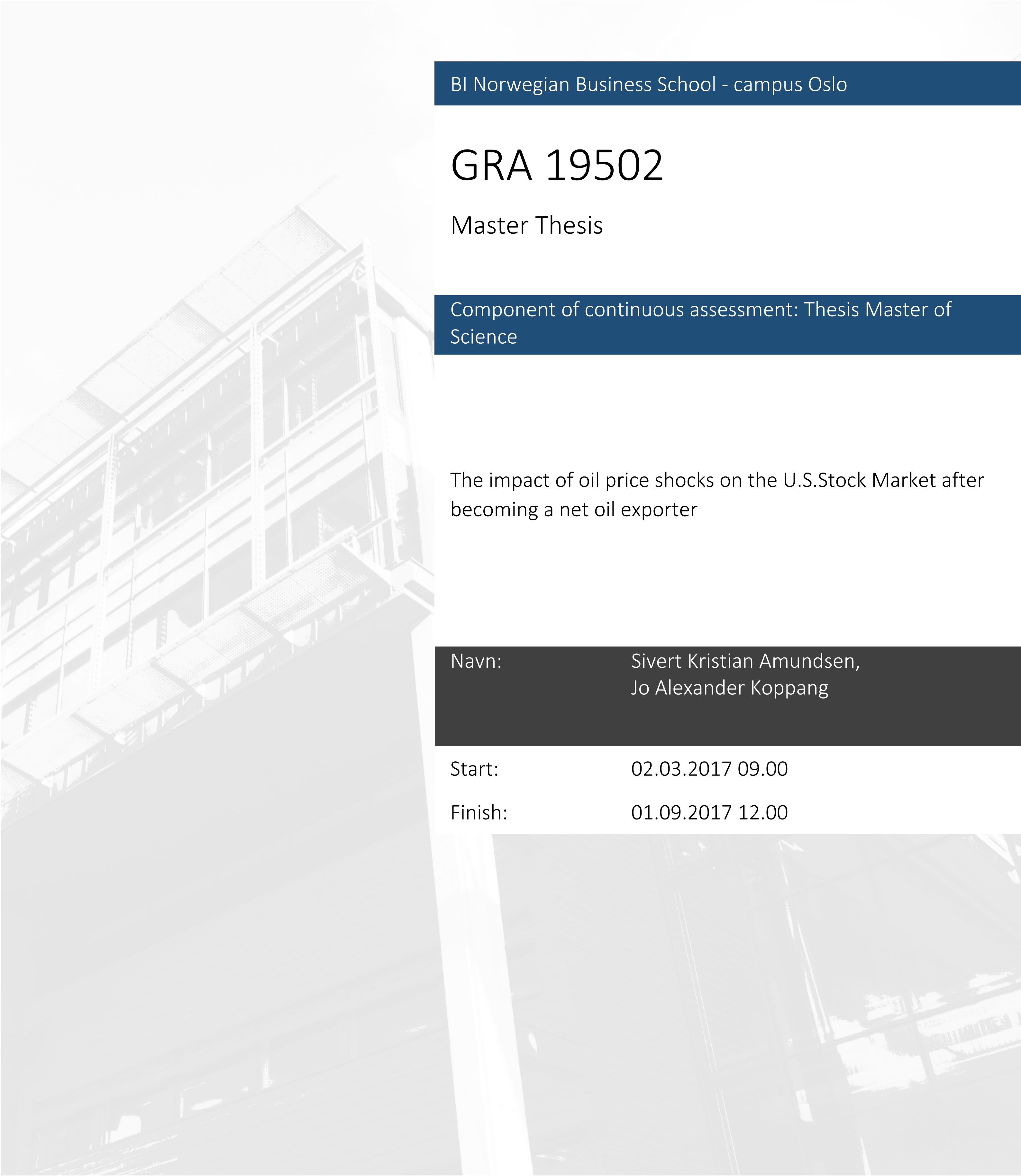

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Master Thesis

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The impact of oil price shocks on the U.S.Stock Market after becoming a net oil exporter

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Abstract

In our thesis, we study the effects of oil price shocks on the U.S. stock market. The U.S. has transitioned from being a net importer of oil, to becoming a net exporter in recent years. This is mainly due to "The Shale Oil Revolution" which was made possible by technological innovation. Our main analysis is motivated by our hypothesis that U.S. real stock returns now react positively to a positive oil price shock. Contrary to the old common perception that stock returns in the U.S. decrease when the oil price increases. We used the framework by Kilian & Park from their article "The Impact of Oil Price Shocks on The U.S. Stock Market" (2009). They used a Structural Vector Autoregressive (SVAR) model, to capture the dynamics between the variables. Using our subsample in our model, we found that U.S. stock returns now respond positively to positive oil price shock. After our main analysis, we offer some critique to Kilian & Park, mainly regarding The Kilian Index, as well as discuss other possible specifications of the model.

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1. Introduction

Out of all the variables that affect the global economy, the oil price might be the one of highest importance. For more than a century, oil’s impact and dependence throughout the world increased, as the world’s demand for oil grew during the 20th century. However, the effects of an oil price shock are still heavily debated, both on an empirical and theoretical level. Many studies over the years have researched the relationship between oil prices and stock markets, but there has not been any clear consensus on the effects of oil price fluctuations on U.S. stock returns[1]. In the paper “The impact of oil price shocks on the U.S. Stock Market” (Kilian & Park, 2009). Kilian & Park argued that demand and supply shocks in the oil market led to different macroeconomic outcomes. They found that precautionary demand shocks, where the oil price increases due to expectations about future oil prices, led to a decline in the U.S. stock market returns. Aggregated demand shocks on the other hand, had a positive effect on stock returns for a year before the pressure of higher oil prices eventually had a negative effect. Supply shocks in the oil market did not seem to have any significant effect. They also found that a fifth of variation in the U.S. Stock Market could be explained by supply and demand shocks in the oil market.

Kilian & Park´s dataset ran until 2006.12, and since then we have had a financial crisis, more volatility in the global economy, and the U.S. has almost doubled their production of crude oil, and subsequently transitioned from being a net importer to a net exporter. The aim of our thesis is to investigate if the U.S. stock market has become more oil dependent, so that the response of the stock market to a structural positive oil price shock now leads to increased returns, as opposed to the previously held common belief of a negative reaction when crude oil prices increased.

In a strict replication of Kilian & Park (2009), we have investigated the robustness of their model, and their results. We have gathered data from the same sources, in an attempt to replicate both their data and their findings. We then extended the data set with 10 years to 2016.12 to see if their results are still valid. Our results were similar

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[1] See Literature Review section 2.2.3

to the original sample, however, it seemed to show signs of change with the extended data. In view of everything that has happened in both the global and U.S. oil markets since Kilian & Park´s paper, we focused on a shorter, more recent subsample to augment the developments in the aforementioned markets. Hence, we specified a subsample from 2001.1 to 2016.12. Primarily to capture the changes that occurred after Kilian & Park´s data set ended, and to study if there had been any changes in the variables we are studying. We compared our results with Killian & Park’s original findings, and the response of U.S. stock returns seems to have changed from reacting negatively to positively, indicating that our hypothesis might have been warranted. This implies that US stock returns’ relationship with the real price of oil appears to have changed in recent years.

After our main analysis, we tested the robustness of Kilian’s Index by comparing it to The World Steel Production Index and The OECD Industrial Production Index, as proxies for global economic activity. The OECD Industrial Production Index is commonly used in economic research, and The World Steel Production Index was proposed by Ravazzolo and Vespignani (2015) as a new proxy for global economic activity. There are a few issues regarding the Kilian Index, and we found that perhaps The World Steel Index is better suited as a proxy for global economic activity as the responses when using it are more in line with economic theory.

The thesis is organized in the following way:
Section 2, describes the background information of our thesis. It starts by presenting our motivation for choosing this topic. After 2006, and Kilian and Park`s paper, a great deal has happened in the US economy, the global oil market and the U.S. petroleum sector. The U.S. has gone from being a net importer to a net exporter of oil. In light of this, we believe the U.S. Stock Market might react differently to fluctuations in the oil price, compared to when Kilian & Park reached their conclusion. In section 2.2 we present the most relevant studies regarding oil price shocks, and how stock prices are influenced by the price of crude oil. The general intuition in these studies is explained, as it is fundamental to have an understanding of the underlying cause and effect of the different shocks, and how they affect

economic activity, and especially how they affect U.S. stock returns.

Section 3 consists of the methodology behind the model we have used. We briefly explain the theory concerning VAR models, structural VAR models, impulse responses and variance decomposition, as well as explaining the model we have used. We describe the structural representation of Kilian & Park's VAR model, along with explaining and motivating the choice of the identifying assumptions, namely global oil production, global real activity, real price of oil and U.S. real stock returns.

Section 4 describes how we collected and processed our data, and how we proceeded in extending our data series to include data from 2006-2016. We then describe how we how we collected, employed and used the data for our replication. The section ends with an explanation for why we ended up with the subsample 2001.01 to 2016.12 as our main analysis.

In section 5 we present our results. We start the section by showing that our replication of Kilian & Park's model is successful, and that our responses of U.S. real stock returns and the real price of oil are close to identical with Kilian & Park's. Our main analysis is focused on our subsample with data from 2001.01 to 2016.12. Comparing the extended sample to the original, resulted in quite modest changes in the reactions of U.S. stock returns and the real price of oil. We believe that it might be due to the changed responses we aim to find "drown" in the extended data set, since we only added 10 years of data to a 33-year long data set. Consequently, we decided focus on a subsample, to isolate the effects, and find evidence to support our hypothesis. While working with Kilian & Park's model, our model, the data and framework, we discovered some issues that warrant further discussion. Hence, in the latter part of section 5 we provide some critique to Kilian & Park. Additionally, we check the robustness of Kilian's index as a proxy for global real activity, by running two other indices through the model in Kilian's Index' place; The World Steel Production Index (see Ravazzolo & Vespignani, 2015) and The OECD Industrial Production Index. We end the section by attempting to explain the reason why US stock returns react in the way they do in the subsample.

Finally, in Section 6, we conclude our thesis by presenting our conclusion. It summarizes our main findings of the previous sections.

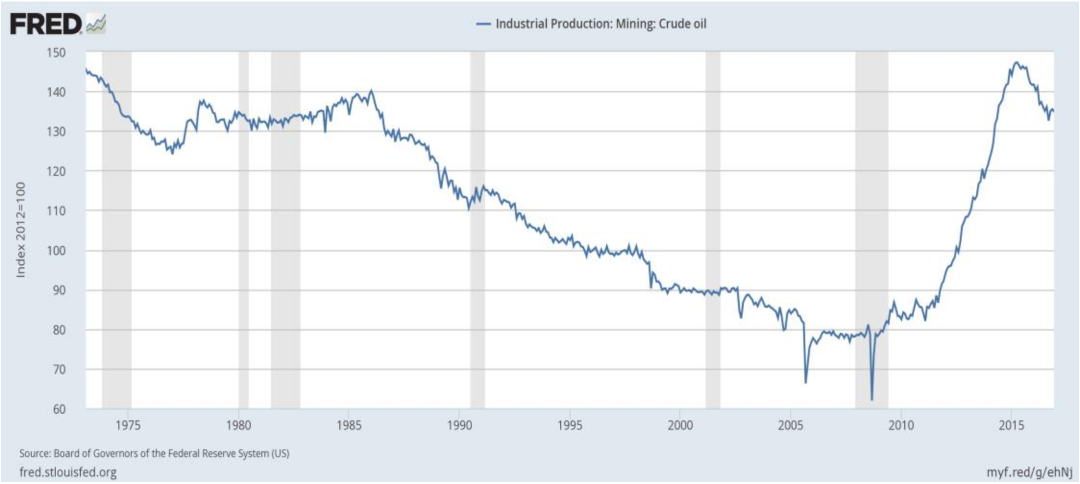
2. Background Information

2.1 Motivation

Kilian & Park’s paper “The impact of oil price shocks on the U.S. Stock Market” (2009) is the basis for our research, and thesis. As mentioned, they analyzed the relationship between different types of oil price shocks and U.S. Stock returns. Instead of treating the oil price as exogenous, like most previous articles, they argue that the oil price responds to the same factors as stock prices and needs to be endogenous to control for reverse causality (Kilian, 2008).
They found that oil price fluctuations accounted for a fifth of stock price variations in the U.S. They also found that supply shocks had little to no effect, and that precautionary demand shocks had a negative and significant effect on U.S. Stock returns between 1973 and 2006.

Since 2006 a lot has happened in the US economy, the global oil market and the U.S. petroleum sector. The world is recovering from a major financial crisis, and the oil market has been very unpredictable as a result of global economic uncertainty, as well as political turmoil in the middle east. However, the most important development concerning the global oil market, is perhaps technical innovation. The invention, and evolution, of Horizontal Directional Drilling (HDD) and fracking has opened enormous reserves for extraction that previously were untouchable, or too costly. “The US Shale Revolution”, as it is commonly termed, has led to US oil output to almost double from 2006 to 2015.

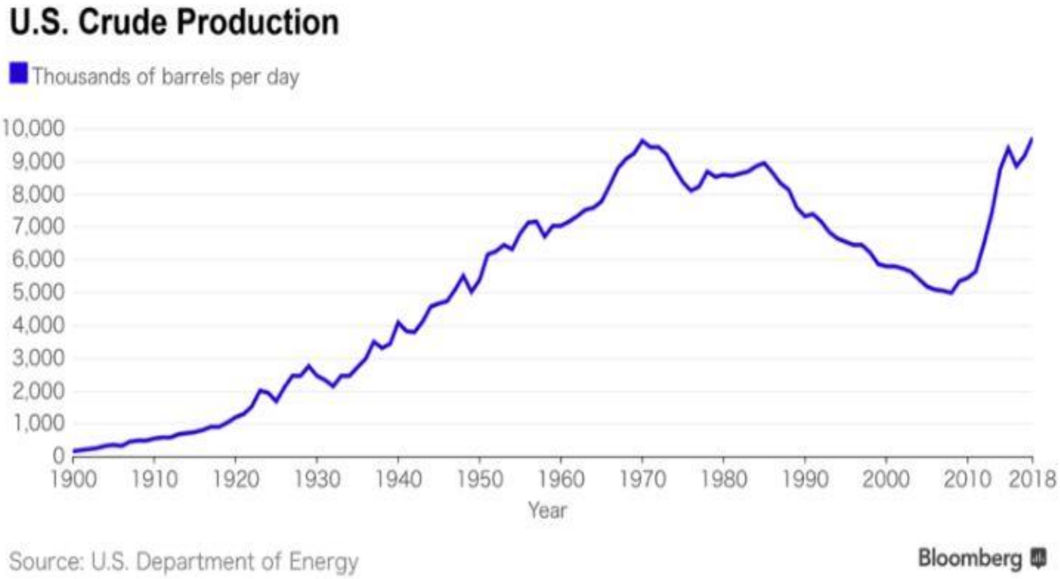
Figure 2.1 U.S. industrial production index for crude oil



U.S. industrial production index for crude oil, FRED.

A natural consequence of this development is that U.S. imports of oil and petroleum products has decreased, and the U.S. is now a net exporter of petroleum liquids.[2]

Figure 2.2 U.S. Crude Production, Bloomberg



This increased production and economic activity in the petroleum sector should spill over into other sectors as well. As more labor and other supporting industries depend

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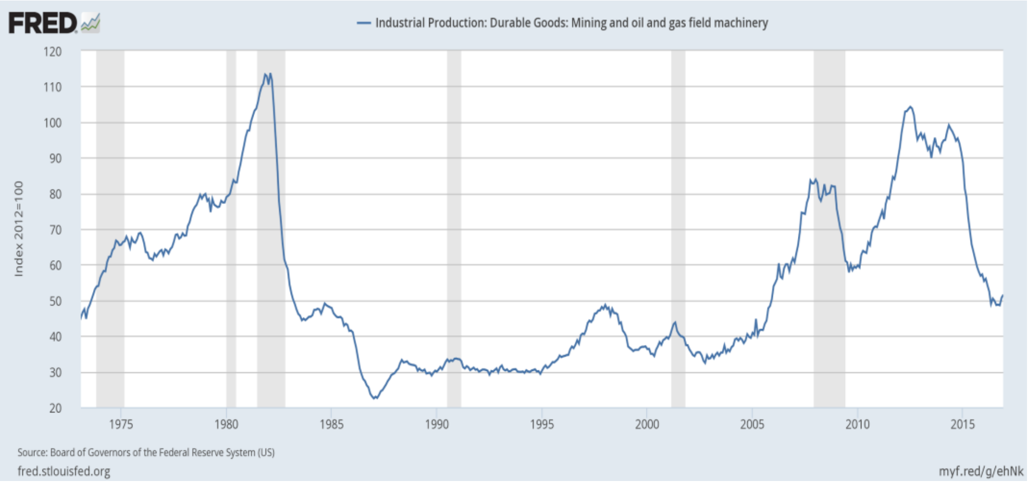
[2] https://www.eia.gov/energyexplained/index.cfm?page=oil_imports

on the oil price, and more capacity in the economy is used towards the oil sector, the U.S. economy and stock market's dynamics and responses could change.

Figure 2.3 Industrial production index for durable goods, oil and gas machinery.



Hence, we believe the US Stock Market currently might react differently to fluctuations in the oil price, compared to when Kilian & Park reached their conclusions.

Therefore, we aimed to first replicate their research to see that we are in fact able to use our model, and to see that it is possible to reach similar results as Kilian & Park with data we collected from the same time period. Then we want to extend the data set to see what happens when we include data through 2016, and finally we want to study a subsample with data from 2001-2016 to examine if the response of U.S. stock returns to oil price fluctuations has in fact changed. Hence, our final analysis is comparing the responses and results of our subsample from 2001.1-2016.12, to Kilian & Park's findings.

2.2 Literature Review

Oil price shocks are considered an important factor for fluctuations in stock prices, yet there is still no clear consensus regarding the relation between stock prices and the price of oil among economists, Kilian and Park (2009). In this part of the thesis we will present a short summary of the vast amount of theory and research that exist in our area of research.

2.2.1 Shocks to the oil price

The impact of an oil price shock to the economy is heavily debated, both empirically, as well as theoretically. In the early eighties one of the most influential papers regarding the importance of oil prices to the economy was by Hamilton (1983). He argued that oil prices shocks and recessions are correlated, and showed that 7 out of 8 US recessions since World War II came approximately 3 quarters after an oil price boom. This led him to conclude that oil price shocks could be a leading indicator for economic recessions, considering the evidence that there was a systematic relationship between the oil price and economic output. In other words, he claimed oil disruptions in oil supply led to higher oil prices and consequently recessions. Later, Kilian & Barsky (2004) argued that supply also played an important role in driving oil prices, and whilst some shocks were exogenous political shocks, most oil price shocks to the U.S. economy are endogenous.

However, other studies show that the relationship might not be that strong, and there is an increasing consensus among academics that since the end of the 1980s the correlation between oil and output has decreased. Hooker (1996) found strong evidence that the oil price no longer Granger cause many U.S. macroeconomic variables, using data after 1973. The study presents several potential explanations for why this is the case. The potential reasons were as followed: that sample stability issues are responsible, that oil prices are now endogenous, and that linear and symmetric specifications misrepresent the form of the oil price interaction. However, none of these hypotheses are supported by the data. Blanchard and Gali (2007), published a paper which presented reasons to why the oil price-output relationship seems to lose footing. They believe that it was because of a decrease in real wage rigidities, increased credibility of monetary policy and a decrease in the share of oil in consumption and production. They argued initially that the shocks in the 1970s “hit at the same time” as other large shocks of different natures. They also argued that the effects of shocks had changed over time, with a decreasing effect on prices, wages, output and unemployment.

The common opinion among researchers is that positive oil price shocks have a decreasing effect on output, Gisser and Goodwin (1986) and Bjørnland (2000). Mork (1989) as an extension to the work by Hamilton (1983), found out that an oil price increase, compared to an oil price decrease, has a larger impact on output.

2.2.2 Demand vs. supply shocks

Peersman and Van Robays (2009) compared the responses in the U.S. and the Euro area. They found that the decisive responses are similar, however, that there are differences in the transmission mechanisms. Some years later, Peersman and Van Robays (2012), found evidence to support that there were differences in the responses to an oil supply shock for industrialized net exporters, compared to net importers. When faced with a demand shock caused by either a rise in oil specific demand or increased economic activity globally, almost all the countries in the study experienced a temporary GDP increase. However, when faced with an exogenous oil supply shock, net oil and energy importing economies experienced a fall in activity whereas in exporting economies the effect was either insignificant or positive.

Kilian (2009) came to a relatable conclusion, that the underlying cause of the shock to oil prices resulted in different effects to the economy. He also noticed that the results were time dependent, meaning that the impact of the shock would vary over time dependent of economic environment and policies. He claimed demand and supply shocks in the oil market led to different macroeconomic outcomes. He distinguished between different types of shocks by splitting them into: crude oil supply shock, shocks to global demand for industrial commodities and demand shocks that are specific to the global crude oil market. He claimed that the different types oil price shocks lead to different effects on the real price of oil. Hence, there are significant differences to the impact on the price of oil depending on the type of shock. Perhaps one of the most important findings, was that an oil supply shock did not account for much of the price fluctuations, and that global demand and oil market specific demand had a persistent and significant effect.

After the steep decline in the price of oil between June and December 2014, Baumeister and Kilian (2016b) found out that a positive oil supply shock accounted for more of the oil price fluctuations than previously assumed. They also showed that more than half of the decline in the price was predictable before the actual downturn. They attributed the predictable decline to the cumulative effects of adverse demand shocks, reflecting a slowing global economy, positive oil supply shocks and shocks to expected oil production. They also stated that "the supply side of the oil market appears to have played an important part in generating the predicted decline".

Kang, Ratti and Vespignani (2016) examined the impact of both U.S. and non-U.S. oil supply shocks on U.S. stock returns in light of the unprecedented expansion in U.S. oil production since 2009. They found that in contrast to the results reported by Kilian and Park (2009), oil demand and supply shocks are of comparable importance in explaining U.S. real stock returns when supply shocks from U.S. and non-U.S. are identified.

2.2.3 Stock prices and the price of oil

There has not been much published about the correlation between oil price shocks and the stock markets, compared to research about the impact on macroeconomic variables. Kling (1985) claimed that increased oil prices are associated with stock market declines. His results indicate that the stock market did anticipate crude oil price changes after 1972, and that students of efficient markets should expect this if crude oil prices are informative of future economic activity. Chen et al. (1986) examined a set of economic state variables to see if they had any systematic influences on stock market returns, and if they had any influence on asset pricing. Their conclusion was that stock returns were exposed to systematic economic news, that they were priced in accordance with their exposures, and that the news could be measured as innovations in state variables whose identification could be accomplished through simple and intuitive financial theory.

Jones and Kaul (1996), studied the responses of international stock markets to fluctuations in oil prices. The study used data from Canada, Japan, the UK and the U.S., and found a detrimental effect on stock returns after an increase in oil prices. Sadorsky (1999) found similar effects from an analysis of the U.S. stock market and crude oil prices. His results showed that oil prices and oil price volatility both play important roles in affecting real stock returns. The analysis presented evidence supporting that the oil price dynamics have changed, and that oil price shocks have asymmetric effects on the economy. However, Huang et al (1996), investigated the relationship between daily oil futures returns and daily U.S. stock returns. They found that oil futures and U.S. stock returns did not have a significant correlation. Ciner (2001) argued that this conclusion could be due to the fact that only linear linkages were examined. Relying on nonlinear causality tests, he concludes that a statistically significant relationship exists between real stock returns and oil price futures. The study also found that the linkage between oil prices and the stock market was stronger in the 1990s.

Kilian & Park (2009) showed that the reaction of U.S. real stock returns to an oil price shock differs greatly depending on the nature of the shock. They also showed that oil price shocks, demand and supply, accounted for almost a fifth of the long run variation in U.S. stock returns. Their approach was a new way of understanding the correlation between oil price fluctuations and stock market fluctuations. Filis, Degiannakis and Floros (2011) investigated the time varying correlation between stock market prices and oil prices for oil importing and exporting countries. They found that demand and supply shocks affect stock markets differently. They examined the correlation between oil prices and stock markets, and found that supply side shocks do not influence the relationship. Degiannakis, Filis and Floros (2013) studied the relationship between industrial stock market returns and oil price returns in a static environment. They found that the link is significantly influenced by the origin of the oil price shock. Their results showed that supply side shocks resulted in low to moderate positive correlation levels, while the aggregate demand shocks generate significant changes in the correlation levels, both upwards and downwards.

Güntner (2014) adopted the econometric methodology of Kilian & Park (2009) to analyze the effects of structural oil supply and demand shocks on national stock markets for six OECD members. The sample contained both net oil importers and net oil exporters. He found that unexpected reductions in world oil supply did not affect stock returns in any of six OECD countries. Also, that oil price shocks accounted for a smaller share of the variation in national stock returns than in aggregate international stock returns.

Diaz, Molero & Gracia (2016) examined the relationship between oil price volatility and stock returns in the G7 economies. By applying a VAR model containing: interest rates, economic activity, stock returns and oil price volatility, they found a negative response of G7 stock markets to an increase in oil price volatility. Their result also indicated that the world oil price volatility was generally more significant for stock markets, than the national oil price volatility.

2.2.4 Indicators of global aggregate demand

Kilian (2006) created a monthly index of global real economic activity, based on dry cargo freight rates. The index was designed to capture changes in the demand for industrial commodities caused by global business cycles, since world economic activity is the major driver of demand for transportation services.

Ravazzolo and Vespignani (2015) proposed a new indicator for global aggregate demand, The World Steel Production Index. They then compared it to two commonly used indicators in economic research; Kilian’s Index of global real economic activity and The OECD Industrial Production Index. Using a new econometric approach, based on desirable properties of monthly global real economic activities, they proved that their world steel production index was the best monthly indicator of global economic activity. When averaging results for all numerical exercises, where a low score indicates better performance, The World Steel Production Index achieved a score of 1.14, while both Kilian's index and The OECD Industrial Production Index received scores of 2.28 and 2.42 respectively.

3. Methodology

In our thesis, our main aim is to replicate and extend the research done by Kilian and Park (2009). Following Kilian and Park we will relate U.S. stock returns to measures of demand and supply shocks in the global crude oil market, by building on a structural decomposition of fluctuations in the real price of oil. VAR models have been commonly used in econometric analysis since Sims (1980), advocated vector autoregressive models as alternatives to multivariate simultaneous equations. VAR models are built up in a way that current values of a set of variables are partly explained by past values of the same variables, and the main advantage is the ability to capture interaction among the economic variables of interest within a linear model.

When applying a VAR model analysis, one typically starts with specifying and estimating a reduced form model before checking the model adequacy. If the reduced form model passes this stage it can then be used for forecasting or structural analysis. Here we use impulse responses, forecast error variance decomposition and historical decomposition of time series as tools for analysis, Luetkepohl (2011). Following we will explain the theory around VAR models, structural VAR models and impulse responses. The presented theory is based on definitions presented in Bjørnland & Thorsrud (2014).

3.1 VAR model

A vector autoregression is a multivariate generalization of the univariate AR(p) model. A reduced form representation of the VAR(p) can be written as:

$$y_t = \mu + \sum_{i}^{p} A_i y_{t-i} + e_t$$

Where y_t is Kx1 vector of endogenous variables, μ denotes a Kx1 vector of intercept terms, A is a KxK coefficient matrix, and e_t is a Kx1 dimension vector of error terms which we assume are white noise. Assuming that the VAR model is stable, covariance-stationary i.e. the effect of the shocks, e, eventually dies out. This is the case when all the eigenvalues of the companion form matrix are less than one in absolute value. We can easily write a VAR(p) model, using the companion form, as a VAR (1) model.

$$y_t = \mu + A_1 y_{t-1} + e_t$$

We can derive the infinite moving average representation of the VAR model by employing the lag operator:

$$A(L)y_t = \mu + e_t$$

where**,** $A(L) = (I - A_1 L)$, in the VAR(p) case the $A(L) = (I - A_1 - A_2 - \cdots - A_p)$.

By multiplying with $A(L)^{-1}$ we end up at the vector moving average representation: Equivalently, this equation can be written in terms of the moving average coefficients:

$$y_t = A(L)^{-1}\mu + A(L)^{-1}e_t = B(L)\mu + B(L)e$$

$$= v + \sum_{j=0}^{\infty} B_j e_{t-j}$$

where we have used the geometric rule:

$$A(L)^{-1} = (I - A_1 L)^{-1} = \sum_{j=0}^{\infty} A_1^j L^j = B(L) = \sum_{j=0}^{\infty} B_j L^j$$

with $B_0 = I$ and $v = \left(\sum_{j=0}^{\infty} B_j\right)$

The same holds for the VAR(p) case.

3.2 SVAR model

From section 4.1 we showed the reduced form moving average representation, which can be written more compactly as:

$$y_t = \sum_{j=0}^{\infty} B_j e_{t-j}$$

The reduced form errors are likely correlated, meaning that the matrix Σ_e is likely not a diagonal matrix. Hence, if one variable is affected by a shock, it is likely that another variable is affected by this shock as well. To be able to perform a structural analysis, we need to make the shocks uncorrelated. Therefore, the analysis will be performed in terms of the moving average representation where the residuals are orthogonal, i.e. they are uncorrelated. The most common way to achieve this, is through the Cholesky decomposition. It states that every positive definite symmetric matrix can be written as the product $\Sigma_e = PP'$, where P is the Cholesky decomposition of Σ_e. P will be a lower triangular matrix with positive diagonal elements, and zero above the diagonal, and P' is its conjugate transpose.

Hence, the compact moving average representation can be written as:

$$y_t = \sum_{j=0}^{\infty} B_j P P^{-1} e_{t-j} = \sum_{j=0}^{\infty} C_j v_{t-j}$$

where $C_j = B_j P$ and $v_t = P^{-1} e_t$ so that:

$$E[v_t v_t'] = P^{-1}[e_t e_t'](P^{-1})' = P^{-1}(PP')(P^{-1})' = I$$

Therefore, given that P is a lower triangular matrix, the components of v_t will be uncorrelated even though the components of e_t may not.

For illustration, the Cholesky decomposition is here represented by a bivariate model. This implies that $j = 2$. In our model, we work with a multivariate model, which implies in our case $j = 4$.

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} p_{11} & 0 \\ p_{21} & p_{22} \end{bmatrix} \begin{bmatrix} v_{1,t} \\ v_{2,t} \end{bmatrix} + B_1 P v_{t-1} + B_2 P v_{t-2} + \cdots$$

At time t, the Cholesky decomposition implies the second shock v_2 does not affect the first variable contemporaneously, yet both shocks can affect the second variable contemporaneously. However, when $j \geq 1$, there are no further restrictions in place and both shocks can affect both variables. The ordering of the Cholesky decomposition above is such that the second shock is restricted from affecting $y_{1,t}$ contemporaneously. Since the ordering of the variables and the type of restrictions imposed affects the results, these decisions should be based on economic theory.

3.2.1 Our model

Kilian & Park`s model is based on monthly data for the vector time series Z_t, consisting of the percentage change in global oil production, Kilian’s index for activity, real price of crude oil and an index for stock returns in the U.S. in the given order.

The structural representation of Kilian & Park`s VAR model is:

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

Where ε_t denotes the vector of serially and mutually uncorrelated structural innovations. e_t denotes the reduced-form VAR innovations such that $e_t = A_0^{-1}\varepsilon_t$. The structural innovations are derived from the reduced-form innovations by imposing exclusion restrictions on A_0^{-1}, Kilian & Park (2009). The model imposes a block-recursive structure on the contemporaneous relationship between the reduced-form disturbances and the underlying structural disturbances. It consists of two blocks, a block which constitutes a model of the global oil market, and a block which consists of U.S. real stock returns.

The oil market block, characterizes fluctuations in the real price of oil to three structural shocks: ε_{1t} captures shocks to the global supply of oil (Hereafter "oil supply shock"); ε_{2t} denotes shocks to the global demand for all industrial commodities (also crude oil) that are driven by global real economic activity ("aggregate demand shock"); and ε_{3t} captures shifts in precautionary demand for crude oil in response to increased uncertainty about the future oil supply shortfalls ("oil-specific demand shock").

Oil-market specific demand shock or precautionary demand shock are caused by the uncertainty about shortfalls of expected supply relative to expected demand, meaning uncertainty regarding the outlook of the oil market, and primarily future supply. It reflects the convenience yield from having access to inventory holdings of oil that can serve as insurance against an interruption of oil supplies, Alquist and Kilian (2010). Such an interruption could arise because of unexpected growth of demand, unexpected declines of supply or both.

The second block is the U.S. stock market block, contains a singular structural shock. ε_{4t} is not a truly structural shock, it is more an innovation to real stock returns not driven by global crude oil demand or supply shocks. Since we are solely concerned with the impact of structural shocks in the crude oil market on the U.S. stock market, we, and Kilian and Park, will not attempt to further unravel the structural shocks driving stock returns.

The model imposes the following identifying assumptions resulting in a recursively identified structural model of the form

$$e_t \equiv \begin{pmatrix} e_{1t}^{\Delta global\ oil\ production} \\ e_{2t}^{global\ real\ activity} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{U.S.stock\ returns} \end{pmatrix}$$

$$= \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{31} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{other\ shocks\ to\ stock\ returns} \end{pmatrix}$$

Following Kilian (2009), these identifying assumptions is motivated as follows: (1) crude oil supply will not be affected by oil demand shocks within the month, because of the costs of adjusting oil production and uncertainty in the crude oil market; (2) increases in the real price of oil caused by shocks that are specific to the oil market will not decrease global real activity within the month, because of the sluggish nature of global real activity; (3) innovations to the real price of oil that cannot be explained by oil supply shocks or shocks to the aggregate demand for industrial commodities must be demand shocks that are specific to the oil market; and (4) because of the block-recursive structure of the model, it implies that all variables, global crude oil production, global real activity, and the real price of oil, are treated as predetermined with respect to U.S. real stock returns. While, U.S. real stock returns are allowed to respond to all three oil supply and demand shocks on impact, it does not affect them within a given month, but only with a delay of at least one month. This assumption is implied by the standard approach of treating innovations to the price of oil as predetermined with respect to the U.S. economy, Lee & Ni (2002).

3.3 Impulse responses and variance decomposition

An impulse response function describes how a shock impacts a variable in the y_t-vector over time. In terms of a structural model, impulse responses are the cause and its propagation as the effect over time. To make a valid, causal, inference, we need to have uncorrelated shocks. Therefore, impulse responses can be found through the moving average representation where the residuals are orthogonal, and they summarize how unit impulses of the shocks at time t impact the level of y at time $t + s$ for different values of s. In consideration of our impulses responses being derived from structural moving average representation of the VAR, the impulse response function can be reported using normalized shocks or not. In our model the oil supply shock has been normalized to represent a negative one standard deviation shock, whereas the aggregate demand shock and oil-market specific demand shock have been normalized to represent positive shocks such that all shocks would tend to raise the real price of oil.

The variance decomposition tells us how much of a change in a variable is a result of its own shock, and how much is explained by shocks in other variables. In Kilian & Park`s model it quantifies how important the different shocks have been on average for U.S. stock returns. In the short term, the effect of the three different shocks is insignificant. However, as the horizon is expanded the explanatory power increases rapidly.

4. Data

4.1 Data gathering and processing

We tried to replicate all data series that Kilian & Park (2009) used as precisely as possible. In their analysis, they used four variables; percentage change in global oil production, a global real economic activity index (Kilian’s Index), the real crude oil price and an index for stock returns in the U.S. (CRSP). We used DataStream to gather oil production and price data, The Centre for Research in Security Prices

(CRSP) provided the value weighted stock returns in the U.S. and the Kilian Index was available on Kilian's website.

The world oil production data was converted to percentage change, and multiplied by 1000 to be in approximately the same range as the other variables.[3]

The index for global real activity is an index Kilian proposed in his paper "Not all oil price shocks are alike", 2009, and that is updated regularly on his website. We discussed using some other source of data to measure global activity, but in order to do a strict replication we used Kilian's index.[4] Since Kilian not just simply adds data to the index, but rather updates the entire index, we decided to use the data from the data-set Kilian & Park (2009) used for their analysis. Later, we will use the updated index for the extension and subsample.

For the oil price, we use refiner's acquisition cost of oil data from the U.S. Department of Energy, starting in 1974.1. Killian & Park (2009) extrapolated the data series back to 1973.1, but we chose a simpler method. To replicate the full series, we took the data we gathered and subtracted the corresponding data in Kilian & Park's series, thereby finding the mean Kilian & Park used. By adding that to Kilian & Park's data in the year 1973.1-1974.1 we acquired their extrapolated price for the missing year. Then we converted it to real values by dividing it by the U.S. CPI from the Bureau of Labor Statistics, and then take the log, and finally subtract the log mean through the series.

Finally, for the stock returns we gathered data directly from CRSP, using the value weighted returns including dividends. Again, we subtracted the inflation, using the CPI data from the Bureau of Labor Statistics, to get real stock returns.

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[3] If the variables in the SVAR are not similar in levels, then the SVAR breaks down and does not function

[4] We have discussion about the robustness of Kilian's index in chapter 5.3

We ran into some minor problems when replicating their results, but in the end, it turned out quite well. We got correlations between our time series data and theirs of 0.9992, 0.9830, 0.9999 and 0.999999, respectively. Perhaps a small surprise is that the Kilian index used in their paper (2009) is only correlated by 0.9830 to the same index when we collected the data. The reason is as mentioned above that the whole index is updated when new data is available, instead of just adding more data to the index.

After the seminal work by Nelson & Plosser (1982) econometricians have been conscious of the fact that most macroeconomic variables are not stationary, i.e. they follow a unit root process (Dickey, Jansen, & Thornton, 1994). When a unit root is present it implies that the effects of a shock persists indefinitely, and cyclical changes cannot be separated from long run growth. Hence, econometricians are accustomed to working with first differences. Thus, testing for a unit root is crucial when working with time series data in statistical analysis. Even though all our variables are in either first differences or logs, we have tested them for the presence of a unit root. All the variables failed the null of a unit root, and are stationary. We performed an Augmented Dickey-Fuller test on all variables using EViews, and present the results in the Appendix[5].

4.2 Extending the data

First, we started by gathering data for the period 2007.1-2016.12 to extend the data set. Then we followed the same steps as explained in section 3.1, when processing the data. The only real change we had to do was change the mean we subtracted from the oil price, depending on the different sample lengths we tried[6].

We also wanted to take a closer look at recent years using a reduced sample, as there has been substantial developments both in the global oil market and the US oil

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[5] See Appendix A.1

[6] This was perhaps arbitrary as subtracting a mean only changes the level of the variable, but not its variance or it's correlation with the other variables.

market, as well as in the global economy. We experimented with different sample lengths, but to not impede our forthcoming robustness analysis in section 5.3, we limited range of possible data to 1991.2-2016.12.

Within that range we tested sample starting points for January of all years between 1991-2001, but ended up going forward with 2001.1-2016.12 as our subsample. We are aware of the short downturn in 2001, but to capture the recent changes and possibly show that the relationship between US stock returns and oil prices has changed we opted for the shortest sample we felt we could use.

5. Results

5.1 Replication

We begin by comparing the empirical results of our replication to the findings of Kilian & Park. In this section, we will briefly compare the two, and in section 5.2, when we present our main analysis, there will be a more detailed discussion of the initial results as well. Before studying the effect on U.S. real stock returns, we review the responses of the real price of oil to the three structural shocks $\varepsilon_{jt}, j = 1,2,3$.

For our replication[7], we acquired and tried to use the same base-codes in Matlab as Kilian & Park used for their paper. However, we were not able to implement confidence bands together with the impulse response functions. Therefore, with the help of Thomas Gundersen at BI, and using codes by Ambrogio Cesa-Bianchi (2015), we created another model. Using this model, we were now able to replicate the results of Kilian & Park. Obviously, our impulse response functions, covariance matrix and historical decomposition were not 100% identical, but it was close enough to comfortably conclude that we were in fact able to replicate their results.

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[7] Initially we attempted to replicate Kilian & Park's results using EViews 7 software, but we were not able to yield any results that resembled Kilian & Park's. Among other things, EViews does not allow you to set sign restrictions, and subsequently we were not able to simulate negative oil supply shocks.

Figure 5.1 Responses to an Oil Supply Shock

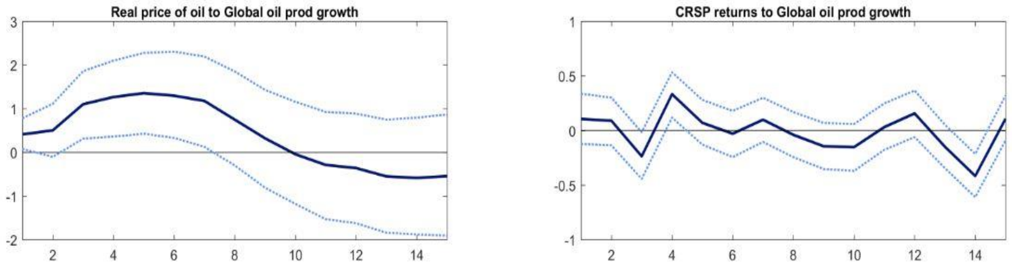


Figure 5.2 Responses to an Aggregate Demand Shock

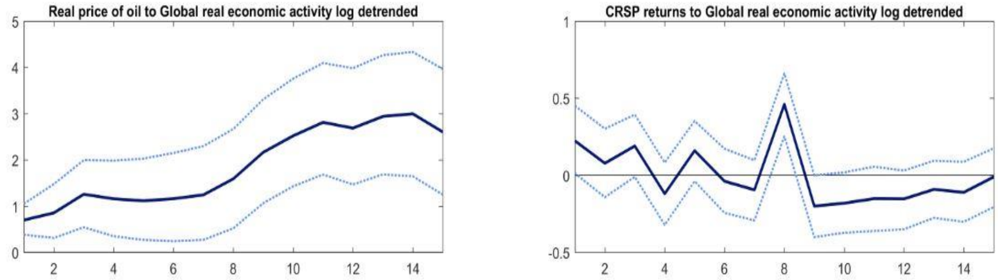
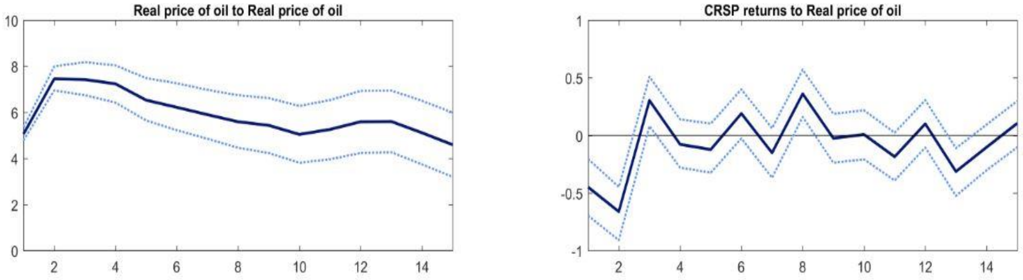
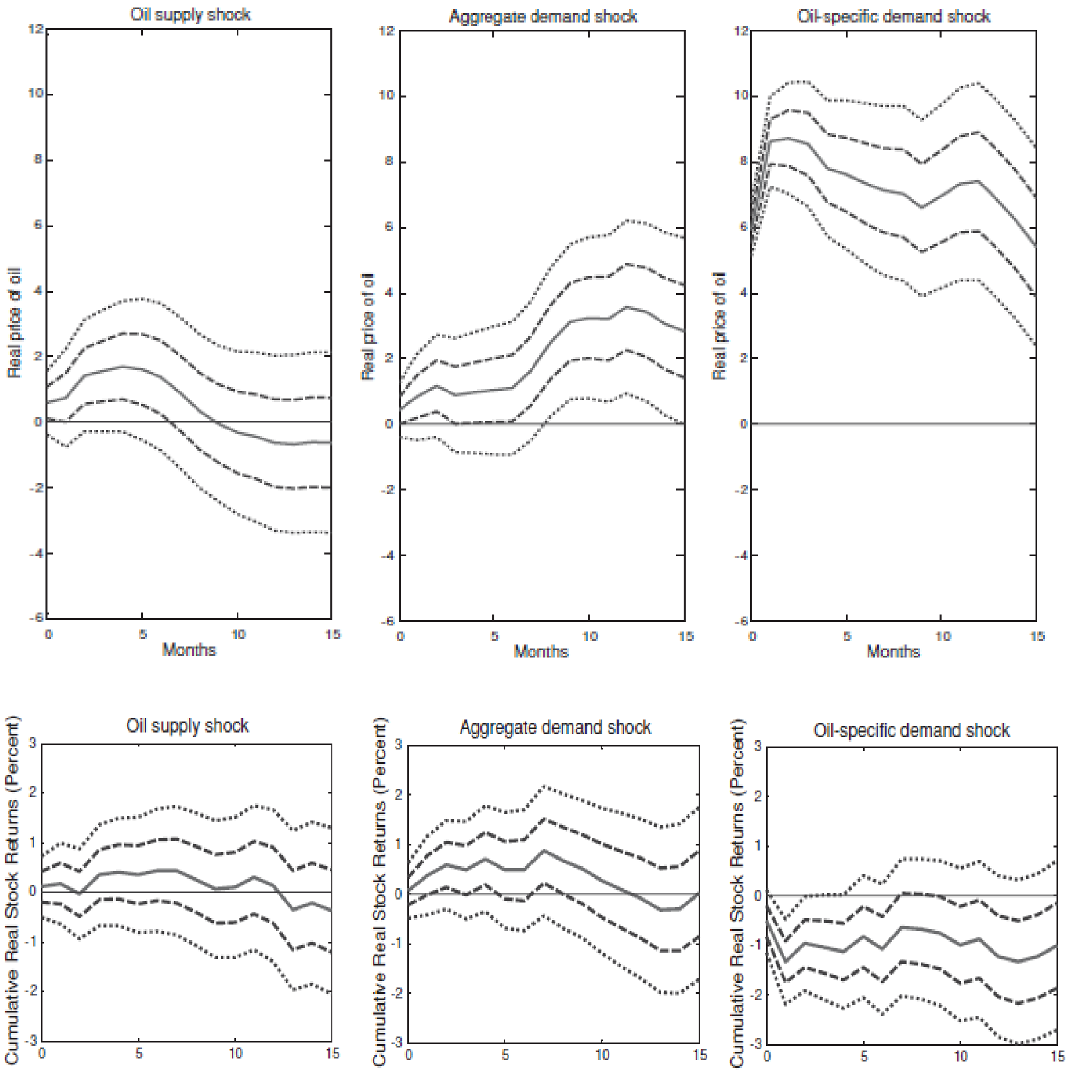


Figure 5.3 Responses to an Oil-Specific Demand Shock



Our responses of U.S. real stock returns and the real price of oil to one-standard deviation structural oil supply shock, for our normal sample (1973.2-2006.12).

Figure 5.4 Kilian & Park's responses of Cumulative Real Stock Returns and the Real Price of Oil



Kilian & Park's responses of U.S. real stock returns and the real price of oil to one-standard deviation structural shocks (1973.2-2006.12.)

As mentioned earlier, the oil supply shock is normalized to simulate a negative one standard deviation shock, whilst aggregate demand and oil-market specific demand shocks are normalized to represent positive shocks. Hence, this ensures that all three shocks should affect the real price of oil in the same manner, leading to a positive reaction. If you compare our responses in Figure 5.1-5.3 and Kilian & Park's in

Figure 5.4 you observe that they are quite similar, and that we have indeed managed to replicate their impulse response functions for the real price of oil to structural shocks.[8] Next, we compare the responses of the value-weighted stock returns. Again, we see that they are quite similar, and that U.S. real stock returns react differently depending on the underlying cause of the shock. Additionally, both the historical decompositions and the variance decompositions appear to be almost identical.[9] Considering that the impulse responses also were very similar, this should be expected, and further confirms that the responses of the real price of oil has been successfully replicated.

5.2 Main analysis

For our main analysis, we have investigated two samples, one were we simply extended the original sample to include 10 additional years of data (1973.2-2016.12), and a subsample with the most recent data (2001.1-2016.12). As mentioned, our interest in studying the subsample is rooted in the enormous output growth the U.S. oil industry has seen in recent years, mainly because of The Shale Oil Revolution. Our aim is to investigate if the U.S. Stock Market has become more oil dependent, so that the response of the stock market to a structural positive oil price shock now leads to increased stock returns, as opposed to the previously held common belief of a negative reaction to increased crude prices. We began by extending the data set to include the data for the period in which we believe the dynamics between crude oil prices and the U.S. Stock Market has changed.

For our replication and extension (1973.1-2006.12 & 1973.1-2016.12) we used 24 lags, or two years, just as Kilian & Park. For our subsample and main analysis, which consisted of 15 years of data we used 12 lags, as the limited amount of data did not warrant the use of 24 lags.

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[8] Using the same model as Kilian & Park we produced responses almost identical, however, were not able to produce confidence bands, and subsequently chose to use this model to present our findings. The responses we obtained using Kilian & Park's model can be found in the Appendix Section A.2.

[9] Historical decompositions and variance decompositions are in the Appendix, section A.3 & A.4

Figure 5.5 Responses to an Oil Supply Shock

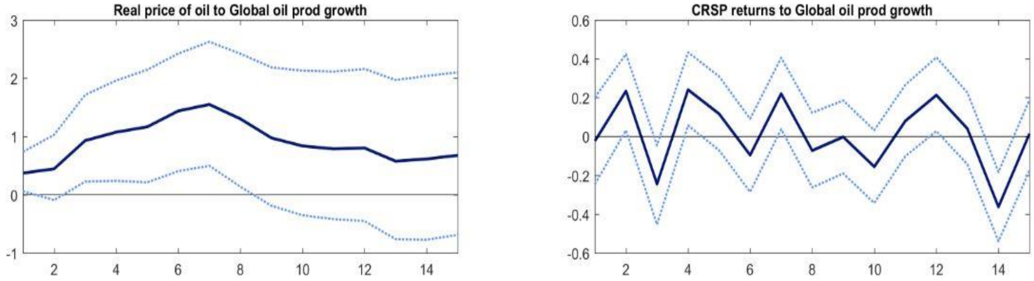


Figure 5.6 Response to an Aggregate Demand Shock

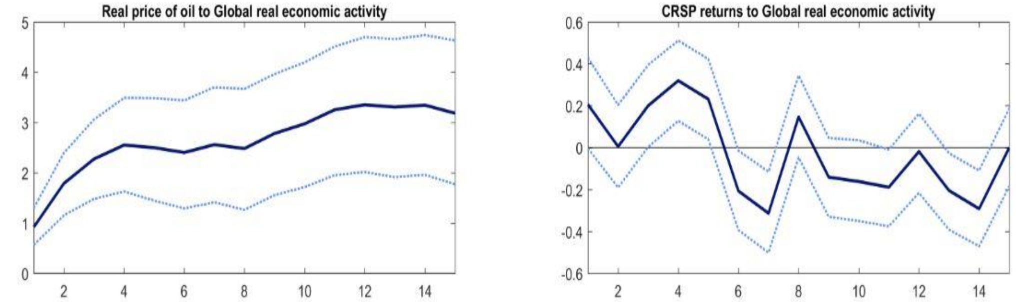
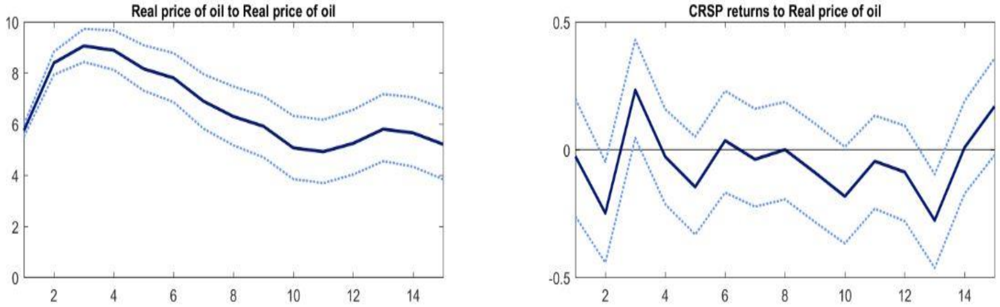


Figure 5.7 Response to an Oil-Specific Demand Shock



Our responses of U.S. real stock returns and the real price of oil to one-standard deviation structural shocks for our extended sample (1973.2-2016.12).

If we compare the responses of the original sample in Figure 5.1-5.3 to those of the extended sample in Figure 5.5-5.7, it shows that adding 10 years of data to the original sample leads to quite modest changes in the reactions of U.S. stock returns and the real price of oil. This is also the case when studying the historical decomposition and variance decomposition[10] Our main interest is how U.S. Stock Returns reacts to an increase in precautionary oil demand, and in the original sample it caused a significant negative reaction on impact. With extended data, U.S. real stock returns now seem to show signs of a slightly different response. Now there is no significant negative reaction on impact, and for the remainder of the horizon it is insignificant around zero. However, this merely shows that when adding more data U.S. stock returns shows signs of reacting differently to an oil price shock. The extension only added 10 years of data to a 33-year long data set, and it could be that the changed dynamics we aim to show "drown" in the amount of data. Thus, we decided to also study a subsample (2001.1.-2016.12), to isolate the effects and hopefully find some evidence to support our hypothesis. The reasoning behind choosing the subsample, is that believe we need at least 15 years of data for the sample to be big enough, a third of the subsample now overlaps with the original sample and it should be short enough to accentuate the responses we aim to find.

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[10] A more thorough analysis of the extension including a historical decomposition and variance decomposition can be found in the Appendix, section A.3 & A.4.

Figure 5.8 Responses to an Oil Supply Shock

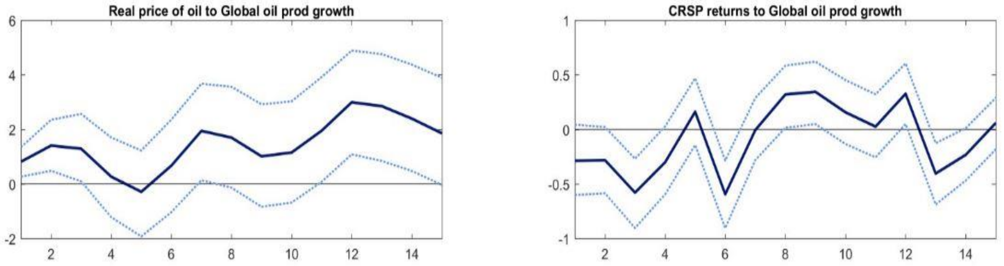


Figure 5.9 Responses to an Aggregate Demand Shock

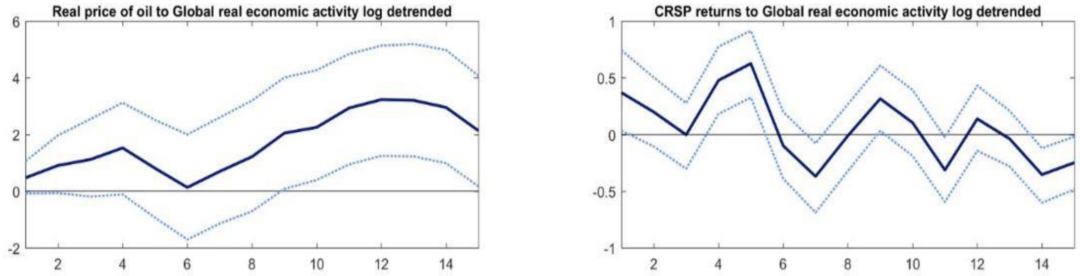
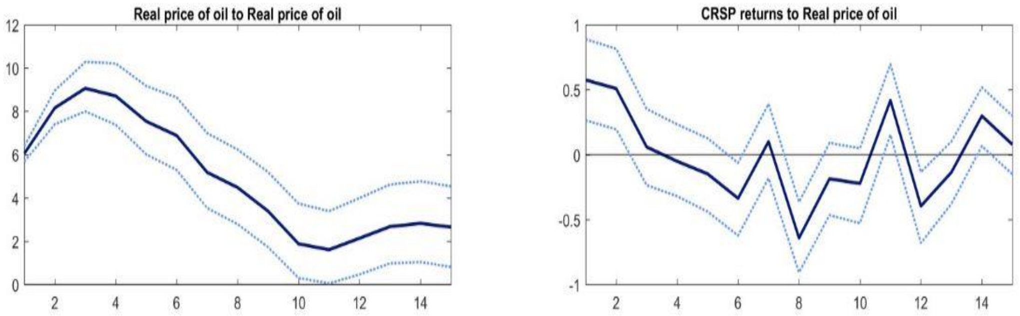


Figure 5.10 Responses to an Oil-Specific Demand Shock



Our responses of U.S. real stock returns and the real price of oil to one-standard deviation structural shocks for our subsample (2001.1-2016.12), using 12 lags.

Kilian & Park found a negative oil supply shock to have no statistically significant effect to cumulative real stock returns. However, when studying our subsample in Figure 5.8-5.10, we see that there is a negative response of U.S. stock returns that persists for some periods of the 15-month horizon, to an unexpected global reduction in oil production. As for an aggregate demand shock, the response is now more positive on average, however, it is not conclusively positive. Finally, we see that U.S. stock returns now has a positive and significant reaction on impact, following an oil-market specific demand shock. Hence, our suspicions might have been warranted, and this indicates that U.S. stock returns' relationship with the real price of oil appears to have changed in recent years. This could be the result of several factors. Mainly, we suspect it is the increased production of domestic oil, and that the U.S. now is a net exporter of oil. Also, as more and more of U.S. manufacturing and other energy intensive industries has moved overseas, or disappeared altogether, oil has become a less important factor of production in the U.S.[11] Hence, when the oil prices fall it does not seem to "boost" the economy in the way it perhaps did in the past.

As for why we observe the other reactions we do; it could be that U.S. stock returns now react negatively to oil production cuts as they could indicate that there has been a period of overproduction, resulting in oil inventories being higher than expected. This could also be a result of lower aggregate demand, lower prices and subsequently lower supply. The increased response of the U.S. stock market reacting more to an aggregate demand shock, could indicate that the U.S. economy has become more volatile to global business cycles than earlier.

The responses of the real price of oil also seem to have changed slightly. When responding to an unanticipated disruption of the production of crude oil, the real price of oil responds mostly positively for the whole horizon, similarly to the extended sample, whereas in the old sample where it was a transitory increase. In the original sample the response never exceeded 2%, but with the subsample the price of oil almost reaches 4% towards the end of the horizon. This leads us to believe that the real price of oil might be more volatile to changes in oil supply than previously, which is also supported in recent literature (Baumeister & Kilian, 2016a). Unexpected changes in aggregate demand spur a very similar reaction regardless of what sample you use, and with the subsample it is a subtle response initially, and eventually it peaks at around 3%. Finally, when faced with an oil market demand shock, the real price of oil, just like with the extended sample, has a more considerable response initially. However, in the long run the response is much weaker for the subsample, compared to either of the previous samples. We are unsure of why this is the case, but

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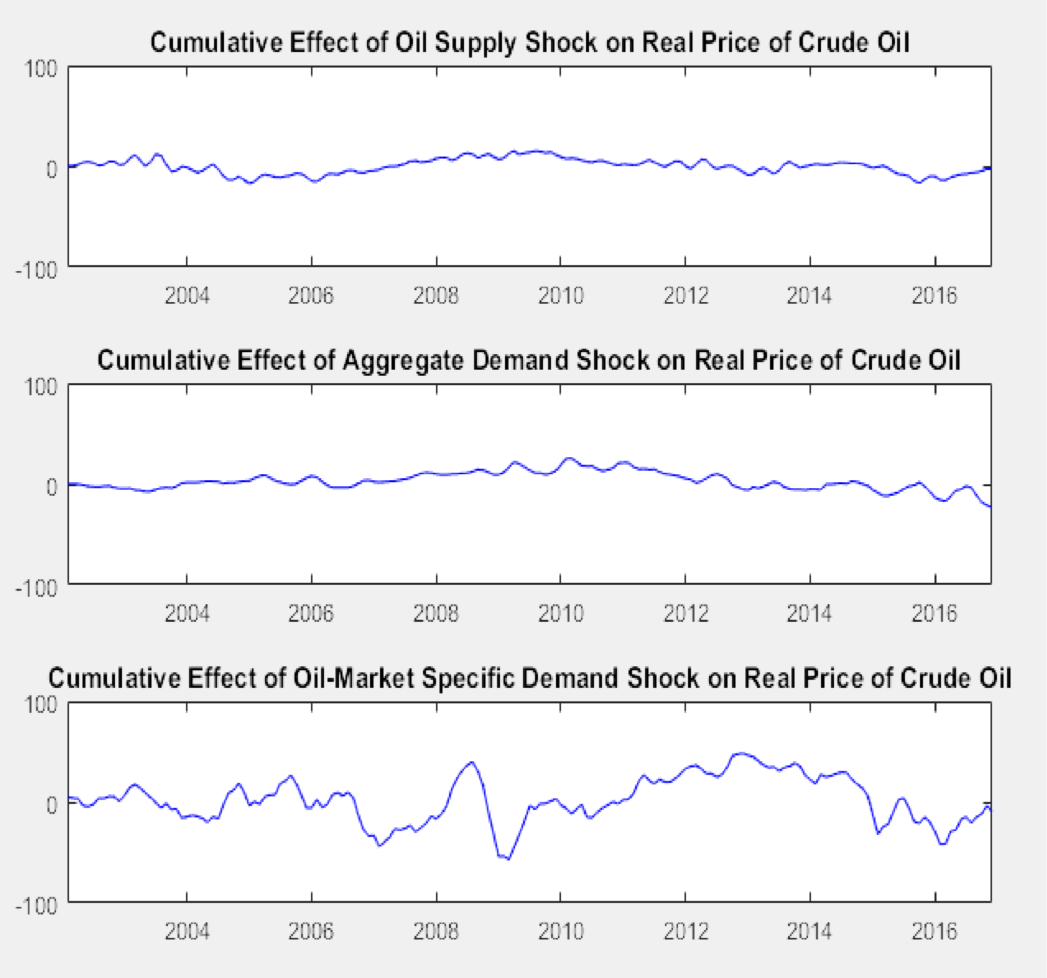
[11] Graphical representation of manufacturing jobs in the US in Appendix, Figure A5.2.

perhaps the oil markets have become more volatile, and news of inventories and expected supply disruptions are more frequent. Or, perhaps the global supply of oil has become more stable, in part by the efforts in the U.S., so that disruptions in unstable parts of the world now lead to a milder reaction in crude oil prices.

Figure 5.11 Historical Decomposition of the Real Price of Oil

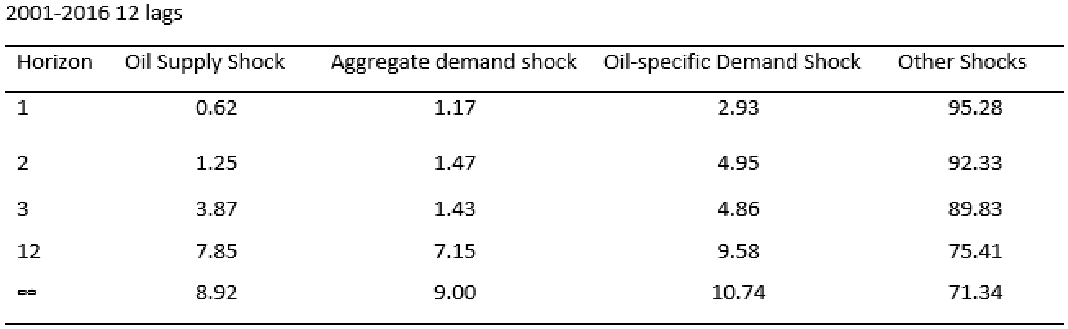


Historical decomposition of real price of oil: 2002.1-2016.12

The impulse responses are the responses to a one-time shock, but in reality, oil price shocks are not limited to single, isolated shocks. A vector of both positive and negative shocks is a better representation of how shocks occur in reality. Therefore, the historical decomposition is a necessary tool to investigate the long term cumulative effect of these shocks. Looking at Figure 5.11, it seems as the historical decomposition for the subsample tells the same story of the cumulative effect of oil supply shocks to the real price of oil as with the original and extended samples[12]; it does not seem to contribute a whole lot. The impulse response indicated some more reaction to supply shocks, but compared to the other samples this subsample does not seem to be any different. Aggregate demand shocks to the real price of oil on the other hand, now contribute much less from the mid-2000s than in the original and extended sample. As for the cumulative effect of oil-market specific demand shocks on the real price of oil, it seems it now is a more important factor in the variation of crude prices than previously.

Kilian & Park did not present any historical decomposition of U.S. real stock returns, so there is no data to compare. However, in The Appendix A.2, we present historical decompositions for real stock returns.

Table 5.1 Variance Decomposition of the subsample



2001-2016 12 lags

Horizon	Oil Supply Shock	Aggregate demand shock	Oil-specific Demand Shock	Other Shocks
1	0.62	1.17	2.93	95.28
2	1.25	1.47	4.95	92.33
3	3.87	1.43	4.86	89.83
12	7.85	7.15	9.58	75.41
∞	8.92	9.00	10.74	71.34

Table 5.1 shows the variance decomposition of the subsample. All shocks now produce variance in the US stock market on impact, unlike the original and extended samples where the shocks almost had no effect on impact. Long run variance is also more affected by the three shocks, as other shocks now only contribute to 71.34%, compared to 76.96% for the original and 83.52% in the extended sample.

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[12] Historical and variance decompositions for the original and extended sample are in the Appendix, A3.1 & A3.3.

5.3 Robustness analysis

Few would argue against the importance of Kilian & Park's article when it was published in 2009, and that it has contributed to the research of oil price dynamics, economics and finance. But, while working with their model, data and framework we have discovered some issues that warrant further discussion.

For starters, Kilian & Park treat the oil price as an endogenous variable, both influencing and reacting to economic activity. Another variable, among others, that is very connected to economic activity, and oil prices, is interest rates. But they are not included in the model. Additionally, interest rates have been very important for the growth of the shale oil revolution, as the enormous increase in drilled wells has been heavily financed by debt. The energy sector's share of the high-yield bond market increased from 12% in 2002 to 17.4% in 2014 (DiChristopher, 2014), making them more sensitive to changes in interest rates. And if the number of wells, and therefore supply of oil, depend on interest rates, then the oil price is dependent on interest rates. The oil price also influence interest rates, as lower oil prices leads to lower inflation. All else equal, that should lead to lower interest rates if we assume inflation was at target before the oil price decline.

The model in itself is also quite limited, only including four variables, which is a major simplification, albeit quite normal in the field of economics. Another variable that is excluded from the model is exogenous extraction costs, which we argue is a very important factor in oil supply. Rystad (2017) examined the breakeven prices for the shale oil producers in the U.S., and found that on average they had cut their breakeven price by 55% between 2013-2016[13]. This led to an increase in active wells, and naturally, oil supply. Active wells, and average US extraction costs could have been useful to include in the model, but at the same time after working with it and the data, we understand it would be exceptionally difficult to both create and manage a very large model. Regardless, the exclusion of these variables, and possibly others, could lead to omitted variable bias.

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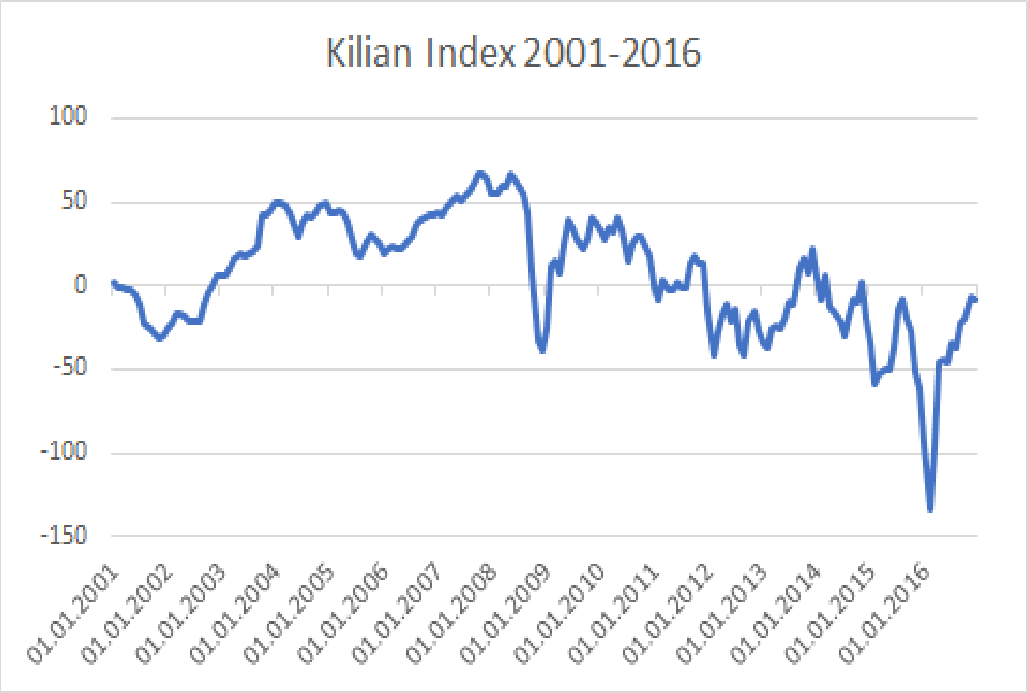
[13] Graphical representation of break-even prices, See Appendix, Figure A5.1

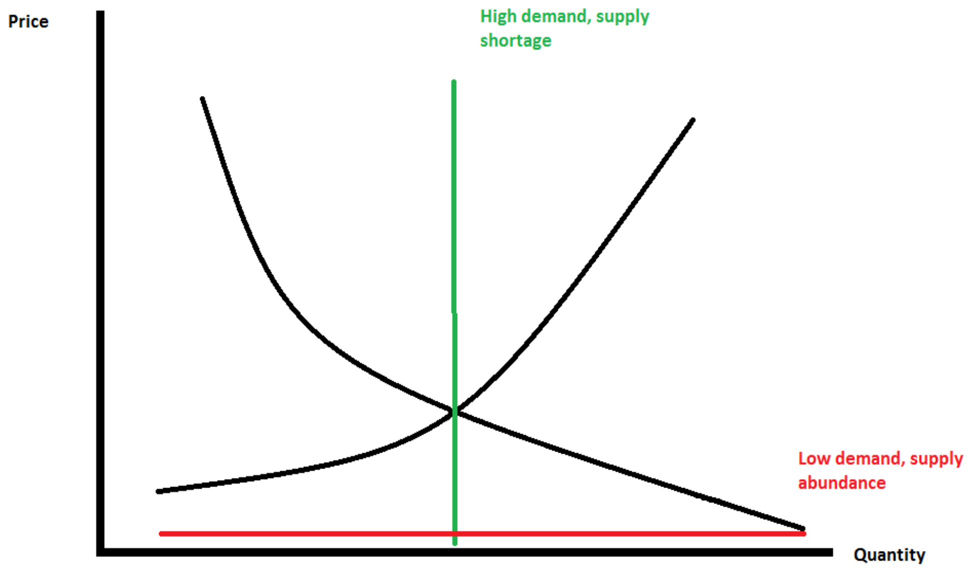
Another, and perhaps a big issue, is the Kilian Index. The Kilian index has been used repeatedly by economists (Ravazzolo & Vespignani, 2015), but as Ravazzolo & Vespignani mention in their article, has a few flaws. We will not go into much detail, but in short; it weights the different shipping routes and shipped commodities equally. This might be a problem as both the different routes and shipping prices relative importance change over time. Yet another issue pointed out by Ravazzolo & Vespignani is that Kilian linearly detrended the data to produce the index, which we suspect is why the linear representation of the index in Figure 5.13 is somewhat strange. As you can clearly see by the graph, the reduced shipping activity due to the oil price decline in 2014-2016 has a much larger, and more persistent, effect on global real activity than the global financial crisis that started in 2008, according to Kilian's Index. To us this seems highly peculiar.

Figure 5.13 Plot of Kilian's Index 2001-2016



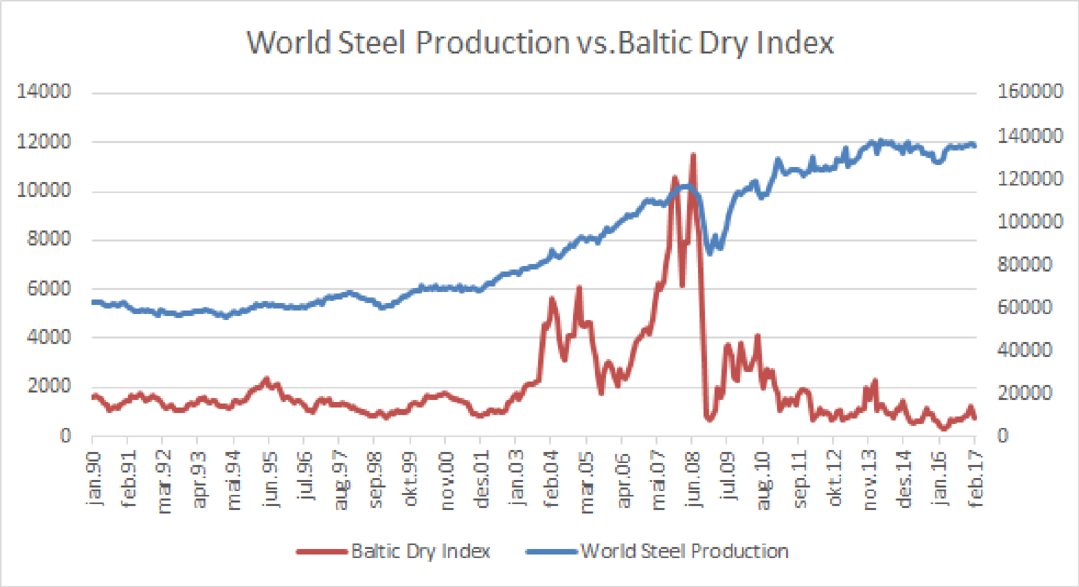
Kilian claim that "...increases in dry cargo shipping rates, given a largely inelastic supply of suitable ships, will be indicative of higher demand for shipping services arising from increases in global real activity" (Kilian, 2006). He proposed the index in his paper “Not all oil price shocks are alike...” (2006), and argues that “the slope of the supply curve becomes increasingly steeper and freight rates increase. “At full capacity, the supply curve becomes effectively vertical, as all available ships are running at full speed” (Kilian, 2006). He goes on to say that the cycle of shipbuilding and scrapping may weaken the link, as it is pro-cyclical, and lagging behind activity. This we completely agree with, and believe is the reason for the index not accurately explaining global economic activity in recent years. As Kilian stated, the supply curve becomes practically vertical when there is high demand and a lack of supply, which also means that in the opposite situation the supply curve could become practically horizontal (see Figure 5.14).

Figure 5.14 Crude representation of short run supply and demand in the shipping industry



Kilian’s index is very closely correlated to the Baltic Dry Index, and if you compare that to the world steel production index graphically in Figure 5.15, you can see the underlying problem. There is correlation periodically, but at first glance they do not appear to both proxy the same thing; global economic activity. Additionally, from the beginning of 2010 their trends seem to move in opposite directions, which makes it hard to justify using Kilian’s Index, without further investigation.

Figure 5.15 World Steel Production vs. The Kilian Index.



To examine if Kilian's Index can proxy global aggregate demand for industrial commodities, we have tested two other variables/proxies, and ran them through our model; The World Steel Index (see Ravazzolo & Vespignani, 2015) and The OECD Industrial Production Index. Ravazzolo & Vespignani proposed the World Steel Index, and claim it is proven that it is the best indicator of global economic activity. They created the index using data from The World Steel Organization, which accounts for 98% of world steel production (Ravazzolo & Vespignani, 2015). "The OECD Industrial Production Index has been widely used as a proxy for global activity" (Ravazzolo & Vespignani, 2015) and consists of data from 35 OECD countries[14], but it struggles to capture the enormous growth in global demand from emerging economies in the late 1990s. This was also part of the reason for Kilian to create his index.

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[14] List of OECD Countries, see Appendix, Figure A5.3.

Figure 5.16 Responses of Global Oil Supply, The Real Price of Oil and U.S. Real Stock Returns using The OECD Industrial Production Index

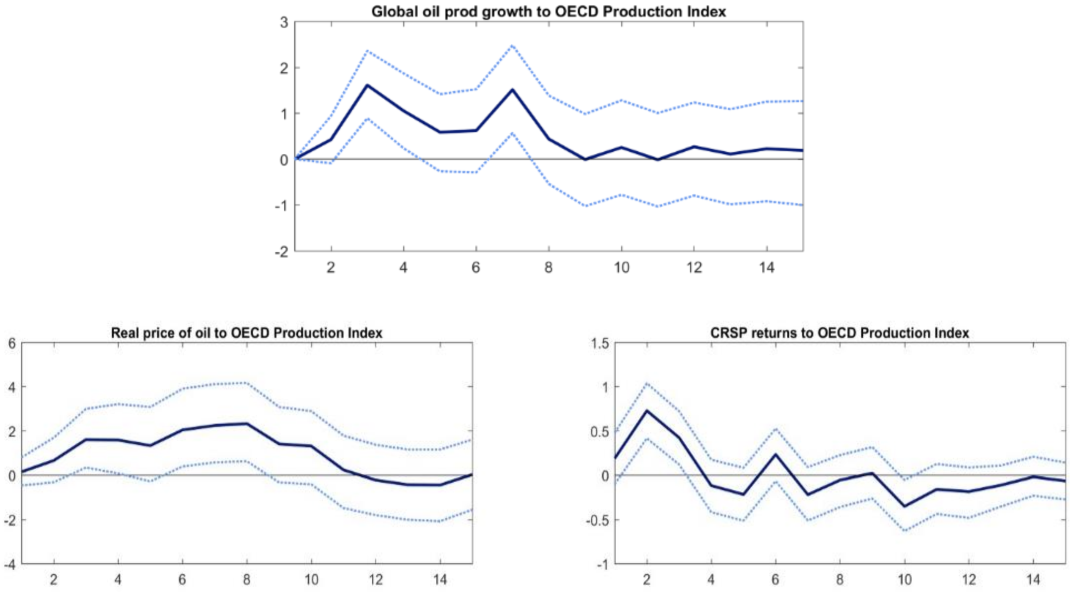
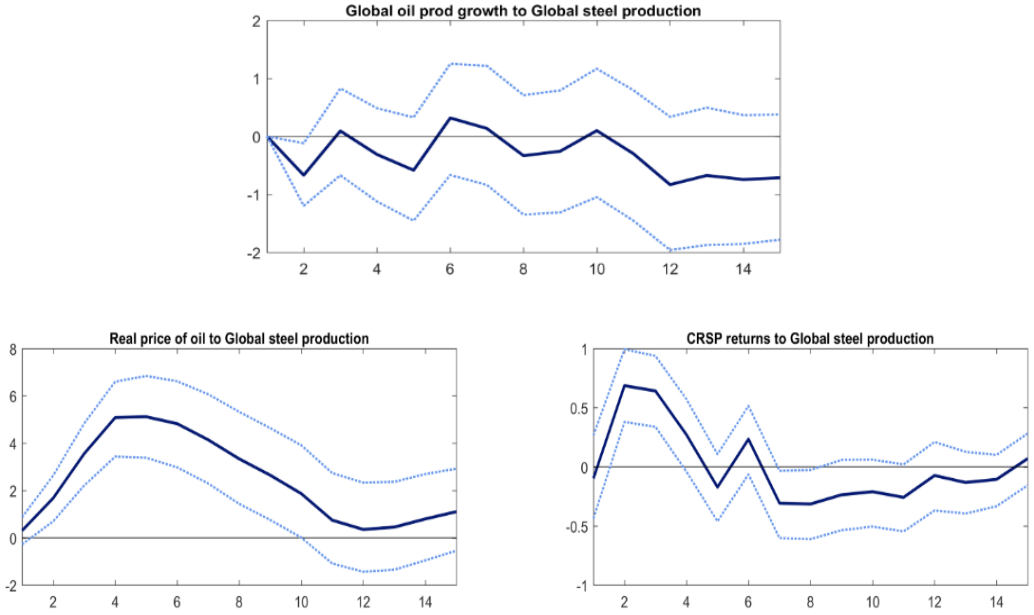


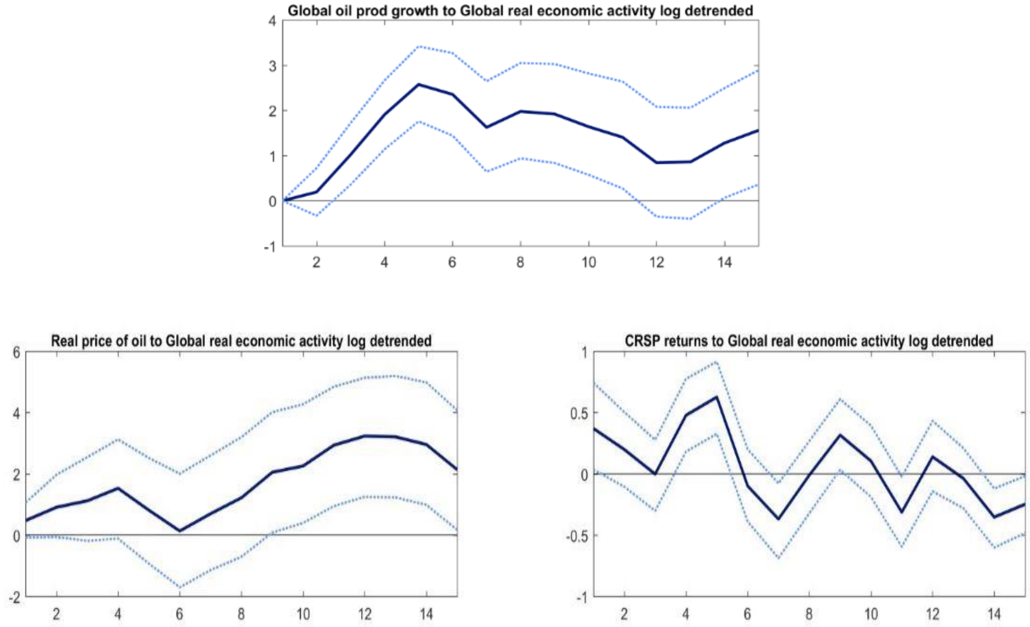
Figure 5.17 Responses of Global Oil Supply, The Real Price of Oil and U.S. Real Stock Returns using The Global Steel Production Index



We chose to compare the indices using the subsample, mainly because we lack data in the alternative indices before the 1990s, making it difficult to compare to the original or extended sample. If we compare Figure 5.16 to Figure 5.18, it looks as if Kilian's Index and the OECD Production Index produce somewhat similar responses. Oil supply reacts much is perhaps the most different as the response of oil supply to a positive shock in the OECD index leads to a quite modest, and barely significant, reaction, that dies out quickly. Using the Kilian index oil supply has a much greater and persistent positive reaction to an aggregate demand shock, which is what is expected when global activity increases. As for the reaction of the oil price it is the most similar, but the real price of oil reacts less using the OECD Index. Finally, real stock returns react very similarly, both responses are quite indecisive, but mostly reacting positively to higher economic activity. This is somewhat surprising, as Kilian wrote that he's motivation for creating his index was because of the OECD Index failing to include activity in the growing Asian economies. We should mention that for our test we used the subsample, whilst Kilian used older data. It could be that the transition to industrialized countries in Asia has led them to react similarly to the OECD countries. Also, the economies across the globe are becoming more and more intertwined, which could be the reason for why The OECD Production Index seems to perform similarly to Kilian's Index in our sample.

However, if we compare Kilian's Index to The World Steel Index, in Figure 5.17, there seems to be some different responses to an unexpected aggregate demand shock. Whereas the responses in Figure 5.18 are quite modest and persistent, in Figure 5.17 both U.S. stock returns and the real price of oil react quite a bit more in the short run, and then the shock dies out towards the end of the horizon.

Figure 5.18 Responses of Global Oil Supply, The Real Price of Oil and U.S. Real Stock Returns using The Kilian Index (as in our main analysis)



Oil supply does not seem to react in any decisive or significant way when using The World Steel Index. The theory that crude oil prices reacts to global demand, is generally accepted by economists. Hence, when observing that aggregate demand shocks produce a bigger, and more decisive, response from the real price of oil, than when using the Kilian Index, that could be an indication that world steel production might be better suited as a proxy for global economic activity than Kilian's Index.

However, U.S. stock returns responded similarly regardless of which proxy we used in the model, so we still feel confident in the results and conclusions we have reached using Kilian's Index as a proxy for global aggregate demand for industrial commodities.

5.4 Discussion

As the issue with the Kilian Index has been discussed at length in Section 5.3, we only feel it necessary to mention one more thing regarding it. We believe a closer comparison of the efficiency in precisely proxying aggregate global demand, between the three indices, is warranted to benefit future studies.

We have briefly discussed why US stock returns react the way they do to a negative oil supply shock, but we struggle to find a clever explanation. However, when looking at the response of the real price of oil to the same shock, there is not a big spike in crude prices. Perhaps therein lies the answer, that the market does not expect the price to jump when global production suffers from a negative shock. Thereby reacting negatively in expectation of lower revenues for oil companies in the U.S., and the fact that they were very sensitive to oil price fluctuations. Or, it could be because of OPEC. In 2014, when the market was close to being saturated with oil after years of increased U.S. production, OPEC responded by flooding the market to secure market shares, in an effort to hurt U.S. competition and restore long term balance in the oil market. Hence, there was a negative supply shock in the U.S., as producers could not continue producing crude oil when market prices were almost half of their break-even prices. This could have led to the lower stock returns as the shale oil sector, and other supporting industry sectors, suffered a massive blowback as a substantial percentage of oil rigs shut down, and many companies suffered losses. OPEC however, underestimated the flexibility and speed in which the U.S. Shale Industry has adapted to the new reality, making this a very interesting field of study as the story unfolds. Hence, we also think it would be interesting to do a similar SVAR study specifying the model differently, and perhaps using active U.S. rigs or average breakeven cost for shale producers in the U.S.

With the Brent Crude Prices plummeting to below $30 in 2015, some producers found themselves in an unsustainable situation. Initially, it seemed the U.S. shale oil producers had dug their own grave, as they were the first to suffer with breakeven prices now well above the market price. But as we know, shale oil producers were able to cut costs at an impressive pace, to quickly recover production and continue to weigh down the oil price. This led OPEC, with a few exceptions, and Russia to commit to production cuts in the fall of 2016, in an effort to stabilize the market. Hence, another interesting specification of the model would be to use U.S. oil supply, as opposed to using global oil output in the model. With OPEC now maintaining their production cuts through 2017, and U.S. producers having dramatically reduced their breakeven price, the increased U.S. production and oil sector activity is not captured in the aggregate production data. In other words, it might be possible that the model is not able to "catch" the effect of increased U.S. production on stock returns, since the OPEC cuts are offsetting the increased shale production in the global market.

Additionally, it would be interesting to examine the long-term effects of the Horizontal Directional Drilling evolution. Research by (H. Bjørnland & L. Thorsrud, 2014) showed that technological innovations caused by "difficult" and costly resource extraction could lead to spillovers to other sectors of the economy, if they are transferable to other industries.

Shale oil reserves are also abundant in other regions[15], and the U.S.' comparative advantage in horizontal directional drilling could possibly also have a positive impact on U.S. stock returns in years to come.

6. Conclusion

The main goal of this thesis was to study if the U.S. Stock Market currently reacts positively to an unexpected increase in crude oil prices, contrary to the negative reaction Kilian & Park found when they published their paper "The Impact of Oil Price Shocks on The U.S. Stock Market" (2009). Our hypothesis was motivated by the increase in U.S. oil production, and the U.S. becoming a net exporter of oil, after being a net importer for decades. In short, the steps we made to achieve this was to replicate, extend and perform a limited robustness analysis, were the latter mainly focused on Kilian's Index for global economic activity, which proxied for global economic activity. We began with a strict replication of their study to see if we could achieve similar results, to be somewhat confident that our main empirical study could be compared to the findings of Kilian & Park. Then we extended the data set, and compared different periods of data to the original sample. Finally, we compared the

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[15] IEA estimated in 2013 that there are reserves five times the size of US reserves, outside the US.

responses produced by Kilian’s Index to those generated using The World Steel Index and The OECD Industrial Production Index.

Our replication was successful, with the data we collected correlating almost perfectly to Kilian & Park’s data set. Our results also matched within reasonable limits, and our model seemed to work well. There were some minor differences, but in practice, it is almost impossible to perfectly replicate results, so we concluded that we had a working model, and that we succeeded in gathering and processing the data similarly to Kilian and Park. When extending the data set, it did not show any major signs of changes in the responses of both U.S. Stock Returns and The Real Price of Oil. The Real Price of oil seemed to react somewhat stronger to both unexpected global demand shocks and precautionary demand shocks on impact, however, not enough to conclude that there had been any major change in the relationships between the variables.

The main purpose of our study was to investigate if the U.S.’ transition from being a net importer, to becoming a net exporter of oil, led the U.S. Stock Market to react differently to oil price shocks. As we did not see any major changes when comparing the original sample to the extended data, we decided to use a more recent subsample (2001.1-2016.12) to accentuate the effects of recent events. We found that U.S. Stock Returns now react negatively to sudden reduction in oil supply, compared to earlier when there was no significant reaction. This could be due to oversupply, prompting a sudden drop in production which subsequently leads to a reduction in active U.S. oil rigs. However, we struggle to find a solid explanation, rooted in economic theory, to explain the way in which the U.S. stock market seem to react to a negative oil supply shock. Next, we found that a global aggregate demand shock led to a stronger positive response in stock returns, compared to the original sample. Perhaps, global business cycles have increased impact on U.S. stock returns, as both companies and financial assets have become increasingly co-dependent globally. Finally, we found that stock returns in the U.S. responded positively to an unexpected oil-market demand shock in the subsample. Combined with correlation between the U.S. stock market and crude oil prices being increasingly positive, this indicates that the relationship between the two has changed in recent years. However, we should mention that the sample size of the reduced sample is less than half of the original sample. The responses of the real price of oil to the same shocks in the subsample, were quite similar to Kilian & Park's findings with the original sample, though a somewhat stronger positive response to a precautionary demand shock.

Lastly, we checked if Kilian's Index is a credible proxy for global aggregate demand. We limited our study to two alternative indexes; The OECD Industrial Production Index and The World Steel Production Index. The OECD Production Index produced similar results to Kilian's Index, despite Kilian creating the index because of limitations of The OECD Index. However, when testing the World Steel Index, we did encounter some changes. Both U.S stock returns and the real price of oil showed stronger responses in the short run, which we argue is more in line with economic theory, and could be an indication that The World Steel Index is better suited as an indicator for global economic activity.

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Appendix

A.1 Augmented Dickey-Fuller test

Dickey-Fuller is the most common way to test for a unit root, due to Dickey & Fuller (1979). It tests if a series is a random walk against the alternative that it is stationary. Given an AR (1) process:

$$y_t = \varphi y_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2).$$

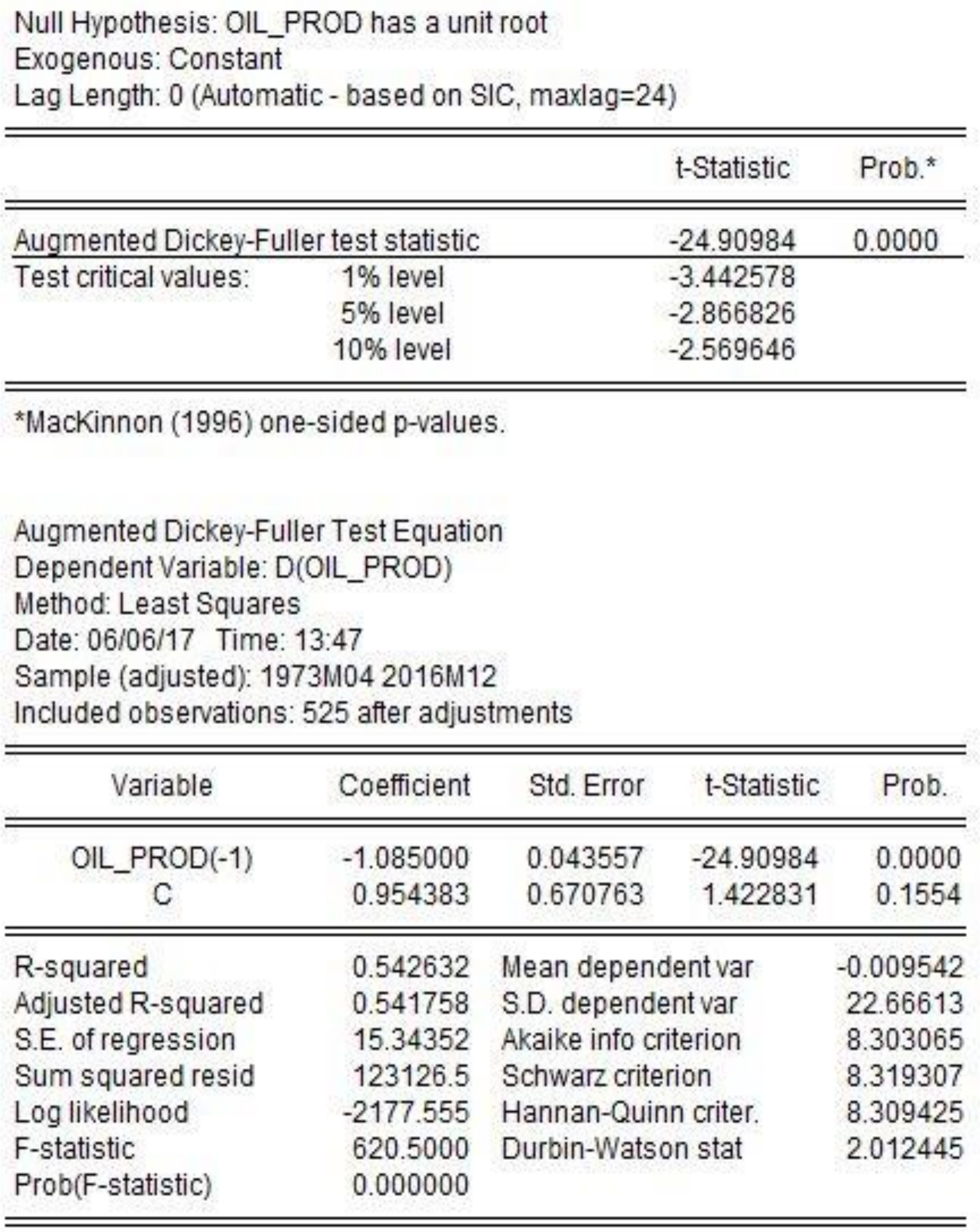
We want to find out whether $\varphi = 1$, or $\varphi < 1$. If $\varphi = 1$, then the AR (1) process reduces to a random walk, if $\varphi < 1$ the AR (1) process is stationary. The AR (1) process can be rewritten as:

$$\Delta y_t = \mu y_{t-1} + \varepsilon_t$$

where $\mu = \varphi - 1$. Hence, using the rewritten AR (1) process, a test for a unit root is just a test on the μ parameter. Where, $H_0\colon \mu = 0$, and $H_1\colon \mu < 0$. This implies that either y_t is integrated of order one or the alternative that y_t is stationary.

The lag structure stated in the illustration over, the rewritten AR (1) process, is not very strong. If the dynamics are richer, residuals will be autocorrelated due to left out dynamics in Δy_t. The Augmented Dickey-Fuller test controls for this be allowing Δy_t to follow a higher order of AR(p) process, and thus augments the standard Dickey-Fuller test with more lags of the dependent variable.

Table A1.1 Augmented Dicky Fuller test for Global Oil Supply



Null Hypothesis: OIL_PROD has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-24.90984	0.0000
Test critical values:	1% level	-3.442578	
	5% level	-2.866826	
	10% level	-2.569646	

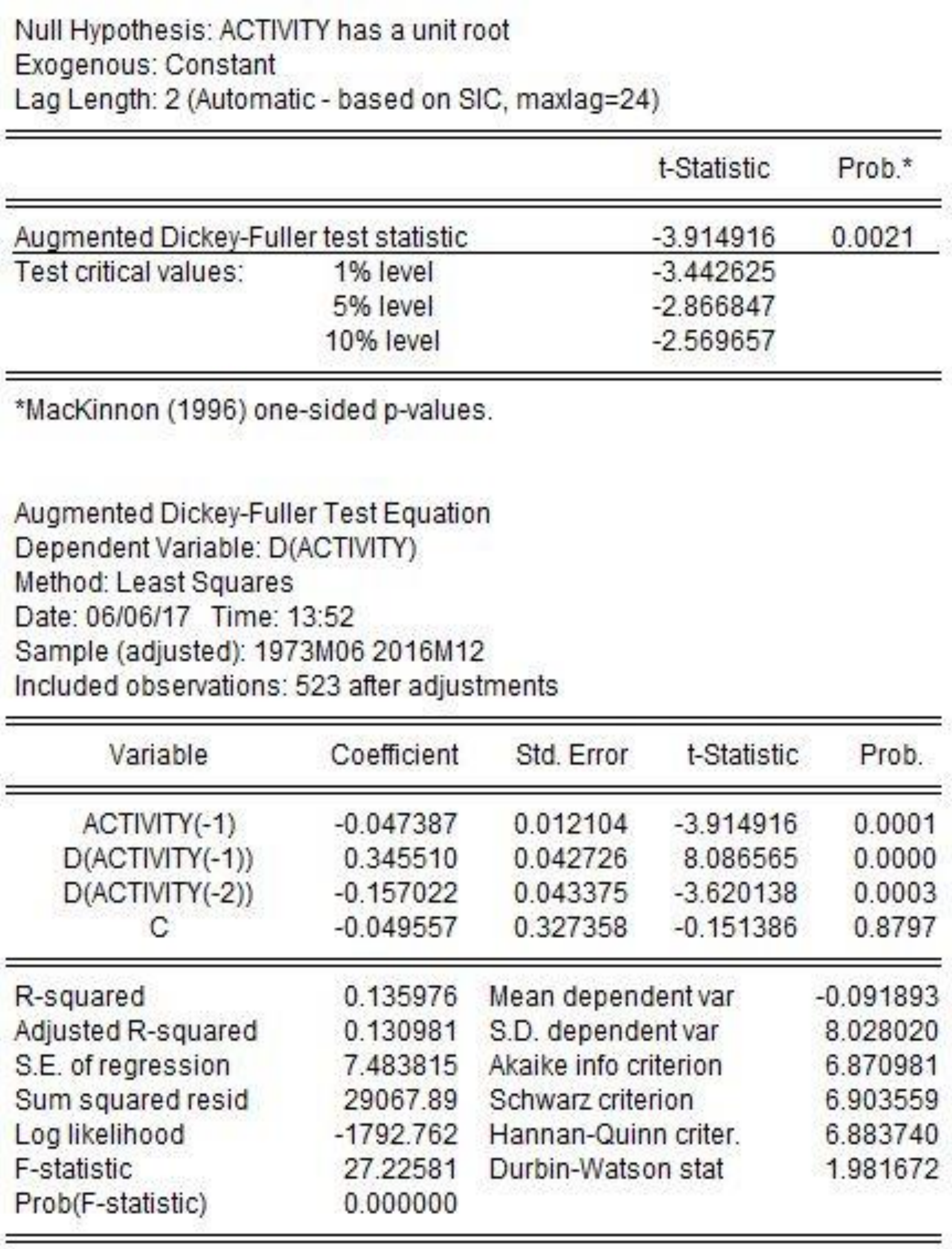
*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OIL_PROD)
Method: Least Squares
Date: 06/06/17 Time: 13:47
Sample (adjusted): 1973M04 2016M12
Included observations: 525 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OIL_PROD(-1)	-1.085000	0.043557	-24.90984	0.0000
C	0.954383	0.670763	1.422831	0.1554

R-squared	0.542632	Mean dependent var	-0.009542
Adjusted R-squared	0.541758	S.D. dependent var	22.66613
S.E. of regression	15.34352	Akaike info criterion	8.303065
Sum squared resid	123126.5	Schwarz criterion	8.319307
Log likelihood	-2177.555	Hannan-Quinn criter.	8.309425
F-statistic	620.5000	Durbin-Watson stat	2.012445
Prob(F-statistic)	0.000000		

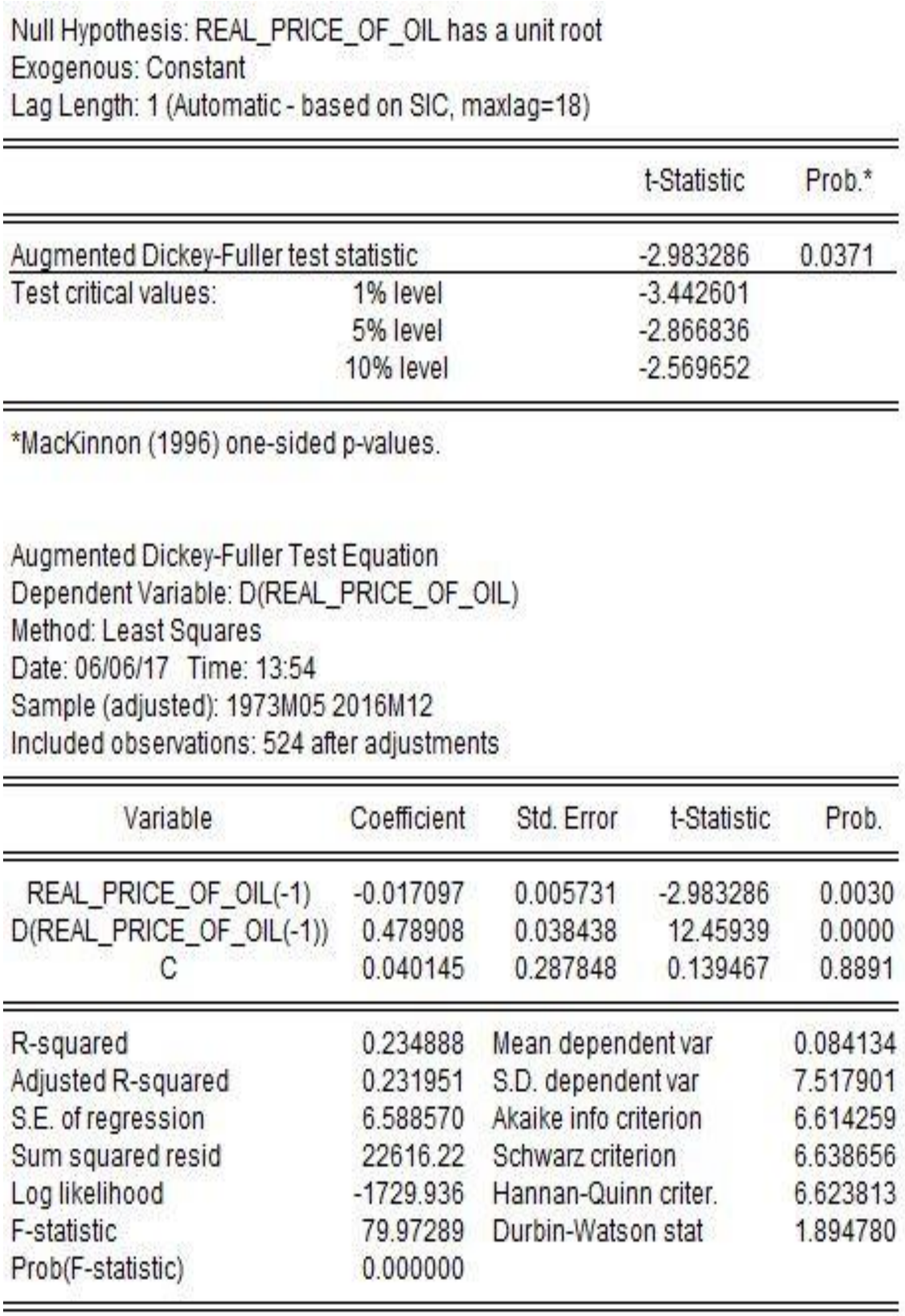
Table A1.2 Augmented Dicky Fuller test for Global Real Economic Activity, Kilian Index



```
Null Hypothesis: ACTIVITY has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=24)
==========================================================================
                                                  t-Statistic    Prob.*
==========================================================================
Augmented Dickey-Fuller test statistic            -3.914916     0.0021
Test critical values:       1% level              -3.442625
                            5% level              -2.866847
                           10% level              -2.569657
==========================================================================
*MacKinnon (1996) one-sided p-values.


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ACTIVITY)
Method: Least Squares
Date: 06/06/17   Time: 13:52
Sample (adjusted): 1973M06 2016M12
Included observations: 523 after adjustments
==========================================================================
        Variable          Coefficient    Std. Error    t-Statistic   Prob.
==========================================================================
      ACTIVITY(-1)        -0.047387      0.012104      -3.914916     0.0001
     D(ACTIVITY(-1))       0.345510      0.042726       8.086565     0.0000
     D(ACTIVITY(-2))      -0.157022      0.043375      -3.620138     0.0003
            C             -0.049557      0.327358      -0.151386     0.8797
==========================================================================
R-squared                  0.135976   Mean dependent var          -0.091893
Adjusted R-squared         0.130981   S.D. dependent var           8.028020
S.E. of regression         7.483815   Akaike info criterion        6.870981
Sum squared resid          29067.89   Schwarz criterion            6.903559
Log likelihood            -1792.762   Hannan-Quinn criter.         6.883740
F-statistic                27.22581   Durbin-Watson stat           1.981672
Prob(F-statistic)          0.000000
==========================================================================
```

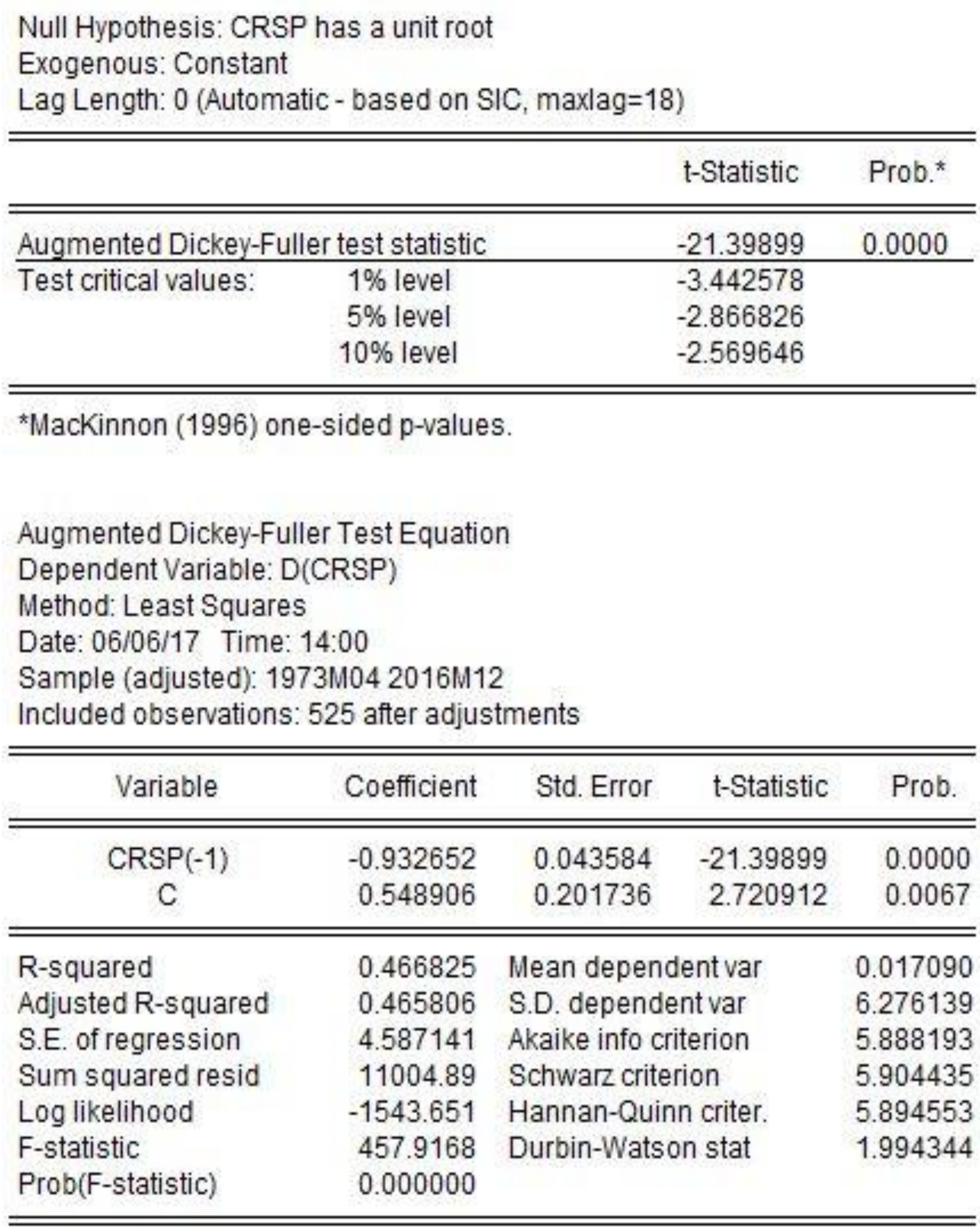
Table A1.3 Augmented Dicky Fuller test for The Real Price of Oil



```
Null Hypothesis: REAL_PRICE_OF_OIL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=18)
==========================================================================
                                                  t-Statistic    Prob.*
==========================================================================
Augmented Dickey-Fuller test statistic             -2.983286    0.0371
Test critical values:          1% level            -3.442601
                               5% level            -2.866836
                               10% level           -2.569652
==========================================================================
*MacKinnon (1996) one-sided p-values.


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REAL_PRICE_OF_OIL)
Method: Least Squares
Date: 06/06/17   Time: 13:54
Sample (adjusted): 1973M05 2016M12
Included observations: 524 after adjustments
==========================================================================
        Variable           Coefficient   Std. Error   t-Statistic   Prob.
==========================================================================
  REAL_PRICE_OF_OIL(-1)     -0.017097     0.005731    -2.983286    0.0030
D(REAL_PRICE_OF_OIL(-1))     0.478908     0.038438     12.45939    0.0000
           C                 0.040145     0.287848     0.139467    0.8891
==========================================================================
R-squared                    0.234888   Mean dependent var        0.084134
Adjusted R-squared           0.231951   S.D. dependent var        7.517901
S.E. of regression           6.588570   Akaike info criterion     6.614259
Sum squared resid            22616.22   Schwarz criterion         6.638656
Log likelihood              -1729.936   Hannan-Quinn criter.      6.623813
F-statistic                  79.97289   Durbin-Watson stat        1.894780
Prob(F-statistic)            0.000000
==========================================================================
```

Table A1.4 Augmented Dicky Fuller test for U.S. Real Stock Returns



```
Null Hypothesis: CRSP has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=18)
=========================================================================
                                               t-Statistic    Prob.*
=========================================================================
Augmented Dickey-Fuller test statistic         -21.39899     0.0000
Test critical values:        1% level          -3.442578
                             5% level          -2.866826
                            10% level          -2.569646
=========================================================================
*MacKinnon (1996) one-sided p-values.


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CRSP)
Method: Least Squares
Date: 06/06/17   Time: 14:00
Sample (adjusted): 1973M04 2016M12
Included observations: 525 after adjustments
=========================================================================
      Variable         Coefficient    Std. Error    t-Statistic    Prob.
=========================================================================
      CRSP(-1)         -0.932652      0.043584      -21.39899     0.0000
         C              0.548906      0.201736       2.720912     0.0067
=========================================================================
R-squared               0.466825    Mean dependent var        0.017090
Adjusted R-squared      0.465806    S.D. dependent var        6.276139
S.E. of regression      4.587141    Akaike info criterion     5.888193
Sum squared resid       11004.89    Schwarz criterion         5.904435
Log likelihood         -1543.651    Hannan-Quinn criter.      5.894553
F-statistic             457.9168    Durbin-Watson stat        1.994344
Prob(F-statistic)       0.000000
=========================================================================
```

A.2 Impulse Responses using Kilian & Park's model

Figure A2.1 Responses 1973.1-2016.12

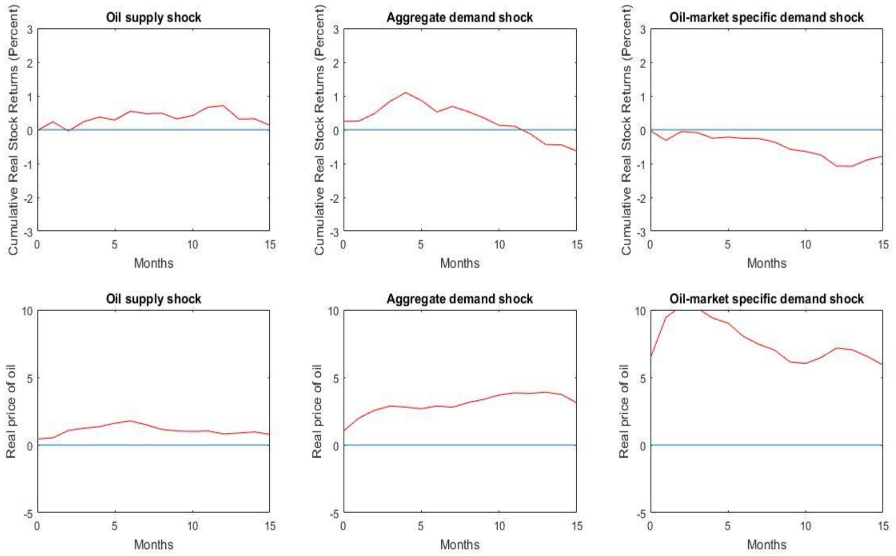


Figure A2.2 Responses 2001.1-2016.12

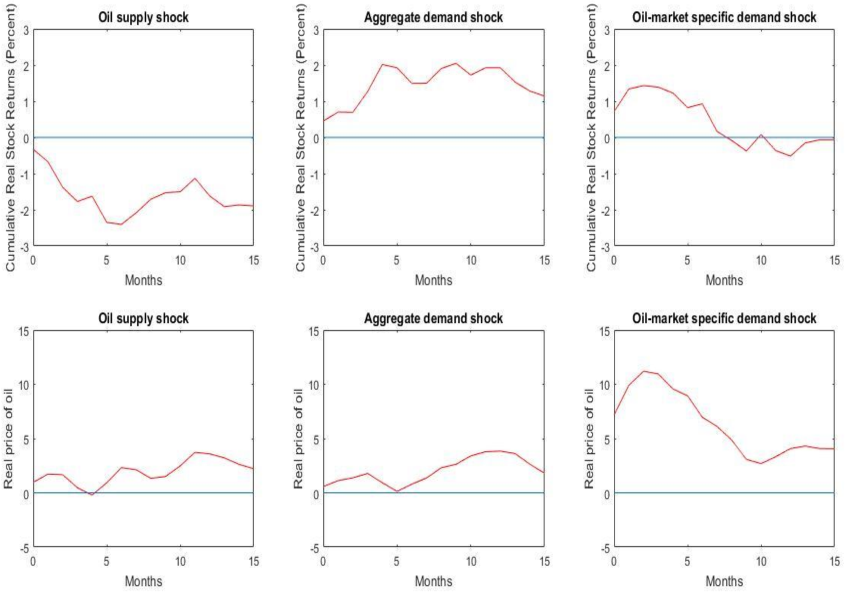


Figure A2.3 Responses 2001.1-2016.12 using The OECD Production Index

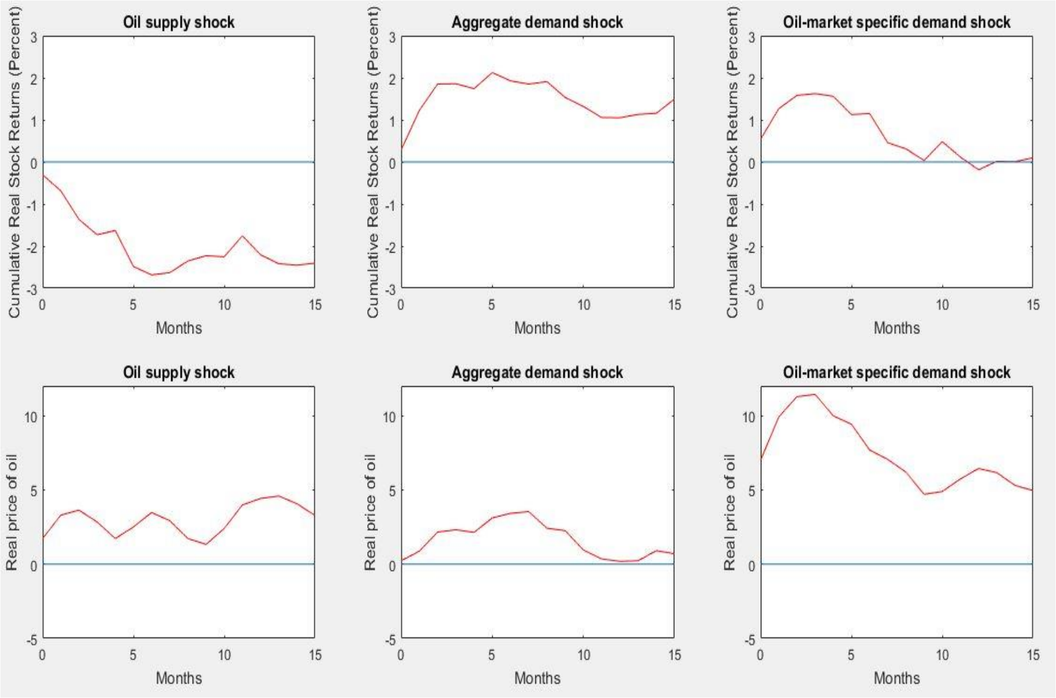
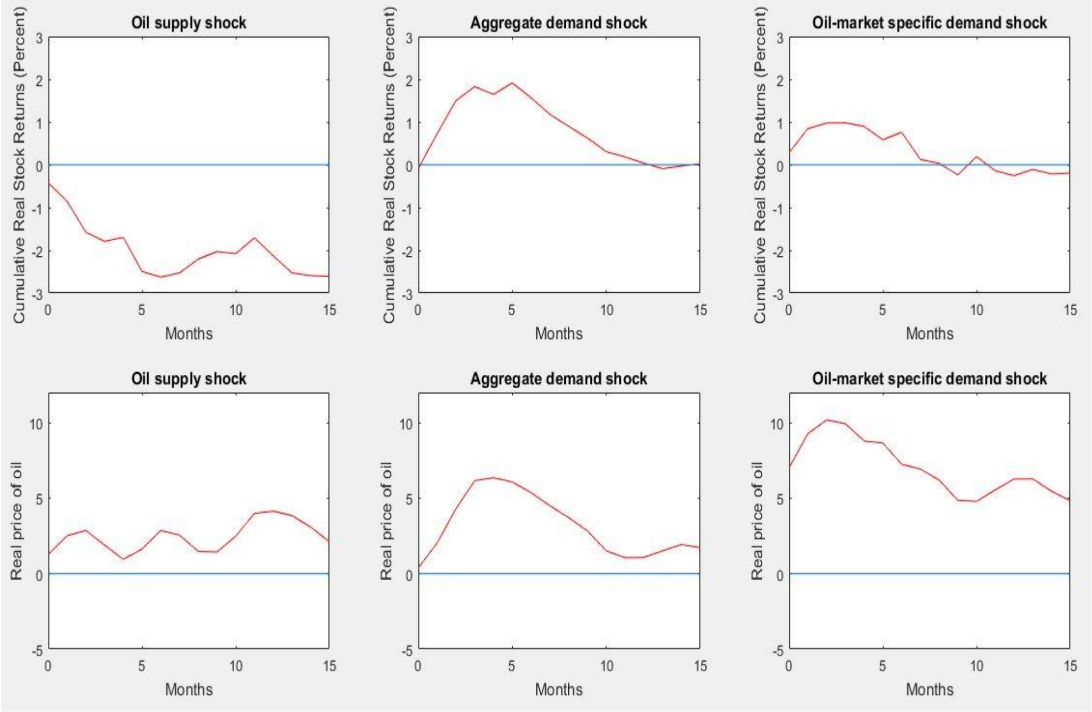
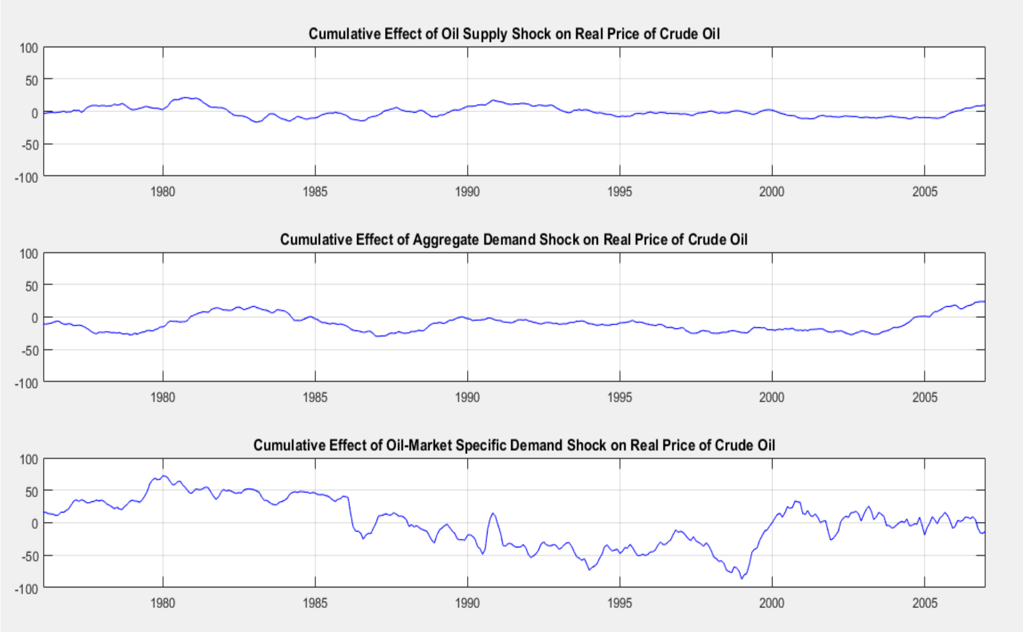


Figure A2.4 Responses 2001.1-2016.12 using The World Steel Production Index



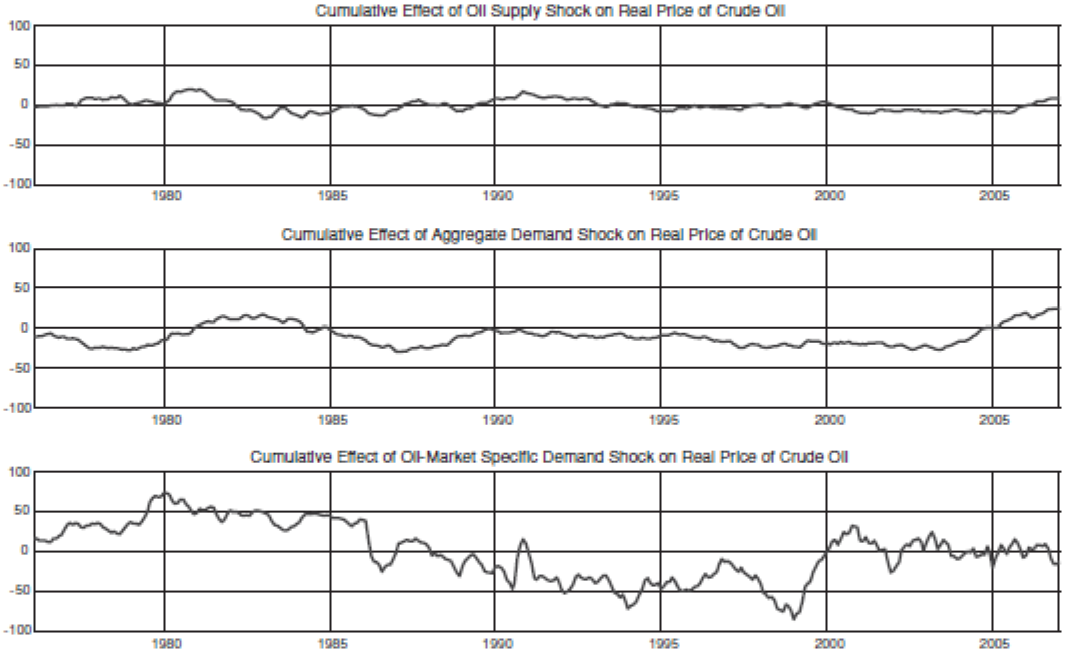
A.3 Historical decompositions

Figure A3.1 Historical decomposition of real price of oil



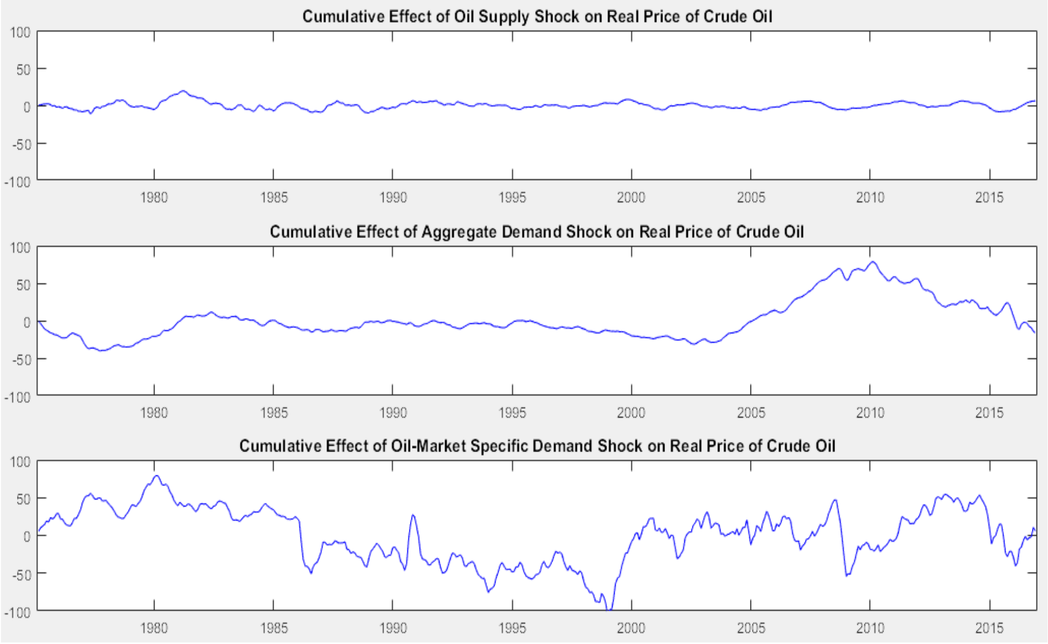
Our historical decomposition of real price of oil: 1975.2-2006.12

Figure A3.2 Historical decomposition of real price of oil, Kilian & Park



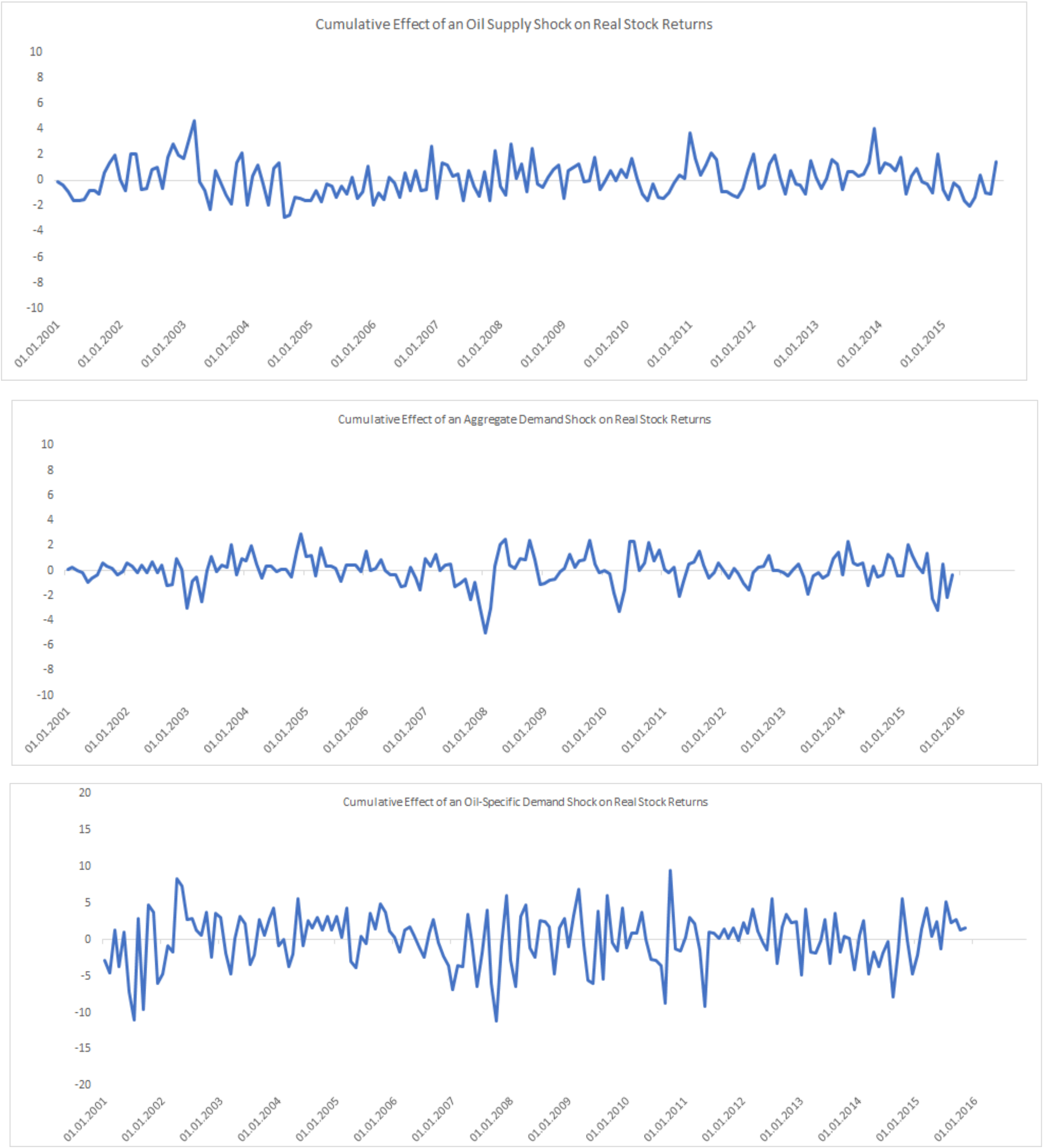
Historical decomposition of real price of oil: 1975.1-2006.12, KP (2009).

Figure A3.3 Historical decomposition of real price of oil, extended



Historical decomposition of real price of oil: 1975.1-2016.12

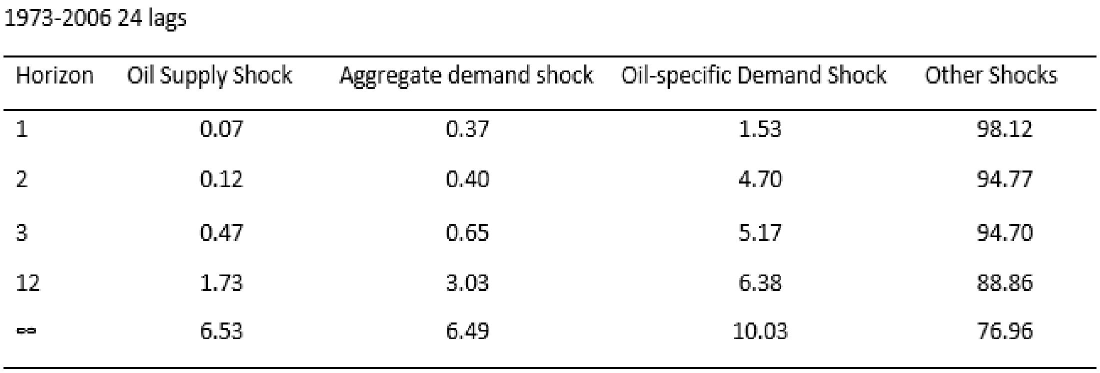
Figure A3.4 Historical decomposition of real stock returns



Historical decomposition of U.S. real stock returns: 2001.1-2016.12

A.4 Variance decomposition

Table A4.1 Variance decomposition

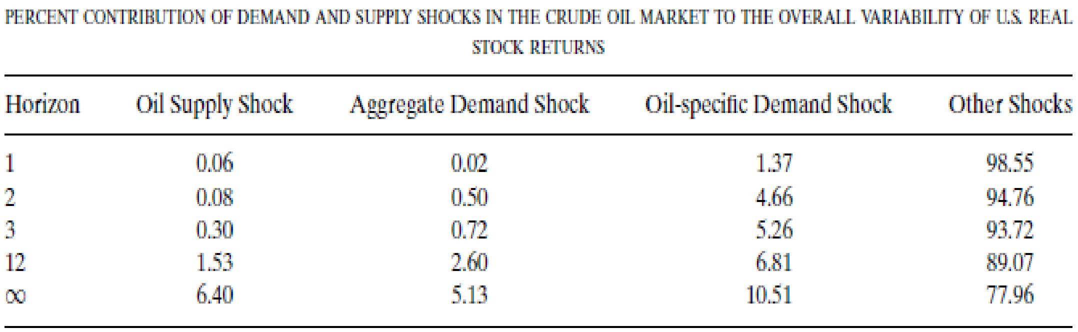


1973-2006 24 lags

Horizon	Oil Supply Shock	Aggregate demand shock	Oil-specific Demand Shock	Other Shocks
1	0.07	0.37	1.53	98.12
2	0.12	0.40	4.70	94.77
3	0.47	0.65	5.17	94.70
12	1.73	3.03	6.38	88.86
∞	6.53	6.49	10.03	76.96

Based on our variance decomposition of the structural VAR model.

Table A4.2 Variance decomposition, Kilian & Park

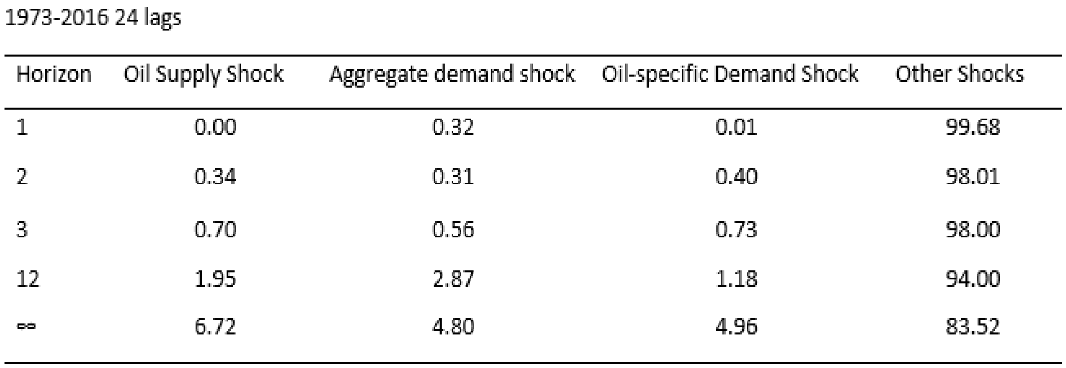


PERCENT CONTRIBUTION OF DEMAND AND SUPPLY SHOCKS IN THE CRUDE OIL MARKET TO THE OVERALL VARIABILITY OF U.S. REAL STOCK RETURNS

Horizon	Oil Supply Shock	Aggregate Demand Shock	Oil-specific Demand Shock	Other Shocks
1	0.06	0.02	1.37	98.55
2	0.08	0.50	4.66	94.76
3	0.30	0.72	5.26	93.72
12	1.53	2.60	6.81	89.07
∞	6.40	5.13	10.51	77.96

Based on variance decomposition of the structural VAR model, KP (2009).

Table A4.3 Variance decomposition, extended sample

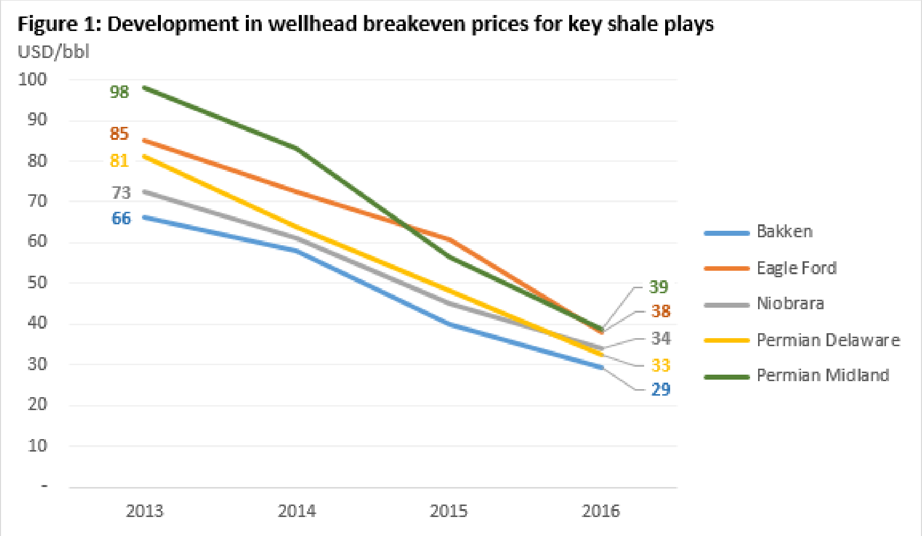


1973-2016 24 lags

Horizon	Oil Supply Shock	Aggregate demand shock	Oil-specific Demand Shock	Other Shocks
1	0.00	0.32	0.01	99.68
2	0.34	0.31	0.40	98.01
3	0.70	0.56	0.73	98.00
12	1.95	2.87	1.18	94.00
∞	6.72	4.80	4.96	83.52

Based on our variance decomposition of the structural VAR model, with the extended sample.

A.5 Miscellaneous



Source: Rystad Energy NASWellCube

Figure A5.1 Break even prices

Breakeven prices for key shale fields, by Rystad Energy.

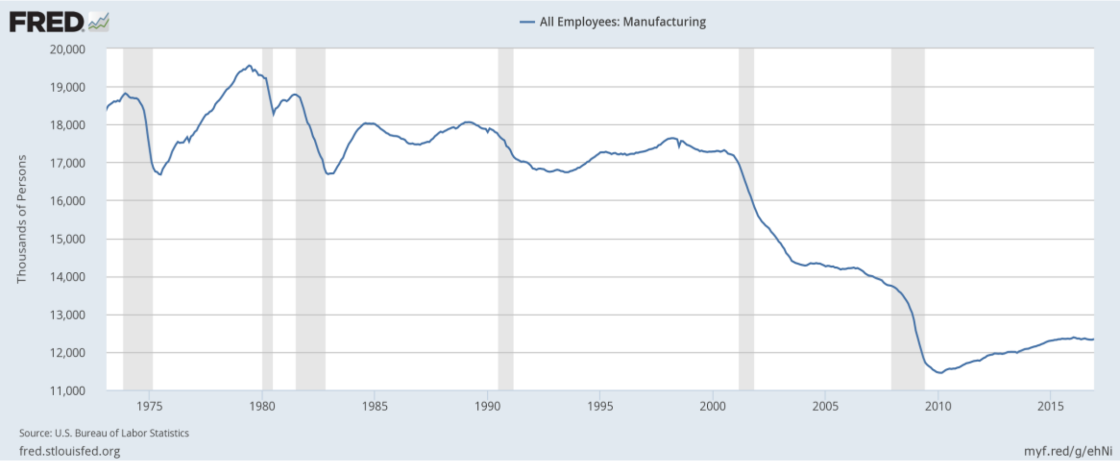
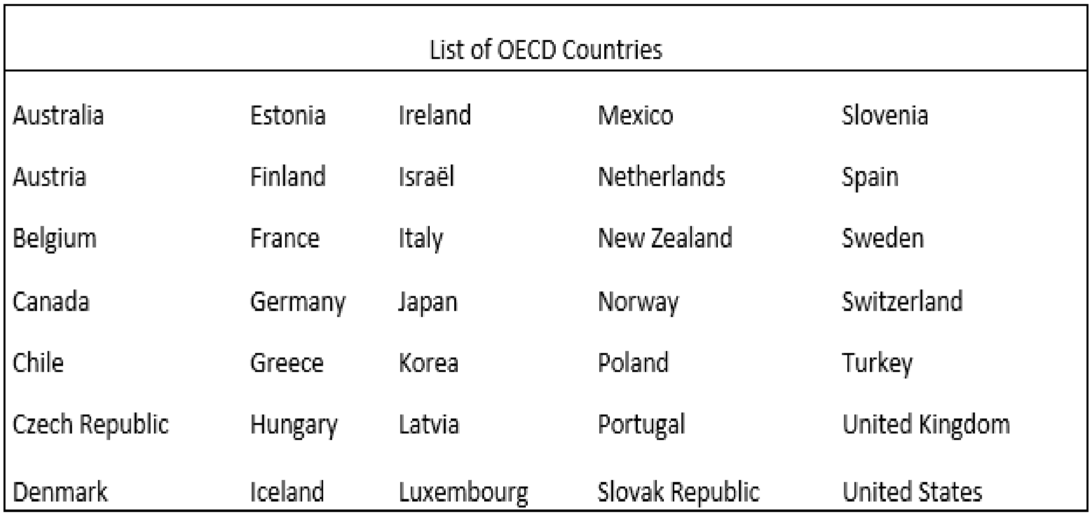


Figure A5.2 Manufacturing jobs

U.S. manufacturing jobs, 1973-2016.

Table A5.1 OECD Countries



List of OECD Countries				
Australia	Estonia	Ireland	Mexico	Slovenia
Austria	Finland	Israël	Netherlands	Spain
Belgium	France	Italy	New Zealand	Sweden
Canada	Germany	Japan	Norway	Switzerland
Chile	Greece	Korea	Poland	Turkey
Czech Republic	Hungary	Latvia	Portugal	United Kingdom
Denmark	Iceland	Luxembourg	Slovak Republic	United States

List of OECD Countries (OECD, 2017).

A.6 Variable plots

Figure A6.1 Plot of World Crude Production

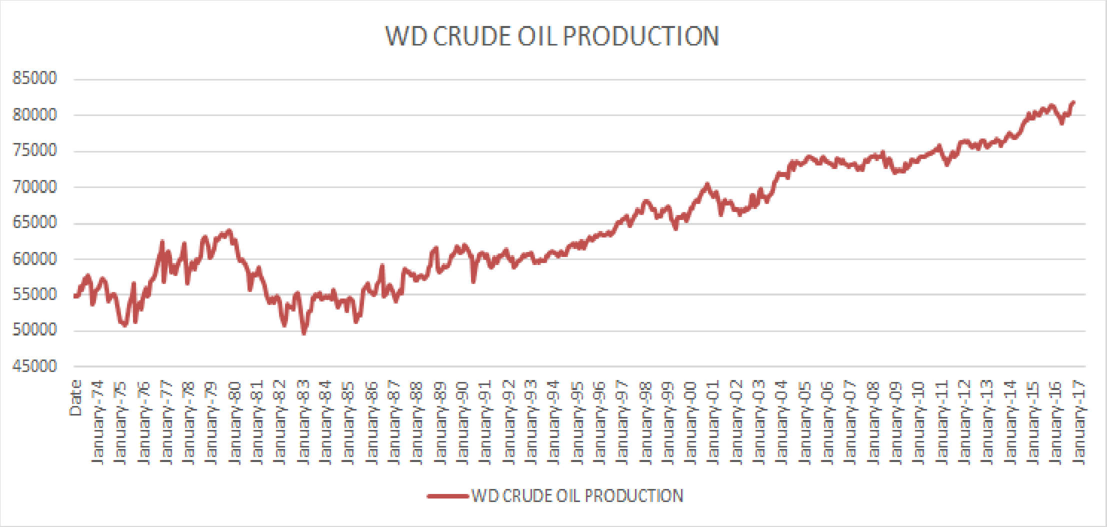


Figure A6.2 Kilian's Index

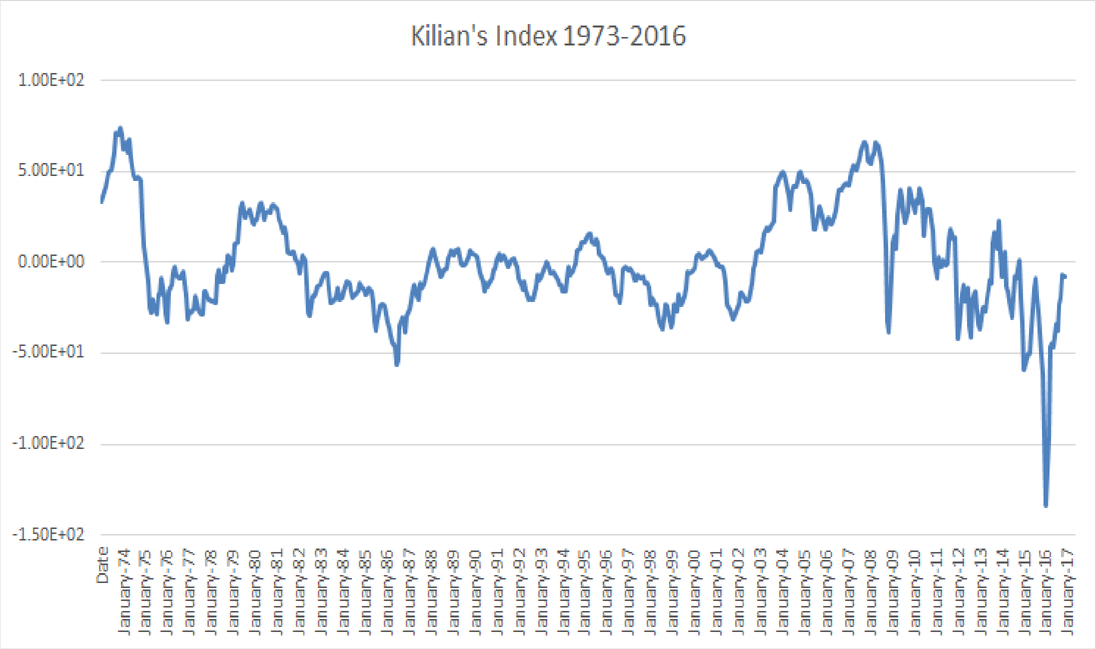


Figure A6.3 The Real Price of Oil

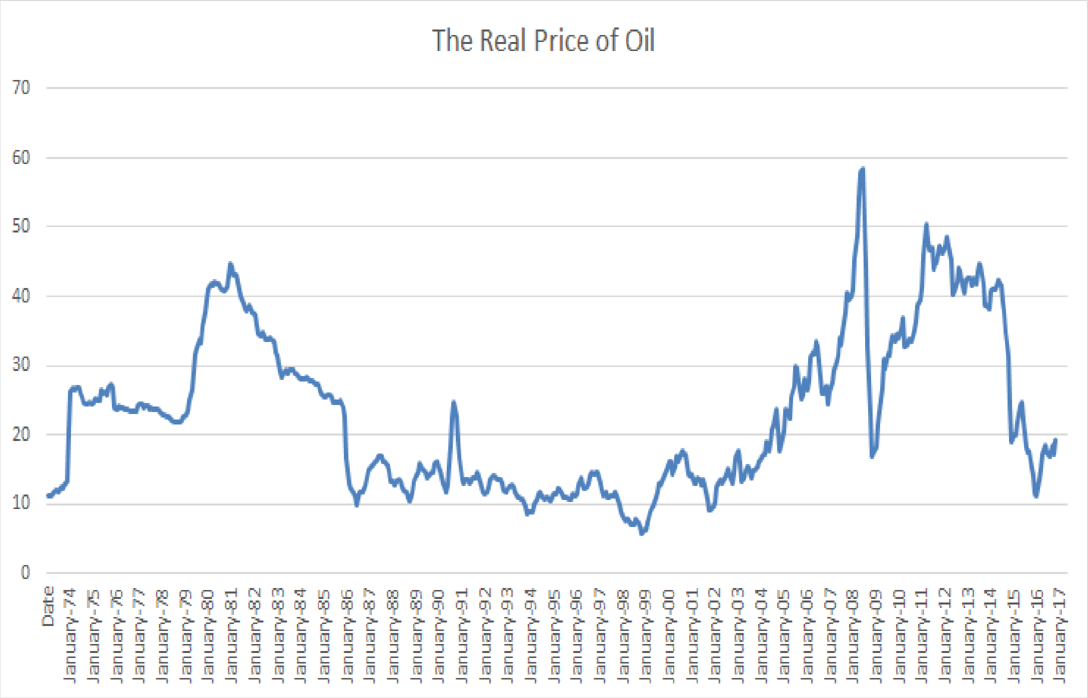


Figure A6.4 U.S. Real Stock Returns

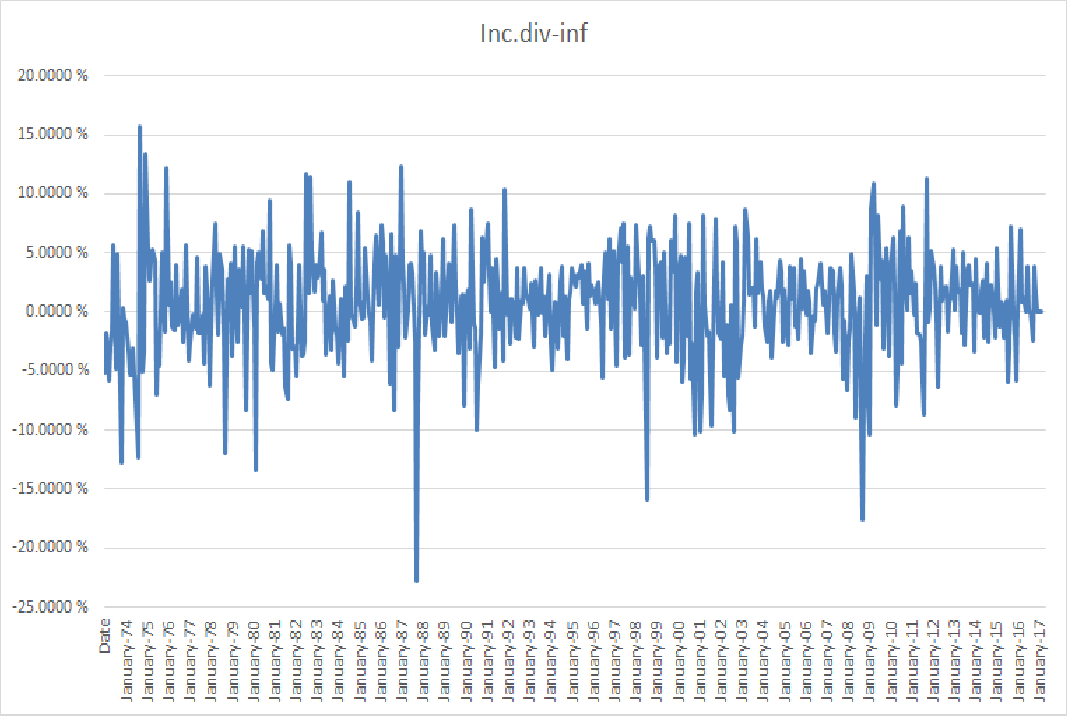


Figure A6.5 Oil production and Price