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Oil Price Shocks on Norwegian Stock Returns

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Abstract

There is a strong presumption that Norwegian stock return is dependent on oil price fluctuations. Previous research has focused mainly on the oil price affecting stock return. In this paper we show how Norwegian stock return is affected by different types of oil shocks. The different types of shocks are divided into oil supply shock, oil demand shock and oil specific demand shock. The methodology used is based upon the article "The Impact of Oil Price Shocks on the U.S. Stock Market" by Kilian and Park (2009). In accordance with their findings, we found that the type of oil shock, does matter for the reaction in the Norwegian market. While the oil supply and oil demand shocks are not statistically significant on the Norwegian market, they contribute with 13% of the long run variation in stock prices. Oil specific demand shock is, not surprisingly, statistically significant on Norwegian stock return, and explains 19% of the long run variation in stock prices. These results were as expected for a small open economy, exporting petroleum. In addition to this analysis, we have substituted Kilian's own index for global aggregate demand with the Baltic Dry Index. This drastically changed the statistical importance of the aggregate demand shock.

Introduction

In the Norwegian financial press, headlines such as “The stock exchange turns with the oil price” (Parr 2016) and “The stock exchange falls with the oil” (Knudsen 2016) are often appearing. It looks like there is an underlying belief that the oil price drives Norwegian stock returns. As the oil price has plummeted since the summer of 2014 (Figure 1), while the stock exchange has remained relatively stable (just a bit negative), we question whether this assumed relationship holds.

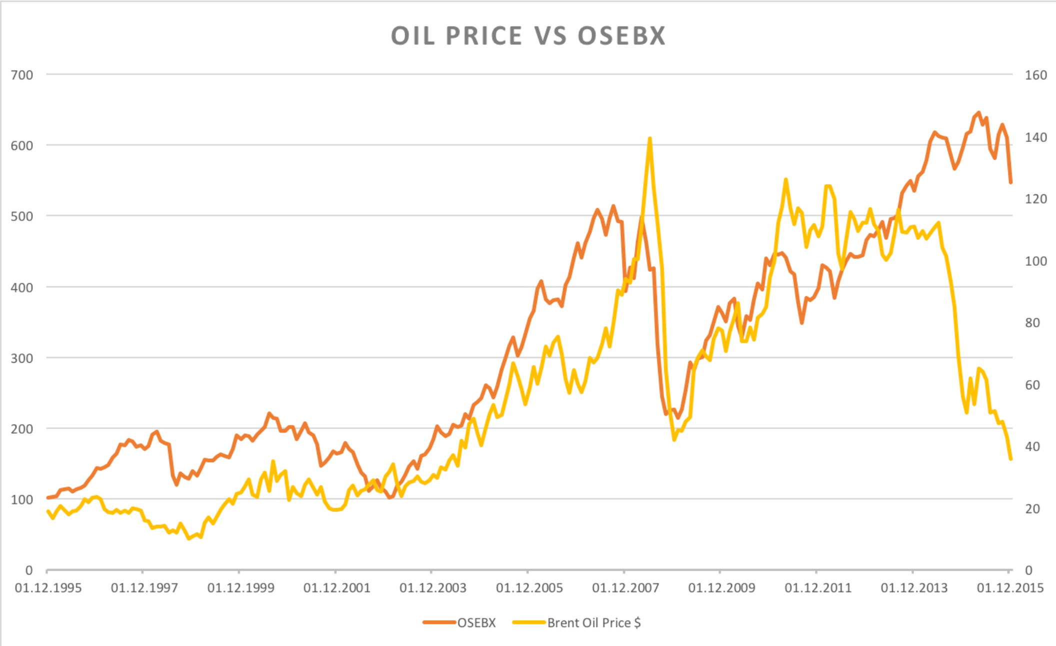

Figure 1: Relationship between the oil price and the OSEBX (Bloomberg).

The oil sector has been of great importance to the Norwegian economy, ever since the first profitable petroleum discoveries on the Norwegian continental shelf on the 23rd of December 1969 (Regjeringen 2016). It is the oil and gas industry that has built much of the foundation of the Norwegian welfare state, and the Government Pension Fund Global will continue to manage the wealth in the years to come. However, with the declining oil and gas prices, the oil sector is no longer as profitable as it used to be. At the same time, the global community is looking for cleaner energy sources to handle the climate challenges. Our aim with the present thesis has therefore been to investigate the importance of oil price shocks to Norwegian stock returns.

The oil market has been driven by political power, the general world economy and significant events over the years. Since 2008, the world has gone through a severe financial struggle and experienced geographical turbulence which has somewhat changed the global supply and demand side of the oil market. Chinas growth has started to stagnate, which will have an impact on the stability of the world economy and oil demand. Increased cost efficiency of the United States (hereafter "U.S.") shale oil production has sparked a fear within the OPEC organization, and the OPEC has therefore increased their production levels, trying to squeeze the U.S. production's margins before the U.S. reach a cost advantage. Together with the threat posed by Russia in relation to the Krim invasion and being an important petroleum producer, Russia has been seen as a big threat to world stability. They have increased their military force clearly wanting to be recognized as a world super power. On the basis of these events, we find the oil market very dynamic and interesting. We therefore wish to analyze whether different types of shocks to the oil price, have different effects on Norwegian stock return.

Our approach will be different from previous work that is performed within the present field relating to oil price shocks to Norwegian stock return. The main difference will be how the variables are measured and how the ordering of the variables in the recursive ordering affect Norwegian stock return. The approach was introduced by Kilian and Park (2009). In our opinion, one of the two most important contributions from their work, was the way they measured the world aggregate demand for the economic activity. They used an equally-weighted index with the percentage growth in dry cargo freight rates as an indication of world aggregate demand. Compared to other measures, this variable takes into account the demand for industrial commodities rather than the concept of real economic activity like real world GDP. This distinction will be important as an increase of the value added by for example the service sector, is likely to have a very different effect on the demand of industrial commodities than value added in manufacturing. The second important contribution was how they chose to order the shock variables. The ordering was based on economic insight, where global macroeconomic fluctuations influenced the price of oil. Their structural vector auto regression (SVAR) model, explains three types of shocks affecting the stock market; oil supply shock, aggregate demand shock, and oil specific demand shock. The latter shock is a shock attributed to the fear of future oil supply shortfalls. The model is structured by means of a recursive ordering, where the first variable affects the second variable in the first period, but not the other way around. In all periods before time t, all variables will affect each other. The mere purpose of this model, is to find out how the different oil shocks affect the stock market variable.

Considering we analyze the Norwegian stock market and the oil price is denominated in U.S. dollars, adjustments to the original model are put forward, trying to explain a larger proportion of the long-run variation of stock return. One of the adjustments is to convert the price of oil into Norwegian Kroner. This is done to see if the NOK/ USD exchange rate automatically captures some of the explanation power for the Norwegian stock market. Secondly, the aggregate demand measure is replaced with the Baltic Dry Index. This is done because it is well-known and its reputation for being the leading measure within dry cargo freight rates. The reason for this substitution, is to find out if the shipping routes included to make up the Baltic Dry Index, is a better choice for the Norwegian market than the shipping routes included in the Kilian Index. Thirdly, the NOK/ USD exchange rate is included as an individual variable to see if it makes a difference in how we adjust for the exchange rate.

Following the Kilian and Park (2009) methodology, we find that the only shock that is statistically significant to affect the Norwegian stock return is the oil specific demand shock. While Kilian and Park find that oil supply and demand shocks combined account for 22% of the long run variation in U.S. stock return, we find that these shocks account for 32% of the long run variation in Norwegian stock return.

Literature Review

As crude oil is one of the world's most important commodities, the relationship between crude oil prices and stock returns has been subject to extensive research. However, the research methodology varies depending on the time period. Kilian and Park (2009) used a structural form VAR model building on Kilian (2009), to test if it mattered for U.S. stock return what was the driving cause of the fluctuation. They divided the "three driving forces" into oil supply shock, aggregate demand shock and oil specific demand shock. Each shock is important for understanding the oil market and together they make up the connection for linking oil price shocks to U.S. stock returns. Kilian and Park defined the magnitude of a shock as one standard deviation. They found that shocks due to the fear of future shortfalls of oil (oil specific demand), accounted for the biggest proportion of variation in real stock returns. Combined, 22% of the long run variation in stock prices could be attributed to oil supply and demand shocks. Their dataset was based on monthly data from January 1973 to December 2006.

Park and Ratti (2008) investigated the relationship between oil price shocks and stock returns in the U.S. and 13 European countries. To analyze this, they used an unrestricted VAR model. In other words, no restrictions on the short-run relationship between the variables existed. The dataset spanned from January 1986 until December 2005. The variables included were the first log difference of short term interest rates, first log difference of industrial production, real stock returns and the first log difference on real oil price. Further, they used lag length criterias to determine how many lags was to be included in the model. On average the criterias selected approximately six lags. We believe the number of lags should be based on economic reasoning. Their paper also differs from Kilian and Park (2009) in the way that they change the ordering of the variables in the regression. We are a bit puzzled by this, as we believe the ordering of the variables should be based on economic intuition. They found that for many European countries, increased volatility of the oil price significantly depressed stock returns. For the U.S. economy they found that the contribution of oil price variability on stock return was greater than the interest rate. For Norway, as a small oil producing nation, a statistically significant positive relationship was detected. 6% of the volatility in real stock returns could be attributed to oil price shocks.

Similarly, Jimenez-Rodriguez and Sanchez (2005) found that Norwegian real economic activity, defined as GDP, benefited from shocks to the oil price. Other oil exporting countries with larger economies, such as the U.K., reacted negatively on the same shocks. Both linear and non-linear multivariate VAR models were used. The lags were selected using information criterias, and the variables included were real GDP, real effective exchange rate, real oil price, real wage, inflation, short and long interest rate. All variables contained quarterly observations and spanned from q3 1972 until q4 2001. The GDP reacts positively to the shocks in the oil price, but the research does not say anything about the underlying reason for the shock that we wish to investigate in our analysis.

There has also been research focusing solely on Norway. Gjerde and Sættem (1999) used several macroeconomic variables, such as stock returns, interest rates, inflation, industrial production and consumption, in order to determine which parameters are affecting Norwegian stock returns. They used a multivariate VAR model with six lags and their dataset had monthly observations from 1974 to 1994. Their findings suggest that real interest changes affect stock returns and inflation, and that the stock market will react accurately to the oil price changes. We expect the reaction of stock prices to be larger towards oil price shocks than what Gjerde and Sættem found, due to the fact that Statoil went public in 2001.

Using a structural form VAR model with recursive ordering, Bjørnland (2009) found that oil price shocks had a stimulating effect on the Norwegian economy. This was consistent with what is expected from a small oil exporting economy. Comparing this study with Kilian and Park, we note that Bjørnland used a broad span of macroeconomic variables to explain the stock price, while Kilian and Park focus solely on oil related shocks. Bjørnland's variables included foreign as well as domestic variables with monthly observations from 1993 to 2005, containing oil price, foreign monetary policy, exchange rate, unemployment and inflation.

The results showed that a 10% increase in the oil price, would immediately increase the stock returns by 2-3%. The full effect of 4-5% was reached after 14-15 months, after which the effects died out. This model is the most related to our methodology that we have found, focusing on Norway. We expect some of the same results, but at the same somewhat different, as her dataset ends in 2005. Since then we have seen dramatic development in the oil market which can impact our results.

Studying the two Norwegian papers focusing on oil price and stock return, we note that the oil price is significant for stock returns. However, an important distinction from their work and ours is that they do not analyze the effects of different types of oil shocks, against the stock market. We therefore believe that this thesis is a useful contribution to the field. Based on previous research, we saw that in general, consuming countries reacted negatively to a positive shock to the oil price. The producing countries on the other hand, in general reacted positively to the same shock. In our analysis, we therefore expected Norway as a small oil producing country, to react positively to a positive shock in the oil price.

Understanding the Oil Market

In our analysis of how different oil shocks influence Norwegian stock return, we are depending our analysis on the fundamental market fluctuations of the oil price. In this section we will therefore describe how the oil market transformed from being restricted by government interventions, into a more market based pricing scheme. We will also describe how Brent became the benchmark oil price, before we elaborate on the history of the Norwegian oil market and define what we refer to as an "oil price shock"

The history of the oil market

The most important distinction to make is whether a country supplies or consumes oil, and whether or not the supplier is a member of the OPEC. The 31st of May

2016, this organization counted 12 member states. The organization, founded in 1960, was an attempt to form control in the oil market by establishing co-ordination between oil supplying countries regarding the structure of the mineral contracts (Carollo 2011, 30-44). The pricing power, however, still remained with the large American oil companies until the Yom Kippur war in 1973. Saudi Arabia then decided to boycott countries that supported Israel, took control of the crude oil prices and started to publish a price, based on their own Arabian Light oil. The combination of OPEC taking control of the oil market and the scare coming from the middle east crisis, made the price of crude oil jump from $2 to $12-15 per barrel (due to the supply shock). Oil-consuming countries responded and founded the IEA (International Energy Agency) in 1974. This establishment served two main purposes; assist each other in the case of a boycott, and to exchange national oil data such as demand, supply, stocks and transport. It was during this time period, that Norway became a larger player in the oil market.

In 1979 Saddam Hussein came to power in Iraq, while there was a revolution in Iran. The Iran-Iraq war broke out in 1980, and the uncertainty lead to an oil-race, which spiked the price following the supply shock. When the rush ended, consuming nations had increased their oil stocks from 30-50 days up to 180 days consumption. The IEA for the first time, became useful. Although they had no influence on the production, they analyzed the data collected and found that the costs related to the storage of oil was disproportionate and unnecessary. The assistance mechanism had worked, giving governments and oil companies the insight that the price had risen dramatically because they all bought way more oil than actually needed. Eventually the Iran-Iraq war came to an end, and there was no longer any uncertainties contributed to the oil supply.

During 1982, all the oil companies in the world started to cut their oil purchases from the producing countries, and in particular from the OPEC countries which continued to price their oil very high. This lead to a new phase in the oil market. The OPEC had been the leading cartel since the 1973, but now they faced challenges. As a result of the demand shock, problems related to a common strategy of pricing the oil to the demand started to emerge. At first they tried to force their customer to fulfill their part of the contract, and purchase as much oil as in the previous years, as they tried to maintain the production level from the record level 1981. However, this forced them to sell the excess oil for spot prices in the market to independent traders, thus creating two markets. The difference in price could be as much as $10 per barrel. In an extraordinary meeting, they therefore decided to cut the prices of the oil, and establish new production quotas. The preceding years, a weakening trend in the oil prices was detected, which was also due to the establishment of nuclear power stations and converting natural gas into electricity.

The production from non-OPEC countries now started to become apparent. Especially production in the North Sea region started to play an important role in the world's political and economic balance. The Prime Minister of the United Kingdom, Margaret Thatcher, had sickened of the OPEC's excessive power. She therefore refused any attempts of cooperation and dialogue with the OPEC countries, regarding regulation of prices. Together with U.S. President, Ronald Reagan, she wanted the oil price to be a result of the free market without any political influence, and especially not from the OPEC cartel. As a result of failing to detect the political patterns and the appropriate demand, OPEC had gradually lost some of its influence.

The Saudi Arabian minister of oil, Ahmed Yamani, reacted by unleashing a war on prices. He brought over to his side all of the producers and the refiners around the world, who had unknowingly pumped excess oil and finished products into the market. As the market could not absorb the supply shock, the price of crude oil fell. In the light of this conflict in July 1986, Royal Dutch Shell UK, introduced an alternative way of fixing the price of crude oil that came from the North Sea in a free market, namely the "15-day Brent contract". This was the first time that the price of crude oil, Brent, was noted on a sort of exchange. Through this "exchange" a selected number of professionals could operate and define the price day by day. It was a very limited and very regional for North Europe, but soon it became a tool used in London's financial district where all of the world's biggest trading companies had their headquarters. In this complex situation, any turmoil around the Middle East region or any decision made by the OPEC cartel, affected the expectations of the London traders. These expectations then fluctuated the price of crude oil. The "15-day Brent contract" came at the worst possible time as Yamani was in the middle of his price war. The price of crude oil dropped severely from $30 to $11 per barrel. This was a big shock for the supporters of the free market of crude oil. The traders in London could handle fluctuations of a few dollars per day, but this started to become serious for many traders, who lost big money. Many of these now had to declare bankruptcy.

Producing countries also started to feel the pain from a low oil price, and many of them had to cut investments and shave budgets. It thus became apparent to most people that an oil price, relying entirely on the laws of the free market did not work, as the marginal cost of production was higher than the spot price. This was not in line with the equilibrium of the world economy and politics. In 1987, it was therefore arranged a meeting with all the players included. Governments, OPEC- and non-OPEC-countries. It was agreed that the oil price could not follow the laws of the free market. Saudi Arabia accepted and signed the agreement in December 1987. The oil price was fixed at $28 per barrel and production levels were kept on a level programmed by the OPEC countries.

At the same time, steps were taken into transforming the physical Brent market into a financial market. The crash in 1986 had created a sphere of panic in the London financial district, as the 15-day contract had proven not to be sufficient for the economic and financial system, and had caused several companies to declare bankruptcy. The biggest oil companies were therefore forced to buy back the oil left behind from the wiped out trading companies. The cost was gigantic, and the intention of making a pure obligation market had failed. However, the financial sector did not give up, and in July 1988 the IPE (International Petroleum Exchange) launched the Brent Futures contract. The event was praised as a solution for the free market against the initiatives from the OPEC cartel.

In December 1988, the OPEC decided to abandon the pricing of the Arabian Light oil and adopt the new benchmark Brent. This meant that all of the oil coming from the Gulf region, was priced based on the Brent crude oil definition. For the sake of national pride, the differential between the Brent and the former Arabian Oil was called OSP. Although it was evident that the crude price of the Arabian oil was no longer published. The event was praised by the market. This was seen as a step leaving the old fashioned world behind, entering a new modern era. However, the true motive of the Arabians was not understood. They wished to start a new price war, using the Brent market as a tool. On the other hand, the Arabians and OPEC, failed to understand that starting a price war in the political atmosphere at the time, was in fact suicidal. It immediately lost much of its foundation for existing. It had now turned into a rival of the IEA. All of the oil producing nations now used the same price benchmark, which in practice made them all a part of the same “cartel”. However, as the “cartel” did not have any agreement of controlling prices and production volume, the market had turned into the free market that Mrs. Thatcher and the traders in London originally wanted.

As the producers did not have any agreements on production, all of the countries could produce the amount that they desired, before trying to sell their crude oil in competition with the others. As a consequence of this, the market reacted just as it did in 1986, and the price of Brent plummeted to $9 per barrel. Those who had previously praised OPEC for its decision to adapting the Brent for pricing their crude, now started to criticize their inability to control the production level. It turned out that commentators wanted a free market, but only if it meant that OPEC cut their production level at the same time.

Simultaneously, the Iran-Iraq war ended and both of the countries were in the middle of a financial crisis. Naturally they both wanted to seize a piece of the oil market. They therefore asked the countries that had taken their market shares during the war, to give these back. The answer was negative. As a result, the oil market was flooded by the increased oil production from Iran and Iraq. It suddenly became very important to find a solution for excess production. It became crucial to find a producer that could vary the production. So far, all of the attempts to find such a producer, either individually or collectively had failed. The OPEC was not interested after what had happened when they adopted the Brent crude oil as benchmark. The problem solved itself with the outbreak of a series of military and political conflicts in the Persian Gulf. The oil market was therefore relatively stable around $20-25 per barrel until 1998. Then countries started to increase their production, and Iraq again started to export oil after a long ban from the UN. By 1999 the price of oil had dropped to $9 per barrel, the lowest price in 20 years (Carollo 2011, 30-44).

In 1969, the first profitable oil field on the Norwegian continental shelf was found and the extraction began in June 1971. This was the beginning of an era, containing several large findings such as Ekofisk, Oseberg, Gullfaks, Troll and Statfjord (Regjeringen 2016). These fields were, and still remain important for the development of the petroleum sector in Norway. The oil production on Norwegian soil, founded the possibility for establishing oil companies which laid the foundation for future welfare. Amongst them, Statoil and Norsk Hydro. They were two of the most important drivers for the Norwegian petroleum sector, and in 2007 Statoil merged with the oil and gas sector of Norsk Hydro. From 1971, the importance of the petroleum sector grew. Around year 2000, the production reached its top peak, making Norway the 3rd largest exporter of oil and gas (Ryggvik 2014). As we entered 2014, the production of oil fell while the production of gas continued to grow. In total the petroleum sector accounted for 52% of the country's total exports.

From the production start in 1971 and up to the middle of the 1990's, a large portion of the petroleum revenues was used to pay outstanding debt and for public consumption. In the early 2000's, most of the revenues contributed to the foundation of the Government Pension Fund Global. To secure a healthy economy, the Stoltenberg-government introduced "handlingsregelen" ("the sustainability rule"), which restricted the government to spend more than 4% of the fund's yearly return (Ryggvik 2014). The spending would follow the cyclical changes in the economy, meaning that the government could spend up to 4% in "bad times" and less in "good times". The funds value by the end of June 2016 exceeded 7400 billion NOK, making Norway one of the most financially independent countries in Europe.

The recent oil demand and oil supply shock

From June 2014, we have seen a sharp decline in the oil price (Figure 2). In contrary to previous price drops, this is driven by both a supply and demand shock (IEA 2015). The IEA report states that the drop occurred because of an increase in

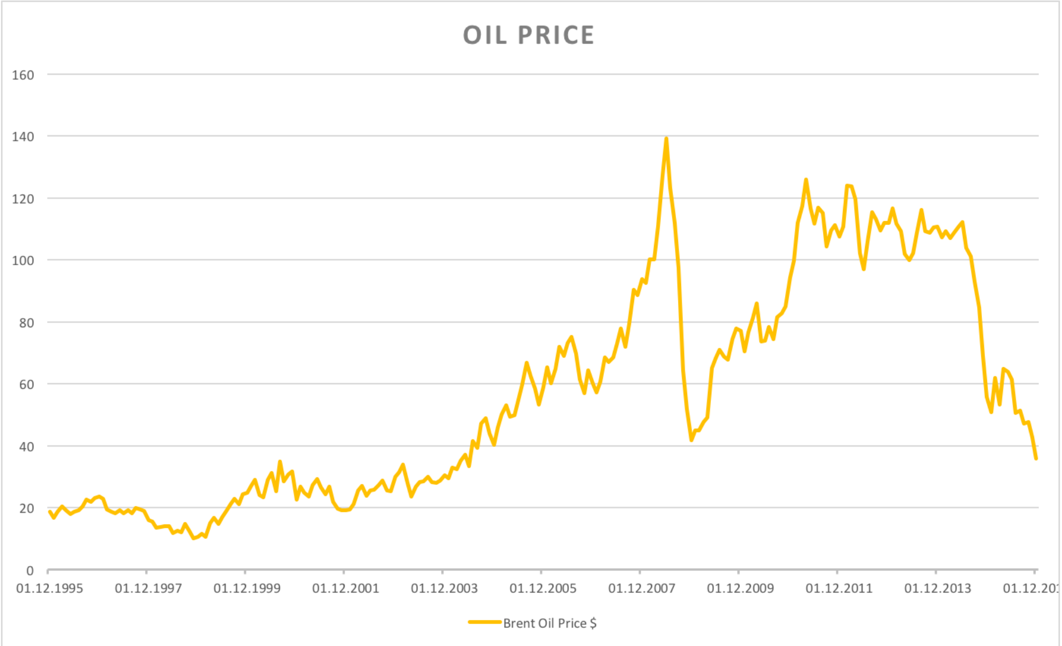

Figure 2: Development of the oil price

non-OPEC oil supply from 2014, and a weakening growth in oil demand from emerging economies. The supply side was largely impacted by an increase in U.S. shale oil production. Production from these formerly hidden resources was something that the market barely registered as possible. However, some analysts today say that only during the last year, the drilling costs for shale oil has been reduced by 35-40% (Crooks 2016). The oil has been banned from exports in the U.S. since the 1970's, but in December 2015, the ban was voted to be ceased (Wingfield 2015). Therefore, OPEC fear that U.S. oil production will be able to outperform their own and with a potential cost advantage of shale oil, the U.S. may in the future be able to capture market shares from the OPEC.

The demand from emerging economies, has during the last 10 years seemed to be never-ending with a demand curve perceived to be nearly vertical. However, many of these countries, with The People's Republic of China (hereafter "China") in front, have now entered a new less oil-intensive stage in their development. Information technology revolution has become a less fuel-intensive way of developing the society. Concerns over the climate changing energy policies and the globalization of the natural gas market, are causing great challenges for the oil industry. Together with competition from renewable energy, due to a steep reduction in costs and availability of clean energy, the oil market is changing in a way that seemed unlikely years ago.

	2015	2016	2017	2018	2019	2020	2021
World Demand	**94.4**	**95.6**	**96.9**	**98.2**	**99.3**	**100.5**	**101.6**
Non-OPEC Supply	**57.7**	**57.1**	**57.0**	**57.6**	**58.3**	**58.9**	**59.7**
OPEC Crude*	32.0	32.8	33.0	33.0	33.2	33.5	33.6
OPEC NGLS etc	6.7	6.9	7.0	7.1	7.1	7.1	7.2
Total World Supply*	**96.4**	**96.7**	**97.0**	**97.8**	**98.7**	**99.5**	**100.5**
Implied Stock Change	**2.0**	**1.1**	**0.1**	**-0.4**	**-0.7**	**-1.0**	**-1.1**

*OPEC actual output in 2015. Assumes a post-sanctions increase for Iran in 2016 and adjusts for OPEC capacity changes thereafter.

Figure 3: Global balance summary (million barrels per day), (IEA 2016, Table ES.1).

In the most recent medium-term oil market report (IEA 2016), we see that the demand will exceed the supply in 2018 from the projected global balance summary (Figure 3). This growth in mainly caused by China, because of their strategic build-up of reserves, which will reach at least 500 million barrels by 2020.

Defining an oil price shock

In similar fashion as Kilian and Park (2009), we define the magnitude of an oil price shock as a one standard deviation change. Taking the percentage changes in our oil price sample, we calculated one deviation to equal 10,61%. Out of the 240 observations in our sample, we found 62 occasions where the oil price had changed positively or negatively 10,61% from one month to the next. The first big oil shock in our sample, occurred in 1998 and lasted for 3 consecutive months. The trigger was a fear that the UN-restricted output of Iraq, whose supply rose by 1 million barrels per day, would someday be able to further increase production. In 1999 there was no obvious exogenous shock, but the price rose from $17,98 to $28,24. A report by the Petroleum Industry Research Foundation had the best explanation. The report concluded that a combination of low stocks, stricter environmental regulations and other technical aspects (Kanovsky 2003), in combination with a cold winter in Europe and a global economic growth faster than expected, increased the demand for oil and pushed the prices upwards.

The price trend peaking in June 2008, was largely driven by speculation from investment banks and hedge funds (Ari 2008). Analyses published by Merrill Lynch and other banks predicted that the oil price would rise to $250 per barrel (Carollo 2011, 103). The next oil shock for consecutive months, was during the financial crisis in 2008. The oil price plummeted from $139 in June to $42 in December. It was quite clear that the demand did not fall this much. When President George W. Bush lifted the ban on offshore drilling (Eggen and Mufson 2008), the price dropped as supply would possibly increase and speculators wanted to cancel their long positions. In the following months, turmoil in the financial markets exploded as Lehman Brothers on the 15th of September 2008 filed for bankruptcy.

Historical development of the OSEBX

By investigating the OSEBX in our sample period, we see that the weight of energy companies, where petroleum accounts for a significant part, has changed over the years. In 1996 (Figure 28) the energy sector only accounted for 14% of the total value, while "industrials" was the biggest sector with 37%. It is worth noticing that Statoil was not listed on the stock exchange at this time, as they went public in 2001. Before the financial crisis in 2007 (Figure 4), the energy sector had grown remarkably up to 47% and Statoil accounted for 11% of the total value on the OSEBX.

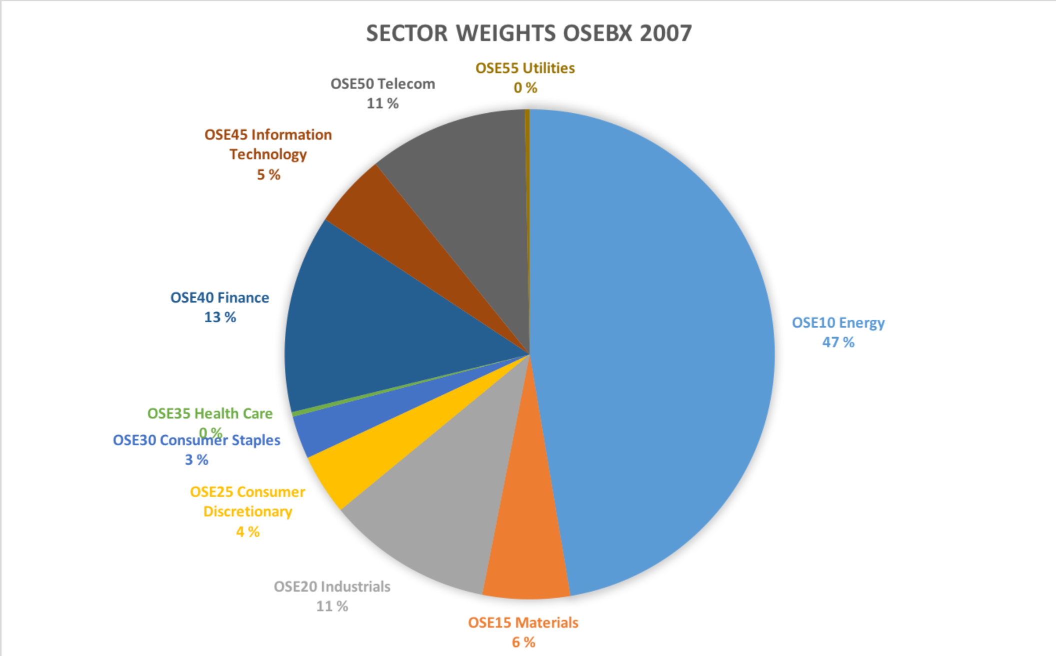

Figure 4: Sector weights in 2007 (Source: Oslo Børs, 2nd of January 2007)

In 2014 (Figure 29) Statoil's weight on the stock exchange had increased up to 22%, while the energy sector in total weighted 39%. In 2016 (Figure 5) however, the weight of the energy sector had dropped to 26%. This evidence could signal that the effect of the oil shock, as mentioned above, has reduced the value of petroleum related stocks. The drop in oil price between 2014 and 2015 equaled 68% and during the same period we noticed that the weight of the energy sector fell by 13 percentage points.

Related to our research question, we believe that the change of these weights will impact the respective returns of the OSEBX. The stock market analysis is partly based on future earnings (EBITDA, EBIT, EPS etc.) and multiples. A higher oil price would therefore increase expected sales and the anticipated stock price. A lower weight of oil stock on the OSEBX depending on the oil price, will result in a smaller fluctuation of the index when the oil price changes.

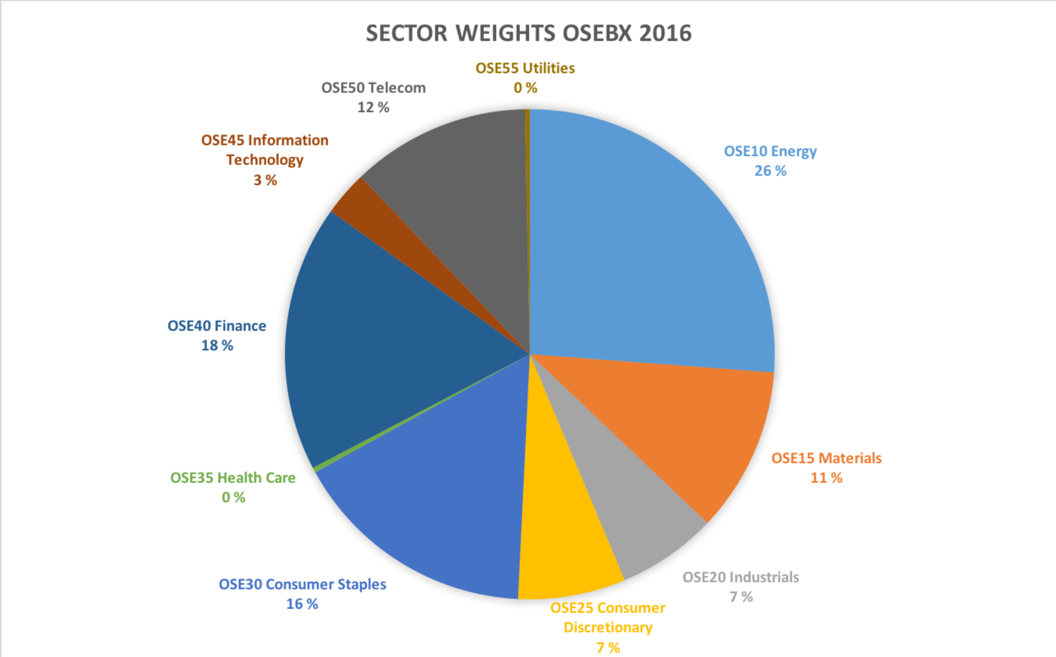

Figure 5: Sector weights OSEBX (Source: Oslo Børs, 18th of July 2016)

How Supply and Demand Form Oil Prices

In this chapter we will look at how oil is priced in the market. Both as a result of supply and demand, and through financial instruments.

Types of oil

"Oil" as we commonly know it, exists in our daily lives through gasoline and a series of other products like plastic and heating oil. Before gasoline or heating oil can be sold as a finished product it needs to go through different processes, depending on which type of oil it is. The oil varies in viscosity, volatility and toxicity. Depending on the type, the color can range from light golden yellow to very dark black. Further, the type of oil varies in quality depending on where it is geographically extracted. Some regions are known for extracting heavy oil, while other regions produce light oil. The lightness of the oil is measured in API Gravity. This measurement tells us how heavy crude oil is compared to water. If API Gravity exceeds 10 degrees, it means that the oil will float on top of water. If it is under 10, it will sink (Dept 2009).

West Texas Intermediate (WTI) is a light, high quality type of crude oil with a API Gravity of 39,6 degrees. It is characterized as “sweet” oil because of its low sulfur content. The refineries will therefore be able to produce more finished products from a given amount of oil. Because of its great quality, the price is often higher than other types.

Brent Blend oil is a combination from 15 different oil fields in the North Sea. Its API Gravity is 38,3, which is defined as a light oil. It is also low in sulfur, but is considered not as sweet as the WTI oil.

OPEC (Organization of Petroleum-Exporting Countries) Basket oil is extracted from oil fields in Algeria, Saudi Arabia, Indonesia, Nigeria, Dubai, Venezuela and the Mexican Isthmus. The OPEC Basket oil has both higher sulfur content and lower API gravity. It is therefore priced lower than the other two types.

The classical industrial model

To describe how supply and demand form oil prices, we use the classical industrial model as starting point. The intention is to show how shocks will influence the price of oil.

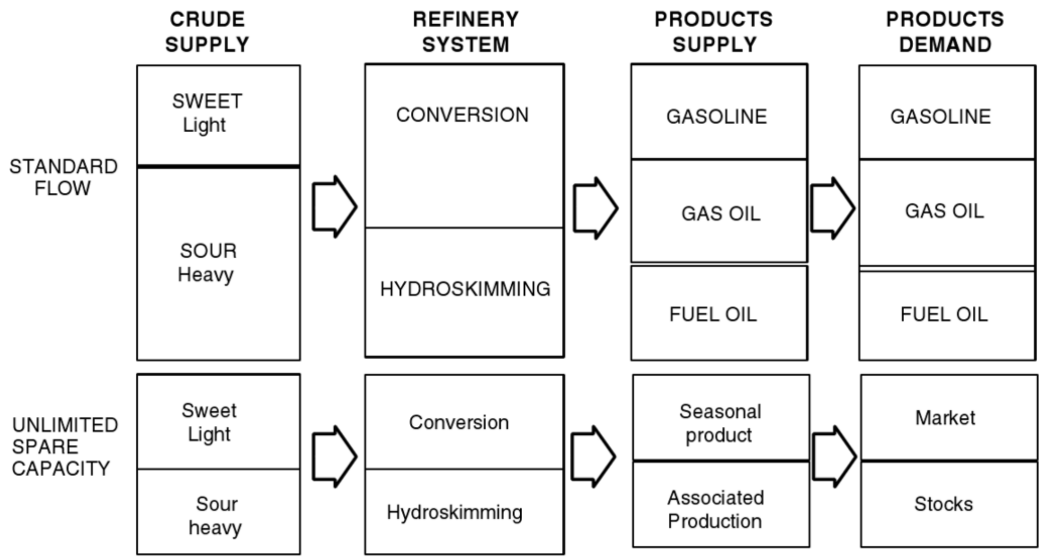

Figure 6: The classical industrial model (Carollo 2011, 82)

The first part of the model (Figure 6) is the supply of crude oil from the oil producers. The supply of crude oil can be divided into two different types, namely a high quality light oil and a low quality heavy oil. The second stage of the model consists of the refiners that convert the crude oil into products ready for sale. The advanced refiners use the conversion method, while the simple refiners use the "hydroskimming" method. The products are then distributed according to the market demand in the last step of the model. Here we find the refiners that purchase oil from the oil companies and the producing countries, and the consumer market that demand the finished products. In the latter market, the prices are determined by the dynamics between the consumers and refiners. The prices of the first market are the outcomes of the negotiating exchanges between the parties. It is here evident that the refiners are the "middle-man", linking the two markets together.

The producers of light crudes plan their production capacity and sell their production for a few months at the time. There is therefore no available capacity in the market. The refiners have bought the light crudes and have planned to use maximum capacity of the conversion plants. In other words, there are no spare capacity for high quality production of gasoline etc. The supply curve is hence, assumed to be vertical (Figure 7). Hence, a positive shift in demand, will lead to an instantaneous increase in the price for gasoline (from P1 to P2).

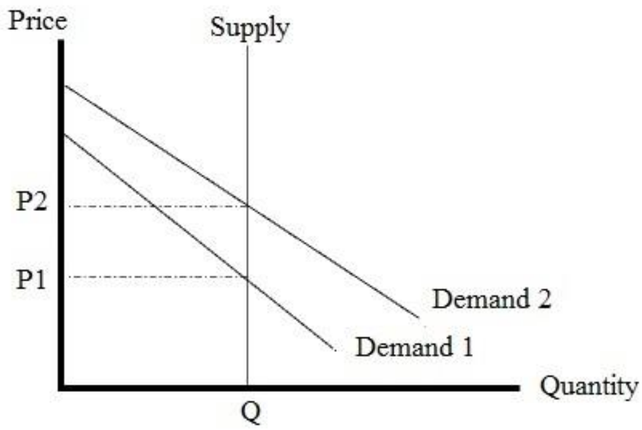

Figure 7: Demand shift with a vertical supply curve

In order to exploit this price shock and make an extra profit, the refiners will go to the market and buy the heavy low quality crudes. As there is no spare capacity in high quality refineries, they will have to refine this crude in facilities that are of lower quality. From these refineries, it is only possible to extract about 10% gasoline. Thus, the refineries are forced to buy 10 tons of crude oil in order to make 1 ton of gasoline (Figure 8). Much more than needed. The rest of the crude oil is used to make other products.

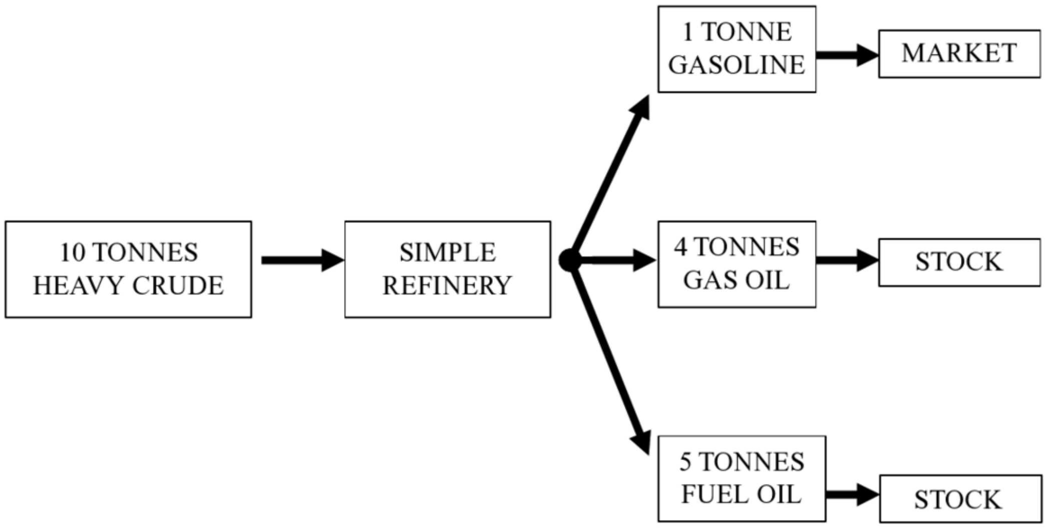

Figure 8: (Carollo 2011, 84)

The market notices a shock in the demand for crude oil, 9 times greater than expected, concentrated in the heavy crude segment, which increases the price of heavy crude. This is a contradiction, as light crude is expected to be more expensive. As the demand for gas and fuel oil are lower than for gasoline, their reserves will fill up, and the price of gas and fuel will decline.

Because of the demand shock for gasoline, the price will increase. The unanticipated supply shock for the other oil products, will push the prices down. Contemporaneously, the raw material price for producing the fuel and gas oil will be relatively higher. We see that seasonality of demand shock for the different products play an important part in the prices of petroleum raw materials, as well as the capacity in the refineries. Put differently, the demand for the raw material itself is not the most important, but the demand for the product output from the plants. The two most crucial demand factors are the demand for gasoline in the U.S. from March to August and the demand for gasoil in Europe from October to February (Carollo 2011, 81-87).

Forward and futures market

Knowing the supply and demand dynamics behind the oil price is not enough in order to understand it fully. It is also important to get a perspective of the financial aspect that drives the oil price. The revolution started by the time that Shell UK introduced the 15-day contract. This contract was standardized, and the only variables in the contract that could be changed were the two counterparties and the price. The quantity was fixed at 500.000 barrels per contract and the delivery date was 15 days from acceptance. The simplification regarding negotiations made it easier to speculate for those not taking part in the oil market. 1988 was, as mentioned earlier, the beginning of a new era in the oil futures and forward markets as the IPE was founded. The contract size was reduced from 500.000 barrels to 1000 barrels, to better fit the size other financial contracts. In 2000 this developed further with the establishment of the Intercontinental Exchange. Today, the Intercontinental Exchange and the 15-day contract co-exist in setting the price of Brent.

Because it is possible to buy oil both today and in the future, these prices must somehow be related. For the financial market to function, these prices must co-exist without any arbitrage opportunities. The future contract therefore needs to be within its upper and lower bound. The cash and carry model defines the no-arbitrage upper bound in the following way:

$$F_{0,T} \leq S_0 e^{(r+\lambda)T}$$

The reverse cash and carry gives us the lower bound:

$$F_{0,T} \geq S_0 e^{(r-\delta_l)T}$$

Where $F_{0,T}$ is the price of the future from date 0 until maturity date T. S_0 is today's Brent spot rate. Further, r is the interest rate, λ is the storage cost while δ is the lease rate. If the inequalities fail to hold there arises an arbitrage opportunity. This can be exploited by traders in the market using the trading strategies above. Today the price of oil is relatively low following the supply shock in recent years. As a consequence, many traders in the market are bull on the future oil price. Therefore, oil is being stored in tankers by many, as they intend to sell it in the future (contango) at a higher price and make a profit (Wallis and Khasawneh 2016).

Theory

From reduced form VAR to structural VAR

Ever since the Vector Autoregressive (VAR) model was introduced by Sims (1980), it has been a popular method for analyzing macroeconomic relationships. Using these VAR models, researchers were able to capture the dependencies between multiple variables. The multiple variables create a system of equations where the variables are dependent on their own lags, and the lags of the other variables in the system.

$$y_t = \mu_0 + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \varepsilon_t$$

This is said to be a reduced form VAR of order p. y_t is the $k \times 1$ vector of random endogenous variables. Further, A is the $k \times k$ coefficient matrix, describing the relationship between the lagged observations of the variables y_{t-p} and the variables at time t. μ_0 is the $k \times 1$ intercept vector of the model. Finally, we have the ε_t. This is the $k \times 1$ vector of error terms, which are assumed to be white noise. White noise means that they are assumed to be serially and mutually uncorrelated with zero mean and finite variance. Simpler put, they are regarded as random shocks to the economic variables. Assuming that we have two variables, $k = 2$, and one lag, $p = 1$, we have the following model on matrix form:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$$

Multiplying out these matrices, we get the equations:

$$y_{1,t} = \mu_1 + \alpha_{11} y_{1,t-1} + \alpha_{12} y_{2,t-1} + \varepsilon_{1,t}$$

$$y_{2,t} = \mu_2 + \alpha_{21} y_{1,t-1} + \alpha_{22} y_{2,t-1} + \varepsilon_{2,t}$$

It becomes clear that each variable depends on its own lag, the lag of the other variable, plus the intercept and error terms. In economics, it makes sense to assume that the variables do not only depend on own lags, but also the lags of other variables. For instance, a country's GDP will not only be influenced by the past observation of GDP, but also lagged observations of variables such as the interest rate, inflation and exchange rate.

In order to obtain a structural VAR, we have to make some adjustments to the reduced form VAR. All lag-vectors are moved over to the left side of the equation and summed up in a lag-polynomial A(L), which makes us able to express the lags in terms of the y_t vector. Assuming no intercept term, we get:

$$y_t - A_1 y_{t-1} - A_2 y_{t-2} = \varepsilon_t$$

$$(I - A_1 L - A_2 L^2) y_t = \varepsilon_t$$

$$A(L) y_t = \varepsilon_t$$

We are then left with the white noise errors on the right hand side. Multiplying the equation with the inverse of the lag polynomial, we get the reduced form moving average representation:

$$y_t = B(L)\varepsilon_t$$

$$= \sum_{j=0}^{\infty} B_J \, \varepsilon_{t-j}$$

$$= \varepsilon_t + B_1\varepsilon_{t-1} + B_2\varepsilon_{t-2} + \cdots$$

Where $\text{B(L)} = A(L)^{-1}$ and since $A_0 = I, B_0 = I$.

There is now a problem in the model, as the reduced form errors are most likely correlated. This means that the variance-covariance matrix of the error terms is not diagonal (zeros over and under the diagonal). A shock in one of the variables, will then lead to shocks in the other variables. The most common way to solve this problem, is through a recursive ordering (Cholesky). The recursive ordering orthogonalises the residuals so that they are no longer correlated. The variance-covariance matrix of the error terms will be decomposed into a lower triangular matrix P, times its own transpose P'.

$$\textstyle\sum_e = PP'$$

The lower triangular matrix will have positive diagonal elements with zeros above the diagonal. Using the property that a matrix times its inverse is equal to the identity matrix, $PP^{-1} = I$, we can write the reduced moving average representation as following:

$$y_t = \sum_{j=0}^{\infty} B_j \, PP^{-1}\varepsilon_{j-t}$$

$$= \sum_{j=0}^{\infty} C_j \, e_{t-j}$$

Where $C_j = B_j P$ and $e_t = P^{-1}\varepsilon_t$.

The error term is now multiplied with the inverse of the lower matrix P. The new error term v_t, which is the old error term multiplied with the inverse lower triangular matrix, is now uncorrelated. Given the recursive structure from the P^{-1} matrix, a shock in variable y_2 is not able to influence variable y_1 contemporaneously. After one period however, the variables are able to influence each other. In order for these restrictions to make sense, the variables must be ordered correctly and the restrictions must be based on economic theory (Bjørnland 2015, 189-247).

Impulse response functions

An impulse response function represents how a given structural shock affects a variable in the y_t vector over time. The y_t vector can be described by its moving average representation. That is its history of shocks. For s periods into the future, the y_{t+s} vector will incorporate the shock given to the system in period t. As previously mentioned, the shocks from the reduced VAR are most likely correlated. An impulse response from the reduced VAR moving average representation is hence, invalid. In order to get a valid result, we need to use a model with orthogonal and uncorrelated shocks. It is therefore normal to use impulse responses from structural models.

$$y_{t+s} = B_0 \Psi^{-1} \Psi e_{t+s} + B_1 \Psi^{-1} \Psi e_{t+s-1} + \cdots + B_s \Psi^{-1} \Psi e_t + \cdots$$

$$= \Theta_0 \Psi e_{t+s} + \Theta_1 \Psi e_{t+s-1} + \cdots + \Theta_s \Psi e_t + \cdots$$

$$= \textstyle\sum_{j=0}^{\infty} \Theta_j \, \varepsilon_{t+s-j}$$

Multiplying out these matrices, the impulse response functions can simply be found by deriving the equations with respect to the different shocks. The impulse responses only depend on time s. That is the time from the shock occurred (ε_t) until the time in the future when the shock is observed (y_{t+s}). The impulse response function of the shock will be the plots of the $\Theta_{ij,s}$. The plots will summarize how a unit impulse at time t will influence the y vector at time t+s. The element i,j of Θ_s represents the impact of a shock j hitting the i-th variable of the system at time t (Bjørnland 2015, 189-247). In our model, the impulse response functions will be analyzed on the 95% level.

Stationarity

When conducting statistical analysis, it is required that the variables are stationary in order for asymptotical analysis to be valid (that is the normal distribution, OLS ect.). Another undesirable property of non-stationarity is that shocks in the time series will persist in time series throughout time. Further, non-stationary time series may lead to spurious regressions. That is, regressions with no economic interpretation. For a variable y_t to be stationary, its mean and variance need to be constant over time. Also the auto covariance between two subsequent observations in time needs to be dependent on the time separating the two observations, not the time t (Brooks 2014, 256). Time series are therefore stationary when:

I. $E(y_t) = \mu$ (Constant mean)

II. $var(y_t) = \sigma^2$ (Constant variance)

III. $cov(y_t, y_{t+s}) = cov(y_t, y_{t-s}) = \gamma_s$ (Covariance dependent on s, and not t)

A common method used when testing for stationarity, is the Augmented Dickey-Fuller test (Brooks 2014, 361). This test is an extension to the Dickey-Fuller test. The objective of the Dickey-Fuller test, is to test the null hypothesis ($\psi = 0$). That is, the series does in fact contain a unit root.

$$\Delta y_t = \psi y_{t-1} + u_t$$

The Dickey-Fuller test can be conducted allowing for intercept or an intercept and deterministic trend. The model will in that case be represented by the following equation:

$$\Delta y_t = \psi y_t + \mu + \lambda t + u_t$$

In order for the Dickey-Fuller test to give accurate results, the error term needs to be white noise. This means that there cannot be any autocorrelation present. In order to make sure this is not the case, an extension is added to the Dickey-Fuller test, which makes it an "Augmented Dickey-Fuller". By including lags of Δy_t, we are able to soak up any dynamic structure present in the dependent variable, to ensure that u_t is not autocorrelated. The test therefore looks like:

$$\Delta y_t = \psi y_{t-1} + \Sigma_{i=1}^{p} \alpha_i \Delta y_{t-i} + u_t.$$

When testing our variables for unit root, we will test for intercept and deterministic trend. Since we will use a Structural form VAR (SVAR), the most important thing is that the system of variables together is stationary. When analyzed independently on their original levels, the variables have a unit root, which make them non-stationary. Following the Kilian and Park procedure, we take first difference of the oil production and first differenced log of the OSEBX. In both cases we could reject the null hypothesis, and the series were therefore stationary. However, the Kilian index and the real oil price still contained unit roots. Although testing all variables together in an endogenous group, we see that when tested together the variables do not contain unit roots. This can be further justified by using an AR roots test (Figure 9). In our SVAR model, we find that all roots have modulus less than one, and hence, lies inside the unit circle. The model is therefore considered as dynamically stable.

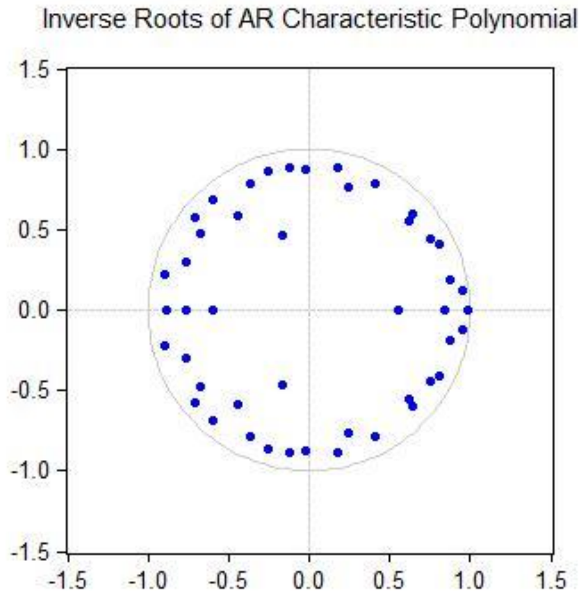

Figure 9: AR roots test for model including the Kilian Index for global aggregate demand.

Methodology

Our model builds on a SVAR decomposition of the real price of oil, which was first presented by Kilian (2009) and then further developed by Kilian and Park (2009). We estimated a SVAR model based on monthly data for the vector time series z_t[1], which included the variables; percentage change in global crude oil production, a measure of real activity in demand for global industrial commodity markets, the real price of oil and Norwegian real stock returns.

(1) $$A_0 z_t = \alpha + \Sigma_{i=1}^{12} A_i Z_{t-i} + \mathcal{E}_t$$

[1] Previously in this paper we have noted the vector y_t as found in theory literature, but as Kilian and Park use z_t we choose to do the same.

In the structural representation of our model (1), $\mathcal{E}_t$ denotes the vector of serially and mutually uncorrelated innovations. e_t represented the reduced form VAR innovations so that $e_t = A_0^{-1}\mathcal{E}_t$. By imposing restrictions on A_0^{-1} from the reduced form innovations we arrive at the structural innovations. The model further imposes a block-recursive structure on the contemporaneous relationship between the reduced form disturbances and the underlying structural disturbances. To resolve this, we will base our approach on the recursive ordering.

The first block[2] models the world crude oil market and the second block contains real Norwegian stock return.

$$(2) \qquad e_t = \begin{pmatrix} e_{1t}^{global\ oil\ production} \\ e_{2t}^{global\ real\ activity} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{Norwegian\ stock\ return} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \mathcal{E}_{1t}^{oil\ supply\ shock} \\ \mathcal{E}_{2t}^{aggregate\ demand\ shock} \\ \mathcal{E}_{3t}^{oil-specific\ demand\ shock} \\ \mathcal{E}_{4t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

In the first block, fluctuations in the real price of oil depend on three structural shocks. $\mathcal{E}_{1t}$ reacts to shocks in the global supply of crude oil (oil supply shock). That is, a large increase in production of crude oil worldwide. $\mathcal{E}_{2t}$ represents shocks to the global demand for all industrial commodities, that are driven by global real economic activity. This is also referred to as aggregate demand. As the global economy is doing well, it starts demanding oil to produce and transport products. $\mathcal{E}_{3t}$is an oil market specific demand shock. Kilian and Park (2009) designed $\mathcal{E}_{3t}$ to capture shifts in precautionary demand. Precautionary demand is the fear of future oil short falls, which is the fear that it is not being produced enough oil in the future to supply the entire market. This shock is constructed to be orthogonal to the other shocks, and arises from a shift in the conditional variance.

[2] In accordance with Kilian and Park, we divide the variables of the model into two blocks, as this provides a more intuitive understanding.

Global oil market block assumptions

The restrictions in the first block (2), are consistent with a vertical-short run supply of global crude oil and a downward sloping demand curve. A shift in the demand curve will therefore lead to an instant increase in the real price of oil. According to Kilian (2009), these shocks are motivated by the following economic assumptions:

I. Crude oil supply will not respond to oil demand shocks within the same month, because the high cost of adjusting oil production and uncertainty about the state of the crude oil market.

II. The global real economic activity will not be lowered by an increase in the real price of oil within the same month.

III. Change to the real price of oil cannot be explained by oil supply shocks or shock to the real economic activity within the same month.

Norwegian stock market block

The second block in (2) consists of one equation and the block-recursive model implies that global crude oil production, global real economic activity and the real price of oil is predetermined with respect to Norwegian stock returns. Norwegian stock return is allowed to respond to all three shocks. The stock specific shock, ε_{4t}, does however not affect global oil production, real economic activity and the real price of oil within the same month. Although from the t-1th period and earlier, it is allowed to influence the other variables. This makes economic sense, as the possibility that the Norwegian stock market would influence the global oil market seems unlikely.

Ordering of the variables

In a structural VAR, the ordering of the variables is crucial. The ordering determines which variable effects which in time t, but let all variables be affected through its lags. Oil supply shock is ordered first, as demand shocks will not influence crude oil production within the same month. That restriction is plausible because oil producing countries will be slow to adjust their production levels due to the cost of changing production levels[3] and the uncertainty of the crude oil market (Kilian 2009). Secondly, the global real economic activity will not be affected by the real price of oil immediately, but with a delay of one month. It suggests a sluggish response of the global real economic activity to the real price of oil (Apergis and Miller 2009). Thirdly, the price of oil will be affected by the two variables mentioned. The price of oil is mainly driven by supply and aggregate demand which makes it necessary to be placed as the third variable. Forthly, Norwegian stock returns will be able to respond to all variables within the same period. Norway is considered as a small and open economy where oil has been one of the most important factors for its growth. The ordering is in accordance with the methodology presented by Kilian and Park (2009) and Apergis and Miller (2009).

Lag length selection

A central issue when estimating a VAR model, is to determine the optimal lag length. Selection of a too short lag length could cause autocorrelation in the error term and thereby cause significant and inefficient estimators. On the other hand, a too large lag length will make the last parameters insignificant and suppress the degrees of freedom, providing too large standard errors and widening the confidence intervals for model coefficients (Brooks 2014, 329). A common way of selecting lag length, is through the use of information criterias. The information criterias select the lag length by trading off the reduction in residual sum of squares when adding a variable, against a penalty term for making the model less parsimonious. There exists several criterias that test for the optimal lag length, but the most used are the AIC, the SBIC and the HQIC. The SBIC has the largest penalty term, and will therefore select the fewest lags. The criteria is very consistent, but not very efficient. On the other hand, we have the AIC. This has a smaller penalty term, and will therefore include more lags in the model. The criteria is less consistent, but more efficient. The HQIC selects a lag length somewhere in between the AIC and the SBIC. It is important to notice that none of the criterias are more correct to use than the others, and sometimes it makes

[3] Oil production plans changes infrequently, which is in accordance with the view of Saudi officials (Yergin 1991). It is consistent with that Saudi oil company produces demand forecasts only time a year.

more sense to choose the lag length based on economic interpretation and research standards.

From running lag length tests, the results showed that AIC chose two lags while the SBIC chose one lag. Economically however, this did not make sense. We therefore chose to adjust our lag length in accordance with economic theory and what practitioners often use. Practitioners normally selects a lag length of four when working with quarterly data and 12 lags when using monthly data. Also, the rule of thumb (where p is number of lags and n is number of variables)

$$p_{max} = 12 * (\frac{n}{100})^{(\frac{1}{4})}$$

presented by Schwert (1989) could be used. In our case, where we have 240 observations, so a lag length of 12 seems appropriate[4]. Kilian and Park (2009) used 24 lags in their model. Their data set however, consisted of 408 observations, which is much larger than ours. They argued that 24 lags would allow the model to detect effects that takes up to 2 years to respond to shocks. We will use 12 lags, as we consider Norway as a small open economy, to react faster to innovations that concerns the country's most important industry.

Data Description

The main variables in our dataset has monthly observations and spans from January 1996 until December 2015. From Bloomberg we found data for the OSEBX index, the NOK/USD exchange rate, world crude oil production, the Brent Spot oil price quoted in U.S. dollars and the Baltic Dry Index. Further we

[4] We conducted tests on both 24 and 12 lags. Our results did not change considerable by changing the lags and we have therefore chosen to use 12 lags. The model was stable in both cases, as we used an AR Roots test.

found the Norwegian CPI on SSB's (Statisktisk Sentralbyrå) homepages, while the Kilian Index was downloaded from Lutz Kilian's personal webpage.

The starting point was chosen to be January 1996, as this was when the OSEBX index was introduced. We found it natural to use this index as the variable for the Norwegian stock market, as this is the most common variable to use. We then had to decide which oil price to use. There are many different prices of oil, depending on the quality, where it is produced and so forth. We at last decided to use the Brent Spot, as this is the price for the oil produced in the North Sea and is therefore the most important for the Norwegian economy.

The Kilian Index, is a constructed measure for the world aggregate demand. The index is constructed to capture the demand for industrial commodities. The growth rates attributed to the different commodities are equally weighted from a panel of single voyage bulk dry cargo shipping rates. The underlying data is gathered from Drewry's Shipping Monthly. Here, a panel data set was used, containing dry cargo shipping rates for commodities such as fertilizer, coal, iron ore, grains and scrap metal for shipping routes all around the world. The panel data was analyzed while controlling for the fixed effects related to the different shipping routes, ship sizes and the types of cargo. The index was then inflation adjusted, by using the U.S. CPI. It was then linearly detrended to remove a scalar trend in the cost of shipping, which resulted in a stationary index of fluctuations in global aggregate demand (Kilian and Park 2009).

Modifications were made to the variables included in the model. The production of crude oil was log-differenced in order to find the monthly changes in production. The Norwegian inflation variable was transformed into an index, such that the first observation of 1996 was the starting point with price level equal to 1. The oil price was then adjusted for inflation, while the stock price variable was "log-ed" before inflation adjusted.

All estimation was conducted using Eviews.

Results

This section will be divided into two sections. In the first section we will present the results, using the same method and variables as Kilian and Park (2009), substituting U.S. stock return with Norwegian stock return. In the second section, we will present the results from our own model, adjusting for exchange rates and using a different measure for aggregate demand. Our reason for presenting our own model, is that we get quite different results in the second section compared to results in the first. It is therefore the reader's own choice to determine which is the appropriate variable. In addition, we want to examine which effects exchange rate fluctuations have on the results. We will in both sections start by presenting the results using cumulative impulse response functions. Then we will present the variance decomposition, which is the result of the recursive ordering, explaining the long run variation in the Norwegian real stock returns. As mentioned before, the data is monthly from 01.1996 to 12.2015.

Looking at the cumulative impulse response functions, we see that a one standard deviation shock in global oil production is insignificant[5] over the whole twelve-month period for Norwegian stock return (Figure 13). Since the shock is insignificant, it is of no statistical importance. The aggregate demand shock, represented by the Kilian Index, is also insignificant over the 12-month period (Figure 14). A one standard deviation shock in aggregate demand will not change Norwegian stock return in any significant way. We find this somewhat strange, as our ex-ante beliefs was that Norwegian stock return would be somewhat influenced by a booming world economy.

The oil specific demand shock is significant with Norwegian stock return the first 5 months (Figure 10).

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[5] Significance is analyzed on the 95% level for all impulse response functions.

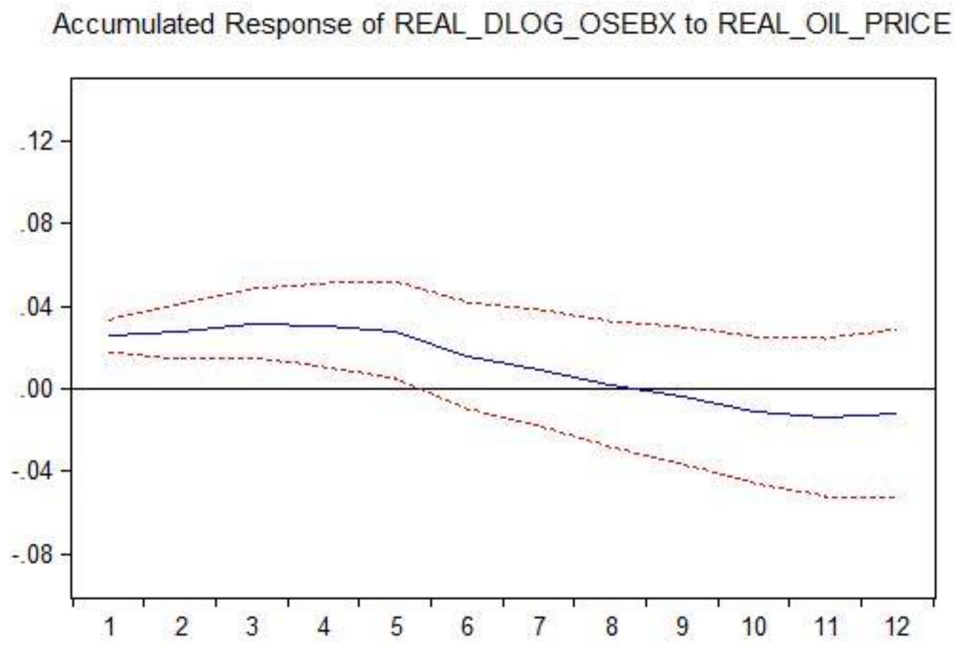

Figure 10: Response of the OSEBX for a one standard deviation shock to the real oil price

A positive standard deviation shock to the oil price will instantaneously influence Norwegian stock returns positively. This is in accordance with earlier research and beliefs about the Norwegian stock market. After the 5-month period, the shock will gradually die out and return to its normal level after 8 months.

The variance decomposition tells us how much the dependent variables, are explained by the explanatory variables. We see that the oil specific demand shock can explain 19,18% of the total long run-variation in Norwegian stock return. The aggregate demand shock can explain 3,41% and oil supply shock 9,19% of the total variation in Norwegian stock return (Table 1).

Our results are both expected and unexpected. The oil price has been seen as being of high importance for Norwegian stock return, both by research papers and the Norwegian business environment in general. After the obvious trend between the oil price and the OSEBX ended in 2014 (see Figure 1), we believed that this relationship had come to an end. However, looking at our dataset dating back to

1996, it is not surprising to find that the Norwegian stock return responds statistically significant to a positive shock in the oil price. Aggregate demand shocks were insignificant. This is something that we were puzzled about, as we assumed that a booming world economy would have influenced Norwegian stock return positively. This assumption was founded on the composition of the value weighted OSEBX, due to the fact that the index today contains a smaller proportion of oil dependent companies. The results, hence show us that even if the OSEBX has become less oil dependent in regard to types of companies (compare figure 4 and 5), the oil price affects future prospects for the Norwegian economy. This will in turn affect expected future cash flow for Norwegian companies not depending on oil.

Results From Model Adjustments

We are presenting this section to show how adjustments of the exchange rate, and using a different measure for aggregate demand, influence the results. Firstly, we replace the Kilian Index with the Baltic Dry Index as measure for aggregate demand (3). The Baltic Dry Index is also being used by practitioners as a predictor for global economic activity (Bakshi, Panayotov and Skoulakis 2012).

$$(3) \qquad e_t = \begin{pmatrix} e_{1t}^{global\ oil\ production} \\ e_{2t}^{baltic\ dry\ index} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{Norwegian\ stock\ return} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

The results are the same as above for oil specific demand shock, being significant for 5-months (Figure 16), while oil production is still insignificant (Figure 15). Interestingly, we find that the Baltic Dry Index is significant over the whole 12-month period when we analyze the impulse response function (Figure 11).

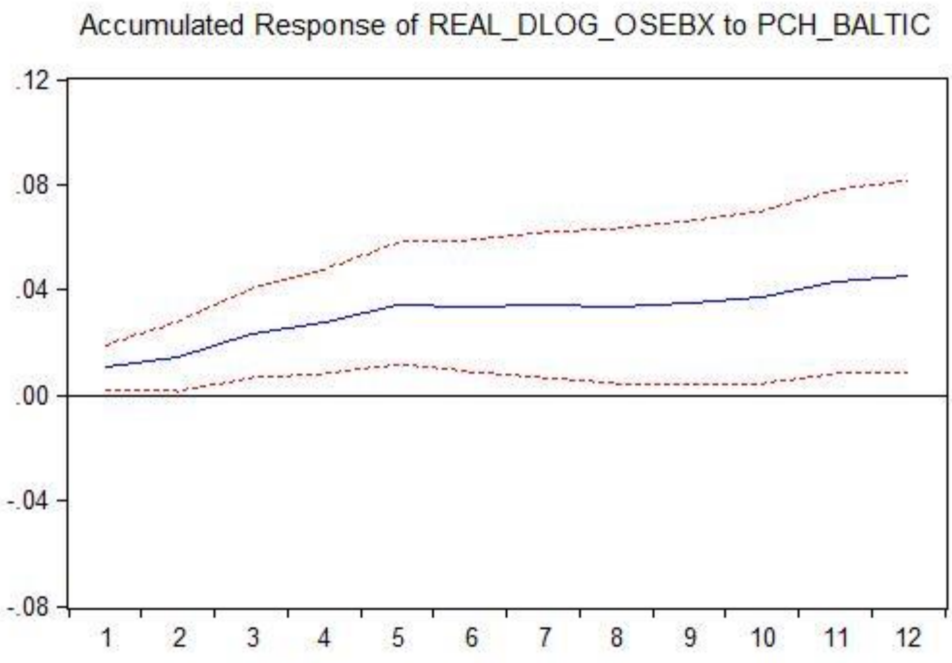

Figure 11: Response of the OSEBX for a one standard deviation shock to the percentage change of the Baltic Dry Index.

The interpretation of Figure 11 is that a standard deviation positive shock to the world economic activity will instantaneously affect Norwegian stock return positively. The shock will stabilize after about 12 months. Studying the variance decomposition (Table 2), we further see that the long run variance of stock returns is now explained 15,95% by the oil specific demand shock, 9,26% by oil production and 8,63% by aggregate demand shock. By changing the world aggregate demand variable to the Baltic Dry Index, we also see that this effect increases by about 5 percentage points, in explaining the long run variance. This is an effect that we expected to find ahead of our analysis. As the Kilian Index and the Baltic dry is constructed a bit differently regarding the composition of the shipping routes included, this could be the reason why we find significance on the Baltic Dry Index, but not in the Kilian Index. This result questions which composition of shipping routes could best explain the world aggregate demand shock on the Norwegian economy. Studying the plot between the two indexes, we notice that during the dotcom bubble in 2001 the Kilian Index increases while the Baltic Dry Index fluctuates less (Figure 12). The financial crisis in 2008, generates a similar pattern in the two indexes. Over our period of study, the correlation coefficient equals 0,13. We consider this relatively low, as both indexes intend to measure some of the same effects. Further, we observe that the correlation between the Baltic Dry Index and the OSEBX is 0,16, while for the Kilian Index and OSEBX is 0,08. In our exchange rate adjusted model we included the Baltic Dry Index as we wanted to highlight the significant difference from the original model containing the Kilian Index. However, using the Baltic Dry Index also has its pros and cons. On the upside, it provides real-time update as a forward looking economic indicator. In addition, the index is difficult to manipulate as the amount of ships is fixed. The reason for this is that one expects to "consume" the good rather than speculation of rising prices. On the downside, although analysts agree that the Baltic Dry Index can be used as a predictor, some argue that it may at times, be too volatile. Commodities by sea tends to be volatile as supply of shipping vessels is inelastic, as the construction of a ship can take up to 2 years.

However, it is ultimately up to the reader to determine which index is the best representation of world aggregate demand.

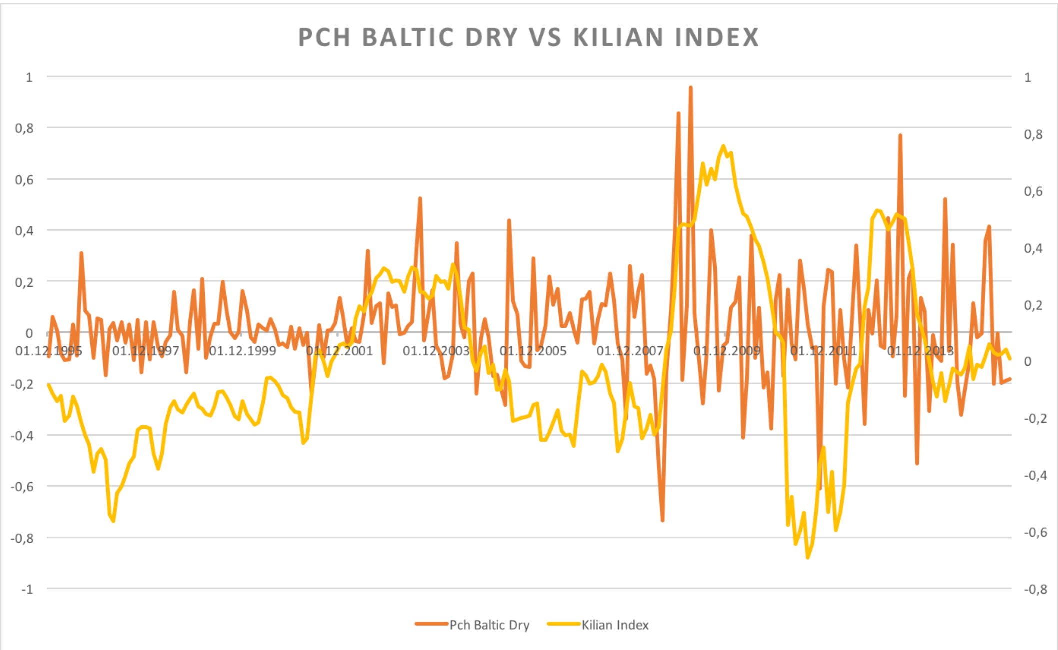

Figure 12: Co-movements Baltic Dry vs. Kilian Index

There are two different ways of adjusting for the exchange rate. The first way is to transform the oil price from quotation in dollars, into Norwegian Kroner (4).

$$(4) \qquad e_t = \begin{pmatrix} e_{1t}^{global\ oil\ production} \\ e_{2t}^{baltic\ dry\ index} \\ e_{3t}^{NOK\ real\ price\ of\ oil} \\ e_{4t}^{Norwegian\ stock\ return} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

This is done by simply multiplying the inflation adjusted oil price in dollars with the NOK/USD-exchange rate. The second way is to keep the inflation adjusted oil price in dollars, but now include a currency variable in the regression. We now have 5 variables (5) instead of 4, placing the new variable between the oil price variable and the Norwegian stock return variable.

$$(5) \qquad e_t = \begin{pmatrix} e_{1t}^{global\ oil\ production} \\ e_{2t}^{baltic\ dry\ index} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{NOK/USD} \\ e_{5t}^{Norwegian\ stock\ return} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{exchange\ rate\ shock} \\ \varepsilon_{5t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

This ordering makes the oil price unaffected by the NOK/USD exchange rate, but the Norwegian stock price will be affected. As the Norwegian economy is small, this makes sense. Thus, it is quite unlikely that the price of oil would be influenced by the Norwegian Krone. At the same time, it appears credible that the Norwegian stock return will be influenced by the exchange rate, depending on whether the Norwegian Krone depreciates or appreciates. Interestingly we find that how we chose to adjust, will have an impact on the results from our model. If we extend our model to include the exchange rate variable, we find that the Baltic Dry Index is significant for 8 months (Figure 18). The currency variable is insignificant (Figure 20) and accounts for 5,24% of the long run variance (Table 3). However, if we simply transform the oil price into Norwegian Kroner, the Baltic Dry Index is significant over the 12-month period (Figure 22) and the oil specific demand shock will become significant for only 3 months (Figure 23).

Comparing the currency real oil price model with the original model including the Baltic Dry Index, we see that there is a difference as to how many periods the real price of oil influences Norwegian Stock return. The difference of 2 periods can be attributed to the fact that the Norwegian Krone appreciates due to a shock in the oil price. This will make the non-oil related sectors in the Norwegian market negatively affected by the decreasing competitiveness compared to the international competitors. This again suppresses stock return.

Conclusion

We have analyzed the impact of oil price shocks to the Norwegian stock returns, using the methodology created by Kilian and Park (2009). By decomposing the oil price shocks into a supply shock, demand shock as a consequence of a booming economy and an oil specific demand shock, we are able to capture how the stock returns are reacting based on different underlying macroeconomic reasons. In order to adjust for the exchange rate, and to make our own mark on the analysis, we have created our own model. In this model we also used a different measure for world aggregate demand.

In the first model, we find that oil demand and supply shocks account for about one third of the long run variation in Norwegian stock return (Table 1). We observe that the response of Norwegian stock return differs, depending on the underlying cause for the oil price shock. A shock to the oil supply is neither statistically significant in the Kilian and Park (2009) approach, nor in either of our adjusted models. The variable does however, account for about 9% of the long run variance in stock return. The aggregate demand, in the first model represented by the Kilian Index, is not significant and accounts for about 3% of the long run variation in Norwegian stock return. Interestingly, when switching to using the Baltic Dry Index as a measure, we achieve significant results and the variable explains about 9% of the total stock return variation. One of the reasons for this could be that the Baltic Dry Index better represents the Norwegian economy's link with the rest of the world economy. The oil specific demand shock, is significant in both models. In both models, it is significant for about 5 months, explaining about 19% and 16% of the long run variation in the unadjusted (Table 1) and adjusted (Table 2) model respectively.

By changing the aggregate demand variable from using the Kilian Index to using the Baltic Dry Index, we have increased the oil variables' explanation of the variation in stock return from 32% to 34%. Comparing these results with those of Kilian and Park (2009), who were able to explain 22% of U.S. real stock returns, while we are able to explain 34% of the real Norwegian stock return.

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Appendix

Table 1: Percent Contribution of Demand and Supply Shocks in the Crude Oil Market to the Overall Variability of Norwegian Real Stock Returns

Horizon	*Oil Supply Shock*	*Aggregate Demand Shock*	*Oil-Specific Demand Shock*	*Other Shocks*
1	0.42	0.72	15.56	83.30
2	0.68	0.91	15.38	83.03
3	0.69	1.27	15.54	82.50
12	8.73	2.69	19.14	69.44
∞	9.19	3.41	19.18	68.22

Note: The Kilian Index is used as the Aggregate Demand measure

Table 2: Percent Contribution of Demand and Supply Shocks in the Crude Oil Market to the Overall Variability of Norwegian Real Stock Returns

Horizon	*Oil Supply Shock*	*Aggregate Demand Shock*	*Oil-Specific Demand Shock*	*Other Shocks*
1	0.35	2.83	11.69	85.13
2	0.50	3.15	11.62	84.73
3	0.65	4.89	11.56	82.90
12	8.95	6.15	15.78	69.12
∞	9.26	8.63	15.95	66.16

Note: The Baltic Dry Index is used as the Aggregate Demand measure

Table 3: Percent Contribution of Demand and Supply Shocks in the Crude Oil Market to the Overall Variability of Norwegian Real Stock Returns

Horizon	*Oil Supply Shock*	*Aggregate Demand Shock*	*Oil-Specific Demand Shock*	*Nok/ Usd*	*Other Shocks*
1	0.13	2.30	12.83	0.58	84.16
2	0.23	2.53	12.80	0.92	83.52
3	0.51	3.71	12.61	1.11	82.06
12	7.92	4.98	17.64	3.16	66.30
∞	8.46	7.93	17.03	5.24	61.34

Note: The Baltic Dry Index is used as the Aggregate Demand measure

Table 4: Percent Contribution of Demand and Supply Shocks in the Crude Oil Market to the Overall Variability of Norwegian Real Stock Returns

Horizon	*Oil Supply Shock*	*Aggregate Demand Shock*	*Oil-Specific Demand Shock*	*Other Shocks*
1	0.25	3.74	5.49	90.52
2	0.35	4.19	5.36	90.11
3	0.59	6.27	5.30	87.84
12	9.01	7.30	10.46	73.22
∞	9.39	9.88	11.09	69.64

Note: The Baltic Dry Index is used as the Aggregate Demand measure and the Oil Price is adjusted to Norwegian Kroner

Figure 10, 13 and 14 represents the results from the model presented by Kilian and Park (2009) using the Kilian Index as the aggregate demand measure.

Figure 13:

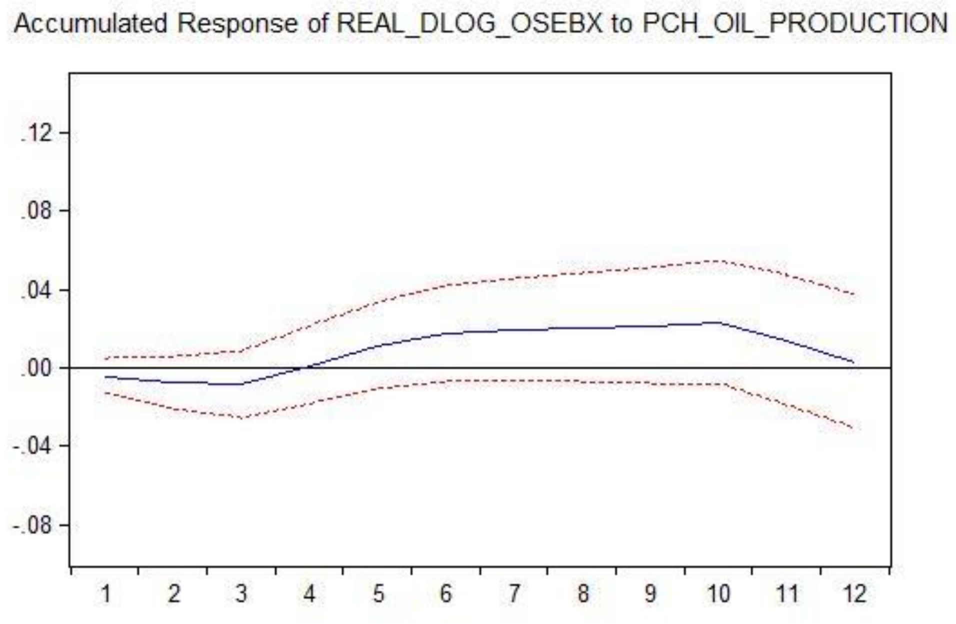


Figure 14:

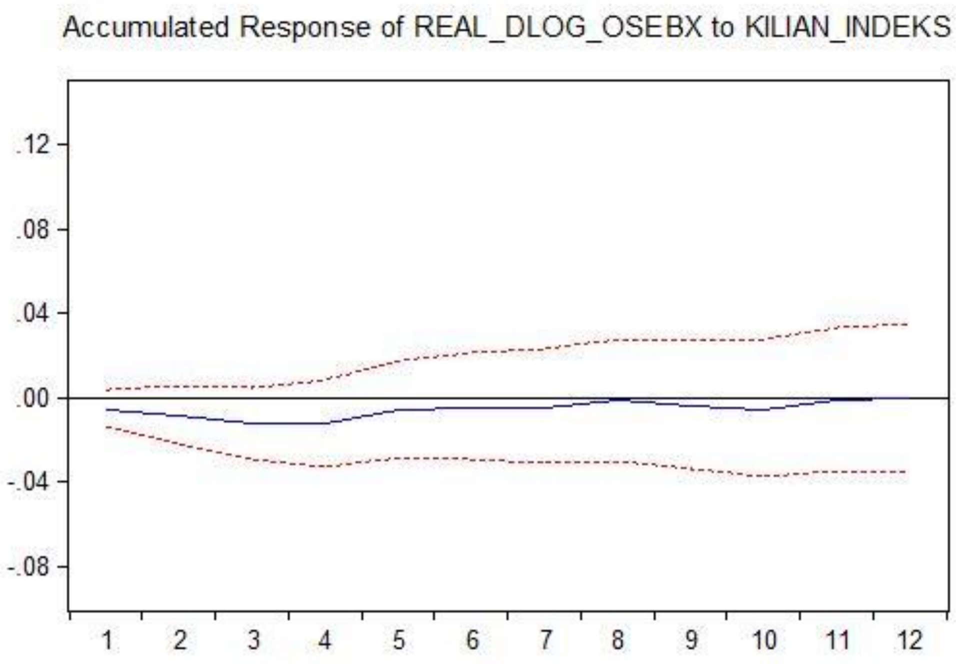


Figure 11, 15 and 16 represents the results from our own model using the Baltic Dry Index as the aggregate demand measure.

Figure 15:

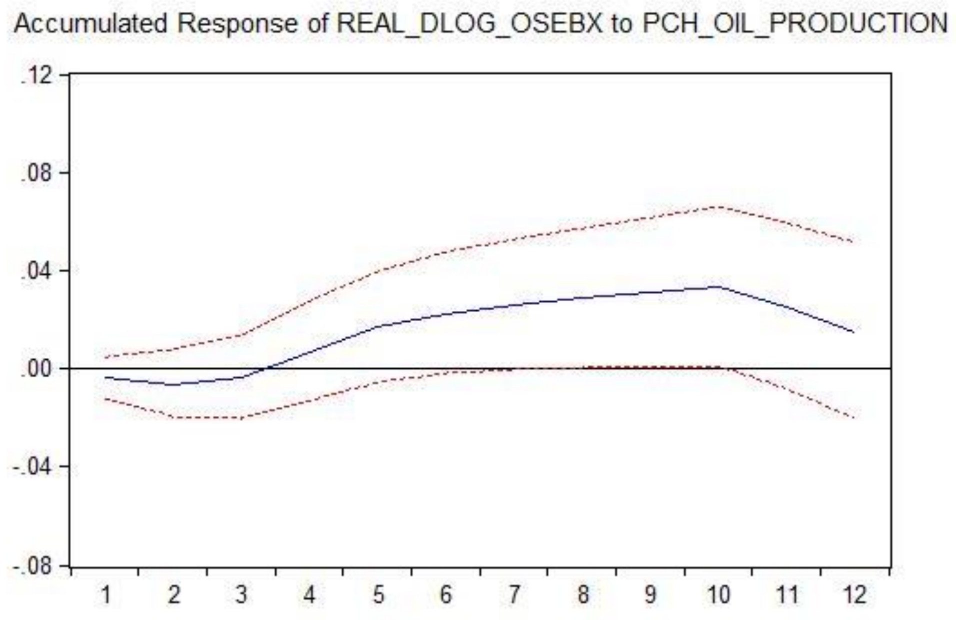


Figure 16:

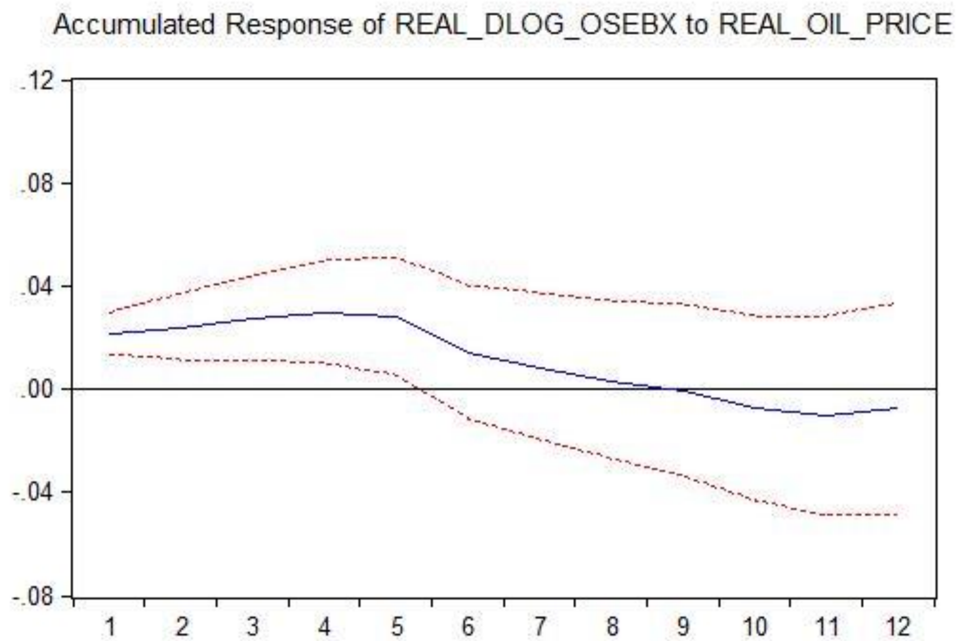


Figure 17-20 represents the results from our own model using the Baltic Dry Index as the aggregate demand measure and including the USD/ NOK exchange rate.

Figure 17:

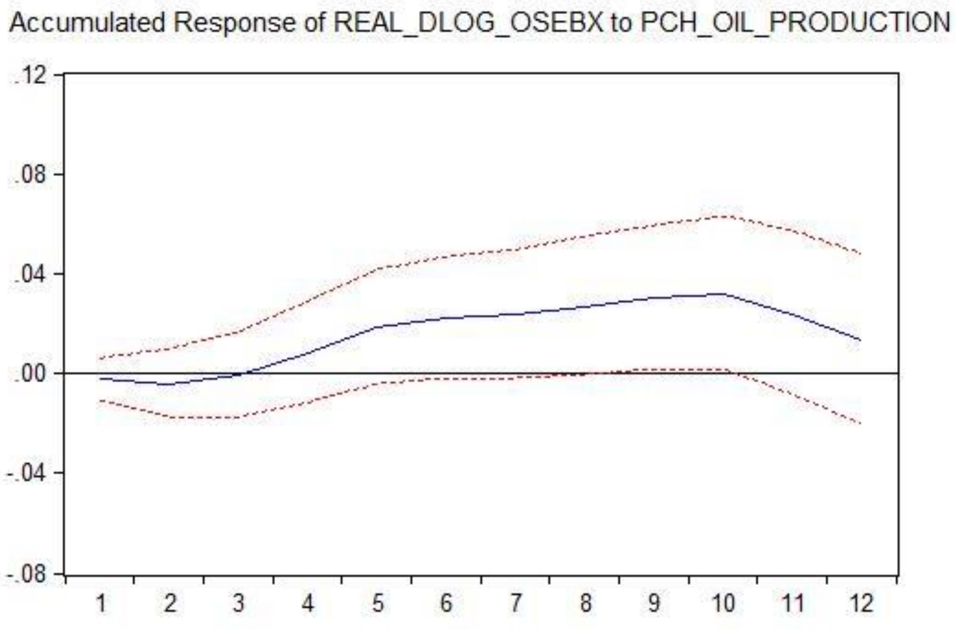


Figure 18:

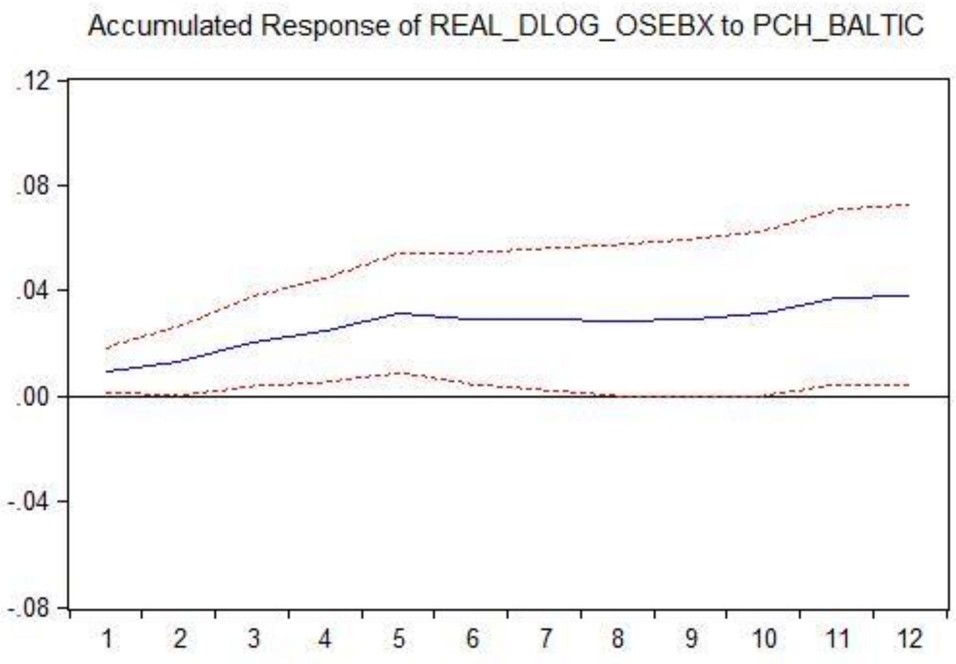
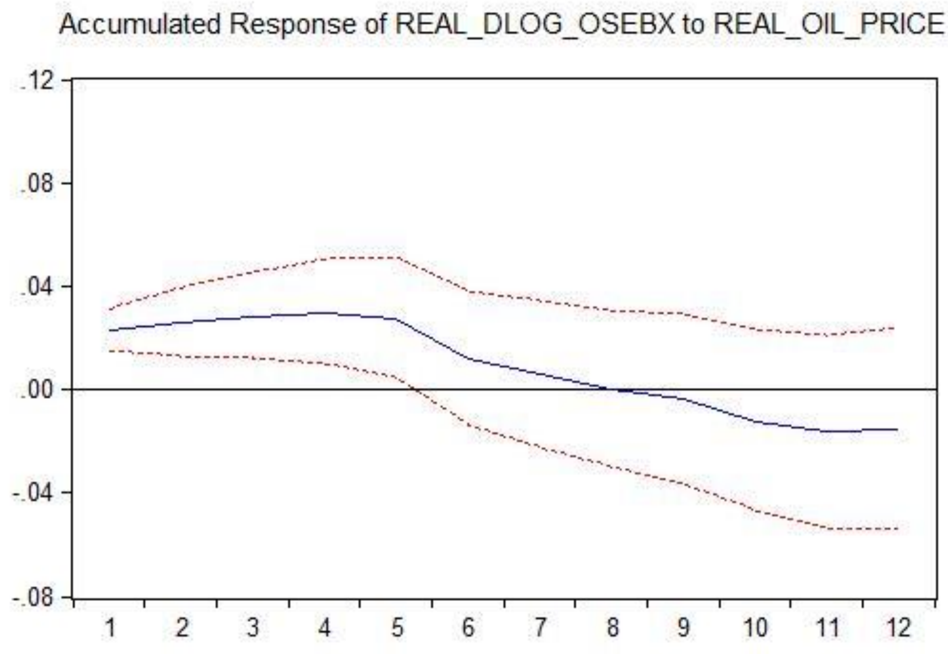


Figure 19:


Accumulated Response of REAL_DLOG_OSEBX to REAL_OIL_PRICE
.12
.08
.04
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-.04
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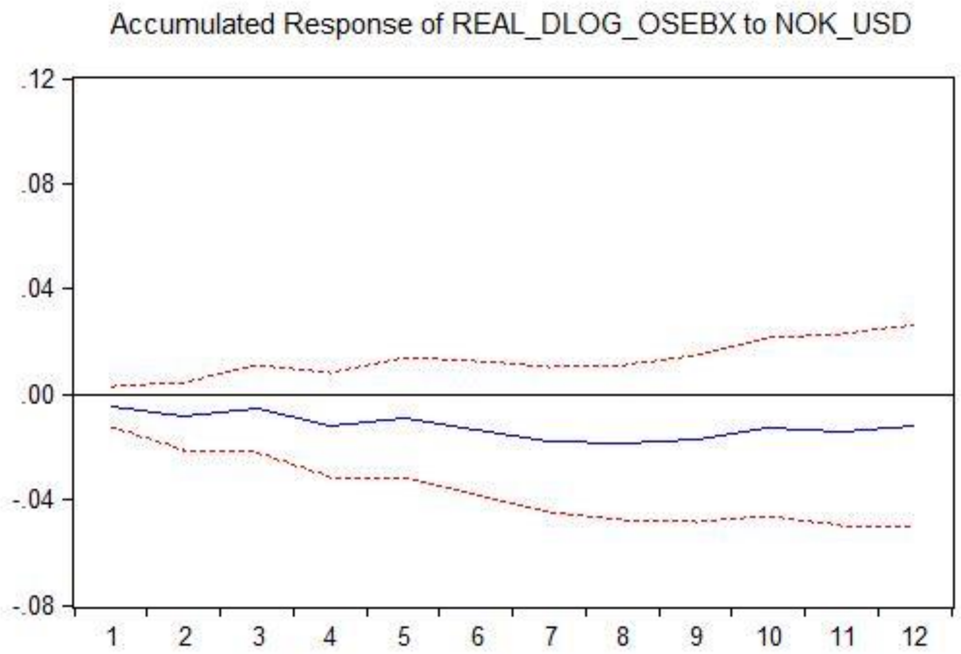
12

Figure 20:


Accumulated Response of REAL_DLOG_OSEBX to NOK_USD
.12
.08
.04
.00
-.04
-.08
1
2
3
4
5
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10
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12

Figure 21-23 represents the results from our own model using the Baltic Dry Index as the aggregate demand measure and exchanging the real oil price into Norwegian Kroner.

Figure 21:

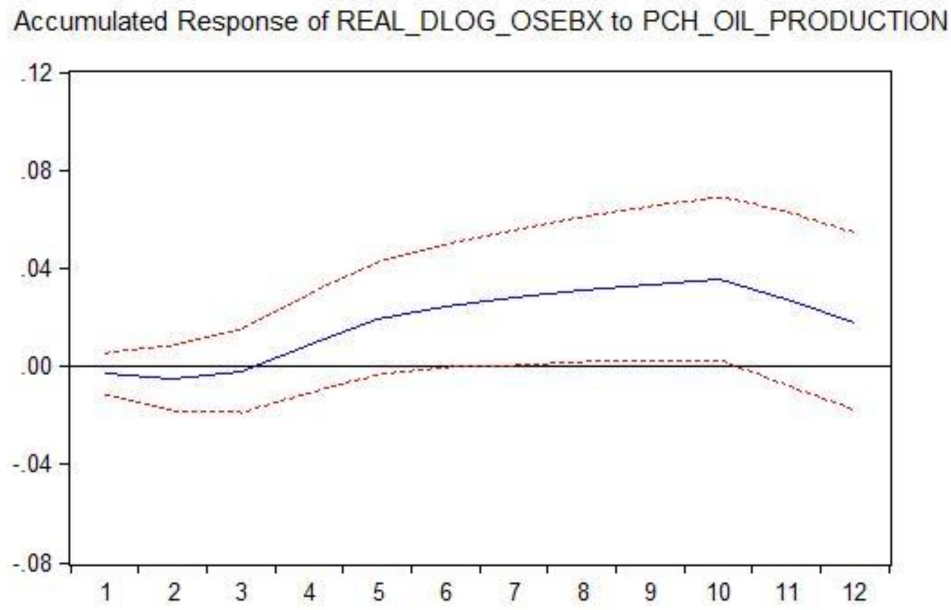


Figure 22:

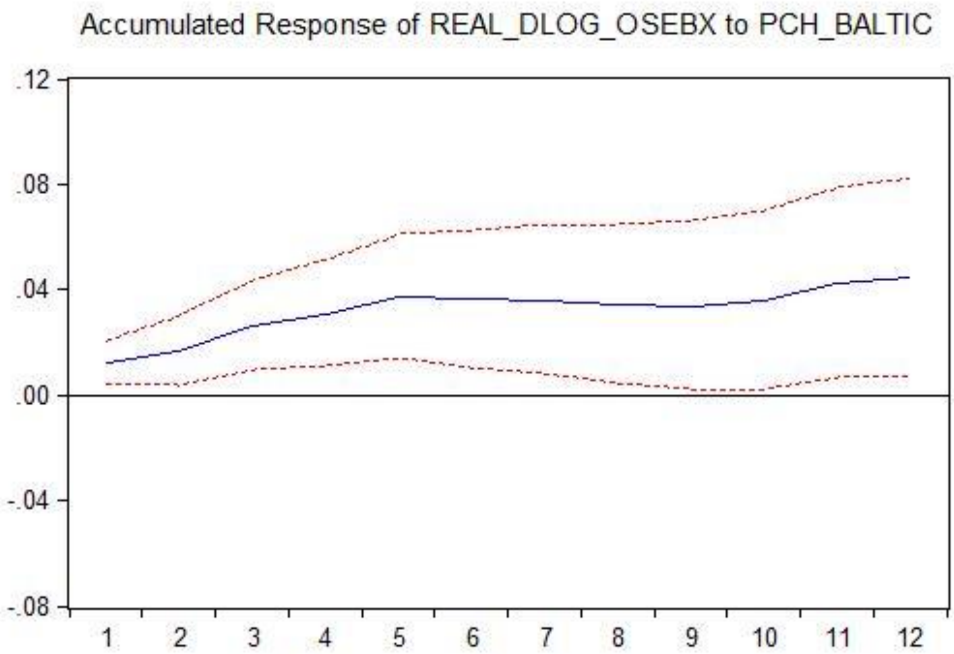


Figure 23:

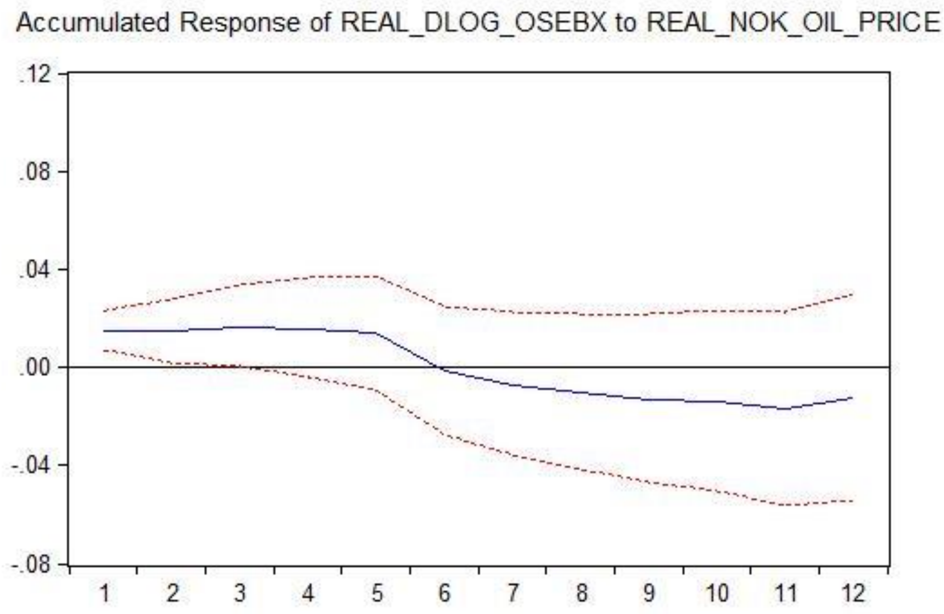


Figure 24-27 are unit root tests with trend and intercept.

Figure 24: Unit root test, Kilian index

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.62622	0.0001	4	952
Breitung t-stat	-1.09540	0.1367	4	948
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-14.9585	0.0000	4	952
ADF - Fisher Chi-square	220.226	0.0000	4	952
PP - Fisher Chi-square	230.985	0.0000	4	954

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 25: Unit root test, unadjusted Baltic Dry

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.84580	0.0000	4	951
Breitung t-stat	-1.53776	0.0621	4	947
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-22.4956	0.0000	4	951
ADF - Fisher Chi-square	328.872	0.0000	4	951
PP - Fisher Chi-square	338.855	0.0000	4	953

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 26: Unit root test, Exchange rate variable

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-4.97688	0.0000	5	1190
Breitung t-stat	0.12886	0.5513	5	1185
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-19.2421	0.0000	5	1190
ADF - Fisher Chi-square	328.920	0.0000	5	1190
PP - Fisher Chi-square	338.948	0.0000	5	1192

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 27: Unit root test, NOK oil price

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-11.9900	0.0000	4	952
Breitung t-stat	-1.91496	0.0277	4	948
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-22.4193	0.0000	4	952
ADF - Fisher Chi-square	328.644	0.0000	4	952
PP - Fisher Chi-square	338.782	0.0000	4	953

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 28 and 29 are sector composition on the OSEBX index.

Figure 28: (Source: Oslo Børs, 2nd of January 1996)

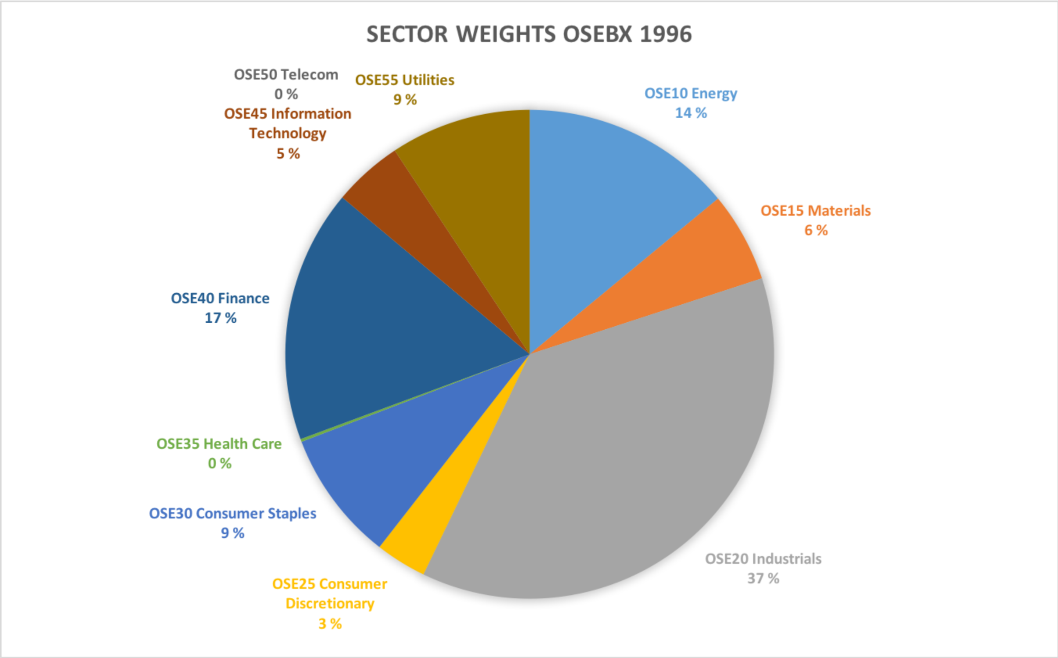
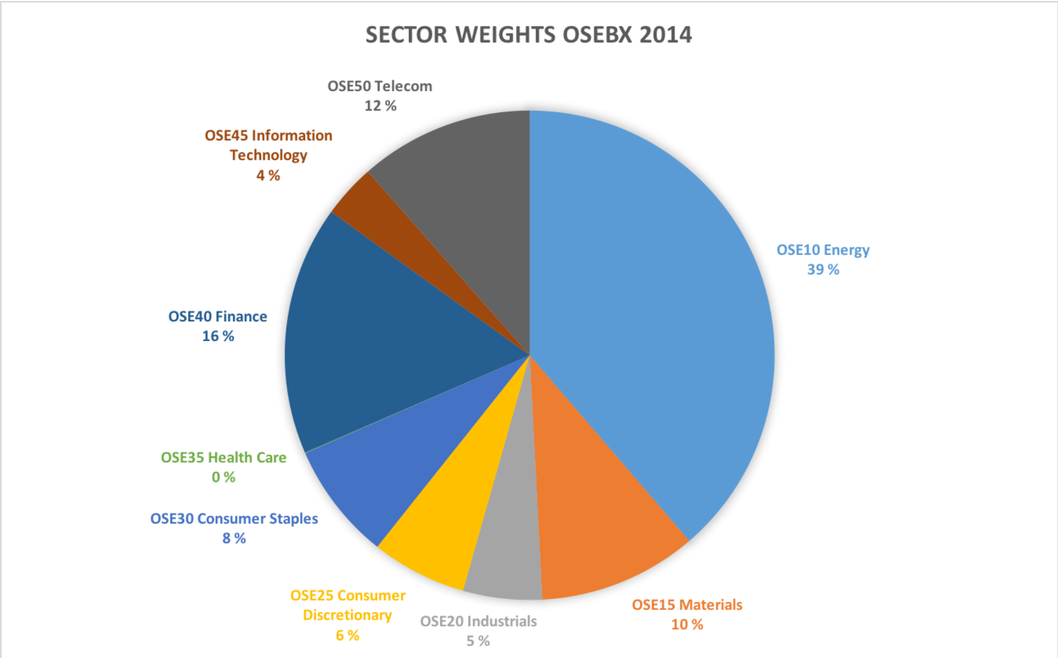


Figure 29: (Source: Oslo Børs, 2nd of May 2014)



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BI Norwegian Business School
Preliminary Thesis Report

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-Oil Price Shocks on Norwegian Stock Returns-

Supervisor:
Håkon Tretvoll

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GRA 19003 – Preliminary Thesis Report

Program:
Master of Science in Business – Major in Finance

Table of content

Introduction

Question

In our master thesis we have chosen a topic of relevance today, the relationship between oil and Norwegian stock return. The oil price has since June 2014 suffered a severe drop, and the world economy has since then experienced turmoil. We have however seen that the Norwegian value weighted portfolio (OSEBX) has steadily increased, and reached 661.32, which is a new all-time high (15.04.2015, Netfonds). Our approach towards the relationship between the oil price and stock returns, is angled differently than other previous papers on this matter. We would like to figure out if the Norwegian stock market is driven by the oil price, but contrary to prior research, how different types of shocks differ in their impact on the Norwegian stock market. When we question the impact of different shocks, they are defined as an event that produces a significant change to the oil price. Shocks have been studied earlier in the Norwegian market, but not in the way we will define supply and demand shocks to the oil price. It will be explained later in this paper.

The relationship between the OSEBX and oil price, based on our ex ante belief seem to have a positive relationship. However, to the naked eye our positive relationship assumptions seem to be challenged, by positive stock return and falling oil price. We therefore question if the Norwegian stock market is as oil dependent as researchers claim (Park and Ratti 2008).

We found an article written by Kilian and Park (2009) which addresses our question at hand. Our methodology will be based on their work, except that we will use data for the Norwegian market. Their work is based on the findings from Kilian (2009), who argues that it exists limitations on prior work on the relationship between the oil price and stock returns. The question we would like to address, is how different supply and demand shocks to the oil market affect stock returns. We would also try to question the relationship between oil shocks and the economy, as we try to treat all variables dependent on each other.

Motivation

The Norwegian economy has for decades relied its wealth on crude oil. Since the 1960´s, the Norwegian government has been pumping out oil of the Norwegian continental shelf and is today the industry that contributes the most to Norwegian value creation (Regjeringen 2015). Crude oil is in general considered as one of the world's most important commodities, as it transforms into a large number of consumer products. In 2014, 30.8% (SSB 2015) of Norwegian export were crude oil. As crude oil is not an everlasting commodity, which has shown to impact the Norwegian economy for decades, we think of oil as an interesting topic.

The Norwegian stock index has for years been considered to have a direct relationship with the price of crude oil. Our belief is however that after the financial crisis, the returns of Norwegian stocks and crude oil price do not have the same relationship as previously assumed. The oil price has plummeted while the index is more or less unchanged. We find this relationship interesting. As the global society is increasingly focusing on green energy, in the light of the recent Paris treaty, we wonder how the Norwegian stock return will behave as we expect a shift towards renewable energy. Has the Norwegian economy managed to shift its reliability away from oil or is it still persistent? As of that, we would like to know more about the foundation for this relationship, if there is one.

We find the U.S. shale oil production to play an interesting part towards our question at hand. As shale oil production incorporates a big learning-by-doing experience, OPEC fear that U.S. oil production will be able to outperform their own. The reason for this fear, is the cost advantage that shale oil has. Oil has been banned from exports in the U.S. since the 1970's. In December 2015, the ban was voted to be ceased (Arnsdorf and Wingfield 2015). The fierce competition between the two parties, may have played a role in the new oil price crisis we have today. It is said that if the U.S. starts to export oil again, we may face a geopolitical storm and a new financial crisis (Tverberg 2015). Our motivation is to understand how the oil market works, and how it impacts the economy.

Given the current market price on crude oil (10th January 2015, Nissen-Mayer), none of the Norwegian oilfields are profitable. This means that about 330 000 employees who work directly or indirectly within the industry, (Norsk Olje og

Gass 2015) will be affected by the consequences of a low oil price. Because of the lack of profitability for the oil fields, it is expected that the number of jobs in oil related industries will decrease, and cause a domino effect in the economy as a whole. This illustrates the importance of our thesis.

Literature review

Our study is based upon the research paper written by Kilian and Park (2009). Their study examines the impact of shocks to crude oil prices on the U.S. stock market. We will however focus on the Norwegian stock market. The article uses a different methodology than prior studies because it takes into account two previous limitations. Firstly, oil price needs to be treated as an endogenous variable with respect to the economy. The reason for that is that crude oil price responds to some of the same factors that drive stock returns, which should be controlled for by reverse causality (Barsky and Kilian 2002, Kilian 2008 a,b). This means that the cause and effect are not well defined in the regression of stock return on oil price changes. Second, they argue that without knowing the underlying reason for changes in oil prices, different shocks to the oil market have different effects on the economy and the price of oil (Kilian 2009 and 2008c). According to Kilian and Park (2009) earlier studies have shown mixed results on the relationship between oil price and stock prices. Kling (1985) found that increase in oil price is associated with declines in U.S. stock returns but Chen, Roll and Ross (1986) found no evidence of that.

Kilian and Park found that the relationship between oil prices and stock returns differ depending on the type of shock to the oil price. They divide shocks into; oil supply shock, global demand for all industrial commodities that are driven by global economic activity (aggregate demand shock) and precautionary demand for oil (oil-market specific demand shock). The framework used, which will be discussed in detail later, is a vector autoregressive (VAR) model. The VAR model is used to understand the importance of oil shocks and the dynamic stochastic general equilibrium (DSGE) model is used to highlight the macroeconomic implications of their findings of the link between stock prices and oil prices.

They found that shocks to crude oil production has no effect on cumulative U.S. stock returns. When the oil price increases, they discovered a negative reaction on U.S. stock prices given precautionary demand shocks. An increase in oil price because of unanticipated global economic expansion have positive effects on cumulative U.S. stock return within the first year of the expansionary shock.

Ratti and Park (2008) investigate some of the similar aspects of the relationship between oil price shocks and stock returns for the U.S. and 13 European countries. They find that oil price shocks have a significant impact on stock returns in the same month as the shock occurs, or within the next month. Similar to Kilian and Park's findings above, Ratti and Park also conclude that that oil shocks matters to U.S. stock returns. In addition, they find that Norway has a significant statistically positive reaction of stock returns to an oil price shock increase. We find this relationship questionable today, because of the development between OSEBX and the oil price. Our data sample will additionally include 9 essential years beyond Kilian and Park's sample, where we have seen two major fluctuations in the oil price, 2007-2008 and 2014. This may impact our findings.

It exists a lot of literature on the topic between oil price and stock returns in Norway. We believe however, that our angle is different in terms of the Norwegian perspective, as we will also focus on the reasons and implications of oil price shocks. Gjærde and Sættem found in 1999 that Norway as a strong oil dependent economy, responds to oil price changes. They also conclude that the interest rate is a substantial factor for explaining stock returns.

Kilian (2009) wrote an article where he explains why it is important to define the different components of oil shocks. As mentioned earlier, the oil price decomposes the oil price shocks into components that can be explained by macroeconomic factors. After reading numerous articles about the topic at hand, with all papers arriving at the same conclusion, that the oil price does effect Norwegian stock returns. It will be interesting to use a different approach than prior research, and also see how the latest data will impact the earlier models.

Theory

VAR model

The vector autoregressive model (Brooks 2014, 326-338) is a systems regression model where it exists more than one dependent variable. The model allows the variables to be dependent on each other. A variable's current value is therefore equal to the lagged previous values of itself and the other variables plus the error term.

$$Y_{1t} = \beta_{10} + \beta_{11}Y_{1t-1} + \ldots + \beta_{1k}Y_{1t-k} + \alpha_{11}Y_{2t-1} + \ldots + \alpha_{1k}Y_{2t-k} + u_{1t}$$

$$Y_{2t} = \beta_{20} + \beta_{21}Y_{2t-1} + \ldots + \beta_{2k}Y_{2t-k} + \alpha_{21}Y_{1t-1} + \ldots + \alpha_{2k}Y_{1t-k} + u_{2t}$$

A useful property of the VAR model is that the researcher does not need to specify which variables are exogenous and endogenous, simply because they are all endogenous. The reason this being so important, is that one of the requirements for simultaneous equations is that all of the variables in the system needs to be identified. In other words, this is a condition that treats some of the variables as exogenous. A second useful property stems from the fact that a variable is able to depend on lags from one or more of the other variables and not just its own. This offers a richer structure, which means that it is able to capture more features of the data. Lastly, provided that there are not any contemporaneous terms on the right hand side (RHS), one can use OLS estimation on each separate equation. This has to do with that all of the variables on the RHS are predetermined prior to time t=0. One of the criticisms against the VAR models is they are a-typical. That is, they are based on empirical research rather than having their foundation based on theory. Further, when estimating a VAR model we end up with so many variables, that it sometimes can be confusing.

Financial theory will have less to say when deciding the appropriate lag length for a VAR model. There are two methods for determining the optimal lag length: cross-equation restriction and information criteria. The coefficients need to be tested on a set of lags on all variables for all equations at the same time.

Block recursive structure

Block recursive means (Dixon 2008) that a system of equations is unidirectional dependency among the endogenous variables. The recursive model will determine the endogenous variables one at a time in sequence, meaning that there is a one-way relationship between the endogenous variables.

$$Y_1 = \beta_1 \mathrm{x} + \epsilon_1$$
$$Y_2 = \beta_2 x + \gamma_{21} Y_1 + \epsilon_2$$
$$Y_3 = \beta_3 \mathrm{x} + \gamma_{31} Y_1 + r_{32} Y_2 + \epsilon_3$$

We see that Y_1 affects Y_2, but Y_2 does not affect Y_1 directly or indirectly.

Ordinary least squares

Ordinary least squares (OLS) method is a common way of estimating the relationship between two variables (Brooks 2014, 75-80). In the simple regression case, we have one dependent and one independent variable. As we plot our sample, we want to draw a line between the observations so that we minimize the squared residuals. That is the squared difference between the drawn line and the different observations. The dependent variable is defined by a constant, the explanatory variable multiplied with a coefficient plus an error term.

$$Y = \alpha + \beta X + u$$

A researcher would be seeking to estimate the values of α and β. By knowing the values of these parameters, one is able to say something about the relationship between the two variables. This can be very useful in certain situations. If for instance X is observable, but not Y, we can for a given value of the independent variable find an approximation for our dependent variable.

Bootstrap method

Bootstrapping (Brooks 2014, 597-600) is a statistical technique that allows for assigning measures of accuracy to sample estimates. It is used to obtain description of the empirical estimators by using the data points themselves and sampling repeatedly with replacement from the actual data.

Given that a sample of data Y = Y_1, Y_2, ….., Y_T are available, and it is needed that we estimate some parameter θ. We get an approximation of the statistical properties of $\widehat{\theta_T}$, when taking N samples of size T with replacement from Y and re-calculating $\hat{\theta}$ with each new sample. A series of $\hat{\theta}$ estimates will be obtained and their distribution can be studied.

Preliminary methodology

We will base our methodology on the work presented by Kilian and Park in 2009. The main difference will be that we base our work on Norwegian data. As mentioned earlier, previous research suffers from two major limitations. Firstly, oil prices have been treated exogenous with respect to the economy, making it difficult to separate cause and effect. Secondly, if one is able to control for reverse causality, previous models show that the effect of an exogenous increase in the price of oil is the same, regardless of the reason for the price increase (Kilian and Park 2009). In order to adjust for these limitations, we will use a VAR model. A VAR model, can often be very effective when working with time series data with multiple variables. It is a system regression model, which means that there is more than one dependent variable.

In the structural VAR model that we will use, we relate stock market variables to measures of shocks in the supply and demand of the crude oil market (Equation 1). The variables of interest are included in the time series vector z_t. In this vector we find the percentage change in world crude oil production, the real activity in global industrial commodity markets, the real price of crude oil, and the Norwegian stock market variable of interest. The latter variable has been replaced to contain Norwegian rather than U.S. data. The structural representation of the model is as following:

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \varepsilon_t$$

Equation 1

As previously mentioned, z_t is the vector where we find the variables of interest. A_0 is an important factor in this model. The A_0 matrix expresses the relationship between the variables included in the z_t vector, and is a result of the fact that the variables influence each other when a shock occurs. The left hand side here responds to the variables on the right hand side of the equation. Here we find the summation sign that represents twenty-four lags of the dependent variable, which equals two years. Each lag is a previous monthly observation. This makes the model able to capture effects that takes more than one year to respond to the different supply or demand shocks of oil. Perhaps the most important part of the model however, is ε_t. This error term denotes the vector of serially and mutually uncorrelated structural shocks to the oil price. Further the α represents the constant vector of the regression.

We then solve the equation for z_t and hence, we must multiply the equation with A_0^{-1}. The result is a reduced form of the VAR model. We let $e_t = A_0^{-1}\varepsilon_t$. In order to explain the contemporaneous relationship between the reduced shocks and the underlying structural innovations, several restrictions are imposed on A_0^{-1}. Using a block-recursive structure, the restrictions form an upper triangular matrix as shown below. The assumptions are based on economic relationships and will be discussed later. The model is now more consistent, and the variables can be estimated using ordinary least squares.

$$e_t \equiv \begin{pmatrix} e_{1t}^{\Delta \, global\ oil\ production} \\ e_{2t}^{global\ real\ activity} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{U.S.\ stock\ returns} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

Figure 1

In the oil market block (Figure 1), the shock in the real price of oil are broken into three different components. ε_{1t} represents a shock in the global supply of crude oil, ε_{2t} captures the shocks related to the demand of all industrial commodities due to aggregate global demand associated with a booming global economy and ε_{3t} denotes the oil-market specific demand shock. An oil-market specific demand shock can for instance capture a shift associated with the fear of future shortfalls, so called precautionary demand. By construction, this shock is orthogonal to the other shocks. When a vector is replicated, and the sum of the first two vectors are not parallel to the original vector, the third and last vector can be constructed orthogonally so that the sum is equal to the decomposed vector. The precautionary demand arises when future expected supply is lower than future expected demand. It reflects the convenience yield of having access to stored inventories of oil in case of oil shortfalls. The last variable in the oil market block, ε_{4t}, has nothing to do with shocks in the oil price. This variable reflects shocks in the real stock returns that are not driven by a shock in crude oil prices.

As mentioned before, this model imposes restrictions based on a block-recursive structure. This means that variable 1 can influence variable 2, but not vice versa. This can be seen from the upper triangular matrix (Figure 1). We can see that a change in global oil production is not affected by any other variables. The global real activity is influenced by the global oil production, and the real price of oil is determined by the global oil production and the global real activity and so on, but it does not affect each other the other way around. This is one of the properties when using a block-recursive structure. In the first block of the matrix, we find that there are 3 restrictions. These restrictions are consistent with the fact that the supply curve of crude oil in the short-run is vertical while the demand curve is downward sloping. A parallel positive shift in the demand curve associated with a higher demand for crude oil, will lead to an instant increase in the price of oil. Adjusting the oil production and the costs associated with it, will lead to a delayed response and is assumed to not to occur within the month. Increases in the real price of oil that are caused by oil-market specific factors, will not lead to a lower global real activity. The last restriction tells us that shocks to the oil price that cannot be attributed to an oil supply shock or a shock to the aggregate demand, must be a demand shock that are specific to the oil-market.

If we look closer on the second block of the matrix that is the Norwegian stock market block, we see that this is consists of only one equation. Through the use of the block-recursive structure, we see that the world's oil production, the world's real activity and the real price of oil, are all treated as predetermined with respect to Norwegian stock returns. In other words, the Norwegian stock returns are allowed to react to all of these variables. The assumption that the last variable ε_{4t} does not affect any of the supply and demand shocks, is still maintained. But as these supply and demand shocks will influence the Norwegian stock market in the long term, the assumption for the ε_{4t} variable is only valid for delays in recent periods.

Normalization is also an important part of the methodology. The oil supply shock has been normalized to represent one negative standard deviation. The aggregate demand shock and the shock in precautionary demand on the other hand, have been normalized to represent a standard deviation in the positive direction. In this way, they are all constructed to represent an increase in the price of oil. These shocks have been analyzed cumulatively by constructing a historical decomposition over a longer period of time, as opposed to using an impulse response function. By using this technique, we will be able to find the result of a shock series over a long period time and not the effect from a particular shock. It is this long term relationship that we are interested in. Further, the standard deviations have been constructed using the bootstrap method. After having run the model and gotten the estimates, the coefficients are being tested in hypothesis tests in order to determine their significance.

By using this model and methodology, we can analyze several economic relationships by changing and adjusting the variables at hand. Since dividends affect stock return, this is also something we would like to investigate. We therefore perform an analysis, where we analyze the oil supply and demand shocks on the Norwegian real dividend growth. This can be done by substituting z_{4t} (real Norwegian stock return) with dividend growth, and running the model again.

We realize that the Norwegian and the U.S. economy is different. Since the Kilian and Park framework is based on the U.S. economy, it may be necessary to impose our own restrictions and assumptions on the methodology described above.

Data

In our thesis, we will need to find data for the variables mentioned in the methodology part. The sample period will be from around 1980/ 1990 until today depending on data availability. All data used will be monthly.

- We will construct percentage change in global production of crude oil using data from U.S Department of Energy (DOE) or from U.S. Energy Information Administration.
- Real price of oil is based on the U.S. refiners acquisition cost of crude oil from U.S. DOE. Kilian and Park (2009) extrapolated their data from January 1974 back to January 1973. If we want to expand our data sample period, this may be plausible. The nominal price of oil needs to be deflated by the Norwegian consumer price index (CPI) from SSB.
- Construct a measure of monthly global real economic activity, to capture across the board shifts in the global demand for industrial commodities. That measure is constructed from an equal weighted index of the percent growth rates obtained from a panel of single voyage bulk dry cargo ocean shipping freight rates measured in dollar per metric ton. Depending on which currency we would like to operate in, we would optionally adjust for this. This data is available in a monthly report on "Shipping Statistics and Economics" published by Drewry Shipping Consultants Ltd. We are able to use this data because an increase in dry cargo ocean shipping rates given inelastic supply of suitable ships, will be indicative from an increase in global activity (Kilian 2009). The nominal index will be deflated using the Norwegian CPI. If the construction of an index is not plausible, we have the possibility to use monthly global real activity from OECD. However, OECD industrial production index exclude real activity in China and India. It would not be optimal, as China and India are thought to be the reason for a surge in demand for industrial commodities.
- Aggregate Norwegian real stock returns will be constructed by subtracting CPI from the log returns of a value weighted market portfolio (OSEBX) found from Bloomberg.
- Aggregate Norwegian dividend growth rate is constructed from monthly returns on the value weighted market portfolio with and without dividend, following a method constructed by Torous, Valkanov and Yan (2004)

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