (OSE10) is the sector that experienced the greatest impact from oil price shocks, and the impact of the shock is significant and may last for 24 months. From the variance decomposition, it seems that negative oil price shocks have a more significant impact than positive shocks on the Norwegian stock market. The Wald test contradict this, and finds little evidence of asymmetric effect between positive and negative changes in oil price on the Norwegian stock exchange. Further, using different models and methods we do get consistent results; however, we do find that coefficient of positive and negative oil price shocks is not jointly zero. We conclude in this paper that in general there is no evidence of any asymmetry between positive and negative oil price changes on the Norwegian Stock market. The remainder of this paper is organized as follows: In section 2 we review the literature and discuss our research questions. Section 3 outlines the data, model and our main predictability results and robustness tests. In section 4 we present our findings. Finally, section 5 concludes.

2. Literature Review and research questions

2.1. Literature Review

Since Hamilton's (1983) pioneering theoretical paper, several research papers have extended the theory regarding the economic impact of oil price. There has been an increasing interest by researches, in the role of oil price fluctuations on the financial markets and stock prices among researchers in recent years. In this section, we present relevant literature, empirical studies and theories which have tested and extended Hamilton's (1983) original theory.

Empirical evidence shows that oil price has an adverse effect on the economy (GNP). International Monetary Fund indicates that a US5$ per barrel increase in the price of oil reduces global economic growth by 0.3% in the following year, and a level of global output by 0.25 % over the first 4 years (Mussa, 2000). Further, evidence shows that oil price changes have asymmetric effects: GNP growth has a definite negative correlation with oil price increases, and a statistically insignificant correlation with oil price decreases (Mork, 1989; Darby, 1982; Mory, 1993; Mork et al, 1994). Huang et al (1996) suggests that nonlinear linkages between oil prices and the stock market could be uncovered based on Mork (1989). For instance, the asymmetric reactions of monetary authorities to oil price changes may nonlinearly affect stock prices through their impact on real interest rate and inflation. Obviously, there exist more asymmetric transmission channels that are active in the case of stock markets; sector shock transmission mechanisms, investment uncertainty, allocative transmission mechanisms and transactions costs. The asymmetric response to oil price changes may be different in the case of financial markets because they are more efficient than real markets. Stock prices should quickly incorporate the expected asymmetric impact of oil price changes on economic variables (Arouri et al, 2011). One can also expect that oil price changes will influence industries and sectors differently, and make a complicated relationship.

The majority of literature focuses on the relationship between economic activity and oil price change, while few studies have analysed the linkage between oil price change and stock markets, which is the basis of this paper. Huang et al (1996) note that if oil price affects output, the increase in oil price will depress aggregate stock prices by lowering expected earnings, or vice versa. Nandha & Faff (2008, pp 987) says that Huang et al (1996) *"Opine that if oil plays an important role in an economy, one would expect changes in oil price to be correlated with changes in stock prices".* Huang et al (1996) approached to test this thought by employing a vector autoregression (VAR) approach on daily oil futures returns and daily US stock returns. They conclude that oil price does not have much influence on the broad-based market indices such as the S&P 500, but their basic thought is a great contribution to the literature.

Notable and pioneering studies from Sadorsky (1999) and Jones & Kaul (1996) employ the approach in Huang et al (1996) and find that oil price fluctuations influence U.S stock returns. Sadorsky (1999) uses an unrestricted VAR on American monthly observation from 1947 to 1996. He concludes that oil price changes and oil price have a significantly negative impact on real stock returns on S&P 500. Furthermore, he finds that industrial production and interests rates respond positively to real stock returns. In particular, he shows an asymmetric effect: Positive oil shocks explained more of the forecast error variance in real stock returns (aggregated stock returns), industrial production and interest rates than negative shocks. This contradicts the more recent findings off Park (2007) and Kilian and Vigfusson (2009). Jones & Kaul (1996) have a different approach and use quarterly data from 1947 to 1991 to test whether the reaction of international stock markets (Canada, UK, Japan and US) can be discovered by current and future changes in real cash flows and/ or changes in expected returns. They apply a standard cash-flow dividend valuation model, and conclude that the reaction of Canada and US stock prices to oil price shocks is entirely accounted for by the impact of real cash flows. The results for Japan and the UK are, however, inconclusive.

Park & Ratti (2008), another important contribution to the literature, estimates the effect of oil price shocks and oil price volatility on the real stock returns of the U.S and 13 European countries from 1986–2005. They find that oil price shocks have a statistically significant impact on real stock returns, but the response of real stock returns to an oil price increase is not equal. More interestingly, they found that Norway, an oil exporter, responds positively to oil price increase. Kilian & Park (2009) explored the relationship between aggregate US real stock returns and the innovation of the real oil price. They find that the reaction of US real stock returns to oil price shocks is substantially different, depending on whether the oil price change is driven by demand or supply shocks in the oil market. Recent studies have however suggested that the linear relationship between oil and stock markets is not so evident in practice. Therefore, nonlinear relationship such as asymmetric relationship between oil and stock markets is inconclusive and deserve more empirical analyses (Li et al, 2012).

However, as discussed above, few studies have investigated the relationship between oil prices and stock markets at the sector level. The above-mentioned studies have almost exclusively examined the short-term relationship between oil price and aggregated stock returns. Faff and Brailsford (1999), focusing on different industries, find significant positive oil price sensitivity of Australian oil and gas, and diversified resources industries. In contrast, some industries demonstrated significant negative sensitivity to oil price hikes like paper and packing, banks and transport.

Sadorsky (2001) and Boyer & Fillion (2007) show that an increase in oil price positively affect the stock returns of Canadian *Oil & Gas* companies. El-Sharif et al. (2005) reach the same conclusion for *Oil & Gas* returns in the UK. The authors also find that non-*Oil & Gas* sectors are weakly linked to oil price changes. Nandha and Faff (2008) used 35 global industries to study the short-term link between the industries and oil price. Where the found that increase in oil price impacts negatively for all industries except *Oil & Gas.* The reason for this as the authors state is that crude oil has a mass of byproducts, everything from airplane fuel to shampoo. Furthermore, they found little evidence of asymmetry in the short-term relationship between oil and stock returns. At the same time, factors such as the degree of competition and price elasticity, could have a say on company's opportunity to pass costs up to consumers when oil price goes up, and minimize the negative impact of oil.

Arouri et al (2011) explore the linear and nonlinear long-term relationship between oil prices and the stock prices at the disaggregated sector level, instead of focusing on the aggregated market level as the previous studies (Jones & Kaul, 1996; Huang et al. 1996; Sadorsky, 1999; Park & Ratti, 2008; Apergis & Miller, 2009). They examine whether oil price changes (increase and decrease) affect sector stock prices equally, by including Dow Jones (DJ) Stoxx 600 and twelve European sector indices in their sample data. Their empirical results confirm asymmetric responses between several European sector stock prices to oil price changes, more precisely, they find support for double asymmetry: the responses of stock prices to oil price changes depend both on the sector and on the sign of the change. The increase in oil price has a strong direct impact on oil-intensive industries such as *Automobile & Parts* and *Oil & Gas,* and more surprisingly on some non-oil-intensive industries such as *Financials* and *Technology.* The authors explain these results with the recent increase in oil price, which has lead to higher expected economic growth and demand for products. Scholtens & Yurtsever (2012) have a similar approach as Arouri et al (2011), but they investigate how 38 different industries in the Euro area respond to oil price shocks, and the possible asymmetric impacts. They also conclude that oil shocks in general are negative but oil intensive industries (oil and gas producing, oil equipment, industrial metals, mining) seem to benefit from the shock. Furthermore, most industries are benefitting from negative oil price shocks. They also found some asymmetric effects, but in most cases and industries, the effect is not significant. This limited asymmetry is consistent with recent studies off Park (2007) and Kilian & Vigfusson (2009). Li et al (2012) also took the approach of exploring the disaggregated sector level, but they only looked at the Chinese stock market. The background for this study is that the strong oil dependence in China (world´s second largest oil consumer since 2003) makes China more prone to oil price fluctuations. They found a significant and long-term association between oil price fluctuations and the financial performance of the sectorial stocks. More interestingly and surprisingly, they found that Chinese sectorial stocks did better against increase in oil price than expected.

The results of the relationship between oil price fluctuations and stock market vary among countries and sectors, depending on whether oil is an input or an output for the sector. Therefore, the results from previous studies are inconclusive, and to our knowledge there is no previous empirical investigation of the long-term relationship between oil price and the stock returns on Oslo Stock Exchange (OSE). Further, OSE is represented by using the disaggregated sector level and the aggregated benchmark index (OSEBX). However, a few researchers have used the benchmark index (OSEBX) or used Oslo Stock Exchange All Shares Index (OSEAX) in their papers. The focus of previous literature on the long-term relationship between oil and stock market has been on the general aggregate index of the markets. This approach may cancel out sector sensitivity to oil price changes and then miss out potential asymmetry between sectors. This paper extends the main thought of past studies and seeks to strengthen the understanding of the relationship between oil price and the Norwegian stock market, by testing for linear and asymmetric long-run relationship at both the sector and the aggregate benchmark index level.

2.2. Research Questions

The theory and literature presented above describe a complicated and interesting relationship between oil price shocks and stock returns. The full impact is yet to be discovered and the impact may vary in different periods, settings and places as shown in the literature. The literature states that oil price changes are important to explain stock price movements. Driesprong et al. (2008) conclude that changes in oil price predict the returns of stock markets worldwide. Furthermore, the economic impact of oil price is a hot debate in Norway, with a huge consensus that oil price has a major impact on the Norwegian economy, more specific on the Norwegian stock market (represented by OSE). We investigate whether this is just a common belief or an empirical fact, and mainly focus on the sectors response to oil price, though we do include the benchmark index (OSEBX) in the analysis. In the next subsections, we discuss our main research questions.

2.2.1. The effect of oil price shocks on OSEBX

The relationship between financial markets and the change in oil price is central for discovering the economic impact of oil, and for understanding whether oil really is an important factor for driving the price of the market. In the literature, there are mixed results on whether oil has an impact on financial markets, or whether other factors have a greater impact (interest rate, industrial production, inflation, GDP and so on). Jones et al. (2004 p. 24) comment regarding oil price and capital markets that: *"Ideally, stock values reflect the market's best estimate of the future profitability of firms, so the effect of oil price shocks on the stock market is a meaningful and useful measure of their economic impact. Since asset prices are the present discounted value of the future net earnings of firms, both the current and expected future impacts of an oil price shock should be absorbed fairly quickly into stock prices and returns without having to wait for those impacts to actually occur"* . Park and Ratti (2008) noted that the real stock returns in Norway have a positive response to an increase in oil price. There is also evidence of asymmetric effects of positive and negative oil price shocks on real stock returns response to positive and negative oil price shocks. This makes it essential to examine how the benchmark index in Norway in the past 20 years have responded to oil price shocks. Especially since Norway is a major exporter of oil and oil accounts for a major part of the GDP. Our first research question (RQ) is as follows:

RQ1: What is the response of the benchmark index on Oslo Stock Exchange to oil price shocks?

2.2.2. The effect of oil price shocks on the different sector indices

Equally important as uncovering the effect oil has on the aggregated market level, is the effect of oil on sector indices. Arouri et al. (2011) provide two main reasons for and the need to explore this relationship: "*First, stock prices for the market as a whole may mask the heterogeneous performance of various sectors. Furthermore, sector sensitivities to changes in oil price can be asymmetric, as some sectors may be more severely affected by these changes than others*". Faff & Brailsford (1999) also mention that: "*analysis at the aggregate market level may hide industry sector effects*". The literature illustrates that the effect of oil price can have substantial different impact on aggregated and disaggregated stock returns. Therefore, the significant impact oil has on the financial market could be overseen. This makes it extremely relevant to exploit the relationship at the sector level. With this in mind, we formulate our second and third questions below:

RQ2: What is the response of the sector stock returns on Oslo Stock Exchange to oil price shocks?

RQ3: How does the response differ among sectors?

2.2.3. Asymmetric effects of positive and negative oil price shocks

The effect of asymmetry between positive and negative oil price shocks is present in all levels according to the literature. The separation between positive and negative oil price shocks is central for a greater understanding of how the stock market reacts to major changes in oil price, and whether there is a difference between them. According to Scholtens & Yurtsever (2012), the issue of asymmetric effect of oil price shocks is of great importance in the literature (Hamilton, 1996; Mork, 1989; Park, 2007; Kilian & Vigfusson, 2009). Furthermore, the impact of positive and negative oil price shocks is essential for the investors to understand the stock market. It is also of great importance to examine whether positive and negative oil price shocks have different effects on the different sectors. The literature suggests that there is asymmetry between positive and negative oil price shocks on sector indices (Arouri et al (2011), Scholtens & Yurtsever (2012), Park (2007) and Kilian & Vigfusson (2009)). Driesprong et al (2008) found that an increase in oil price would influence the stock market negatively and have a positive effect on an oil price decrease. Hammoudeh and Li (2005) found that both Mexico and Norway where greatly affected by oil price changes. Some of the literature finds limited asymmetry effect, but Arouri et al (2011) find and confirm that an asymmetric effect is present on Dow Jones (DJ) Stoxx 600, and twelve European sector indices. Moreover, they found the presence of double asymmetry as mentioned in the literature review. We seek to answer two question:

RQ4: Do sectors respond in a similar way to oil price increases and decreases?

RQ5: Does OSEBX respond in a similar way to oil price increases and decreases?

3. Data, Methodology, and Summary Statistics

3.1. Data types and Data Sources

The data used in this thesis is sourced from Bloomberg Terminal, Thomson Datastream and Statistics Norway (Statistisk sentralbyrå/SSB), see appendix A. Equity indices at the sector level at OSE are based on Global Industry Classification Standard (GICS) developed by MSCI and Standard & Poor (S&P), which provide a range of equity indices across countries and sectors worldwide. First off, we gathered monthly data from all 10 GICS sectors at OSE, and we focus on the last 20 years, from 1997 to 2017. We follow the predictability literature on the basis that monthly data tend to be less noisy than daily data (Driesprong et al, 2008). The sample period covers several booms and crises in both the oil market and the financial market, and we separate the sample into two sub-periods as such. They will be presented as such; 1997:1-2007:1, 2007:1 – 2017:1 and 1997:1 – 2017:1. The GICS breaks down the industries in a four-tiered, hierarchical industry classification system. It consists of 10 sectors, 24 industry groups, 67 industries and 147 sub-industries (Næs et al, 2008), where companies are assigned a single GICS classification at the sub-industry level according to its principal business activity. In the GICS classification, revenue is the key factor in determining a firm´s principal business activity. In september 2016 a new sector was introduced on OSE, Real Estate (OSE60) which means that there is a new GICS classification and in total 11 sectors. We do not include this sector in our analysis, because the long-term relationship between this sector and oil price will not be relevant for our analysis since this sector was only introduced in the last six months of our sample period. The variables used in this analysis and how they are measured are presented below.

3.1.1. Data variables and Oil price specifications

The nominal oil price is measured by the price of Crude Oil - Brent FOB U$/BBl ($O_t$); the oil price in Norwegian currency is obtained using the NOK/US exchange rate (EX_t) and deflated by the CPI (CPI_t) of Norway. The real oil price in time t is $roil_t = \log\left(O_t * \frac{EX_t}{CPI_t}\right)$. All prices used in this thesis are in NOK, or converted into NOK. We employ real stock returns, which are the difference between continuously compounded returns ($\log\left(\frac{p_t}{p_{t-1}}\right)$) on the stock price, and the inflation rate (we use the first logarithmic difference of the consumer price index as a proxy for the inflation rate). The variable industrial production (IP) is included in the analysis as a measure of economic activity. The short-term interest rate is the Norwegian Interbank Offered Rate 1 month (NIBOR) to measure Norwegian monetary policy, which can also be argued to be the risk-free rate in Norway. A list of the key variables can be found in Table 1.

Table 1
List of key variables

dlroil	First log difference of oil price
dlroilp	First log difference of oil price (positive)
dlroiln	First log difference of oil price (negative)
SOPI	Scaled oil price increase
SOPD	Scaled oil price decrease
NOPI	Net oil price increase
NOPD	Net oil price decrease
Nibor	Interest rate
dlNibor	First log difference of interest rate
ip	Industrial production
dlip	First log difference of industrial production
rose	Real sector stock return
rosebx	Real Oslo Stock Exchange Benchmark Index return

The different oil price specifications are used as proxies for the oil price shocks, following the existing literature (Hamilton (1983), Mork (1989), Lee et al. (1995) and Hamilton (1996)):

1. Linear specification (dlroil)

   Hamilton (1983) studied, as mentioned above, the impact of oil price shocks on the economy. He used the conventional first log difference of the nominal oil price as the specification for a linear relationship between oil price shocks and the economy. In accordance to Hamilton (1983), the linear specification is the first log difference of the real oil price variable.

   $(dlroil_t = lroil_t - lroil_{t-1})$

2. Asymmetric specification

   Mork (1989) found that an increase in oil price had a greater impact on GDP than an oil price decrease. Therefore, it is interesting to see how this applies to the equity market, if informationally efficient, all available information should be incorporated into prices. Furthermore, the asymmetric specification distinguishes between the positive rate of change in real oil price ($dlroilp_t$) and its negative rate of change ($dlroiln_t$), which are defined as follows:

$$dlroilp_t = \max(0, dlroil_t)$$

$$dlroiln_t = \min(0, dlroil_t)$$

3. SOP_t: Scaled oil price (SOP)

Lee et al. (1995) argued that *"an oil shock is likely to have greater impact in an environment where oil prices have been stable than in an environment where oil price movement has been frequent and erratic"*. This scaled model builds on the linear oil price specification, while at the same time it employs a transformation of the oil price that standardizes the estimated residual of the autoregressive model by its time-varying (conditional) variability. The effect of the SOP is that a small shock that occurs in a calm period will be scaled up, whereas a large shock in a volatile period will be scaled down. Lee et al. (1995) used a GARCH model with quarterly data and included four quarters in the conditional mean equation. Our paper uses monthly data and therefore we include 12 lags in the mean equation. Furthermore, Lee et al (1995) proposed the following GARCH(1,1) model as a representation of oil price:

$$dlroil_t = \alpha + \sum_{i=0}^{p} \alpha_i \, dlroil_{t-i} + \varepsilon_t$$

where $$\varepsilon_t | \mathrm{I}_{t-1} \sim N(0, h_t)$$

and $$h_t = \gamma + 0 + \gamma_2 \varepsilon_{t-1}^2 + \varepsilon_2 h_{t-1}$$

$$SOP_t = \frac{\hat{\varepsilon}_t}{\sqrt{\hat{h}_t}}$$

Separated into scaled oil price increase $SOPI_t$ and decrease $SOPD_t$

$$SOPI_t = max\left(0, \frac{\hat{\varepsilon}_t}{\sqrt{\hat{h}_t}}\right) \text{ and } SOPD_t = min\left(0, \frac{\hat{\varepsilon}_t}{\sqrt{\hat{h}_t}}\right)$$

4. NOP (Net oil price)

This oil price specification proposed by Hamilton (1996), suggests that if one wants a measure of how unsettling an increase in oil price is likely to be for the spending decisions of consumers and firms, it seems more appropriate to compare the current oil price with where it has been over the previous years, rather than during the previous month alone. Many authors have used this NOP specification, often referred as NOPI (Net Oil Price Increase); if the oil price is higher than what it has been at some point during the most recent years, positive oil shocks have occurred. If the difference is negative, then there has not occurred an oil price shock. Hamilton (1996) considered a 4-quarter horizon as an appropriate construction of a net oil price increase measure. In this thesis, we use a monthly frequency, and for this reason it is not possible to define net oil price increase exactly as Hamilton (1996). However, we do employ the same horizon length, where we consider a 12-months horizon. Therefore, the n in this paper is 12, for both NOPI and NOPD. Scholtens & Yurtsever (2012) also uses the NOPD (Net Oil Price Decrease) specification, where they assume that if the oil price is lower than what it has been at some point during the most recent years, negative oil shocks have occurred.

$$NOPI_t = \max(0, lroil_t - \max(lroil_{t-1} \dots \dots lroil_{t-n}))$$

$$NOPD_t = \min(0, lroil_t - \min(lroil_{t-1} \dots \dots lroil_{t-n}))$$

3.1. The vector autoregressive models (VAR)

This paper uses an unrestricted VAR model for estimating the data. It is a straightforward way to model dynamic relations between economic variables without making several assumptions (Scholtens & Yurtsever, 2012). The vector autoregressive models (VAR) were introduced by Sims (1980), and is an econometric model often used in the literature to capture the relationship between oil price and the economic variables that are of interest. More specifically, a VAR model is a system of equations where all the variables are treated as endogenous. Each variable in the system is expressed as a linear combination of its own lagged values and the lagged values of all the other variables in the system (Baltagi, 2003). Kilian and Vigfusson (2009) criticize the use of VAR model that estimates the response of macroeconomic aggregates to an unanticipated innovation in the price of crude oil. They argue that this will generate inconsistent estimates of the true effects of unanticipated increase in energy prices. In line with Scholtens & Yurtsever (2012), we use different oil price specifications to decrease the probability of inconsistent estimates, and focus particularly on the sector level when investigating oil price shocks, though we do include the benchmark index. Additionally, several alternative approaches will be engaged to investigate asymmetry.

This thesis follows the exact ordering of the variables in the VAR system as Scholtens & Yurtsever (2012) and Kilian & Vigfusson (2009). Scholtens & Yurtsever (2012) estimate the VAR with five variables (interest rate, real oil price change, industrial production, real Benchmark Index/all shares index returns and real sector stock return) for researched sectors. Kilian & Vigfusson (2009) have the same ordering but do not include sectors in their research. This paper follows the ordering from past papers since ordering in a VAR model is important (Brooks, 2013 and Sims, 1980), the ordering of variables is also one of the VAR models' biggest flaws. Ordering means placing the variables in the decreasing order of exogeneity. Wrong ordering in a VAR system could lead to spurious results, and therefore it is important to follow the VAR ordering from previous literature to enhance the robustness of the VAR model. Kilian & Vigfusson (2009) and Scholtens & Yurtsever (2012) put the interest rate variable first as they assume that interest rate (monetary) shocks are independent of contemporaneous disturbances to the other variables, but that interest rate shocks influence oil prices. The optimal order of lags (p) is important in a VAR model, and wrong lag length could lead to inconsistent results or what worse is. Lütkepohl (1991) indicates that overfitting (selecting a higher order lag length than the true lag length) causes an increase in the mean-square forecast errors of the VAR, and that underfitting the lag length often generates autocorrelated errors. This makes the optimal lag order an important factor in a VAR model, and Brooks (2013) mentions optimal lag length as one of the issues with the VAR model. In this thesis, we use the Likelihood Ratio (LR) test statistic, the Akaike and Schwartz information criterion to find the optimal lag length. Whenever there is a disagreement among the different tests, the optimal lag length is chosen using the Likelihood Ratio test. Based on this we have decided to use a lag level of 5 for all the VAR models in the first part of this thesis.

We consider the following vector auto regression model of order p (or simply, VAR(p)) following Scholtens & Yurtsever (2012) and Kilian and Vigfusson (2009):

$$y_{it} = A_0 + \sum_{j=1}^{p} A_{j,i}\, y_{it-j} + u_{it} \qquad\qquad i = 1 \ldots 10$$

y_{it} = [interest rate, real oil price changes, industrial production, real OSEBX returns and real sector stock return]

A_t is a 5×5 matrix of coefficients, A_0 is a column vector of deterministic constant terms, i represents each individual sector, u_t is a column vector of errors with the property of

$$E(u_t) for\ all\ t, \quad E(u_t \acute{u}_t) = \Omega\ if\ s = t, \quad E(u_t \acute{u}_t) = 0, if\ s \neq t,$$

where Ω is the variance–covariance matrix. u_t's are not serially correlated but may be contemporaneously correlated. Thus, Ω is assumed to have non-zero off-diagonal elements. When analysing OSEBX, we use the same VAR model as above but we do not include real sector stock returns in the model consistent with Kilian & Vigfusson (2009). Therefore, y_t = [interest rate, real oil price changes, industrial production and real OSEBX return]

A_t is a 4×4 matrix of coefficients, and i does now not represent each individual sector. Further, i do not represent the 10 sectors any more in the VAR model for OSEBX.

The prerequisites for running an unrestricted VAR is to examine whether the variables are stationary or not, we use a unit root test and cointegration test. Checking for unit root is done with PP (Philips–Perron) (Philips and Perron, 1988) and KPSS (Kwiatkowski, Philips, Schmidt, Shin) (Kwiatkowski et al., 1992) for all series (the test result is not presented in this paper). The results from these tests are consistent with the results from Scholtens & Yurtsever (2012), where the real stock returns series reject the null hypothesis that each variable has a unit root with a constant and trend factor. The macroeconomic variables (Nibor and IP) and the real oil price have a unit root problem. In log-difference these variables reject the null hypothesis. Taking the log-difference of these series prevents us from estimating "spurious regressions" with no economic meaning (Granger & Newbold, 1974). Since the unit root test indicate that Nibor, IP and oil price variables contain a unit root, it is necessary to conduct a cointegration test to examine whether these variables have a common stochastic trend. To test for cointegration, we employed both the maximum eigenvalue and the trace statistics in this thesis. The null hypothesis of no cointegration between the variables is rejected at 0.000% level of significance. The economic meaning is that it seems to be a long run relationship among these variables.

3.2. Descriptive statistics

Before the analysis and presentation of the empirical results from a VAR estimation of oil price on Oslo Stock Exchange, we will present the descriptive statistics of the real returns in the 10 sectors and for the benchmark index (OSEBX), which are shown in Table 2. It is apparent from the table that the mean returns from all the sectors and OSEBX are positive, but interest rate and industrial production have a negative mean. The consumer staples (OSE30) and telecommunication services (OSE50) have the highest average monthly return. More interestingly is that all the stock returns have a positive correlation with oil price changes. This positive correlation is probably because that Norway is a net- exporter of crude oil. Energy (OSE10) and OSEBX have the highest correlation with oil price. The correlation between interest rate and oil price is very close to zero, but positive. Industrial production has a negative correlation with oil price. There is also evidence of real returns having a possible non-normal distributional property. The skewness is negative for a great proportion of the variables. In addition, the Kurtosis is above three for all variables, which may be indicating a leptokurtic distribution.

Table 2

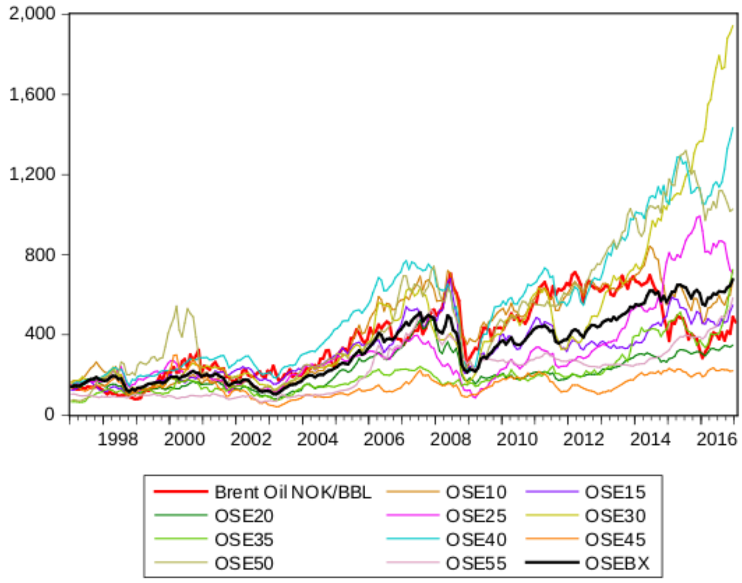
Descriptive statistics: Real monthly return data, 1997:1 to 2017:1

Sector	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Correlations	
								Market	Oil
OSE10 - Energy	0,004	0,014	0,149	-0,292	0,069	-1,03	5,14	0,85	0,46
OSE15 - Materials	0,004	0,008	0,216	-0,504	0,072	-1,68	12,89	0,80	0,28
OSE20 - Industrials	0,002	0,012	0,173	-0,347	0,061	-1,34	7,62	0,86	0,29
OSE25 - Consumer Discretionary	0,005	0,012	0,213	-0,302	0,077	-0,91	5,71	0,73	0,13
OSE30 - Consumer Staples	0,009	0,014	0,268	-0,415	0,073	-1,11	8,79	0,74	0,24
OSE35 - Health Care	0,008	0,009	0,333	-0,200	0,072	0,40	4,85	0,49	0,22
OSE40 - Financials	0,008	0,016	0,224	-0,407	0,063	-1,51	11,75	0,82	0,28
OSE45 - Information Technology	0,000	0,010	0,329	-0,295	0,087	-0,52	4,70	0,72	0,25
OSE50 - Telecommunication Services	0,009	0,013	0,251	-0,383	0,089	-1,04	6,82	0,62	0,17
OSE55 - Utilities	0,005	0,003	0,271	-0,242	0,058	-0,02	6,77	0,58	0,15
OSEBX - Benchmark Index	0,005	0,013	0,163	-0,357	0,058	-1,64	9,59	1,00	0,38
Brent oil	0,003	0,007	0,286	-0,449	0,100	-0,52	5,11	0,38	1,00
Interest rate	-0,005	0,003	0,231	-0,287	0,057	-0,94	7,85	-0,21	0,02
IP	-0,001	0,000	0,113	-0,098	0,030	0,16	4,42	-0,07	-0,06

Notes: This table shows the descriptive statistics for the real sector returns from OSE, Benchmark Index (OSEBX), oil price, interest rate (Nibor) and industrial production (IP) and the correlation with oil price and the benchmark index

Graph 1 shows the returns on the Oslo Stock Exchange, and as mentioned it is not using the same unit as the descriptive statistics, where we use the real returns and not the stock prices. The movement of OSE represented by sectors and OSE with oil price is presented in Graph 1, with monthly data from 1997:1 to 2017:1. The oil price is calculated into NOK to make it more comparable to the sectors and the benchmark index. Here we see that OSE30 – Consumer Staples and OSE40 - Financials have the highest value. Also, one can see that some sectors do decrease with oil price and others increase even when oil price goes up. In 2008 – 2009 we find that the market in general did increase (same with oil price). In this period, the financial crises had its biggest impact on the market.

Graph 1
The sector indexes and OSEBX with Oil price in NOK



The correlation coefficients for the different oil price specifications used in this paper are shown in Table 3. In general, the correlation between the oil price shocks is high. The highest correlation is between dlroil and SOP which is 93%, and dlroil positive/negative and SOP increase/decrease. The lowest is between dlroilp and NOPI which is 21%. From the t-statistic we can see that all correlations are significant at 1% level.

Table 3
Correlation coefficients among different oil price specifications. T-statistics are given in parentheses.

	dlroil	dlroiln	dlroilp	SOP	SOPD	SOPI	NOPI	NOPD
dlroil								
dlroilp	0.819							
	(21.42)							
dlroiln	0.854	0.401						
	(24.61)	(6.56)						
SOP	0.937	0.780	0.788					
	(40.11)	(18.71)	(19.20)					
SOPI	0.746	0.909	0.366	0.811				
	(16.79)	(32.82)	(5.90)	(20.77)				
SOPD	0.814	0.424	0.916	0.856	0.392			
	(21.03)	(7.02)	(34.17)	(24.88)	(6.39)			
NOPI	0.438	0.532	0.216	0.461	0.561	0.230		
	(7.30)	(9.43)	(3.32)	(7.80)	(10.17)	(3.55)		
NOPD	-0.413	-0.407	-0.290	-0.435	-0.429	-0.305	-0.745	
	(-6.80)	(-6.68)	(-4.55)	(-7.25)	(-7.13)	(-4.81)	(-16.74)	

Notes: This table shows the correlation coefficients among different oil price specifications: logarithmic first difference of oil price (dlroil), logarithmic first difference of negative oil price (dlroiln), logarithmic first difference of positive oil price (dlroilp), scaled oil price (SOP), scaled oil price decrease (SOPD), scaled oil price increase (SOPI), net oil price increase (NOPI), net oil price decrease (NOPD).

4. Empirical results

In this section, we analyze the empirical results for the relationship between the different oil price specifications and returns in the 10 sectors, and the benchmark index for sample periods 1997:1-2007:1, 2007:1-2017:1 and 1997:1-2017:1. The impulse response functions and variance decomposition are used for examining the impact of oil price shocks on the sectors stock returns and the benchmark index. Furthermore, we investigate if the different sectors and the benchmark index have an asymmetric response to oil price increases and decreases.

4.1. Impulse response functions and accumulated response

4.1.1. Impulse response

The impact of oil price changes is assessed using impulse response function and accumulated response for the linear, SOP, NOPI and NOPD oil price specification. Impulse response functions are a dynamic system that shows the response of an endogenous variable over time to a given shock (Sadorsky, 1999). Brooks (2013) explains impulse response as a system that races out the responsiveness of the dependent variables in the VAR to shocks, to the error term. Here, a unit shock is applied to each variable, and its effects are presented.

Table 4 presents the accumulated orthogonalized impulse response of real sector returns and real benchmark index returns to oil price shocks after 1,12 and 24 months with the different oil price (Scholtens & Yurtsever, 2012), where the different oil price specification are labeled as *n* for negative response and *p* for positive response, and the superscripts ***,** and * denotes the statistical significance at the 1%, 5% and 10%

level respectively (The Monte Carlo standard error is used to assess the significant impact). The data linked to Table 4 is presented in the appendix B, in Table B1 to B3, where we only show the data from the linear specification. The data from the other oil price specifications and the graphs that follow the impulse response functions are available upon request. The effect in 1, 12 and 24 months can be seen, and the significance can be gauged by looking at the Monte Carlo standard error.

Table 4
Orthogonalized impulse response functions of real sector stock returns and real OSE Benchmark Index return to oil price shocks with different specifications.

		Oil price specifications											
		Linear			SOP			NOPI			NOPD		
Sectors	After x months	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1
OSE10 - Energy	x =1	p***	p***	p***	p***	p***	p***	p**	p*	p***	n*	n***	n***
	x = 12	p	p	p**	p	p	p*	p	n	p	n	n	n
	x =24	p	p	p**	p	p	p**	p	n	p	n	n	n
OSE15 - Materials	x =1	p	p***	p***	p	p***	p***	p	p	p	p	n	n
	x = 12	p	p	p	n	p	p	p	n	n	n	p	n
	x =24	p	p	p	n	p	p	p	n	n	n	p	n
OSE20 - Industrials	x =1	p	p***	p***	p	p***	p***	p	p	p	p	n	n
	x = 12	p	n	p	n	n	n	p	n	n	n	p	n
	x =24	p	n	p	n	n	n	p	n	n	n	p	n
OSE25 - Consumer Discretionary	x =1	n	p*	p	p	p*	p	n	p	p	p	n	n
	x = 12	n	n	n	n	n	n	p	n	n	n	p	p
	x =24	p	n	n	n	n	n	n	n	n	p	p	p
OSE30 - Consumer Staples	x =1	p	p***	p**	p	p***	p**	p	p	p	p	n	n
	x = 12	p	n	n	p	n	n	p	n	n	n	p	p
	x =24	p	n	n	p	n	n	p	n	n	n	p	p
OSE35 - Health Care	x =1	p	p**	p**	p	p***	p***	n	p	p	p	n	n
	x = 12	n	n	n	n	n	n	n	p	p	p	n	p
	x =24	n	n	n	n	n	n	n	p	p	p	n	p
OSE40 - Financials	x =1	n	p***	p***	n	p***	p***	p	p	p	n	n	n
	x = 12	n	p	p	n	n	p	p	n	n	n	p	p
	x =24	p	p	p	n	n	p	p	n	n	n	p	p
OSE45 - Information Technology	x =1	p	p***	p***	p	p***	p***	p	p	p	p	n	n
	x = 12	p	n	p	p	n	p	p	n	p	n	p	n
	x =24	p	n	p	p	n	p	p	n	p	n	p	n
OSE50 - Telecommunication Services	x =1	n	p**	p	n	p***	p*	p	p	p	n	n	n
	x = 12	n	p	p	n	p	p	p	n	p	n	p	n
	x =24	n	p	p	n	p	p	p	n	p	n	p	n
OSE55 - Utilities	x =1	p	p***	p**	p	p***	p**	p	p	p	p	n	n
	x = 12	n	p	n	n	n	n	p	n	n	n	p	p
	x =24	n	n	n	n	n	n	p	n	n	n	p	p
OSEBX - Benchmark Index	x =1	p*	p***	p***	p	p***	p***	p	p**	p**	n	n*	n*
	x = 12	p	p	p	p	p	p	p	p	p	n	n	n
	x =24	p	p	p	p	p	p	p	p	p	n	n	n

Notes: This table shows the accumulated response of real sector stock returns and real OSE Benchmark Index return to oil price shocks after 1, 12 and 24 months with different specifications (linear, scaled oil price (SOP), net oil price increase (NOPI) and net oil price decrease (NOPD)). Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance, respectively. n(p) indicates a negative(positive) impulse response.

From Table 4 we see that the results from the first sub-period (97:1-07:1) are not significant for most sectors and the benchmark index, across the different oil price specifications. In great contrast to the second sub-period (07:1-17:1) and the full period (97:1-17:1), where the impact of oil price shocks is somewhat significant in the same month or within the same month the shock occurs.

Furthermore, we address the linear oil price specification, where Table 4 reveals that most of the sectors only respond significantly positive within a month of the shock. OSE10 – Energy is the only sector that is highly significant in period 97:1-07:1, the benchmark index is also significant at the 10% level, but both are only significant within a month of the shock. The results for period 07:1-17:1 show that all sectors and the benchmark index respond significantly within one month and most of the sectors are highly significant at 1%. The whole sample period provides some interesting results where the impact of oil price shocks on OSE10 are significantly positive at the 5% level after 24 months. For the rest of the sectors and the benchmark index the results are much the same as the previous period, but the impact of oil price shocks on OSE25 and OSE50 are no longer significant within one month.

The scaled oil price (SOP) specification is used as a proxy for oil price volatility. The results are somewhat the same as the linear specification, in the first sub-period OSE10 is the only sector that is significant (within one month). The benchmark index is no longer significant in this period when using SOP. The impact of SOP specification is significant within one month for period 07:1-17:1 and 97:1-17:1 for all sectors and the benchmark index, the only exception is OSE25 that is not significant in period 97:1-17:1. Similar to the linear oil price, the scaled oil price shocks have a positive impact on OSE10 after 24 months. Interesting to note here is that even if scaled oil price includes information on price (volatility) in the past, the response of the sectors indexes and benchmark index remains significantly positive.

In general, Table 4 shows that the impact from linear and SOP oil price specification is mostly the same across the sample periods used. We expected that period 97:1 – 07:1 would have yielded more significant results under the SOP specification, since a shock that occurs in a calm period would be scaled up, and large shocks in volatile period will be scaled down. Lee et al (1995), propose that oil shocks are likely to have greater impact when oil price have been stable than when oil price have been volatile. From Graph 1 in the descriptive statistics, we do see that in period 97:1 – 07:1 oil price was more stable, and in period 07:1-17:1 more volatile. However, from Graph 1 we see that the magnitude of oil price shocks is much greater in period 07:1 – 17:1 than 97:1 – 07:1, which can explain the different level of significance in the sub-periods.

The response of Hamilton´s net oil price (NOP) specification is separated into net oil price increase (NOPI) and net oil price decrease (NOPD). Here we get the first look at how the asymmetry of the response of the various stock returns to oil price shocks may unfold. Table 4 reveals that the response of all sectors stock returns is statistically insignificant, except the energy sector (OSE10) for both NOPI and NOPD across the sample periods. The benchmark index is significant for the full sample and the second sub-period.

For NOPI, the results show that the energy sector (OSE10) is positively significant within one month, and for NOPD the results are opposite where the energy sector is negatively significant within one month, across the sample periods. The benchmark index is also positively significant within one month for NOPI, and negatively significant within one month for NOPD, but not for the first sub-period. The results from Table 4 show that the Norwegian stock market mostly does not respond significantly to oil price shocks under the NOPI and NOPD specification. The literature show that stock markets of many countries do not respond to oil price shocks under the NOPI specification (Scholtens & Yurtsever, 2012). Park (2007) and Park & Ratti (2008) use NOPI specification, and analyses the impact between NOPI and the Norwegian stock market. The results from Park (2007) and Park & Ratti (2008) are that the response from NOPI on the Norwegian stock market is insignificant. However, they do not look at sector indices, but at an aggregated index like the all shares index on Oslo Stock Exchange. The results from Scholtens & Yurtsever (2012) say that industries respond more significantly to NOPD, than NOPI. Industries that have a significant respond to NOPI, respond significantly negatively and the significant response of NOPD is positive. However, Scholtens & Yurtsever (2012) look at European industries indexes and not a net oil exporting economy.

The relationship between the different oil price specification and the Norwegian stock market are mostly positive, which is not surprising since Norway is a net-exporter of oil, and the only negative association is with NOPD. It hereby seems that oil price increase and decrease have somewhat similar impact on the Norwegian stock market and the Norwegian GDP. Moreover, the sectors that shows the most significant response to the different oil price specifications is OSE10, where the major production-output is oil and gas, therefore this response is as expected and consistent with the existing literature (Scholtens & Yurtsever, 2012; Faff & Brailsford, 1999; Nandha & Faff, 2008). The significance of the response of the sectors and the benchmark index on oil price shocks as shown in Table 4 is mostly present after 1 month, and not significant after 12 and 24 months. The explanation for this is that the VAR systems seem to be stable, and therefore the shocks should gradually die away (Brooks, 2013). A fair assumption to make is that OSE10 – Energy is not stable and is volatile, when influenced by oil price. In addition, almost all sectors have a significant positive response to the different oil price specifications. The exception is NOPD, that have only significant negative responses, and this is not unexpected since Norway is a net-exporter of oil. Sadorsky (1999) note that, initially a positive oil price shock should have a negative and statistically significant initial impact on stock returns in a net oil importing economy. The explanation for this is that an increase in oil prices will cause earnings to decline. If the stock market is efficient an increase in oil prices will cause an immediate decline in stock prices. If the stock market is not efficient then an increase in oil prices will bring about a lagged decline in the stock market (Sadorsky, 1999). The explanation for Norway will be opposite where an increase in oil price will cause earning to increase. If the stock market is efficient, this increase will cause a rise in stock prices. The response of Norwegian stock market to positive and negative changes in oil price cannot be concluded from NOPI and NOPI, since these two oil price specifications often yield insignificant responses. Therefore, we will conduct an analysis of asymmetry between positive and negative changes in oil price by using the linear and SOP oil price specifications. The asymmetric response is presented in section 4.2.

4.1.2. Variance decomposition

The variance decomposition shows how much of the unanticipated changes of the variables are explained by different shocks. This thesis examines the contribution of each source of shock to the variance of the prospective forecast error for real sector stock market returns and real benchmark index return. This is presented in Table 5, but only the impact of the different measures of oil price shocks have on the forecast error for real sector stock returns and real benchmark index return. The full results are found in the appendix B in Table B4, which shows the results for interest rate, oil price, industrial production, real benchmark index returns and real sector returns shocks to the variance of the future forecast error of sector returns after 24 months. The same is presented for real benchmark index return, there the results from interest rate, oil price, industrial production are shown in full. With the linear oil price specifications and Monte Carlo constructed standard errors after 100 repetitions are in parentheses to provide insight in the significance of these contributions. A simplified table of the variance decomposition with different oil price specifications is in Table 5.

The findings show that real benchmark index returns and real sector stock returns are the main contribution for most of the periods tested. In other words, they account for the highest forecast error variance in real stock returns for all the sectors. This is rather not surprising, and is consistent with Scholtens & Yurtsever (2012), Ferderer (1996), Park (2007), Sadorsky (1999) and Kilian & Vigfusson (2009). For the benchmark index, the real benchmark index returns and the different oil price specifications are the greatest source of variance. The variance decomposition suggests that oil price shocks are a considerable source of volatility for many of the variables in the model.

For real sector stock returns, the different oil price specification, together with interest rate, are the largest source of shocks, other than the variable itself and real benchmark index returns for most sectors. Innovation in interest rate represents monetary shocks in our model. The contribution of oil price and interest rate differ across sectors, periods and across the different oil price specifications. The contribution of oil price shocks to the variability in sector stock returns and the benchmark index is greater than that of interest rate in all models, consistent with (Sadorsky, 1999 and Park & Ratti, 2008).

Consistent with the results from the impulse response, we see that the results in period 97:1 – 07:1 is in general non-significant across the different oil price specification in the variance decomposition. The variance is also relatively low across the sectors in this period, except for the sectors that show significance. For the linear approach, oil price shocks are a significant source of volatility and accounts for 8,50% of the variance in OSE10 and 8,60% in OSE55. The oil price specifications SOP and NOPI are not a significant source of volatility in the different sectors and for the benchmark index in this period. The exception is NOPI, that accounts significant for 10.58% of the variance in OSE45.

Table 5

Simplified variance decomposition of variance in real sector stock returns and real benchmark index return due to different oil price specifications after 24 months

	Linear			SOP			NOPI			NOPD		
Sectors	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1
OSE10 - Energy	8.5**	39,35***	2134***	7,81	45,13***	23,00***	6,08	8.42	5.77*	6.18	17.01***	5.33*
OSE15 - Materials	1,94	7,75*	3,55*	3,54	9,83*	5,38***	4,31	4.08	2.92	7.66	4.08	1.43
OSE20 - Industrials	1,12	12,52*	4,82	0,93	15,65***	5,87*	3.18	4.47	1.28	8.78	4.47	0.43
OSE25 - Consumer Discretionary	7,25	6,78	5,48*	7,70	7,47	4,97	5.38	9.81	2.47	6.28	9.08	2.38
OSE30 - Consumer Staples	1,85	14,88**	5,00	2,37	16,34**	5,83	4.14	13.72*	1.78	3.51	13.71	1.53
OSE35 - Health Care	7,66	6,39*	4,48*	10,00	8,51**	5,66**	2.12	2.41	0.98	2.99	2.41	0.33
OSE40 - Financials	3,76	26,96***	5,22	3,85	26,99***	6,45*	1.96	5.96	1.68	5.12	5.96	1.00
OSE45 - Information Technology	5,30	13,02**	4.94**	5,49	15,94***	4,68*	10.58*	14.52**	2.70	9.14	14.51*	2.67
OSE50 - Telecommunication Services	1,61	7,26*	1,43	1,90	11,56**	2,05	2.58	4.24	0.97	4.32	4.24	0.74
OSE55 - Utilities	8,60*	13,32**	6.57**	9,02	13,29***	5,71*	2.45	7.13	3.03	4.07	7.13	2.50
OSEBX - Benchmark Index	3,49	25,36***	10.54***	3,33	28,85***	10,66***	4,72	15,55**	2.71	6.79	9.82	2.22

Notes: The table presents variance decomposition of real sector stock market returns and real benchmark index return to oil price shocks after 24 months with different specifications (linear, scaled oil price (SOP), net oil price increase (NOPI) and net oil price decrease (NOPD)). Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance, respectively

The results in the second sub-period is the most significant across the different oil price specifications, when compared to the first sub-period and the full sample period. The linear specification is significant for 9 out of 10 sectors, and it is shown that 39.35% of OSE10 and 26.96% of OSE40 variance is accounted for by oil price shock. The benchmark index is also significant in this period and 25,36% of the variance is due to oil price shock. The results for SOP is the same where 9 out 10 are significant, OSE25 is the only sector that is insignificant, for both linear and SOP. Here, the contribution of oil price shock to the variance of OSE10 is 45.13%, 26.99% for OSE40 and 28.85% for OSEBX. NOPI and NOPD give some different significant results. OSE45 is the only significant sector in both NOPI and NOPD. Further OSE30 and the benchmark index are significant for NOPI in this period. Interestingly, OSE10 is highly significant for NOPD in the second sub-period, but not for NOPI.

The contribution of oil price shocks to variability in real stock returns in the whole sample (97:1 – 17:1) is not as significant as in the period 07:1 – 17:1. OSE10 is the only sector that is significant across the different oil price specifications in the full sample. Further, OSEBX is highly significant in this period for the linear and SOP oil specification, but not for NOPD and NOPI. Period 97:1 – 17:1 is not very significant in general, but more sectors are significant for linear and SOP specification than for NOPI and NOPD. The relative low contributions of NOPI and NOPD to the variation in sector stock index returns and benchmark index returns is consistent with the results from the impulse response functions in the previous section (see Table 4).

From the variance decomposition, we see that oil price shocks accounts for high variation in many of the sectors and for the benchmark index, especially in period 07:1 – 17:1. It is fair to conclude that oil price shocks are a significant source of monthly volatility in real sector stock returns and for real benchmark index returns in recent years. The probable explanation for this is that oil price has been unstable and volatile in this period. The linear and SOP oil price specifications are a considerable source of volatility for real stock returns in the Norwegian stock market, shown in Table 5. Further, the linear and SOP oil price specifications show a bigger contribution of an oil price shock to the Norwegian stock market than NOPI and NOPD. Consistent with Park (2007) and Park & Ratti (2008), the contribution of linear and SOP oil price specification is a significant source of volatility on the benchmark index. Our results for NOPI contradict Park (2007) for the second sub-period for the benchmark index. We find that NOPI is statistical significant, and that Park (2007) finds no evidence for this. Further, Kilian & Vigfusson (2009) as well as Scholtens & Yurtsever (2012), mentions that use of net oil price increases and decreases in a VAR model may cause problems with the impulse responses. Therefore, like Scholtens & Yurtsever (2012) we will investigate the response with increases and decreases in the linear and scaled oil price specifications for all the periods. Here we will also apply a coefficient test to investigate for asymmetric response to oil price increases and decreases, by following the method by Park & Ratti (2008).

4.2. Asymmetric effect of oil price shocks

The increase and decrease of oil price in recent years is of great importance globally, since many countries are highly dependent on oil as a commodity. This applies both to net exporting and net importing oil economies. Where net exporting economies are assumed to benefit from an increase in oil prices, and net importing benefits from decrease in oil price. Further, the literature concludes that oil price increases have a greater (or significant) influence on the GDP than oil price decrease (Mork, 1989; Darby, 1982; Mory, 1993; Mork et al, 1994). The relationship between stock market returns and oil price increases and decreases is different from the findings on GDP, where this relationship in the literature does not show consistent findings, and differs from methods, models and data used. The relationship between oil price and stock market returns has been an important issue in studies by Hamilton (1996), Mork (1989), Park & Ratti (2008), and Kilian & Vigfusson (2009). They follow the thought that if there is an effect on GDP, we would expect an effect on the stock market too. This thesis takes this one step further and focuses on the sectors, though we do include the benchmark index.

The findings in section 4.1 show that the impact from the different oil price specifications differ among the different sectors and the benchmark index. The different impact from oil price makes it important to see if positive and negative oil price shocks have different impacts. From the NOPI and NOPD in Table 5, it seems that the different sectors and the benchmark index respond differently to an oil price increase and decrease and over different periods. Therefore, in addition to the oil specifications above, we include linear and SOP specifications in an asymmetry test where the oil price specifications are separated into positive and negative oil price changes or shocks.

We follow the model and method used by Park and Ratti (2008) and Scholtens & Yurtsever (2012). They run a similar VAR as before, but now with six variables and splitting oil price changes into positive ($dlroilp_t$ and $SOPI_t$) and negative ($dlroiln_t$ and $SOPD_t$). We use the same sub-periods as before: 1997:1 - 2007:1, 2007:1 – 2017:1 and the full sample period 1997:1 – 2017:1, here we use 5 lags. The VAR(p) for the different sectors now look like this:

$$y_{it} = A_0 + \sum_{j=1}^{p} A_{j,i}\, y_{it-j} + u_{it} \qquad\qquad i = 1 \dots 10$$

y_t = [interest rate, positive real oil price changes, negative real oil price changes, industrial production, real benchmark index returns and real sector stock returns]

A_t is a 6×6 matrix of coefficients, A_0 is a column vector of deterministic constant terms, i represents each individual industry, u_t is a column vector of errors with the property of

$$E(u_t) for\ all\ t, \quad E(u_t \acute{u}_t) = \Omega\ if\ s = t, \quad E(u_t \acute{u}_t) = 0, if\ s \neq t,$$

where Ω is the variance–covariance matrix. u_t's are not serially correlated but may be contemporaneously correlated. Thus, Ω is assumed to have non-zero off-diagonal elements.

The VAR for the benchmark index is the same as for the sectors with same lag order. The only difference is that real sector stock returna is not included. Therefore, y_t = [interest rate, positive real oil price changes, negative real oil price changes, industrial production and real benchmark index return] for the VAR used for OSEBX and A_t is now a 5×5 matrix of coefficients, i does not represents each individual industry, and the rest stays the same.

4.2.1. Variance decomposition

The output of the variance decomposition of the forecast error variance in real sector stock returns and for real benchmark index returns from the VAR models above is presented in Table 6. Starting off with the significance level, the results in period 97:1 – 07:1 are still the least significant, the results in period 07:1 – 17:1 are the most significant, and the results in the full sample period are also somewhat significant. Looking closer at the impact the data shows, we find that negative changes in oil price is generally greater than that of a positive oil price change. Negative changes in oil price are also in general more significant than positive changes in oil price, for both the linear and SOP oil price specification.

For the linear specification in period 97:1 – 07:1, negative changes have a greater impact than positive changes, on the benchmark index and for sector stock returns for 7 out 10 sectors. However, most of impacts are not significant, only positively significant for OSE10 and negatively significant for OSE35. In period 07:1 – 17:1, there is almost an equal amount of significant positive and negative impact on the sector stock and the benchmark index. However, negative changes contribute to more of the significant variance than positive changes. In the full sample negative changes explain significant more of the variance in the sector indexes returns and the benchmark index returns. In general, from the linear oil price specification, it seems that from our findings that negative oil changes explain more of the variance in returns on the Norwegian stock market, than positive changes do.

Table 6

Simplified variance decomposition of variance in real sector stock returns and real benchmark index return return due to postive and negative oil price changes after 24 months

	Linear						SOP					
	97:1-07:1		07:1-17:1		97:1-17:1		97:1-07:1		07:1-17:1		97:1-17:1	
Sectors	P	N	P	N	P	N	P	N	P	N	P	N
OSE10 - Energy	8,79*	4,35	25,86***	21,89***	15,73***	8,56***	5,18	5,94	22,16***	26,90***	13,27***	12,11***
OSE15 - Materials	2,63	3,52	6,94*	16,31**	2,58	4,89*	3,39	4,55	6,88	13,75*	3,93	5,63**
OSE20 - Industrials	3,18	2,08	9,64*	8,42*	5,20*	2,13	1,83	2,59	11,30**	10,08**	4,93	2,68
OSE25 - Consumer Discretionary	4,42	4,57	4,38	12,47*	4,24	3,18	6,18	4,50	6,26	8,60*	3,62	2,83
OSE30 - Consumer Staples	2,84	5,38	11,56**	16,19**	2,68	5,79**	3,27	6,35	12,48*	17,60**	3,67	6,76**
OSE35 - Health Care	4,92	9,92*	6,09	5,64	3,58	3,60	4,64	10,67*	5,11	6,69	4,26	2,83
OSE40 - Financials	1,53	5,28	15,26**	20,49***	2,46	4,66	2,00	5,25	14,06**	23,11***	2,68	6,36**
OSE45 - Information Technology	2,48	5,69	11,48**	12,64**	1,92	6,70***	5,53	5,47	14,92***	16,02***	1,94	7,14**
OSE50 - Telecommunication Services	3,55	6,80	5,59	12,41**	1,36	4,67*	2,87	5,26	7,68	12,69*	1,87	4,30
OSE55 - Utilities	8,18	6,73	9,07**	14,42***	6,88	3,83***	8,80*	7,05	9,86	12,35**	6,31*	3,63
OSEBX - Benchmark Index	2,53	3,67	15,97***	20,82***	6,25*	6,84***	2,37	4,82	17,61***	23,76***	5,92*	7,47***

Notes: The table presents variance decomposition of real sector stock returns and real benchmark index return to oil price shocks after 24 months with postive (*dlroilp and SOPI*) and negative (*dlroiln and SOPD*) oil price changes for Linear and SOP oil price specifications. Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance, respectively

For the SOP specification, the results in the first sub-period are that negative changes in oil price have a greater impact than positive changes in 7 out of 10 sectors and for the benchmark index. However, only OSE55 is positively significant, and OSE35 is negatively significant as under the linear specification. The results from period 07:1 – 17:1 show that the negative changes in oil price impact are greater than positive changes for 9 out of 10 sectors. The results from OSEBX do also show that negative impact is greater than positive. The negative impact is also more significant than the positive impact, in relation to the variance of the returns on the Norwegian stock market. Further, in the full sample, the greater impact from positive and negative oil price changes on the different sectors are 5 each, also here the negative change impacts OSEBX more. However, the negative changes in oil price are more significant for the variance than positive changes.

The conclusion is that negative oil price changes have the greatest impact on real sector stock returns and on real benchmark index returns, and negative oil price changes are also much more significant than positive oil price changes. These results for SOP and linear specification are somewhat consistent with Park (2007), who finds that negative changes are more significant than positive changes for the Norwegian stock market. Park (2007) also concludes that an oil price decrease has a greater impact on the stock market than an oil price increase in net oil exporting countries. Moreover, to make sure of the proposed asymmetry effect from the variance decomposition, we also use the Wald test, which compares the coefficient of oil price increase and decrease.

4.2.2. Test for asymmetric effect

Following the work of Park and Ratti (2008), we conduct a Wald test in addition to the VARs variance decomposition. From the variance decomposition, it is fair to conclude that negative oil price shocks greater (or significantly) influence the returns of the Norwegian stock market, than positive oil price shocks. However, by conducting a Wald test, it is possible to compare the effect of oil price increase and decrease, and examine where they are the same, e.g., whether there are any evidence of asymmetric impacts of the increase and decrease in oil price. This Wald test further enhances the robustness of this paper and contributes to a better understanding of the effect oil price has on the stock market returns in Norway.

The Wald test, which is a Chi-square (χ2) test, where the null hypothesis is that the coefficients of positive and negative oil price shocks in the VAR, are equal at each lag. The hypothesis, are consistent with Park and Ratti (2008) and Scholtens & Yurtsever (2012), is presented as:

$$H_0: \alpha_{2j} = \alpha_{3j} \qquad\qquad H_1: \alpha_{2j} \neq \alpha_{3j}$$

The equations for real sector stock returns are the following with positive/increase and negative/decrease oil price specifications from Mork (1989) and Lee et al (1995):

$$rose_{it} = \alpha_0 + \sum_{j=1}^{5} a_{1j} dlNIBOR_{t-j} + \sum_{j=1}^{5} a_{2j} dlroilp_{t-j} + \sum_{j=1}^{5} \alpha_{3j} dlroiln_{t-j}$$
$$+ \sum_{j=1}^{5} \alpha_{4j} dlip_{t-j} + \sum_{j=1}^{5} \alpha_{5j} rosebx_{t-j} + \sum_{j=1}^{5} \alpha_{6j} rose_{it-j} \quad i = 1 \dots 10$$

$$rose_{it} = \alpha_0 + \sum_{j=1}^{5} a_{1j} dlNIBOR_{t-j} + \sum_{j=1}^{5} a_{2j} SOPI_{t-j} + \sum_{j=1}^{5} \alpha_{3j} SOPD_{t-j}$$
$$+ \sum_{j=1}^{5} \alpha_{4j} dlip_{t-j} + \sum_{j=1}^{5} \alpha_{5j} rosebx_{t-j} + \sum_{j=1}^{5} \alpha_{6j} rose_{it-j} \quad i = 1 \dots 10$$

The equation for real benchmark index returns are much the same as above. The main difference is that real sector stock returns is not included in the model. Further, the hypothesis stays the same for this Wald test, and the equations are the following:

$$rosebx_t = \alpha_0 + \sum_{j=1}^{5} a_{1j} dlNIBOR_{t-j} + \sum_{j=1}^{5} a_{2j} dlroilp_{t-j} + \sum_{j=1}^{5} \alpha_{3j} dlroiln_{t-j}$$
$$+ \sum_{j=1}^{5} \alpha_{4j} dlip_{t-j} + \sum_{j=1}^{5} \alpha_{5j} rosebx_{t-j}$$

$$rosebx_t = \alpha_0 + \sum_{j=1}^{5} a_{1j} dlNIBOR_{t-j} + \sum_{j=1}^{5} a_{2j} SOPI_{t-j} + \sum_{j=1}^{5} \alpha_{3j} SOPD_{t-j}$$
$$+ \sum_{j=1}^{5} \alpha_{4j} dlip_{t-j} + \sum_{j=1}^{5} \alpha_{5j} rosebx_{t-j}$$

The results obtained by carrying out this test of pair-wise of equality of the coefficients on positive and negative oil price shocks, can be found in the Table 7. Here we see that for all cases, we fail to reject the null hypothesis at 5% (or 1% and 10%) level of significance, across sectors and sample period. Although, if the results from the variance decomposition indicated that the impact of negative oil price changes is dominant, the results from the Chi-square (χ2) test shows no evidence, for asymmetric effects between oil price shocks, and real sector stock returns and real benchmark index returns in Norway. The results from the Chi-square (χ2) test suggest that the coefficients of positive and negative oil price shocks in the VARs, are not significantly different from each other at each lag. Thus, we conclude from the Wald test that there is no evidence of asymmetric effects of positive and negative oil price shocks on the different sectors. The benchmark index also shows evidence of non-asymmetric responds between positive and negative oil price shocks from the Wald test. The Norwegian stock market does therefore not seem to react any differently to positive and negative oil price shocks, contradicting Park & Ratti (2008) that rejected the null hypothesis for Norway at 10% level for the SOP oil price specification, but not for the linear specification. They concluded that there is evidence for asymmetric effects of oil price shocks on the Norwegian stock returns. The sample period and the methods used for calculating oil price are somewhat different than what is used in this paper. Park (2007) also found evidence of asymmetry on the Norwegian stock market, but only in sample period 1986 – 1996.4. Further the results from Park (2007) for sample period 1986 – 2005 for SOP specification contradicts Park and Ratti (2008). This further makes it evident that the relationship between oil price and stock market is intricate and different results are presented even when the ordering of the VAR and the sample period is consistent between research papers.

The probable explanation of the somewhat different results in the variance decomposition VAR and the Wald test, is the way the tests are conducted. The variance decomposition determines how much of the forecast error variance of a given variable is explained by innovation to each explanatory variable (Brooks, 2013). More explained, the variance decomposition shows how much of the unanticipated changes of the variables are explained by different shocks. The Wald test, use the coefficients of the lagged variables, and the coefficients is a measure of the strength of association between a given variable and the explanatory variables (Brooks, 2013). Further these coefficients are tested with restrictions or null hypothesis, and these restrictions (or null hypothesis) are rejected or failed to be rejected. In this paper, the restriction was that the coefficients of positive and negative oil price shocks in the VAR, are equal at each lag. The variance decomposition is different where a given variable is impacted by shocks in other variables. So, in the variance decomposition used in section 4.2, we show how sector stock returns and the benchmark index returns are effected by shocks in positive and negative oil price specification. In the variance decomposition, we can´t test for restrictions, but we can compare the results from the positive and negative shocks. Hereby we`ve concluded that innovation in negative oil price was greater than positive innovation in oil price. In the Wald test, the conclusion is somewhat different where the coefficients of the lagged value from oil price increase and oil price decrease seem to be equal. Although, the results from the variance decomposition indicated that the impact of an oil price decrease was more significant than oil price increase. However, the results from the Wald test obtain no evidence for asymmetric effects. We do conclude that there are no asymmetric effects of oil price shocks and the Norwegian stock market. Further, the relationship between positive and negative oil price specifications, and the Norwegian stock market is further explored with the use of different methods in section 4.3.

Table 7

Wald coefficent test of asymmetric effect of linear oil price shocks and SOP shocks on real sector stock return and real benchmark index return

	Oil price specifications					
	Linear			SOP		
Sectors	97:1-07:1	07:1-17:1	97:1-17:1	97:1-07:1	07:1-17:1	97:1-17:1
OSE10 - Energy	4,755074	2,712875	7,818273	4,344899	4,554717	6,824662
	(0.4465)	(0.7441)	(0.1665)	(0.5009)	(0.4726)	(0.234)
OSE15 - Materials	6,657736	5,944108	8,828137	6,700278	4,121644	5,914836
	(0.2474)	(0.3117)	(0.1161)	(0.2439)	(0.532)	(0.3146)
OSE20 - Industrials	4,399627	0,816079	6,822852	3,303426	0,464637	5,044392
	(0.4934)	(0.976)	(0.2342)	(0.6533)	(0.9934)	(0.4105)
OSE25 - Consumer Discretionary	3,828215	7,463994	5,574412	4,689754	7,130728	5,255798
	(0.5744)	(0.1884)	(0.3499)	(0.4549)	(0.2111)	(0.3855)
OSE30 - Consumer Staples	5,76525	8,674811	9,205829	6,040272	8,2876	8,818715
	(0.3297)	(0.1228)	(0.1011)	(0.3023)	(0.1411)	(0.1165)
OSE35 - Health Care	7,68165	6,510125	6,430588	8,462473	4,998366	4,763607
	(0.1747)	(0.2597)	(0.2665)	(0.1325)	(0.4161)	(0.4454)
OSE40 - Financials	3,173843	2,955813	1,22783	7,200609	4,27784	1,01108
	(0.6732)	(0.7068)	(0.9422)	(0.2061)	(0.5101)	(0.9617)
OSE45 - Information Technology	3,326803	5,087893	4,117574	3,936972	9,221292	2,26651
	(0.6497)	(0.4052)	(0.5326)	(0.5585)	(0.1006)	(0.8112)
OSE50 - Telecommunication Services	6,914348	6,176373	5,157874	4,35827	6,621668	4,611729
	(0.2271)	(0.2894)	(0.3969)	(0.4991)	(0.2503)	(0.4651)
OSE55 - Utilities	5,250083	4,221226	8,368323	4,04166	3,134574	7,840525
	(0.3861)	(0.518)	(0.1371)	(0.5434)	(0.6792)	(0.1652)
OSEBX - Benchmark Index	3.4227535	2.603282	4.944011	3.989696	4.088905	3.747395
	(0.6344)	(0.7609)	(0.4228)	(0.5509)	(0.5367)	(0.5863)

Notes: This table presents Chi-square ($\chi 2$) test results of H_0: $\alpha_{2j} = \alpha_{3j}$. The p-values are shown in the paranthesis.

Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance

4.3. Alternative methods of estimating the relationship between oil price and Oslo Stock Exchange

4.3.1. Multivariate model for real sector stock returns

The analysis in this thesis concludes by using a different methodology to examine the relationship between oil price shocks and OSE, which enhances the robustness and empirical findings in this thesis. We will use the multivariate linear regression model (MLRM) to assess the exposure of sector stock market returns to the oil price shocks. This model follows the standard market model presented by Nandha & Faff (2008) and used by Scholtens & Yurtsever (2012). The model can be written for sector i as follows:

$R_{it} = \alpha_i + \beta_{1i} R^{O}_{wrosebxt} + \beta_{2i} R_{Nibort} + \beta_{3i} R_{ipt} + \beta_{4i} R_{oilt} + \varepsilon_{it}$ and $i = 1\ to\ 10$,

where R_{it} is the real sector stock returns for the ith sector in period t, defined as $\log(sector_{it}/sector_{it-1})$, where $sector_{it}$ is the value of the ith sector for period t. $R^{O}_{wrosebxt}$ represents the orthogonalized world market returns measured as

$R_{rosebx} - E(R_{rosebx})$, where

$E(R_{rosebx}) = \alpha^{*} + \beta_1{}^{*} + \beta_2{}^{*} R_{Nibort} + \beta_3{}^{*} R_{ipt} + \beta_4{}^{*} R_{oilt}$, α^{*} and β^{*} are the estimates of α and β in $R_{rosebx} = \alpha + \beta_1 R_{Nibort} + \beta_2 R_{ipt} + \beta_3 R_{oilt} + \varepsilon_t$ such that R_{rosebx}, R_{Nibort}, R_{ip} and R_{oilt} are log returns for OSEBX, oil price, interest rate and industrial production, respectively, and are measured as one lag difference of log values. The sample periods stay the same as before, which means that we still test period 97:1 – 07:1, 07:1 – 17:1 and 97:1 – 17:1. Further we follow as Scholtens & Yurtsever (2012) and Nandha & Faff (2008) to only use the linear oil price specification from Hamilton (1983) to test this model.

The full results are not presented in this paper, but are available upon request. In Table 8 we present a simplified output from the model, where we show the oil price coefficient, adj.R^2 and Durbin-Watson, which are the most important for this paper. The real sector stock returns have a significant correlation with OSEBX for all sector and across the different sample periods. The only exception is OSE15 – Materials in period 97:1 – 07:1. The correlation between OSEBX and the different sectors is not surprising, and the results are consistent with the results from the VAR model. Both interest rate and industrial production mostly give insignificant results across the sample periods. The results between oil price shocks and the different real sector stock returns are of the greatest interest in this analysis. Interestingly, in this analysis all the 10 sectors exhibit positive "oil" coefficients. This contradicts the findings from Nandha & Faff (2008), who only found this in the mining, and oil and gas industries. The explanation from Nandha & Faff (2008) is that oil is the primary output for the oil and gas industry. The probable explanation from our data set is that Norway is a net exporter of oil, and even if oil price is not significant across all sectors, they are still affected by oil price in one way or other.

Table 8
Simplified MLRM results

	97:1-07:1			07:1-17:1			97:1-17:1		
Sectors	Oil price coefficent	Adj. R^2	DW	Oil price coefficent	Adj. R^2	DW	Oil price coefficent	Adj. R^2	DW
OSE10 - Energy	0.2259***	0.28	1.70	0.4433***	0.42	2.06	0.32***	0.30	1.77
	(4.21)			(8.84)			(8.47)		
OSE15 - Materials	0.0595	0.05	1.28	0.3894***	0.26	1.37	0.1977***	0.13	1.29
	(1.27)			(5.09)			(4.52)		
OSE20 - Industrials	0.0890**	0.16	1.36	0.2598***	0.24	1.63	0.17***	0.17	1.46
	(1.99)			(4.43)			(4.62)		
OSE25 - Consumer Discretionary	0.0560	0.14	1.40	0.1023	0.19	1.46	0.0912*	0.14	1.37
	(0.98)			(1.34)			(1.96)		
OSE30 - Consumer Staples	0.0587	0.12	1.40	0.3154***	0.38	1.27	0.1712***	0.21	1.26
	(1.09)			(4.83)			(4.05)		
OSE35 - Health Care	0.1450**	0.08	1.76	0.1605**	0.05	1.69	0.1538***	0.08	1.75
	(2.36)			(2.30)			(3.40)		
OSE40 - Financials	0.0056	0.09	1.47	0.3858***	0.40	1.68	0.16745***	0.17	1.38
	(0.13)			(6.65)			(4.49)		
OSE45 - Information Technology	0.1542*	0.12	1.48	0.2719***	0.22	1.62	0.2140***	0.16	1.52
	(1.91)			(4.27)			(4.12)		
OSE50 - Telecommunication Services	0.0682	0.05	1.44	0.2287***	0.19	1.65	0.1399**	0.10	1.46
	(0.83)			(3.22)			(2.54)		
OSE55 - Utilities	0.0031	0.02	1.43	0.1833***	0.17	1.46	0.0777**	0.06	1.44
	(0.06)			(3.73)			(2.14)		

Notes: This table reports the results from the asymmetric MLRM model. There the oil price coefficients are shown and the T-Statistics are in parenthesis. Adjusted and Durbin-Watson are given in the last two columns. Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance.

Consistent with the previous analysis in this paper, period 97:1 – 07:1 is the least significant period, where only a few sectors are significantly affected by oil shocks: OSE10 – Energy is highly significant, further OSE20, OSE35 and OSE45 are the other significant sectors. Period 07:1 – 17:1 is surprisingly not the most significant period in this model. Here, 8 out of 10 sectors are significant at 1% level, and OSE35 is at 5% level. The only sector that shows no significance is OSE25 - Consumer Discretionary. The explanation for this is that consumer discretionary can be seen as luxury. This sector consists of goods and services that can be considered non-essential by consumers, but appealing if income is sufficient to purchase them. In the full sample OSE25 is significant at 10% level, so there seems to be a minor correlation between oil price and consumer discretionary in the long-term. Further, 7 out of 10 sectors are significant at 1% level, and OSE50 and OSE55 are at 5% level. Across all samples, there are only 3 sectors that show significance in all periods. OSE20 – Industrials and OSE35 – Health Care are at least significant at 5% level. Not surprisingly, the only sector that is significant at 1% level is OSE10 – Energy. This sector also has the highest oil price coefficient and Adj.R^2. The reason for this is probably consistent with the explanation mentioned above in Nandha & Faff (2008).

Following Nandha & Faff (2008), we also conduct an asymmetry test. The model presented is used for all sectors:

$R_{it} = \alpha_i + \beta_{1i} R^{O}_{wrosebxt} + \beta_{2i} R_{Nibort} + \beta_{3i} R_{ipt} + \beta_{4ui} D * R_{oilt} + \beta_{5di}(1 - D) * R_{oilt} + \varepsilon_{it}$ and $i = 1\ to\ 10$,

Where D is the dummy variable taking value of unity if the oil price variable is positive (i.e. $R_{oil\,t} > 0$ and $D = 0$ otherwise; β_{4ui} and β_{5di} are indicative of ith industry coefficients corresponding to up and down movements in the oil factor.

The oil price dummy Nandha & Faff (2008) use the same as the asymmetric specification in Mork (1989), since we only test for the linear oil price specification from Hamilton (1983).

Nandha & Faff (2008) also present a hypothesis that we intend to follow, which is corresponding to the hypothesis used in the Wald test in the VAR, which is found in section 4.2. Nandha & Faff (2008) also conduct the Wald test for this model. The null hypothesis is therefore that no asymmetry exists, in which case the two coefficients should not be significantly different from each other.

$$H_{01}: \beta_{4ui} = \beta_{5di}$$

A more specific version of this test is that there is no asymmetry and, indeed, the sensitivity for both cases is jointly equal to zero. More formally, this test is:

$$H_{02}: \beta_{4ui} = \beta_{5di} = 0$$

The results from the asymmetry test are presented in Table 9, where we only show a simplified version of the full results; the positive (β_{4ui}) and negative (β_{5di}) oil coefficients, the two Wald hypothesis, Adj.R2 and Durbin-Watson, which are most interesting to this paper. The full results are not presented in this paper, but are available upon request. From Table 9, we see that across the different sample periods, the negative oil price coefficients are more significant than the positive. Therefore, from the coefficients, it seems that negative oil price is more correlated with the sector returns than positive. The same results are found for the sectors in the variance decomposition from the VAR in section 4.2, where negative oil price changes outperform positive oil price changes.

The Wald test can contradict the assumption that negative oil price changes has a greater impact than positive, which is evident from the VAR in section 4.2. There we found no evidence of asymmetry between positive and negative oil price shocks. The Wald test rejects the null $H_{02}: \beta_{4ui} = \beta_{5di} = 0$ for 2 out of 10 sectors at 5% level and 4 out of 10 at 10% level in period 97:1 – 07:1. The results in period 07:1 – 17:1 are that the hypothesis is rejected for 9 out of 10 sectors at 1% level and all sectors at 5% level. The full sample gives almost the same results, where 8 out of 10 sectors reject the null hypothesis of symmetry at 1% level and all sectors reject this hypothesis at 10% level of significance. This means that for this Wald test, there is asymmetry, and indeed, the sensitivity for both cases is not jointly equal to zero.

Table 9
Simplified MLRM asymmetric results

	97:1-07:1						07:1-17:1						97:1-17:1					
Sectors	β_{ui}	β_{di}	$H_{02}: \beta_{ui} = \beta_{di} = 0$	$H_{01}: \beta_{ui} = \beta_{di}$	Adj. R^2	DW	β_{ui}	β_{di}	$H_{02}: \beta_{ui} = \beta_{di} = 0$	$H_{01}: \beta_{ui} = \beta_{di}$	Adj. R^2	DW	β_{ui}	β_{di}	$H_{02}: \beta_{ui} = \beta_{di} = 0$	$H_{01}: \beta_{ui} = \beta_{di}$	Adj. R^2	DW
OSE10 - Energy	0.2262**	0.2254**	17.5709***	0.0000	0.27	1.70	0.2564**	0.5814***	84.0722***	3.9463**	0.43	2.03	0.2406***	0.3898***	73.3942***	1.5486	0.30	1.77
	(2.21)	(2.27)	(0.000)	(0.996)			(2.41)	(6.81)	(0.000)	(0.047)			-3.23	(5.80)	(0.000)	(0.21)		
OSE15 - Materials	0.0671	0.0521	1.6208	0.0102	0.04	1.29	0.1437	0.5708***	29.2329***	2.9031*	0.27	1.35	0.1162	0.2682***	21.6684***	1.2051	0.13	1.28
	(0.75)	(0.60)	(0.445)	(0.920)			(0.88)	(4.37)	(0.000)	(0.088)			(1.35)	(3.45)	(0.000)	(0.272)		
OSE20 - Industrials	0.1388	0.0411	4.4296	0.4761	0.16	1.38	0.0888	0.3861***	22.2867***	2.3878	0.25	1.62	0.1297*	0.2003***	21.6818***	0.3768	0.17	1.46
	(1.63)	(0.50)	(0.109)	(0.490)			(0.71)	(3.85)	(0.000)	(0.122)			(1.81)	(3.10)	(0.000)	(0.539)		
OSE25 - Consumer Discretionary	0.1467	-0.0309	1.9050	0.9528	0.14	1.38	-0.2637	0.3727***	8.57826**	6.6917***	0.22	1.51	0.0193	0.1534*	4.6551*	0.8254	0.13	1.38
	(1.34)	(-0.29)	(0.385)	(0.329)			(-1.65)	(2.90)	(0.014)	(0.009)			(0.21)	(1.85)	(0.098)	(0.364)		
OSE30 - Consumer Staples	0.0640	0.0536	1.1924	0.0037	0.11	1.40	-0.0089	0.5550***	31.8294***	7.21179***	0.41	1.26	0.0533	0.2730***	19.2317***	2.7118*	0.22	1.26
	(0.62)	(0.54)	(0.550)	(0.951)			(-0.07)	(5.07)	(0.000)	(0.007)			(0.64)	(3.65)	(0.000)	(0.099)		
OSE35 - Health Care	0.1507	0.14	5.5370*	0.0032	0.08	1.76	0.2926*	0.0629	6.30220**	0.9964	0.05	1.72	0.1970**	0.1164	11.8465***	0.31568	0.08	1.74
	(1.28)	(1.23)	(0.063)	(0.955)			(1.96)	(0.52)	(0.043)	(0.318)			(2.21)	(1.45)	(0.003)	(0.574)		
OSE40 - Financials	-0.002	0.0125	0.0281	0.01090	0.08	1.47	0.0774	0.6137***	55.4322***	8.3393***	0.44	1.71	0.0398	0.2778***	24.5392***	4.1133**	0.19	1.38
	(-0.02)	(0.16)	(0.986)	(0.917)			(0.64)	(6.33)	(0.000)	(0.004)			(0.54)	(4.22)	(0.000)	(0.043)		
OSE45 - Information Technology	-0.0360	0.3365**	5.8301*	2.1402	0.13	1.44	0.0604	0.4282***	21.6500***	3.1081*	0.24	1.63	0.0059	0.3940***	22.9791***	5.6694**	0.18	1.50
	(-0.24)	(2.27)	(0.054)	(0.144)			(0.45)	(3.94)	(0.000)	(0.078)			(0.06)	(4.31)	(0.000)	(0.017)		
OSE50 - Telecommunication Services	-0.3004**	0.42***	8.9105**	8.1766***	0.11	1.52	0.0563	0.3560***	12.0706***	1.6420	0.20	1.70	-0.1467	0.3876***	16.4371***	9.7382***	0.13	1.52
	(-1.98)	(2.87)	(0.012)	(0.004)			(0.37)	(2.92)	(0.002)	(0.200)			(-1.38)	(4.04)	(0.000)	(0.002)		
OSE55 - Utilities	0.1093	-0.0986	1.5411	1.5376	0.03	1.47	0.0752	0.2632***	15.2934***	1.3448	0.17	1.41	0.1109	0.0490	4.8313*	0.2876	0.06	1.45
	(1.09)	(-1.01)	(0.463)	(0.215)			(0.71)	(3.11)	(0.000)	(0.246)			(1.54)	(0.76)	(0.089)	(0.592)		

Notes: This table reports the results from the asymmetric MLRM model. There the oil price coefficients are shown and the T-Statistics are in parenthesis. The Wald test coefficent for the hypothesis and in the parenthesis is the p-value. Adjusted and Durbin-Watson are given in the last two columns. Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance for the oil coefficients and denotes rejection of the hypothesis for the Wald test

More interesting is the null of equality, $H_{01}: \beta_{4ui} = \beta_{5di}$ which is more or less the same hypothesis tested in the asymmetric Wald in the VAR model in section 4.2. Starting off with the first sample period, we see that we fail to reject the null hypothesis for 9 out of

10 sectors. The only sector where we do reject the null hypothesis, is for OSE50 – Telecommunication Services. So, in the first sample period there is no evidence of asymmetry between positive and negative oil price changes. Period 07:1 – 17:1 is different, here 4 out of 10 sectors reject the null hypothesis at 5% level. Further, at 10% level, 6 out of 10 sectors reject the null hypothesis. The full sample period 97:1 – 17:1 fails to reject the null hypothesis of equality for 6 out of 10 sectors. By using 5% level of significance as a benchmark for all the sample periods, we can conclude that only 1 of 10 sectors reject the null hypothesis for 97:1 – 07:1, 4 out of 10 for 07:1 – 17:1 and 3 out of 10 for 97:1 – 17:1. In general, these results suggest that the impact of oil price changes on the equity markets are mostly non-asymmetric, which is consistent with the results from Nandha & Faff (2008).

Nandha & Faff (2008) also explain this by saying that *"if a large oil price increase is bad news for an industry (e.g. transport), a large oil price decrease is likely to have a positive impact on its share price; and if an oil price increase is likely to have a positive impact on an industry such as oil and gas, the impact of an oil price decrease is expected to be the opposite"*. Further financial markets are in general efficient and highly sensitive to news, so a large fall in oil price will probably be noticed by capital markets.

The conclusion of symmetry from the null of equality, $H_{01}: \beta_{4ui} = \beta_{5di}$ in the MLRM, is also consistent with the results found in $H_0: \alpha_{2j} = \alpha_{3j}$ in the Wald coefficient test for asymmetric effect in the VAR in section 4.2. However, the results from the Wald test in Table 9 show that there could exist some asymmetric effects between positive and negative changes in oil price on the different sectors. In general, there is no evidence of asymmetric effect between negative and positive oil price changes on the sectors.

Therefore, it is possible to conclude that there are non-asymmetric effects between the impact of positive and negative oil price changes and the sectors on Oslo Stock Exchange, across sample periods and methods.

4.3.2. Standard market model for the benchmark index (OSEBX)

To analysing whether oil price has a systematic impact on the benchmark index (OSEBX) on the Oslo Stock Exchange, we apply a somewhat different model than in section 4.2.1. Where $R^{O}_{wrosebxt}$ represents the orthogonalized world market returns. We are now analysing OSEBX, and we can no longer let OSEBX represent the world market returns. Therefore, we include S&P as a proxy for the world market returns. We do however, still follow much of the same approach as Scholtens & Yurtsever (2012) and Nandha & Faff (2008) for the variables used in this analyse, but the model and method are consistent with Hammoudeh & Li (2005) and Faff & Brailsford (2000). There they present a two factor "market and oil" pricing model, that only includes oil price and a market index. Brooks (2013) says that a two-factor model can be used to test CAPM, but arbitrage pricing theory does not pre-suppose that there is only a single factor that affects returns. Thus, it could be debated that a two-factor model is consistent with the APT framework. Therefore, we do follow the two-factor model in Hammoudeh & Li (2005) and Faff & Brailsford (2000). The model used for capturing oil price effect on OSEBX is the following:

$$R_{rosebxt} = \alpha + \beta_1 R_{S\&Pt} + \beta_2 R_{oilt} + \varepsilon_t$$

where $R_{rosebxt}$ is the real benchmark index returns for period t, defined as $\log(OSEBX_t/OSEBX_{t-1})$, where $OSEBX_t$ is the value of OSEBX for period t. $R_{S\&P}$ is the S&P 500 index, which consists of 500 large companies listed on NYSE or NASDAQ. In this two factor model the S&P 500 represents the world market index, and is calculated into Norwegian Krone, and we use the real returns for S&P defined as $\log(S\&P_t/S\&P_{t-1})$. Like the multivariate model from Nandha & Faff (2008) and Faff & Brailsford (2000), we do only include the linear oil price specification. The results from this two factor model are presented in Table 10.

Here, we do see that the oil price coefficients are significant for all the sample periods. Consistent with linear oil price specification in the VAR model in section 4.1, the result in the first sub-period is not as significant as in the second sub-period or the full sample period. We do see that the oil price coefficients are positive and significant, which is consistent with VAR model in section 4.1. However, in the VAR model we only find the impact of linear oil price shocks significantly positive in a month or within a month. When using a two-factor model, we cannot see the monthly significant impact as we do in a VAR model. We do conclude that the results from the two-factor model is consistent with the significant impact from the linear specification in the VAR model from section 4.1.

Table 10
Two factor model results

	OSEBX - Benchmark Index				
Sample period	α_i	$\beta_1 R_{S\&P}$	$\beta_2 R_{oil}$	Adj. R^2	DW
97:1-07:1	0.0058	0.3482***	0.1099**	0.16	1.49
	(1.21)	(3.86)	(2.52)		
07:1-07:1	-0.0005	0.3691***	0.3813***	0.36	1.79
	(-0.11)	(3.40)	(7.89)		
97:1-17:1	(0.0023)	0.3297**	0.2214***	0.21	1.62
	(0.69)	(4.67)	(6.69)		

Notes: This table reports the results from the two factor model. Where the coefficients are shown and the T-Statistics are in parenthesis. Adjusted and Durbin-Watson are given in the last two columns. Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance.

We do also conduct an asymmetry test for this two factor model. Here, we follow the same method as above from Nandha & Faff and conduct a Wald test. The two-factor asymmetric model is the following:

$$R_{rosebxt} = \alpha + \beta_1 R_{S\&Pt} + \beta_{2u} D * R_{oilt} + \beta_{3d}(1 - D) * R_{oilt} + \varepsilon_t$$

Where D is still the dummy variable taking value of unity if the oil price variable is positive (i.e. $R_{oil\,t} > 0$ and $D = 0$. Otherwise; β_{2u} and β_{3d} are indicative OSEBX coefficients corresponding to up and down movements in the oil factor. There the null hypothesis and the specific version stay the same as before, and are presented in Table 11.

$$H_{01}: \beta_{2u} = \beta_{3d}$$

and

$$H_{02}: \beta_{2u} = \beta_{3d} = 0$$

Here we see that we fail to reject $H_{01}: \beta_{2u} = \beta_{3d}$ for all sample periods. For $H_{02}: \beta_{2u} = \beta_{3d} = 0$, we reject the hypothesis that the oil price coefficients are jointly zero. The results from the two-factor model are consistent with the asymmetric effect of oil price shocks in section 4.2. From the linear oil price specification in variance decomposition in section 4.2, it seems that negative oil price shocks have a greater impact on the benchmark index than positive oil price shocks. In Table 11, the results for the coefficients also indicate that negative oil price changes are greater than positive changes in oil. However, consistent with section 4.2, the Wald test finds no evidence of asymmetric effect between positive and negative oil price changes on the benchmark index. Therefore, we conclude that there is no evidence of asymmetric effect between the impact of positive and negative oil price changes on the benchmark index on Oslo Stock Exchange, across sample period and method.

Table 11
Asymmetric two factor model results

	OSEBX - Benchmark Index							
Sample period	α_i	$\beta_1 R_{S\&P}$	$\beta_{2u} D{*}R_{oil}$	$\beta_{3d}(1-D){*}R_{oil}$	$H_{02}: \beta_{2u} = \beta_{3d} = 0$	$H_{01}: \beta_{2u} = \beta_{3d}$	Adj. R^2	DW
97:1-07:1	0.0092	0,3527***	0.0681	0.1504*	6.709273**	0,369395	0.14	1.49
	(1.24)	(3.89)	(0.84)	(1.89)	(0.034)	(0.543)		
07:1-07:1	0.0061	0.3475***	0.2702***	0.4612***	64.12932***	1,608001	0,36	1,75
	(0.90)	(3.17)	(2.70)	(5.81)	(0.000)	(0.204)		
97:1-17:1	0.0081	0.3295***	0.139925**	0.292426***	47.32225***	2,285464	0.22	1.61
	(1.59)	(4.68)	(2.22)	(5.09)	(0.000)	(0.131)		

Notes: This table reports the results from the asymmetric two factor model. T-Statistics are shown in parenthesis for the coefficients. The Wald test coefficent for the hypothesis are shown and in the parenthesis is the p-value. Adjusted and Durbin-Watson are given in the last two columns. Subscripts ***,**, and *denote statistical significance at the 1%, 5%, and 10% level of significance for the coefficients and denotes rejection of the hypothesis for the Wald test.

5. Conclusion

The primary objective in this paper was to analyse the response of the Norwegian stock market returns to oil price shocks, and see if the effect is different from positive and negative shocks. The Norwegian stock market returns are represented by 10 sectors and the benchmark index. Our sample period spans between 1997-2017 and is divided into sub-periods. We use different oil price specifications from the literature to investigate the relationship between stock market returns and the oil price. Moreover, we use different methods, models and tests to estimate and assess the sectors and the benchmark index responses to oil price shocks. This paper takes inspiration and follows method and models presented in influential papers from the literature.

Throughout the VAR impulse response analysis, we find that the stock returns in the period 1997:1 – 2007:1 are not so much effected by oil price changes. The results are consistent when using different methods and oil price specifications. The probable reason for this is that oil price was relatively stable, and the firms on the Norwegian stock market were not that oil dependent during this time. Period 2007:1 – 2017:1 tells a different story, where oil price shocks have a statistically significant impact on both sector stock returns and benchmark index returns in the same month or within one month, across the oil price specifications. Period 1997:1 – 2017:1 shows the same significant impact of oil price as the previous period. The only major result in this period is that OSE10 – Energy is significant in or within 24 months after an oil price shock occur. This is not unexpected seeing as this sector has oil and gas as an output. OSE10 also shows the greatest impact of oil price shocks. The impact of oil price is mainly positive on the Norwegian stock market returns.

The sectors and benchmark index do show to have an asymmetric relationship between positive and negative oil price changes from the variance decomposition in section 4.2 and from the oil price coefficients in section 4.3, where negative changes in oil price seem to have a greater impact than positive changes on the Norwegian stock market returns. On the contrary, findings from the Wald asymmetric test show non-asymmetric effect on the relationship between positive and negative oil price shocks, across methods, sample periods and oil price specifications. In this paper, we do conclude that in general there is no evidence of asymmetric effect between positive and negative oil price shock on the real stock returns on the Norwegian stock market.

In all, this paper has provided an overview of the relationship between oil price shocks and Norwegian stock market returns at a detailed level. The asymmetric pattern of the sector index returns and benchmark index returns have been investigated with respect to different oil price specifications. We conclude that oil price shocks affect the Norwegian stock market. The impact of oil price is consistent when using different methods and models. The findings in this paper seem to be robust, seeing as different models and methods yield consistent results. Initially, we expected the results to be greater, since Norway is a net-oil exporter and is highly dependent on the oil price. It seems that the Norwegian stock market is mostly efficient where oil price information is quickly incorporated into the stock prices, seeing as the impact of oil price shocks is not significant for a long period after its occurrence.

5.1. Further research

From the data sample and the results, it would be interesting to analyse the effect in a 5-year period instead of the 10 year sub-periods we used. The 5-year period could show some different results, especially in period 1997:1 – 2007:1, where the 5-year period closer to 2007 could be more significant than the period closer to 1997. The same can be said for 2007:1 – 2017:1, where the 5 years from 2007 could be more significant than from 2012. Further, it seems that OSEBX and the oil price have moved differently since 2012, so it would be interesting to analyse the mechanics behind this. Furthermore, this thesis does only include sectors and the benchmark index. It is possible to analyse at a more disaggregated level and look at the 24 industry groups to see if this give added significant results. The effects may have been canceled out when accumulated into sectors. It would also be interesting to use the same methods and sample period in this paper and extend the thought to Denmark and Sweden, to see the different response between the Scandinavian countries.

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7. Appendix

7.1. Appendix A

Data source

All data are from Bloomberg Terminal (BT), Thomson Datastream (TD) and Statistics Norway (SSB)

Monthly data from 1997:1 to 2017:1

1. **Interest rate:** Norwegian Interbank Offered Rate 1 month (NIBOR1M) from TD
2. **Industrial production:** Table 07095: Index of production, by industry (SIC2007) and main industrial grouping (2005=100), seasonally adjusted from SSB
3. **Nominal Oil Price:** Crude Oil-Brent Current Month FOB U$/BBL from TD
4. **Real Oil Price in Norway:** Nominal Oil Price * Exchange Rate deflated by CPI index in Norway
5. **Consumer Price Index:** Table 11446: Consumer Price Index, by consumption group (1998=100) (Closed Series) data range 1997:1 to 2016:12 from SSB
6. **Stock Market Indexes:** Sector stock market indexes classified with Global Industry Classification Standard (GICS). The Benchmark Index comprises the most traded shares listed on Oslo Stock Exchange. S&P 500 Index is based on the market capitalization of 500 large firms on NYSE or NASDAQ all stock market data from BT
7. **Exchange Rate:** Datastream Stream Exchange from US$ to NOK from TD

7.2. Appendix B

Table B1: Orthogonalized impulse response functions after 1, 12 and 24 months for period 97:1 to 07:1. (Linear specification)

This table shows the accumulated response of interest rate (dlnibor), oil price (dlroil), industrial production, real benchmark index returns (rosebx) and real sector stock return (rose) to oil price shocks after 1, 12 and 24 months for the linear oil price specification. Monte Carlo constructed standard errors after 100 repetitions are shown in parentheses. Ordering of the variables dlnibor, dlroil, dlip, rosebx, rose for the different sectors and dlnibor, dlroil, dlip, rosebx for the benchmark index.

Indexes	After x months	dlnibor	dlroil	dlip	rosebx	rose
OSE10 - Energy	x=1	-0.016959 (0.00732)	0.024746 (0.00701)	0.00199 (0.00652)	0.055991 (0.00489)	0.036773 (0.00247)
	x=12	-0.081955 (0.03723)	0.038458 (0.03486)	0.005415 (0.02403)	0.045306 (0.03747)	0.028582 (0.02431)
	x=24	-0.095517 (0.05366)	0.043904 (0.04173)	0.003944 (0.02436)	0.028346 (0.05228)	0.031278 (0.02789)
OSE15 - Materials	x=1	0.001119 (0.00485)	0.002833 (0.00545)	-0.005325 (0.0055)	0.04011 (0.00466)	0.035962 (0.0025)
	x=12	-0.026394 (0.02464)	0.000616 (0.02097)	-0.006574 (0.01636)	0.012486 (0.02843)	0.053766 (0.02282)
	x=24	-0.029926 (0.03437)	0.001871 (0.02717)	-0.007073 (0.01903)	0.008172 (0.03941)	0.055543 (0.02777)
OSE20 - Industrials	x=1	-0.010409 (0.0055)	0.005715 (0.00529)	-0.004543 (0.0045)	0.047557 (0.00474)	0.027882 (0.00185)
	x=12	-0.047881 (0.03025)	0.005066 (0.03029)	-0.008363 (0.01649)	0.059076 (0.03696)	0.039018 (0.02588)
	x=24	-0.05246 (0.04112)	0.008132 (0.03634)	-0.009124 (0.0175)	0.051221 (0.05143)	0.039102 (0.0303)
OSE25 - Consumer Discretionary	x=1	-0.010431 (0.00643)	-0.00016 (0.00635)	0.000511 (0.00636)	0.047361 (0.00519)	0.042858 (0.00304)
	x=12	-0.06775 (0.03134)	-0.003288 (0.02602)	-0.005735 (0.01622)	0.025206 (0.03624)	0.027801 (0.02752)
	x=24	-0.074683 (0.04149)	0.000812 (0.03549)	-0.00636 (0.01668)	0.014585 (0.04864)	0.029169 (0.03544)
OSE30 - Consumer Staples	x=1	-0.009296 (0.00668)	0.006004 (0.00668)	0.000714 (0.00662)	0.04856 (0.00483)	0.040954 (0.00278)
	x=12	-0.049936 (0.03718)	0.009123 (0.02684)	0.004406 (0.01687)	0.057734 (0.03438)	0.020682 (0.02421)
	x=24	-0.054224 (0.05196)	0.012304 (0.03244)	0.003374 (0.01768)	0.050162 (0.04694)	0.017831 (0.02469)

Table B1 - Continued

OSE35 - Health Care	x=1	-0.00742	0.007733	0.015454	0.040413	0.059509
		(0.00676)	(0.0065)	(0.00772)	(0.00603)	(0.00424)
	x=12	-0.041542	-0.025348	0.042906	0.051196	0.087717
		(0.04106)	(0.03454)	(0.02863)	(0.05358)	(0.03066)
	x=24	-0.040602	-0.022733	0.040637	0.048976	0.085401
		(0.06119)	(0.03962)	(0.03313)	(0.07896)	(0.0351)
OSE40 - Financials	x=1	-0.001084	-0.004011	-0.002046	0.040402	0.026446
		(0.00514)	(0.0051)	(0.00483)	(0.00396)	(0.00174)
	x=12	-0.033801	-0.0000817	0.003952	0.044055	0.006931
		(0.02311)	(0.01606)	(0.01169)	(0.02831)	(0.01238)
	x=24	-0.037476	0.002028	0.003116	0.038399	0.005483
		(0.03465)	(0.01798)	(0.0121)	(0.04328)	(0.01652)
OSE45 - Information Technology	x=1	-0.012148	0.012247	0.009712	0.070149	0.057818
		(0.00795)	(0.00875)	(0.00851)	(0.00727)	(0.00382)
	x=12	-0.075423	0.023469	0.024434	0.059318	0.067662
		(0.04357)	(0.04069)	(0.03123)	(0.04924)	(0.02891)
	x=24	-0.085475	0.025941	0.021987	0.043175	0.062091
		(0.06173)	(0.04873)	(0.03737)	(0.06766)	(0.03652)
OSE50 - Telecommunication Services	x=1	-0.01317	-0.00215	-0.000194	0.056181	0.075944
		(0.009)	(0.00905)	(0.00954)	(0.0074)	(0.00455)
	x=12	-0.025684	-0.01216	-0.014576	0.057519	0.11832
		(0.05374)	(0.04969)	(0.03511)	(0.05852)	(0.04558)
	x=24	-0.024632	-0.011776	-0.012923	0.059798	0.119424
		(0.11153)	(0.10022)	(0.04493)	(0.12901)	(0.05958)
OSE55 - Utilities	x=1	-0.003534	1.96E-06	-0.003704	0.032103	0.051331
		(0.00592)	(0.00521)	(0.00613)	(0.00619)	(0.00404)
	x=12	0.015813	-0.011899	0.002283	0.036259	0.094355
		(0.03632)	(0.02914)	(0.02346)	(0.0348)	(0.03695)
	x=24	0.025634	-0.015157	0.002948	0.046848	0.096743
		(0.0601)	(0.04286)	(0.02975)	(0.05764)	(0.05818)
OSEBX - Benchmark Index	x=1	-0.010123	0.008772	0.000192	0.051324	
		(0.0048)	(0.00444)	(0.00566)	(0.00351)	
	x=12	-0.055407	0.011882	0.003322	0.047982	
		(0.02543)	(0.02227)	(0.01594)	(0.03804)	
	x=24	-0.061466	0.01508	0.002456	0.038303	
		(0.03885)	(0.02844)	(0.01809)	(0.06234)	

Table B2: Orthogonalized impulse response functions after 1, 12 and 24 months for period 07:1 to 17:1. (Linear specification)

This table shows the accumulated response of interest rate (dlnibor), oil price (dlroil), industrial production, real benchmark index returns (rosebx) and real sector stock return (rose) to oil price shocks after 1, 12 and 24 months for the linear oil price specification. Monte Carlo constructed standard errors after 100 repetitions are shown in parentheses. Ordering of the variables dlnibor, dlroil, dlip, rosebx, rose for the different sectors and dlnibor, dlroil, dlip, rosebx for the benchmark index.

Indexes	After x months	dlnibor	dlroil	dlip	rosebx	rose
OSE10 - Energy	x=1	-0.002205 (0.0057)	0.039975 (0.00498)	0.000306 (0.00436)	0.040392 (0.00302)	0.023539 (0.00147)
	x=12	-0.023176 (0.0179)	0.033948 (0.02531)	0.002473 (0.01511)	0.039055 (0.0254)	0.018912 (0.02042)
	x=24	-0.018068 (0.01401)	0.036277 (0.0255)	0.002684 (0.01367)	0.031917 (0.02147)	0.021663 (0.01937)
OSE15 - Materials	x=1	-0.009928 (0.0066)	0.024338 (0.0061)	-0.003685 (0.0065)	0.055988 (0.00597)	0.037689 (0.00234)
	x=12	-0.02851 (0.03079)	0.004548 (0.0434)	0.00052 (0.02468)	0.058789 (0.03962)	0.041759 (0.03099)
	x=24	-0.023616 (0.03121)	0.001118 (0.04131)	0.000857 (0.02328)	0.058303 (0.03571)	0.048894 (0.03139)
OSE20 - Industrials	x=1	-0.002782 (0.00471)	0.016029 (0.00486)	-0.005971 (0.00455)	0.038063 (0.00428)	0.030113 (0.00177)
	x=12	-0.036486 (0.02256)	-0.008686 (0.02735)	-0.002405 (0.01902)	0.064892 (0.03237)	0.046311 (0.02491)
	x=24	-0.033999 (0.02345)	-0.011999 (0.03407)	-0.002454 (0.02045)	0.058741 (0.0433)	0.049682 (0.03311)
OSE25 - Consumer Discretionary	x=1	-0.01912 (0.00524)	0.010258 (0.00617)	-0.012391 (0.00528)	0.044431 (0.00526)	0.043472 (0.00301)
	x=12	-0.082146 (0.03282)	-0.015687 (0.0454)	-0.011057 (0.02459)	0.059894 (0.03968)	0.054224 (0.03445)
	x=24	-0.063808 (0.02603)	-0.020895 (0.05151)	-0.00968 (0.02244)	0.045603 (0.04207)	0.046072 (0.03091)
OSE30 - Consumer Staples	x=1	-0.013104 (0.00601)	0.018012 (0.00566)	-0.004846 (0.00472)	0.035789 (0.00428)	0.043633 (0.00266)
	x=12	-0.066923 (0.02488)	-0.046067 (0.03385)	-0.010573 (0.01923)	0.019682 (0.03316)	0.080412 (0.02462)
	x=24	-0.060141 (0.02961)	-0.04393 (0.05007)	-0.008505 (0.0204)	0.021895 (0.0386)	0.076998 (0.03247)

Table B2 - Continued

OSE35 - Health Care	x=1	-0.001908 (0.00635)	0.01367 (0.00618)	-0.004672 (0.00592)	0.024088 (0.00596)	0.061085 (0.00397)
	x=12	-0.030414 (0.02656)	-0.00386 (0.03419)	-0.022291 (0.02141)	0.028621 (0.03643)	0.083977 (0.03255)
	x=24	-0.028822 (0.02937)	-0.003869 (0.039)	-0.02238 (0.02577)	0.01813 (0.04874)	0.08841 (0.04708)
OSE40 - Financials	x=1	0.0000904 (0.00577)	0.031879 (0.00547)	-0.009436 (0.0051)	0.042772 (0.00367)	0.027352 (0.00173)
	x=12	-0.060144 (0.02403)	0.001665 (0.02902)	-0.026979 (0.01964)	0.033345 (0.02684)	0.052569 (0.02017)
	x=24	-0.046861 (0.02325)	0.002348 (0.02862)	-0.018352 (0.01664)	0.020626 (0.02362)	0.040491 (0.02)
OSE45 - Information Technology	x=1	-0.009489 (0.00585)	0.02041 (0.00562)	-0.004088 (0.00619)	0.039165 (0.00425)	0.045862 (0.00332)
	x=12	-0.050695 (0.02831)	-0.015274 (0.03517)	0.006302 (0.02069)	0.047265 (0.03707)	0.081795 (0.03428)
	x=24	-0.046176 (0.02801)	-0.011691 (0.04987)	0.005485 (0.02693)	0.043481 (0.0452)	0.076081 (0.05222)
OSE50 - Telecommunication Services	x=1	-0.009237 (0.00664)	0.013848 (0.00611)	-0.013037 (0.00564)	0.039788 (0.0054)	0.044633 (0.00255)
	x=12	-0.054826 (0.02734)	0.021114 (0.03495)	-0.004787 (0.02503)	0.045862 (0.03666)	0.063628 (0.02648)
	x=24	-0.042061 (0.02209)	0.017471 (0.03004)	-0.005171 (0.01598)	0.040076 (0.02938)	0.049933 (0.02195)
OSE55 - Utilities	x=1	-0.006154 (0.00431)	0.016705 (0.00383)	-0.001684 (0.00367)	0.023025 (0.00356)	0.032992 (0.00222)
	x=12	-0.032436 (0.0234)	0.003075 (0.02588)	-0.007322 (0.01925)	0.05474 (0.03379)	0.055757 (0.03023)
	x=24	-0.033802 (0.03486)	-0.001568 (0.03974)	-0.00819 (0.02604)	0.048862 (0.05337)	0.065618 (0.05652)
OSEBX - Benchmark Index	x=1	-0.004367 (0.00513)	0.02887 (0.00414)	-0.005413 (0.00402)	0.045226 (0.00319)	
	x=12	-0.034324 (0.01772)	0.009288 (0.02181)	-0.003899 (0.0121)	0.046289 (0.02859)	
	x=24	-0.028585 (0.0143)	0.012595 (0.01854)	-0.003467 (0.01016)	0.04181 (0.0233)	

Table B3: Orthogonalized impulse response functions after 1, 12 and 24 months for period 97:1 to 17:1. (Linear specification)

This table shows the accumulated response of interest rate (dlnibor), oil price (dlroil), industrial production, real benchmark index returns (rosebx) and real sector stock return (rose) to oil price shocks after 1, 12 and 24 months for the linear oil price specification. Monte Carlo constructed standard errors after 100 repetitions are shown in parentheses. Ordering of the variables dlnibor, dlroil, dlip, rosebx, rose for the different sectors and dlnibor, dlroil, dlip, rosebx for the benchmark index.

Indexes	After x months	dlnibor	dlroil	dlip	rosebx	rose
OSE10 - Energy	x=1	-0.010587 (0.00434)	0.032562 (0.004)	0.002365 (0.00393)	0.048834 (0.0032)	0.031063 (0.00142)
	x=12	-0.046382 (0.01657)	0.029966 (0.01591)	0.005691 (0.01012)	0.041689 (0.02002)	0.028195 (0.01439)
	x=24	-0.047098 (0.01614)	0.031739 (0.01441)	0.005689 (0.00968)	0.03587 (0.02072)	0.032627 (0.01531)
OSE15 - Materials	x=1	-0.005146 (0.00412)	0.013236 (0.00412)	-0.003426 (0.00462)	0.047396 (0.00314)	0.039188 (0.00201)
	x=12	-0.025675 (0.01491)	0.001608 (0.01346)	-0.001336 (0.01232)	0.037603 (0.01904)	0.051084 (0.01607)
	x=24	-0.025353 (0.01412)	0.001309 (0.01217)	-0.001165 (0.01222)	0.037028 (0.01538)	0.054863 (0.01474)
OSE20 - Industrials	x=1	-0.006351 (0.00366)	0.011445 (0.00343)	-0.00581 (0.00335)	0.044155 (0.00308)	0.028654 (0.00141)
	x=12	-0.034274 (0.01844)	0.001667 (0.01387)	-0.007068 (0.01071)	0.064423 (0.01745)	0.043144 (0.01397)
	x=24	-0.034612 (0.02106)	0.001233 (0.01341)	-0.007262 (0.01065)	0.061115 (0.0208)	0.043547 (0.01508)
OSE25 - Consumer Discretionary	x=1	-0.014284 (0.00477)	0.006016 (0.00392)	-0.006611 (0.00422)	0.046451 (0.00312)	0.046467 (0.00249)
	x=12	-0.062478 (0.01907)	-0.004107 (0.01702)	-0.004178 (0.01173)	0.046631 (0.02356)	0.046814 (0.02179)
	x=24	-0.059637 (0.01595)	-0.004091 (0.01552)	-0.004576 (0.01045)	0.037922 (0.02293)	0.045082 (0.01914)
OSE30 - Consumer Staples	x=1	-0.0097 (0.00441)	0.011311 (0.00396)	-0.001805 (0.00424)	0.042738 (0.00365)	0.043341 (0.00216)
	x=12	-0.060495 (0.01716)	-0.009071 (0.01678)	-0.006487 (0.01108)	0.0308 (0.02082)	0.049916 (0.01685)
	x=24	-0.058159 (0.01529)	-0.006063 (0.01564)	-0.005713 (0.01025)	0.027829 (0.02059)	0.049046 (0.0159)

Table B3 - Continued

OSE35 - Health Care	x=1	-0.004099 (0.00444)	0.010375 (0.00444)	0.002388 (0.00463)	0.033029 (0.00415)	0.061449 (0.003)
	x=12	-0.030355 (0.018)	-0.015098 (0.01872)	-0.00296 (0.01255)	0.042417 (0.02436)	0.084482 (0.01936)
	x=24	-0.030831 (0.01964)	-0.015482 (0.01927)	-0.00312 (0.01222)	0.037604 (0.02777)	0.083817 (0.02123)
OSE40 - Financials	x=1	0.00056 (0.00401)	0.011996 (0.00394)	-0.006156 (0.00327)	0.044844 (0.00328)	0.030737 (0.00145)
	x=12	-0.040995 (0.01658)	0.005961 (0.01243)	-0.007028 (0.01011)	0.042901 (0.01686)	0.042351 (0.0134)
	x=24	-0.038351 (0.01445)	0.00738 (0.00981)	-0.006309 (0.00818)	0.0372 (0.01427)	0.035931 (0.00981)
OSE45 - Information Technology	x=1	-0.011418 (0.0053)	0.016101 (0.00467)	0.000706 (0.00525)	0.053837 (0.0043)	0.053682 (0.00251)
	x=12	-0.051734 (0.01792)	0.007528 (0.01786)	0.015125 (0.0124)	0.047774 (0.02137)	0.072357 (0.01525)
	x=24	-0.051938 (0.01697)	0.007651 (0.01676)	0.015019 (0.01156)	0.043294 (0.02072)	0.070963 (0.01356)
OSE50 - Telecommunication Services	x=1	-0.011267 (0.00493)	0.008594 (0.00521)	-0.005544 (0.00494)	0.048614 (0.00451)	0.064441 (0.00286)
	x=12	-0.035039 (0.02435)	0.007403 (0.01993)	-0.005146 (0.01591)	0.05955 (0.0252)	0.096368 (0.02286)
	x=24	-0.034019 (0.02302)	0.007375 (0.0197)	-0.005029 (0.0158)	0.054414 (0.02446)	0.09168 (0.01973)
OSE55 - Utilities	x=1	-0.003647 (0.00339)	0.007299 (0.00355)	-0.002579 (0.00337)	0.029449 (0.00309)	0.04284 (0.00179)
	x=12	-0.001019 (0.01714)	-0.000525 (0.01855)	-0.002405 (0.01234)	0.050417 (0.01618)	0.078314 (0.01844)
	x=24	0.001678 (0.021)	-0.000932 (0.02104)	-0.001711 (0.01354)	0.053649 (0.02175)	0.081219 (0.02369)
OSEBX - Benchmark Index	x=1	-0.007303 (0.00328)	0.018721 (0.00327)	-0.002455 (0.00328)	0.049561 (0.00246)	
	x=12	-0.039674 (0.01244)	0.011703 (0.00995)	0.0000109 (0.0077)	0.047623 (0.01507)	
	x=24	-0.039519 (0.0109)	0.012276 (0.00904)	0.0000409 (0.00694)	0.043091 (0.0137)	

Table B4: Variance decomposition of forecast error variance after 24 months.

This table shows the contribution of interest rate (dlnibor), oil price (dlroil), industrial production, real benchmark index returns (rosebx) and real sector stock return (rose) to the variance of future forecast error of oil price shocks after 24 months for the linear oil price specification. Monte Carlo constructed standard errors after 100 repetitions are shown in parentheses. Ordering of the variables dlnibor, dlroil, dlip, rosebx, rose for the different sectors and dlnibor, dlroil, dlip, rosebx for the benchmark index.

Indexes	Sample period	dlnibor	dlroil	dlip	rosebx	rose
OSE10 - Energy	97:1-07:1	12.07116	8.954376	4.717738	51.12393	23.13279
		(7.73451)	(4.38153)	(3.56647)	(7.64133)	(6.90069)
	07:1-17:1	6.251992	39.35053	3.150242	36.18689	15.06035
		(4.35238)	(6.67869)	(3.76832)	(6.0918)	(4.63208)
	97:1-17:1	7.223574	21.33725	1.601406	49.11676	20.72102
		(3.17351)	(3.9532)	(2.09901)	(4.73852)	(3.29893)
OSE15 - Materials	97:1-07:1	4.122906	1.941924	2.008183	49.42803	42.49896
		(4.15078)	(3.61199)	(3.7174)	(7.73423)	(7.83132)
	07:1-17:1	13.60093	7.751447	4.572194	48.43933	25.63611
		(5.45325)	(4.14554)	(4.60003)	(8.41617)	(6.73674)
	97:1-17:1	8.232899	3.552813	0.970788	48.27323	38.97027
		(3.09773)	(1.9338)	(1.51513)	(5.2282)	(5.14677)
OSE20 - Industrials	97:1-07:1	9.645917	1.120067	2.372802	67.35608	19.50513
		(7.26638)	(3.83857)	(3.89361)	(8.02213)	(5.22687)
	07:1-17:1	7.532083	12.51274	4.160764	38.62305	37.17137
		(4.9324)	(6.47357)	(4.34521)	(6.5466)	(6.85172)
	97:1-17:1	7.05586	4.818109	1.870072	58.05935	28.19661
		(3.60406)	(2.92492)	(1.95498)	(4.96831)	(4.32884)
OSE25 - Consumer Discretionary	97:1-07:1	10.33449	7.246007	2.315394	43.80879	36.29532
		(6.07067)	(4.83242)	(5.25481)	(6.20994)	(5.78426)
	07:1-17:1	16.3985	6.787201	4.285981	43.00222	29.5261
		(5.20574)	(4.76767)	(4.52822)	(6.9237)	(5.23236)
	97:1-17:1	10.4253	5.476048	1.714025	42.10335	40.28127
		(3.70229)	(2.8509)	(2.02786)	(5.23221)	(4.54443)
OSE30 - Consumer Staples	97:1-07:1	8.05752	1.846861	1.637224	49.94602	38.51237
		(4.79413)	(4.28873)	(3.16938)	(7.67103)	(7.37264)
	07:1-17:1	8.881134	14.88632	2.151134	40.79729	33.28412
		(4.26687)	(6.24313)	(3.608)	(8.26324)	(7.16348)
	97:1-17:1	8.961665	5.001122	0.988323	44.31688	40.73201
		(3.11383)	(3.34712)	(1.77467)	(5.00461)	(5.23409)

Table B4 - Continued

OSE35 - Health Care	97:1-07:1	7.066455	7.658628	11.65344	24.9661	48.65538
		(4.30814)	(5.5588)	(5.03916)	(5.84604)	(6.71231)
	07:1-17:1	5.364834	6.388652	4.419536	14.56856	69.25842
		(4.03763)	(3.72223)	(4.0781)	(5.84713)	(8.22027)
	97:1-17:1	5.044193	4.482556	4.244199	20.94805	65.281
		(2.68307)	(2.48729)	(3.45151)	(4.50964)	(5.44451)
OSE40 - Financials	97:1-07:1	6.176965	3.762317	2.740154	65.00118	22.31938
		(5.34485)	(4.77118)	(3.56376)	(7.63242)	(5.16601)
	07:1-17:1	8.169604	26.96138	3.333644	45.98446	15.55091
		(4.62625)	(6.79345)	(4.57172)	(6.35717)	(3.99382)
	97:1-17:1	5.921598	5.224347	1.95957	63.03029	23.86419
		(3.21556)	(3.13381)	(1.92821)	(4.562)	(2.95857)
OSE45 - Information Technology	97:1-07:1	7.376379	5.304797	5.520284	49.4719	32.32664
		(5.13386)	(3.97417)	(4.46497)	(7.13547)	(5.79004)
	07:1-17:1	9.473668	13.02472	3.716215	32.83375	40.95165
		(5.07975)	(6.15723)	(3.94385)	(6.66077)	(7.98596)
	97:1-17:1	7.153526	4.949127	2.316278	43.55967	42.0214
		(3.32496)	(2.44492)	(3.0275)	(4.85465)	(4.64515)
OSE50 - Telecommunication Services	97:1-07:1	2.381653	1.613927	11.21704	30.94548	53.8419
		(3.76948)	(4.00255)	(4.80434)	(6.34927)	(7.65732)
	07:1-17:1	14.24251	7.262392	5.366103	40.73557	32.39342
		(7.05788)	(3.71989)	(4.25828)	(6.40757)	(5.24914)
	97:1-17:1	4.173037	1.43074	5.437341	35.52844	53.43044
		(2.47868)	(2.00711)	(2.84985)	(4.79758)	(5.2584)
OSE55 - Utilities	97:1-07:1	2.839782	8.60199	1.204227	31.37308	55.98092
		(6.1979)	(4.53748)	(4.29738)	(7.73819)	(9.82629)
	07:1-17:1	12.7927	13.32377	3.839611	29.22532	40.8186
		(5.81256)	(5.77169)	(4.18906)	(6.42488)	(7.19641)
	97:1-17:1	3.695028	6.573298	1.710875	31.72453	56.29627
		(3.00203)	(2.55769)	(2.51923)	(4.94898)	(5.06485)
OSEBX - Benchmark Index	97:1-07:1	12.34512	3.488006	3.581467	80.58541	
		(6.36129)	(3.48971)	(4.32055)	(7.35398)	
	07:1-17:1	9.48176	25.35788	3.154966	62.0054	
		(5.08227)	(6.09276)	(3.82656)	(6.50229)	
	97:1-17:1	9.225276	10.54322	1.203156	79.02835	
		(3.76404)	(3.77909)	(2.25893)	(5.55009)	