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Essays on Effects of Government Policies and Investors’ Expectations on Crude Oil Market Dynamics

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Essays on Effects of Government Policies and Investors' Expectations on Crude Oil Market Dynamics

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Economics

by

Zi Rui Peng

Dissertation Committee:
Professor Eric Swanson, Chair
Professor William Branch
Professor Fabio Milani

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DEDICATION

To my grandparents, Biao Peng, Yuwei Peng, Xu Rui, Zhaowen Qin, and my parents, Xiaojun Peng, Zhen Rui, for their trust, love, care, and support.

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ABSTRACT OF THE DISSERTATION

Essays on Effects of Government Policies and Investors' Expectations on Crude Oil Market Dynamics

By

Zi Rui Peng

Doctor of Philosophy in Economics

University of California, Irvine, 2022

Professor Eric Swanson, Chair

Chapter 1 proposes a set of new methods to measure the effects of investors' reactions and expectations on crude oil market dynamics. I measure investors' reactions to unexpected events in the crude oil market using high-frequency changes in oil futures prices around significant event dates. I classify each unexpected event into one of three categories: supply shocks, demand shocks, and market influence shocks, and show how these shocks have statistically significant effects on crude oil prices, crude oil production, and economic activity. Moreover, I construct indexes of media coverage and investor interest of the crude oil market using Google Trends data and the New York Times article archives. I demonstrate that both indexes have statistically significant effects on crude oil prices, production, and economic activity. I thus identify statistically significant effects of investors' reactions and expectations on crude oil market dynamics, which have largely been ignored in previous research.

Chapter 2 focuses on checking the validity of the original Kilian (2009) Index and extends Kilian (2009) model to include future supply expectation shocks and future demand expectation shocks. In the first part of this chapter, I find that the results have changed by applying the corrected

Kilian index suggested by Hamilton (2018), as well as the index constructed using the OECD industrial production level. Though the results have changed, the conclusion of the original Kilian paper stays valid. In the second part of this chapter, I extend the Kilian (2009) model by replacing crude oil spot price with future contract ETF price, which increases the effects of oil market-specific shocks. I then further extend the model to include crude oil supply and demand forecast values from the OPEC monthly reports and has shown significant future supply and future demand expectation shocks on crude oil prices. Finally, I show possible political and unanticipated events as part of crude oil market-specific shocks on crude oil prices.

Chapter 3 investigates the impact of the U.S. fracking boom and the lifting of the U.S. crude oil export ban on crude oil price spreads, pass-through effects on U.S. domestic inflation, and crude oil investors' reactions to petroleum data report releases. I find that the price spread between WTI and Brent became wider after the U.S. fracking boom started, and narrower after the lifting of the crude oil export ban. Further, I find the crude oil price pass-through effects are significant in the first month, and the effects are slower after the U.S. fracking boom started. Finally, I find that with the lifting of the crude oil export ban, WTI crude is more integrated with the global oil market, and the effects of the U.S. government weekly reports on WTI crude prices become smaller.

Chapter 1

The Effects of Investors’ Reactions and Expectations on Crude Oil Market Dynamics

1.1 Introduction

Crude oil prices have always been an important factor for oil production, economic activity, and other macroeconomic variables. Hamilton (1983) finds that all but one of the U.S. recessions since World War II have been preceded by large increases in crude oil prices. Moreover, the literature has widely established the association between crude oil prices and inflation, especially in the 1970s, when the dramatic increases in crude oil prices were associated with high inflation and severe recessions (see, e.g., Hooker (2002)).

In this paper, I study the effects of investors’ reactions to and expectations about oil prices, oil production and economic activity. The methodologies of this paper are based on a structural vector autoregression (SVAR) with external instruments approach with high-frequency identification. My method to construct the surprise shock series is inspired by Faust, Swanson, and Wright (2002). I focus on capturing the investors' reactions to major news events in the crude oil market by considering the daily changes in the WTI futures prices around the news events. With high-frequency identification analysis, I can isolate investors' reactions to those events from other factors in the crude oil market by considering narrow windows around news events. Other factors in the crude oil market are already priced in at the time of the events and are unlikely to be changed within the narrow one-day window of time. By constructing series of investors' reactions using high-frequency identification analysis, I develop external instruments to identify investors' expectation shocks and their effects on crude oil market dynamics. The adoption of the SVAR with external instruments method to analyze the shock effects on the crude oil market is based on the model implementation by Gertler and Karadi (2015) on macroeconomic effects of monetary policy shocks and the method introduced by Stock and Watson (2012).

One recent paper by Kanzig (2021) introduces the implementation of investors' reactions by applying the high-frequency identification approach and considers narrow windows of crude oil price movements around OPEC meeting announcements to construct a news supply shock series and found statistically significant effects on crude oil market dynamics. In contrast to Kanzig's paper, this paper is different in two ways. First, Kanzig only looks at news supply shocks, and does not consider demand shocks. In this paper, by considering a variety of unexpected events in the crude oil market, I can separate the events into three category groups, oil supply, oil demand, and financial market influence, and construct three shock series: oil supply expectation shocks, oil demand expectation shocks, and financial market influence shocks. I then analyze the effects of each shock series on crude oil market dynamics. In contrast, Kanzig focuses on market reactions to the OPEC meeting announcements, mainly consisting of OPEC's production level decisions. Deviations from production agreements by OPEC members are possible. However, most of the time, the decisions will follow through until the following decision agreements are made, which means that investors' reactions and expectations to the OPEC meeting announcements are mostly correct. In contrast, the events considered in this paper are unexpected events that might or might not be realized. These unexpected events are associated with future uncertainties when investors make their investment decisions.

In the second half of this paper, I further investigate investors' role in the crude oil market by considering media coverage and investor interest in the crude oil market. The construction of the investor interest index is based on data from Google Trends. By considering the changes in the frequency of oil-related term searches, I construct a proxy index to capture changes in investor interest in the crude oil market. The construction of the media coverage index is based on the method introduced by Baker, Bloom, and Davis (2016). In their paper, the authors construct the economic policy uncertain (EPU) index by counting the frequencies of the political uncertainty terms showing up in ten leading US news papers. The authors then consider the effects of the EPU index on Macroeconomic variables. Similar to the method by Baker, Bloom, and Davis (2016), I obtain the frequencies of the term "crude oil" on both the printed and electronic articles of the New York Times and construct a media coverage index that can proxy for the changes in the media's coverage in the crude oil market. After constructing both the media's coverage index and crude oil investors' interest, I apply the traditional SVAR model approach to analyze the effects of both indexes on crude oil prices, production, and demand. Finally, in the last section of this paper, I further investigate the correlations between crude oil prices and the media coverage and investor interest in the crude oil market by applying the Granger causality framework to consider the changes in the net futures position.

1.1.1 Related Literature

The main methodologies of this paper relate to two strands of literature. The first strand of literature focuses on decomposing the drivers of fluctuations in crude oil prices and their effects on the dynamics of the crude oil market. For example, Kilian (2009) uses an SVAR model and recursive ordering restrictions to decompose the crude oil price fluctuations into crude oil supply shocks, crude oil demand shocks, and precautionary demand shocks. As the literature evolves, one emphasis has been put on imposing different restrictions on the baseline SVAR model introduced by Kilian. For example, Kilian and Murphy (2012) and Baumeister and Hamilton (2019) consider imposing sign restrictions, and Kilian (2009) considers zero restrictions. Another emphasis focuses on finding a better proxy variable for global economic activity. Baumeister, Korobillis, and Lee (2020) evaluate alternative global economic activity indicators and find that world industrial production is one of the most useful indicators. Hamilton (2018) finds that best proxy variable for global economic activity is the OECD countries' industrial production level. On the other hand, Kilian and Murphy (2014) suggest the usage of global crude oil inventory. My paper relates to this strand of literature by considering investors' expectations and reactions as a driver of crude oil prices and quantities.

The second strand of literature focuses on SVARs with external instruments and high-frequency identification. The high-frequency identification approach is implemented in Faust, Swanson, and Wright (2002). The authors construct a measure of monetary policy shocks by considering high-frequency asset price movements in narrow windows of time around monetary policy announcements to capture the structural effects of those monetary policy announcements on the other variables of the VAR. Stock and Watson (2012) developed the SVAR with external instruments methodology to identify the effects of the shock of interest in the SVAR by using an external instrumental variable correlated with the shock of interest but uncorrelated with other shocks in the model. Kanzig (2021) adopts the high-frequency identification and the SVAR with external instruments approach by using oil price movements around OPEC announcements as an external instrument for oil supply news shocks in the crude oil market. My paper relates to this strand of literature by constructing three shock series using the high-frequency identification approach considering oil price movements around significant unexpected events. The shock series are used as my external instruments for my SVAR.

I structure the rest of this paper as follows. In section 1.2, I discuss the construction methods of the shock series and indexes used in this paper and related crude oil market data. In section 1.3, I explain the baseline SVAR model and my SVAR with external instruments model. In section 1.4, I present the effects of the supply expectation, demand expectation, and market influence shocks on crude oil market dynamics. Section 1.5 extends the results of this paper by considering the effects of media coverage and investor interest on the crude oil market. In section 1.6, I investigate the associations between crude oil prices and media coverage and investor interest by considering the changes in the net crude oil futures positions. Finally, section 1.7 concludes.

1.2 Index Construction and Data

The analysis of this paper is based on indexes and data from three areas. First, I construct three shock series based on investors' reactions to supply-related, demand-related, and market influence events to create external instruments for investors' supply expectation, demand expectation, and market influence shocks. Second, I construct the media coverage and investor interest indexes to capture media coverage and investor interest in the crude oil market. Finally, I include oil price, oil production, and real economic activity data to measure crude oil market dynamics.

1.2.1 Unexpected Event Shock Series

The purpose of constructing this index is to evaluate the effects of investors' expectations shocks from unexpected events on crude oil market dynamics and related variables. To construct this index, I consider unexpected events that led to large movements in crude oil prices using daily WTI futures data. For an event to be recorded as a special event with large price movements, its daily price movement must be greater than plus or minus four standard deviations (+ 5.88%/-5.88%). The decision to only focus on large and significant price movement events is for two reasons. First, with a smaller amount of dates, the data set is more manageable, and second, events that led to significant oil price movements are more likely to have medium to long-term effects on the crude oil market.

The sample of trading days considered in this section is from January 1, 1984, to December 31, 2019, for a total of 9110 trading days. With the decision threshold above, 160 trading days can be categorized as large price movement trading days.

Each large price movement trading day is then matched with the event(s) that caused the price movements by reading news articles from the New York Times and Wall Street Journal electronic archives. I then categorize all the events into three categories: Supply-related, demand-related, or market influence events. Supply-related events are events associated with a potential future increase or decrease in crude oil production. These events mainly come from OPEC production level decision announcements and events in the Middle East. For example, on November 27, 2014, OPEC announced that it would not cut production even though investors were expecting a production cut, which led to a 17.53 percent decrease in crude oil prices that day. On the other hand, on December 16, 1998, expectations of the execution of airstrikes in Iraq caused WTI futures price to rise 7.2 percent during the trading day. The decision by the U.S. and U.K. to execute the bombing strikes was due to Iraq's leader Saddam Hussein's refusal to cooperate with the United Nations weapons inspectors to find and dismantle chemical, biological and nuclear weapons.

An event is categorized as a demand-related event if it can lead to possible increases or decreases in future crude oil consumption. One example of a demand-related event is the news report by the Wall Street Journal on the crude oil price increase of 7.58 percent on January 22, 2016. The reported reason was market anticipation that an upcoming snowstorm in the U.S. boosted fuel demand expectations, and traders speculated Japan's central bank stimulus could increase fuel demand. Another example of a demand-related event is when OPEC or government agencies such as the U.S. Energy Information Agency (EIA) contribute to large price movements with their inventory data releases. For example, the EIA weekly data on February 19, 2009, showing a surprise draw on U.S. oil inventories that offered hope to the markets that oil demand was recovering, which led to a 12.76 percent increase in WTI futures prices. A related Wall Street Journal article states that it was the first withdrawal of oil from the U.S. inventories since December. Oil inventories fell by 200,000 barrels, while analysts polled by the Dow Jones Newswires had on average forecasted a build of 2.9 million barrels.

Finally, market influence events are events that led to large price movements in the crude oil futures market but are not associated with demand or supply-related events. An example is May 5th, 2011, when crude oil prices fell 8.62 percent, both the New York Times and Wall Street Journal attributed the decrease to the surging dollar.

By applying this method, 81 trading days are categorized as supply-related events, 39 trading days are categorized as demand related events, and 38 trading days are categorized as market influence events. Two trading days are dropped from the sample because it is unclear how to categorize them.

For the construction method, if there is a qualifying event within the month, the event's associated price change within the daily trading window is recorded for that month's series; otherwise, zero is recorded. In the case of two or more events happening in the same month, the sum of the price changes is recorded for the month's shock. By considering a narrow trading window around the news events, I construct three shock series: the supply expectation shocks, demand expectation shocks, and the market influence shocks. To ensure the events considered are the only source that contributed to the large price movements, I also check news articles one trading day before and one trading day after the events considered to ensure no other events are associated with the large oil price movements.

1.2.2 Media Coverage Index

In extension of my basic results below, I consider measures of media coverage and investor interest in the crude oil market. The media coverage index captures the changes in the media's attention to the crude oil market. It is constructed based on the number of crude oil market-related news articles presented in the New York Times. With the changes in the index, I can capture how the media changes their interest in covering the crude oil market. To construct this index, I focus on the monthly number of articles that contain discussions of the crude oil market, including discussions of the crude oil market as the main topic and financial news articles that include information relating to the crude oil market. Both printed articles and electronic articles are included. To normalize the number of articles into an index value range between 0 and 100, I divide the raw number of articles by the max number of articles between January 1984 and December 2019. To correct for the increasing number of articles due to more electronic articles published in recent years, I linearly detrended the index and obtained the residuals as my final index values for further analysis. The index ranges from January 1984 to December 2019.

1.2.3 Investor Interest Index

The investor interest index focuses on capturing investors' interest in the crude oil market. The construction of the investor interest index is based on the number of searches by Google users related to the crude oil market for a specific period. By considering the changes in the frequencies of crude oil-related searches, I can obtain a proxy index for changes in investors' interests in the crude oil market. The frequency of searches is recorded by Google Trends and is available to the public to obtain. I have considered 12 search words related to the crude oil market and investment opportunities (Table 1.1). To normalize the search frequency of the 12 crude oil market related terms, I take the arithmetic average and normalize the value to range between 0 and 100 by dividing by the max number of searches from 2004 to 2019. One possible concern in this index is the increase in popularity of online searches; we may see an increase in searches because more and more people have adopted the internet. To adjust for this possibility, I detrend the index linearly and use the residuals as the final index for further analysis. The investors' interest index ranges from January 2004 to December 2019 due to the availability of Google Trends data starts in January 2004.

1.2.4 Crude Oil Market Data

Crude oil price data are based on West Texas Intermediate (WTI)'s current month futures data from January 1984 to December 2019. I choose WTI crude futures instead of Brent crude oil futures due to the larger trading volume of WTI futures compare to Brent crude oil futures. The crude oil futures market and data availability started in late 1983. Since my analysis with the crude oil price data depends on daily price changes and cannot be substituted using the monthly crude oil spot price, I decided to start the data set from January 1984. On the other hand, the data sets end in December 2019 to exclude the data in 2020, which contains two negative crude oil price data points related to the Covid-19 pandemic. The two negative price data points are extreme outliers to the data set, which should be considered in a different setting. The data sources for WTI crude oil future price data are obtained from the CME Group and Bloomberg Terminal.

I obtained global crude oil production data from the US Energy Information Administration (EIA) to capture the global crude oil supply information, which contains monthly global crude oil production data from January 1984 to December 2019. To capture the global crude oil demand changes, I adopt the method suggests by Hamilton (2018) and constructed a crude oil demand proxy index based on OECD countries' industrial production level. I also consider the Kilian index which is constructed by using the dry cargo shipping rates as a different proxy variable for economic activity and use it for the robustness check for the results.

1.3 Methods and Models

In this section, I first discuss the baseline model introduced by Killian that is widely adopted in the literature to analyze the drivers of crude oil price fluctuations. I then explain the modifications I make to the baseline model, introduce the SVAR with external instruments model I adopt for the analysis in this paper, and discuss the shocks of interest. Finally, I consider the validity of the instruments I construct for the shocks of interest in this paper.

1.3.1 Baseline SVAR Model

Kilian (2009) introduces the baseline structural vector autoregression (SVAR) model in decomposing the main drivers of crude oil price fluctuations. The three corresponding variables in the baseline model are monthly percent changes in global crude oil production, an index of global economic activity, and real crude oil prices, so X_t= ($\Delta LogProduction_t$,$\Delta \text{Log} Y_t$,$\Delta \text{Log} Poil_t$)'. This baseline model focuses on disentangling the effects of crude oil supply shocks, crude oil demand shocks, and oil market-specific shocks. The oil market-specific shocks introduced by Kilian capture shifts in the price of oil driven by higher precautionary demand associated with market concerns about the availability of future oil supplies.

$$X_t = \alpha + B(L)X_{t-1} + S\varepsilon_t \tag{1}$$

$$B(L) = \sum_{i=1}^{16} B_i \, L^{i-1}$$

$$S\varepsilon_t = \begin{bmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Supply\ Shock} \\ \varepsilon_t^{Demand\ Shock} \\ \varepsilon_t^{Oil\ Market-Specific\ Shock} \end{pmatrix}$$

The SVAR model in structural form is listed in (1). The 3 by 3 B_i matrices are estimated using Ordinary Least Squares on the reduced form equation $X_t = \alpha + B(L)X_{t-1} + U_t$, where U_t is the residual matrix with variances of Var (U_t) = Ω. L denotes the lag operator and $B(L)$ is a matrix polynomial in the lag operator. The baseline SVAR model assumes a 16-period lag, based on minimizing the Akaike Information Criterion test. ε_t is the vector consisting of the three structural shocks analyzed in the model with mean "0" and variances Var (ε_t) = I_3, a 3 by 3 identity matrix, and S is the matrix describing the impact effects of the structural shocks on the variables X_t , where $S\varepsilon_t = U_t$ and $SS' = \Omega$. The data frequency in the baseline model is monthly because all shock series and media coverage and investor interest indexes are constructed in monthly frequency.

To disentangle and consider the structural shock effects, Kilian proposes imposing recursive ordering restrictions on the S matrix and uses the Cholesky decomposition method to obtain the structural impact S matrix and construct the impulse response functions to capture the effects of the three structural shocks above. To impose the recursive ordering restrictions, Killian assumes crude oil production levels are not affected by the current month's unexpected aggregate demand shocks and unexpected oil specific-demand shocks. Due to the high costs of adjusting production levels and the crude oil market's uncertainty, producers are unlikely to adjust their production levels during the current month of the shocks. Killian also assumes that real global economic activity reacts to the supply shock in the current month but not to oil market-specific shocks. Finally, crude oil prices react to both oil supply shocks and unexpected aggregate demand shocks in the current month. The restrictions above result in the S matrix being a lower triangular matrix, which together with the restriction $SS' = \Omega$ is enough to uniquely identify S.

1.3.2 SVAR with High-Frequency External Instruments

The primary model in this paper adopts the SVAR with external instruments with the high-frequency identification approach. I consider a similar SVAR model to the baseline model discussed in the previous subsection. However, there are four main differences in my model (2)

$$X_t = \alpha + A(L)X_{t-1} + W\varepsilon_t \quad (2)$$

$$A(L) = \sum_{i=1}^{16} A_i \, L^{i-1}$$

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^{Supply\ Expectation} \\ \varepsilon_t^{Demand\ Expectation} \\ \varepsilon_t^{Market\ Influence} \\ \varepsilon_t^{Other} \end{bmatrix}$$

$$W = \begin{bmatrix} w_{11} & w_{12} & w_{13} & w_{14:n} \\ w_{21} & w_{22} & w_{23} & w_{24:n} \\ w_{31} & w_{32} & w_{33} & w_{34:n} \end{bmatrix}$$

1. For model differentiation, I use the letter "A" to denote the time-series matrices in this model, and letter “W” to denote the matrix describing the impact effects of the structural shocks ε_t on the variables X_t. The A_i matrices are estimated using Ordinary Least Squares method on the reduced from equation $X_t = \alpha + A(L)X_{t-1} + U_t$, where U_t is the residual matrix.
2. I use OECD countries' global industrial production level as the proxy index to measure real global economic activity. As discussed in Baumeister et al. (2020), the industrial production levels for OECD countries perform better in forecast ability than the Kilian Index for data after 2010.
3. I consider 3 structural shocks of interest plus the “other” shock representing all other possible structural shocks that affect crude oil market dynamics. I discuss each structural shock in detail in the next subsection.
4. I apply the external instruments method to identify the W matrix and do not impose recursive ordering restrictions on the W matrix in my model. Thus, the W matrix is not necessarily a lower triangular matrix.

1.3.3 Structural Shocks

In the traditional SVAR model, the matrix describing the impact effects of the structural shocks is usually a square matrix with the number of structural shocks equal to the number of variables included in the SVAR model. As in the baseline model, the "S" matrix is a 3 by 3 square matrix, in which each column represents the impact effects of one of the 3 internal shocks on 3 variables in the model. However, instead of having only 3 structural shocks in my SVAR with external instruments, I consider 3 structural shocks of interest plus the "other" shock representing all other possible structural shocks affecting crude oil market dynamics. I can include more structural shocks than the number of variables in the model because by applying the SVAR with external instruments approach, the external instruments allow the econometrician to consider shocks from outside of the model. In contrast, traditional SVAR models only consider internal shocks coming from the variables included in the model. Thus, in my model, the "W" matrix is a 3 by N matrix containing the effects of the N possible structural shocks on 3 variables in the model.

The first two structural shocks are crude oil market supply expectation and crude oil market demand expectation shocks. These two shocks focus on investors' expectations of the future changes in the oil market supply and demand. These changes are potential changes expected by investors and have no immediate effects on the physical market.

The third structural shock is the market influence shock from the financial market through investors' reactions to related financial events. The shocks capture events in the financial market but exclude events in the crude oil market. Thus, the market influence shocks are uncorrelated with both the expectation and physical supply and demand shocks.

Finally, the last structural shock, the "other" shock in my model, captures all other possible structural shocks that affect the dynamics of crude oil. The crude oil market-specific shocks in Kilian's paper are also included in the "other" shock. Moreover, the "other" shock also includes many other potential shocks to the crude oil market, such as government regulation and incentive shocks. One example is U.S. government taxes and duties applied to import and export crude oil, which significantly impacts both the U.S. and global crude oil market. On the other hand, government incentive programs such as the Clean Vehicle Rebate Project in California promote using alternative energy and affect crude oil consumption and crude oil market dynamics. Another potential shock is a pandemic shock. One recent example of the Covid-19 pandemic shock demonstrates its significant effects on crude oil market dynamics. The Covid-19 shock negatively affected the crude oil demand and supply and led to negative WTI futures prices. In addition, the Covid-19 shock has long-term effects on the crude oil market from decreases in new investments in the oil supply market. All potential shocks included in the "other" shock can be estimated with corresponding external instruments.

For the interests of this paper, I focus on measuring the effects of the crude oil supply expectation shocks, crude oil demand expectation shocks, and market influence shocks on oil market dynamics.

1.3.4 External Instruments

To identify the three shocks of interest, I consider three external instruments: supply expectation shock series, demand expectation shock series, and market influence shock series, as constructed in the previous section. As discussed in Stock and Watson (2012) and Mertens and Ravn (2013), for the external instruments Z_t to be valid, I need my external instruments to satisfy both the relevance and exogeneity conditions in (3).

$$\begin{aligned} &\mathrm{E}\,[Z_t \varepsilon_t^i] \neq 0 \qquad i = shock\ of\ interest \\ &\mathrm{E}\,[Z_t \varepsilon_t^j] = 0 \qquad j \neq i \end{aligned} \tag{3}$$

In (3), ε_t^i represents each of the three structural shocks of interest in the SVAR. Each of the three external instruments discussed above and denoted by Z_t needs to be correlated with the corresponding structural shock of interest ε_t^i (the relevance condition) and uncorrelated with the other N-1 structural shocks in the model denoted by ε_t^j(the exogeneity condition).

1.3.4.1 Supply Expectation Shock Series

I construct the supply expectation shock series based on investors' reactions around unexpected crude oil supply-related events. This instrument correlates with the supply expectation shocks in the model because investors' expectations of the future oil supply are reflected in their reactions to unexpected supply-related events. This instrument is uncorrelated with demand expectation and market influence shocks. The construction method of this instrument excludes demand and financial market-related events. This instrument is also uncorrelated with other structural shocks in the model.

1.3.4.2 Demand Expectation Shock Series

The demand expectation shock series is constructed based on investors' reactions to the crude oil market's unexpected demand-related events. This instrument correlates with investors' demand expectation shocks, as investors' reactions reflect their future oil demand expectations. This instrument is uncorrelated with both the supply expectation and market influence shocks because supply-related and financial market-related events are excluded in the demand expectation shock series construction process. This instrument is also uncorrelated with other structural shocks in the model.

1.3.4.3 Market Influence Shock Series

I construct the market influence shock series to capture investors' reactions to unexpected events in the financial market. This instrument correlates with the market influence shocks as investors' reactions to the financial market events potentially affect crude oil market dynamics, but uncorrelated other structural shocks in the model.

1.3.5 Model Identification

Measuring the effects of supply expectation, demand expectation, and market influence shocks on crude oil market dynamics requires the identification of the corresponding impact effect columns of the matrix W. The first column (w_1) represents the effects of the crude oil supply expectation shocks on the dynamic variable oil production, economic activity, and prices. The second column (w_2) represents the effects of crude oil demand expectation shocks on the dynamic variables. Finally, the third column (w_3) represents the effects of the market influence shock on crude oil market dynamic variables.

To obtain the impact effect vectors, I regress the residual matrix U_t obtained from OLS estimation of the reduced form model, on each of the three external instruments above separately. With the relevance and exogeneity conditions satisfied, I identify the impact effect vector of each shock of interest up to the scale of $W_i\left(\frac{E\left[\varepsilon_t^i Z_t\right]}{Var(Z_t)}\right)$ with i representing the shock of interest position. To obtain the impulse response functions for each of the three shocks of interest, I rescale the impact effect vectors identified above to have the shock size of one-standard-deviation positive effect on the crude oil price variable for the supply expectation shocks and market influence shocks. Likewise, I rescale the impact effect vector to have the shock size of one-standard-deviation negative effects for the demand expectation shocks. The reason is most of the supply-related and market-related events are associated with oil price increases, and demand-related events are associated with oil price decreases. I present the effects of the three shocks of interest in the next section.

1.4 Results

This section presents the effects of the demand expectation, supply expectation, and market influence shocks on oil market dynamics. Moreover, as a robustness check, I consider the shock effects on oil market dynamics using the Kilian Index as the proxy variable for the real global economic activity. In each impulse response function figure, the solid line represents the effects of one-standard-deviation expectation shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using the bootstrap method with 2000 replications (Goncalves and Kilian, 2004).

1.4.1 Supply Expectation Shocks

Figure 1.1 plots IRFs of the impact of a supply expectation shock on the crude oil price, oil production, and economic activity. The solid line in each plot represents the effects of a one-standard-deviation negative supply expectation shock on each of the three variables of interest. The dashed lines plot one-standard-error bands constructed using a bootstrapping with 2000 replications.

Figure 1.1 demonstrates the estimated effects of a negative supply expectation shock. The supply expectation shocks have long-term positive effects on crude oil prices. The effects have to do with investors' expectations for future supply disruptions or voluntary decreases in production, and prices are likely to increase. This finding is similar to Kanzig (2021)'s conclusions on the effects of supply expectation shocks on oil prices.

In contrast to Kanzig's result that supply expectation shocks have long-term negative effects on crude oil production, the effects of the supply expectation shocks considered in my case do not contribute to significant decreases in crude oil production. This observation has to do with Kanzig’s analysis only considering OPEC announcement events, mainly consisting of OPEC member countries’ production decisions, and OPEC members tend to follow their production decisions, which means investors’ supply expectations are mostly correct. However, for events I consider, investors have often overestimated the supply disruptions. As a result, many of the expected crude oil supply disruptions ended up not being fully realized. One example of this is that wars in the Middle East led to smaller oil production disruptions than investors expected because OPEC member countries such as Saudi Arabia have often quickly made up crude oil production disruptions with their spare production capacity.

Finally, I estimate that supply expectation shocks have positive effects on real economic activity. In this case, the real economic activity variable is proxied by OECD industrial production.

In comparison with Killian’s results of physical oil supply shocks with recursive ordering restrictions, my supply expectation shocks again have similar effects on crude oil market dynamics. Killian found that negative oil supply shocks initially negatively impact crude oil production, but the decline in production has a partial reversal within a year. Kilian explains this observation by oil supply disruption in one region triggers increases in production elsewhere in the world. My finding is in line with Kilian's findings as my results also demonstrate that world oil producers tend to increase their production to compensate for possible future disruptions in production. Both Kilian's results and my results show that negative oil supply shocks and supply expectation shocks positively affect crude oil prices. However, with the different proxy variables used for global economic activity, Kilian's results show negative effects on global economic activity, different from the results I found. But, the effects of my supply expectation shocks on global economic activity become negative when I switch to using the Kilian Index as my proxy variable in the robustness check section below.

1.4.2 Demand Expectation Shocks

Figure 1.2 demonstrates that a negative oil demand expectation shock negatively affects crude oil prices. This result can be explained by when investors are presented with news related to potential oil demand deceases, and they expect future crude oil surplus and drop in prices. Besides, we see that negative demand expectation shocks have negative impacts on crude oil production. This observation follows that facing potential declines in crude oil consumption, crude oil-producing countries, especially OPEC countries tend to make agreements to reduce their crude oil production to fight the increase in crude oil inventories. Finally, the result shows that the demand expectation shocks negatively affect OECD industrial production, which can be explained by reductions in crude oil demand are associated with the economic downturns.

The results in this section are similar to those found by Kilian (2009), considering the effects of physical oil demand shocks by imposing recursive ordering restrictions. Killian focuses on the effects of positive demand shocks, which scaled to have positive effects on oil prices. Kilian found that positive demand shocks have significant and persistent effects on crude oil price and production. In addition, positive demand shocks also positively affect global economic activity proxy by the Kilian Index.

1.4.3 Market Influence Shocks

Results of the market influence shocks are presented in Figure 1.3. The market influence shocks are the shocks that led to significant oil price movements, and news articles report that the movements are financial market-driven and are not associated with demand nor supply-related events. The financial and market effects considered range from futures contract expiring to financial market event spillovers. The results show that the shocks have initial positive effects on the prices but negative effects for the longer term. On the other hand, the shocks negatively affect crude oil production and OECD industrial production activity.

1.4.4 Robustness Check with Kilian Index

A central discussion in the oil market literature has been the proxy variable for crude oil demand and real economic activity. The two commonly used proxies are the Kilian index and OECD industrial production level. This section will consider the results above again using the Kilian Index as a robustness check to compare if the results are similar to those with the OECD industrial production levels.

1.4.4.1 Supply Expectation Shocks with Kilian Index

The results for Kilian Index supply expectation shocks are presented in Figure 1.4. Based on the results, changing the real economic activity proxy to the Kilian index does not change the effects of supply expectation shocks on prices and production. However, the impact on real economic activity becomes insignificant. This difference can be explained by crude oil supply are more likely to be correlated with industrial production than shipping costs which is what the Kilian Index is based on.

1.4.4.2 Demand Expectation Shocks with Kilian Index

The results for the demand expectation shocks are presented in Figure 1.5. Negative demand expectation shocks have insignificant initial effects on the crude oil prices compared to using the OECD industrial production level as real economic activity proxy. However, the longer-term negative effects are the same as in the previous case. On the other hand, the crude oil producers' reaction effects stay the same, which again signals that crude oil producers react to demand disruptions by reducing their production. Finally, demand disruption forecasts are associated with decreases in real economic activity, which follows our intuition that the market is negatively correlated with economic downturns.

1.4.4.3 Market Influence Shocks with Kilian Index

The results are presented in Figure 1.6. The effects of market influence shocks on crude oil price, crude oil production, and real economic activity stay the same with slight changes in magnitude.

The results demonstrate that the effects of the financial market shocks stay the same even with the changes of the proxy variable for the real economic activity.

1.5 Media Coverage and Investor Interest in the Crude Oil Market

As an extension to the previous results, in this section, I consider other factors that have contributed to the estimations of investors' reactions to the market and their effects on crude oil market dynamics.

This section of the paper utilizes two non-traditional methods to analyze investors' reactions and perceptions of crude oil market dynamics. The first method adopts public data obtained from the Google search engine. The method is inspired by a growing literature using Google search information from Google Trends to capture market participants' interests in the topic of research. Using this method, I focus on looking at investor interest in crude oil market dynamics by constructing an investor interest index based on the Google Trends data.

The second method is inspired by Caldara et al. (2018). Their paper created the geopolitical risk (GPR) index based on a tally of newspaper articles covering geopolitical tensions and examine their effects on the market. To replicate their method and apply it to the crude oil market, I focus on the number of articles published in the New York Times. To locate related articles, I consider the number of news articles that contain crude oil-related terms. The goal is to capture media coverage in the crude oil market with changes in the number of crude oil market-related articles.

Figure 1.7 demonstrates the correlation between the media coverage index with the nominal crude oil prices. From the plot, before 2008, the correlation between the coverage index and crude oil prices is more apparent where media coverage tends to be positively correlated with the crude oil prices. However, during 2014-2016, the media tend to cover more when there were significant drops in crude oil prices. This observation might have to do with the sharp price drops from 2014 to 2016 due to the shale oil production boom, capturing more media attention than usual.

Figure 1.8 gives a simple preview of the correlation between the investor interest index and the nominal WTI crude oil prices. From the plot, I observe jumps in the investors' search in the crude oil market whenever there are periods of significant increases and decreases in crude oil prices. The three most important events that led to increases in investors' searches in the crude oil markets are 2008, 2014, and the 2016 crude oil prices drop.

1.5.1 Methods and Models

To analyze the effects of media coverage and investor interest, I modify the baseline model by adding the percent changes in each of the two indexes as a fourth variable, so X_t = ($\Delta LogProduction_t$,$\Delta \text{Log}Y_t$,$\Delta \text{Log}Index_t$, $\Delta \text{Log}Poil_t$)

$$X_t = \alpha + C(L)X_{t-1} + K\varepsilon_t \tag{4}$$

$$C(L) = \sum_{i=1}^{16} C_i \, L^{i-1}$$

$$K\varepsilon_t = \begin{bmatrix} s_{11} & 0 & 0 & 0 \\ s_{21} & s_{22} & 0 & 0 \\ s_{31} & s_{32} & s_{33} & 0 \\ s_{41} & s_{42} & s_{43} & s_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Supply\ Shock} \\ \varepsilon_t^{Demand\ Shock} \\ \varepsilon_t^{Index\ Shock} \\ \varepsilon_t^{Oil\ Market-Specific\ Shock} \end{pmatrix}$$

The SVAR model in structural form is listed in (4). To differentiate with the baseline model, I choose the letter "C" to represent the time series matrix and letter "K" to represent the matrix describing the impact effects of the structural shocks on the variables X_t. The matrices C_i are again estimated using the Ordinary Least Squares method on the reduced form equation $X_t = \alpha + C(L)X_{t-1} + U_t$, where U_t is the residual matrix, and $K\varepsilon_t = U_t$.

To estimate the effects of the media coverage and investor interest shocks, I impose recursive ordering restrictions on the K matrix and use the Cholesky decomposition method to obtain the structural impact K matrix and construct the impulse response functions. The decision to impose the recursive ordering restrictions instead of adopting the SVAR with external instruments approach is based on two reasons. First, as shown in section 1.4, both the recursive ordering restriction method and SVAR with external instruments method produce similar results for the effects of the shocks on interest. Second, I constructed the media coverage and investor interest index to capture the media coverage and investors' interest in the crude oil market. However, there are no satisfactory high-frequency instruments for investors and media interest in the crude oil market.

The recursive ordering restriction assumptions are based on the same assumptions discussed in the baseline model, and the new assumption is that the crude oil price movements can affect the index values within the current month, but crude oil prices are not affected by the index changes within the current month.

To obtain the impulse response functions, I scale the oil supply shocks, oil demand shocks, and oil market-specific shocks to have the shock size of one-standard-deviation positive effects on crude oil price variable as in the baseline model by Kilian (2009). Likewise, I scale the media coverage and investor interest shocks to have one-standard-deviation negative effect on the crude oil price variable.

1.5.2 Results

This section presents the effects of the media coverage and investor interest shocks on oil market dynamics. In each impulse response function figure, the solid line represents the effects of one-standard-deviation-shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using the bootstrap method with 2000 replications.

1.5.2.1 Media Coverage Index

Focusing on the effects of negative crude oil supply shocks (Figure 1.9), I see supply disruptions have significant initial negative impacts on crude oil production. The reductions in production partially recover as other oil-producing countries tend to compensate for the lost production. Crude oil supply shocks also significantly raise oil prices and have negative effects on real economic activity. More importantly, crude oil supply shocks negatively affect media coverage. This observation can be explained by media likes to report potential crude oil disruptions events such as wars in the Middle East, crude oil worker strikes, and OPEC meeting production decisions.

Positive oil demand shocks (Figure 1.10) positively affect crude oil production, as oil producers increase production to meet demand. Positive oil demand shocks also increase crude oil prices. In addition, crude oil demand shocks have initial negative effects on media coverage, which shows media increases coverage with positive demand events.

Changes in crude oil prices (Figure 1.11) have short-term negative impacts on crude oil production and short-term positive effects on real economic activity. Moreover, changes in crude oil price positively affected the media coverage, which shows that media coverage tends to cover more about the crude oil market when the crude oil prices go up.

Considering the effects of the media coverage index (Figure 1.12), the initial effects on crude oil production are positive; however, the media coverage shocks negatively affect crude oil production in later periods. One explanation of this observation is that news media tend to increase coverage with potential supply disruptions. However, due to the nature of crude oil production, the decreases in crude oil production lag the news reports. Finally, media coverage shocks have negative effects on crude oil prices. In this case, with media increases coverage in the crude oil market, crude oil prices tend to decrease. Section 1.6 further considers the possible relationship between crude oil prices and the media coverage index by focusing on changes in net crude oil futures positions.

1.5.2.2 Investors Interest Index

The effects of negative oil supply shocks are presented in Figure 1.13. Oil supply shocks negatively impact oil production and real economic activity but positively affect crude oil price. In addition, negative oil supply shocks have negative effects on the investor interest index. One explanation is investors increase their interest in the crude oil market when they hear potential supply disruptions; however, when the disruptions are realized, investors' interests diverge to different areas.

The effects of positive oil demand shocks are shown in Figure 1.14. Again, the oil demand shocks positively affect crude oil production and real economic activity, similar to the results found with the media coverage. However, the effects on crude oil prices are insignificant. Finally, oil demand shocks negatively affect investor interest. This observation can be explained by the possibility that investors become more interested in the crude oil market as they seek investment opportunities with decreases in the possible economic activity and lead to price drops.

The effects of positive oil market-specific shocks (Figure 1.15) have significant positive impacts on the crude oil price and short-term positive effects on crude oil production and real economic activity. The initial effects of oil market-specific shocks on investor interest index are negative, which can be interpreted as decreases in prices are likely to be associated with increases in investors' search as investors look for investing opportunities. This result is different from the effects on the media coverage index, where the effects are positive for the media coverage.

Finally, consider the effects of investor interest index (Figure 1.16). Investor interest shocks have negative impacts on crude oil production. Compared with the media coverage index's effects, the effects are similar, but the effects on production lag longer for investor interest shocks. In addition, the effects on real economic activity are negative, which are the same as shown in the media coverage case. Finally, I observe long-term negative impacts on crude oil prices. This observation indicates that crude oil prices decrease as investors grow more interested in the crude oil market.

1.6 Futures Positions Analysis

The previous section demonstrates both the media coverage and investor interest index have negative effects on oil prices. This section considers the possible correlation between the media coverage and investor interest index with changes in crude oil traders' net futures positions to explain further the observation of the negative effects of the two indexes on crude oil prices.

1.6.1 Data

To investigate the changes in traders' net futures positions, I adopted the data from the Commitments of Traders (COT) reports from the Commodity Futures Trading Commission (CFTC). The reports separate crude oil traders into three categories: commercial, non-commercial, and non-reported traders. Commercial traders are mostly crude oil producers, merchants, and processors, who trade crude oil futures for hedging purposes. Non-commercial traders are mostly large institutional speculators. Both commercial and non-commercial traders are required to file their trading activities with the CFTC. Non-reported traders are traders who are not required to report to the CFTC due to their small amount of futures holdings. This group of traders is mostly retail traders or small institutional speculators.

The Commodity Futures Trading Commission keeps track of daily futures positions data, and weekly data has been available to the public since January 1986. Bi-weekly data has been available since October 1992. For this paper, last week's futures position data each month is adopted as the futures position for that month. Depending on the media coverage and investor interest index's data availability, data from January 1986 to December 2019 is analyzed for the media coverage index, and data from January 2004 to December 2019 is analyzed for the investor interest index.

1.6.2 Models and Methods

The model in this section follows the Granger causality framework. Equation (3) considers the effects of the media coverage and investor interest index on traders' net futures positions. Equation (4) considers the reverse effects of changes in the net futures positions on the media coverage and investor interest index. The number of lags for each model is determined by the minimization of Akaike's Information Criteria.

$$NLFPR_t = \alpha + \sum_{i=1}^{m} \beta_i NLFPR_{t-i} + \sum_{j=1}^{n} \pi_j Index_{t-j} + \omega_t \qquad (3)$$

$$Index_t = \gamma + \sum_{i=1}^{m} \lambda_i NLFPR_{t-i} + \sum_{j=1}^{n} \mu_j Index_{t-j} + \nu_t \qquad (4)$$

The net long futures position ratio (NLFPR) for non-commercial, commercial, and non-reported traders are calculated suing formula (5) and (6).

Non-commercial traders' Net Long Futures Position Ratio (NLFPR):

$$NLFPR_t = \frac{Long\ Positions_t - Short\ Positions_t}{Long\ Positions_t + Short\ Positions_t + 2(Spread\ Positions_t)} \quad (5)$$

Commercial traders and non-reported traders:

$$NLFPR_t = \frac{Long\ Positions_t - Short\ Positions_t}{Long\ Positions_t + Short\ Positions_t} \quad (6)$$

1.6.3 Results

1.6.3.1 Media Coverage Index

The results of the media coverage index are shown in Table 1.2. The media coverage index has significant negative effects on large institutional and retail traders' net futures positions. On the other hand, the effects on commercial traders' net futures positions are positive and significant, unlike the effects of the investor interest index in next section. One explanation for this observation is that commercial traders pay attention to the events reported in media coverage to adjust their positions but pay less attention to the investor sentiments.

1.6.3.2 Investor Interest Index

As the results in Table 1.3 demonstrate, the effects of the investor interest index on net futures positions of non-commercial and non-reported traders are negative and significant. This result signals that institutional traders and retail traders are likely to be affected by investor sentiment and interest in the market. In addition, the magnitudes of the aggregate effects on non-reported traders are larger than those of the non-commercial traders, which denotes that retail traders are more sensitive to the changes in investor sentiment than institutional traders. On the other hand, the effects of investor interest on the commercial traders' net positions are positive but insignificant. This result shows that commercial traders are less likely to be affected by investor sentiment.

1.6.3.3 The Reverse Effects

The reverse effect results of changes in net futures on media coverage and investor interest index are shown in Table 1.4 to Table 1.6. Changes in all three types of investors' net futures positions have insignificant effects on media coverage and investor interest index. This result demonstrates that net futures positions changes are less likely to affect investors' sentiment or media coverage of the crude oil market. This is because changes in futures positions are usually not a topic of interest in media coverage. This result also aligns with the results shown in Sanders' (2004) paper that changes in futures positions have no significant effects on crude oil prices.

Finally, as a conclusion for this set of results, both the media coverage index and the investor interest index negatively affect the net futures positions for both the institutional speculators and retail traders. It is possible that with the increase in the media coverage and investor interest in the crude oil market, the decreases in the net positions of the institutional investors and retail investors are likely to outweigh the commercial investors' hedging activities. Thus, the results here give a possible explanation for long-term negative effects on crude oil prices from media coverage and investor interest as the decreases in net futures positions amplify the decreases in crude oil prices.

1.7 Conclusion

In this paper, I propose a set of new methods to consider the effects of investors' expectations and reactions on crude oil market dynamics by using an SVAR model with high-frequency external instruments. Using price movements around supply-related, demand-related, and financial market events, I constructed three external instruments for supply expectation shocks, demand expectation shocks, and market influence shocks.

I found that negative demand expectation shocks negatively affect crude oil prices as investors facing negative demand events expect reductions in crude oil demand in the future and, therefore, lead to decreases in crude prices. Demand expectation shocks also lead to reductions in oil production, as oil producers decrease their productions, facing future potential decreases in crude oil consumption. In addition, negative demand expectation shocks also lead to long-term negative effects on real economic activity. On the other hand, negative supply expectation shocks positively impact crude oil prices as investors expect future disruptions will lead to supply shortages and, therefore, drive up oil prices. Furthermore, supply expectation shocks do not contribute to a significant decrease in crude oil production as potential oil supply disruptions are compensated by other oil producers, such as Saudi Arabia and other OPEC members. Finally, the supply expectation shocks have an ambiguous effect on economic activity: There is a positive effect on OECD industrial production but a negative effect on real economic activity as measured by the Kilian Index. The oil market influence shocks, which capture investors' reactions to financial events, have positive effects on oil price on average and negative effects on oil production and economic activity.

In addition to the expectation shock effects, I also consider media coverage of the crude oil market using news articles from the New York Times and investor interest in the crude oil market using data from Google Trends. Results show that negative oil supply shocks negatively affect media coverage, negative oil demand shocks have short-term negative effects on media coverage, and oil market-specific shocks have significant positive effects on media coverage. On the other hand, positive shocks to media coverage have short-term positive effects on crude oil production and negative effects on crude oil prices and economic activity. Turning to the effects of investors' interest, I found negative oil supply shocks positively impact investors' interest, but both the negative oil demand shock and oil market-specific shock negatively impact investor interest in the crude oil market. Finally, the investor interest shock has negative impacts on oil price, oil production, and economic activity.

In the last section of this paper, I further investigate the potential reasons for the negative effects of investor interest and media coverage shocks on crude oil prices by considering correlations between the two shocks and changes in investors' net WTI futures positions. I found that the decreases in investors' net futures positions associated with the increases in media coverage and investor interest can potentially explain amplified negative effects on crude oil prices.

The results of this paper have shown that investors' reactions and expectations have statistically significant effects on crude oil market dynamics, which have been largely ignored in previous literature.

1.8 Figures and Tables

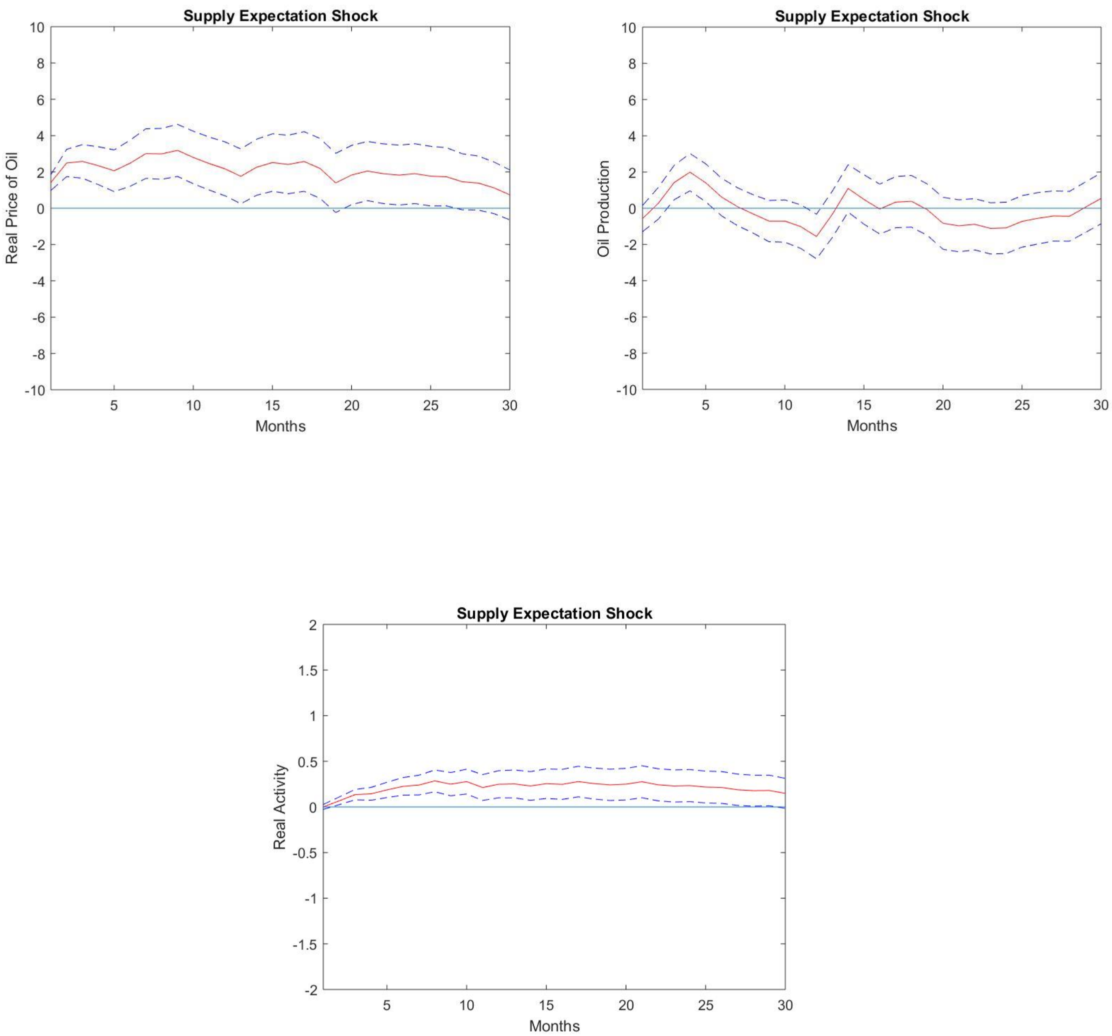


Figure 1.1: IRFs of supply expectation shocks on oil price, oil production and real economic activity (OECD countries' industrial production level). Supply expectation shocks are scaled to have one-standard-deviation positive effects on oil prices. Supply expectation shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation expectation shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

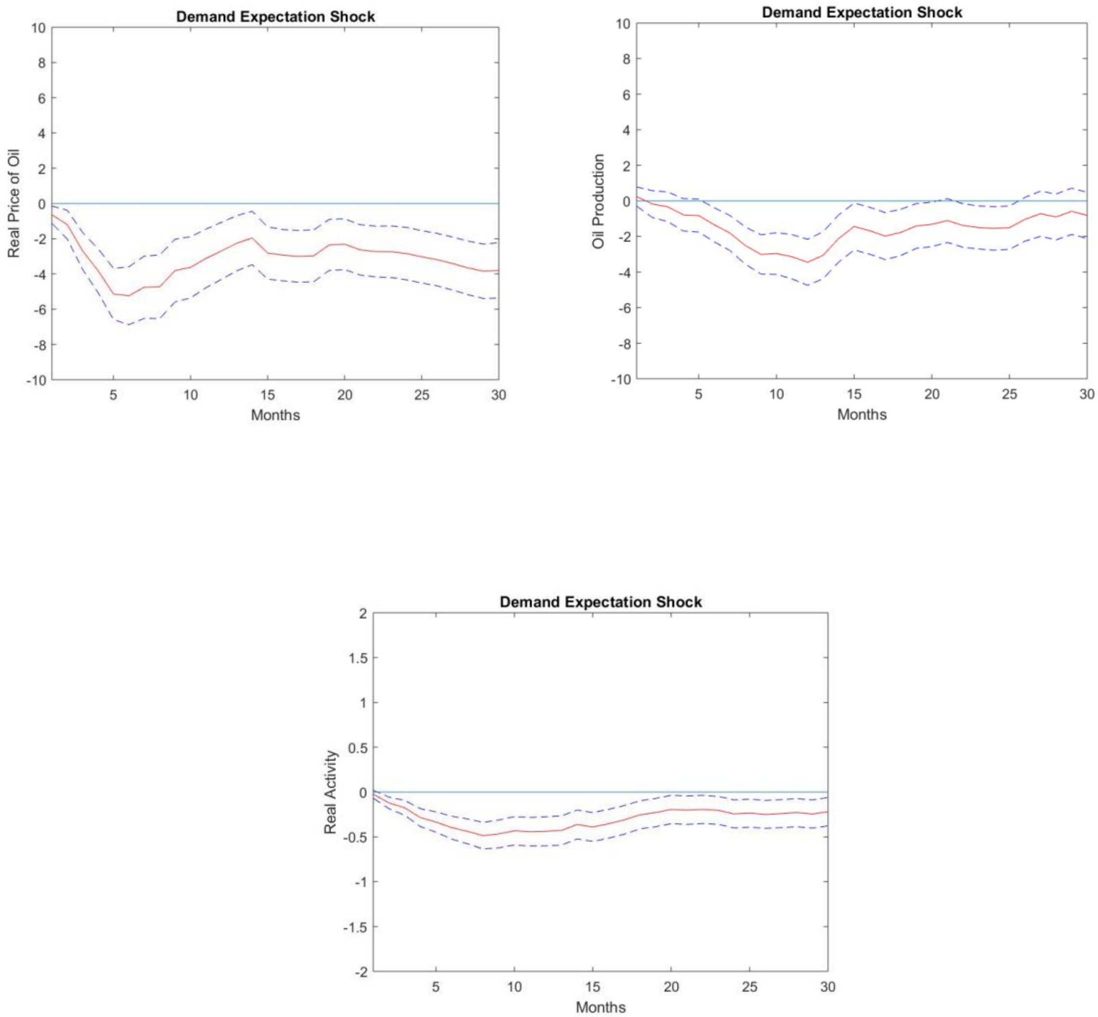


Figure 1.2: IRFs of demand expectation shocks on oil price, oil production and real economic activity (OECD countries' industrial production level). Demand expectation shocks are scaled to have one-standard-deviation negative effects on oil prices. Demand expectation shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation expectation shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

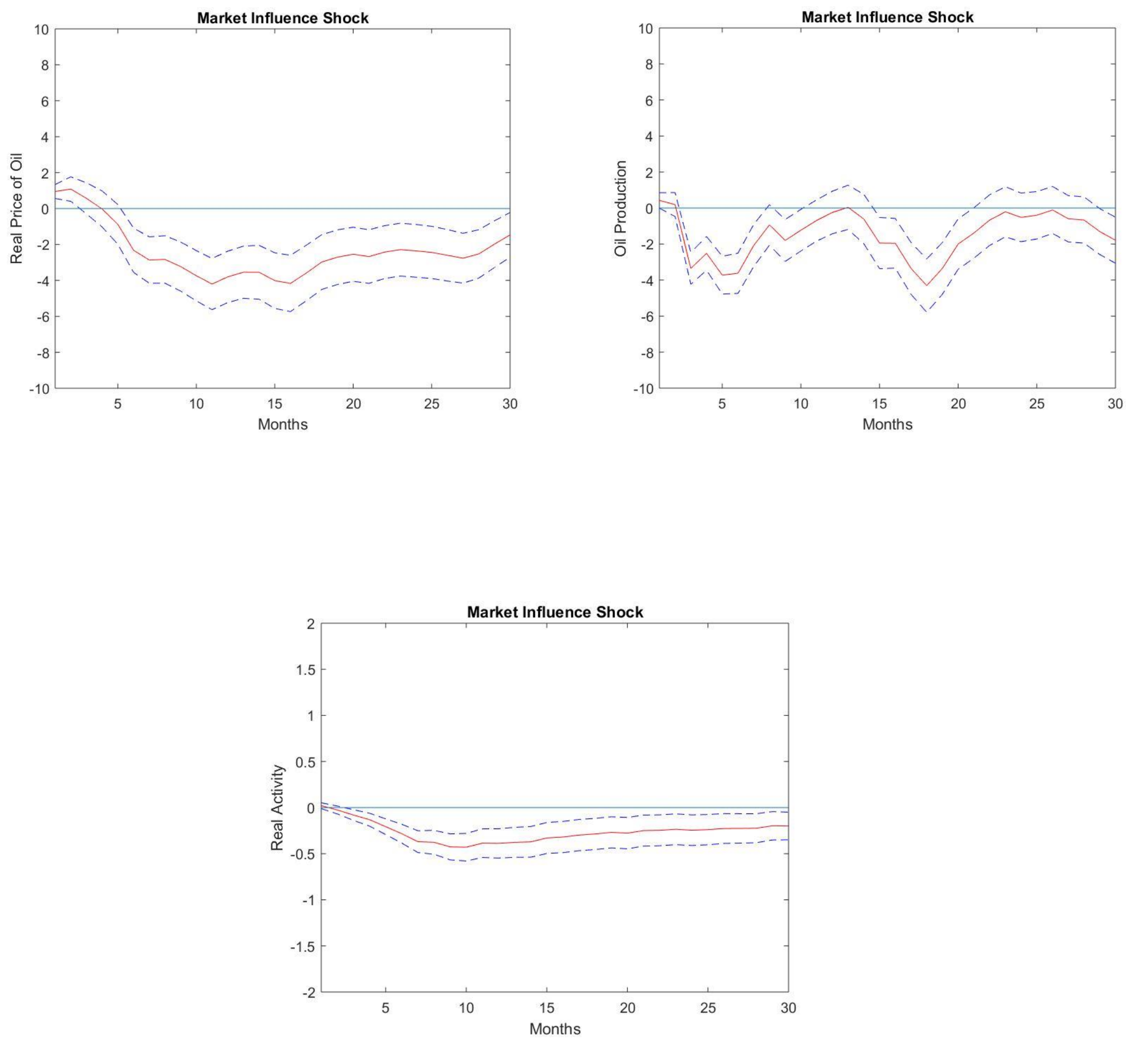
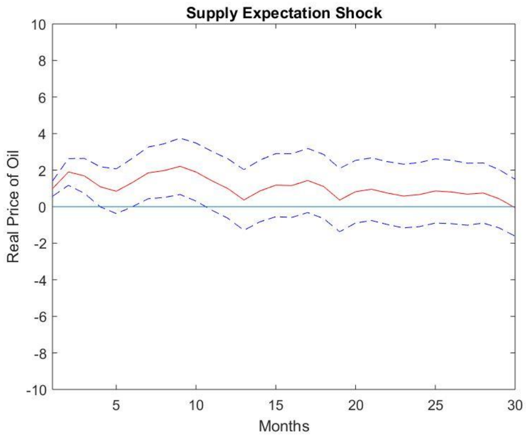
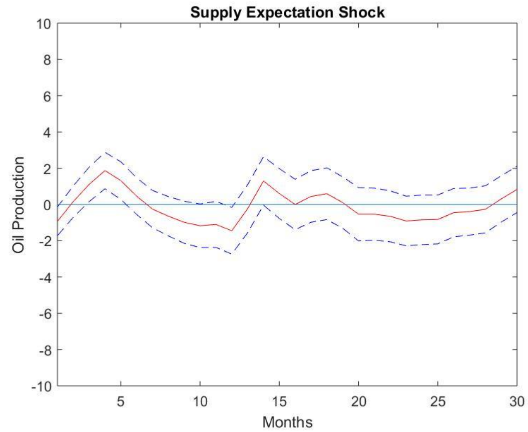


Figure 1.3: IRFs of market influence shocks on oil price, oil production and real economic activity (OECD countries' industrial production level). Market influence shocks are scaled to have one-standard-deviation positive effects on oil prices. Market influence shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation market influence shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.





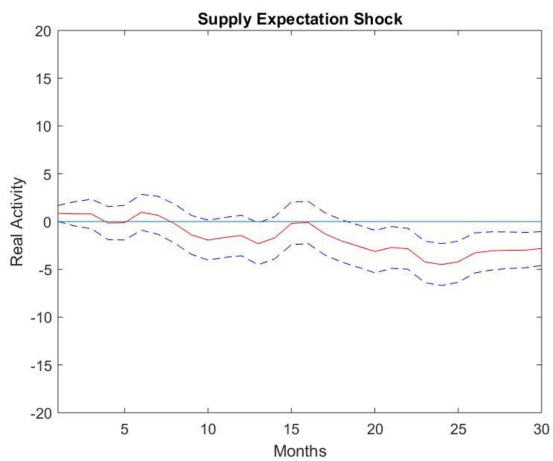
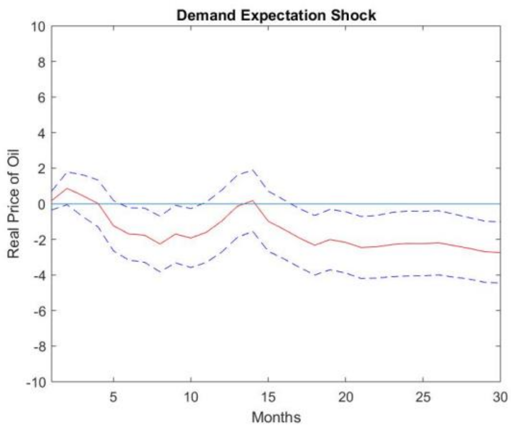
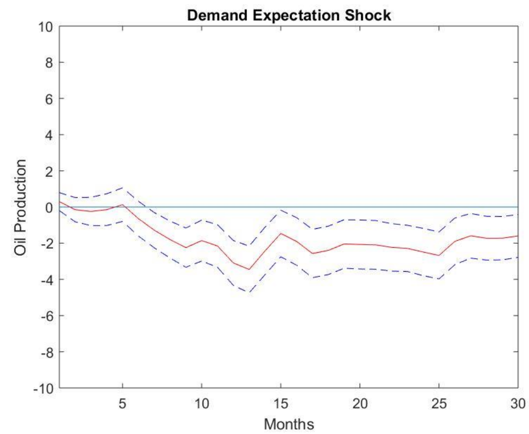


Figure 1.4: Killian Index robustness check IRFs of supply expectation shocks on oil price, oil production and real economic activity (Killian Index). Supply expectation shocks are scaled to have one-standard-deviation positive effects on oil prices. Supply expectation shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation expectation shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.





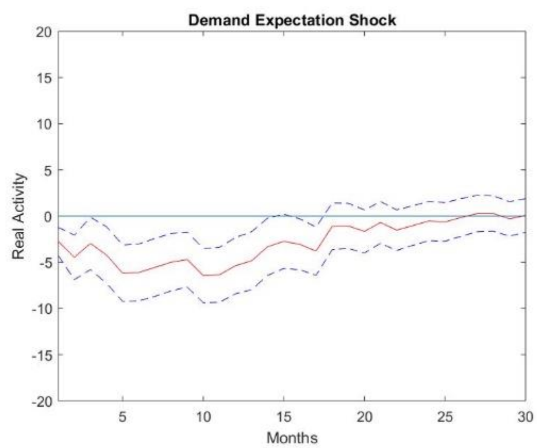


Figure 1.5: Killian Index robustness check IRFs of demand expectation shocks on oil price, oil production and real economic activity (Kilian Index). Demand expectation shocks are scaled to have one-standard-deviation negative effects on oil prices. Demand expectation shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation expectation shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

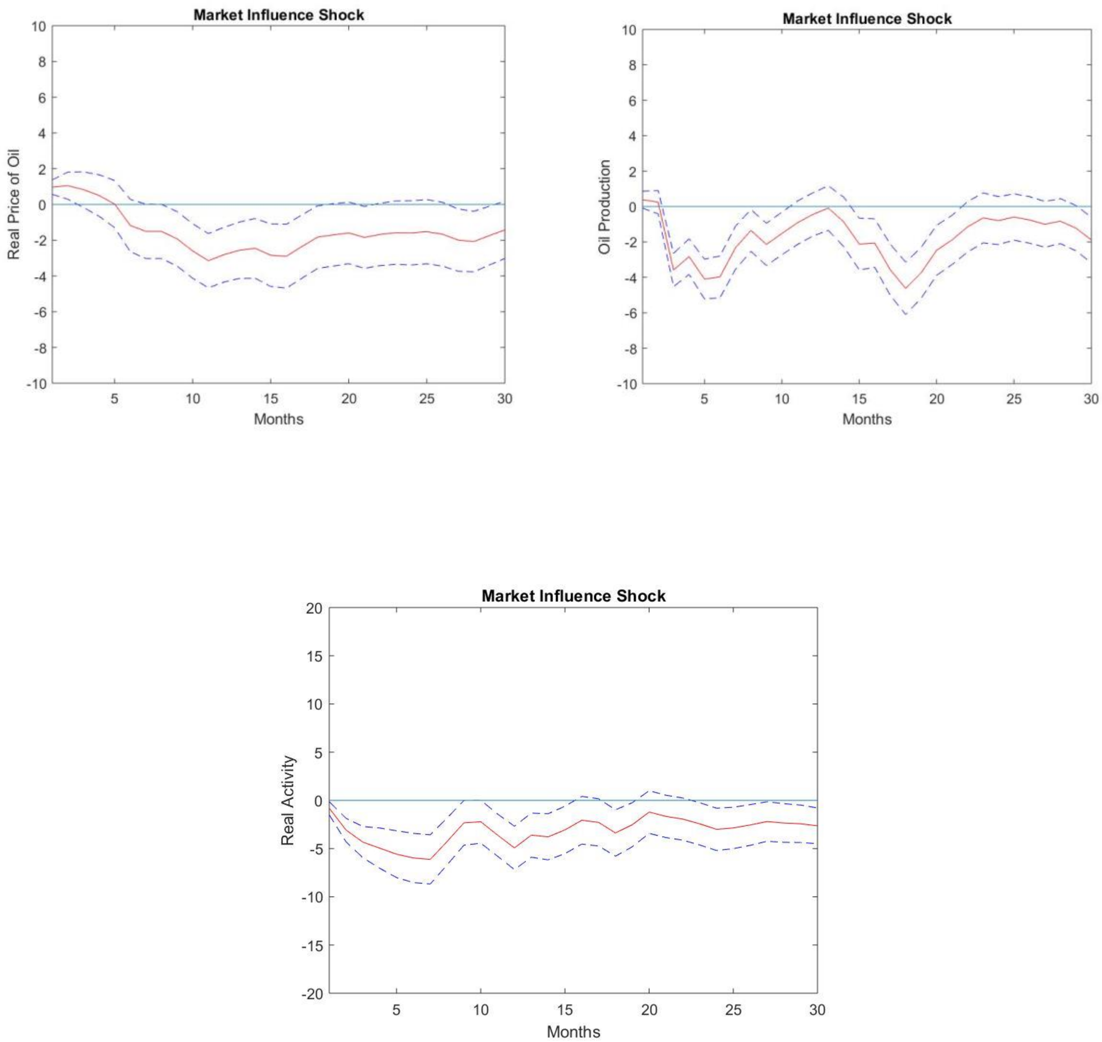


Figure 1.6: Killian Index robustness check IRFs of market influence shocks on oil price, oil production and real economic activity (Killian Index). Market influence shocks are scaled to have one-standard-deviation positive effects on oil prices. Market influence shocks are identified using the high frequency external instrument approach. Solid line represents the effects of one-standard-deviation market influence shock on crude oil market variables, and dashed lines represent one standard-error-band around the shock effects constructed using bootstrap method with 2000 replications.

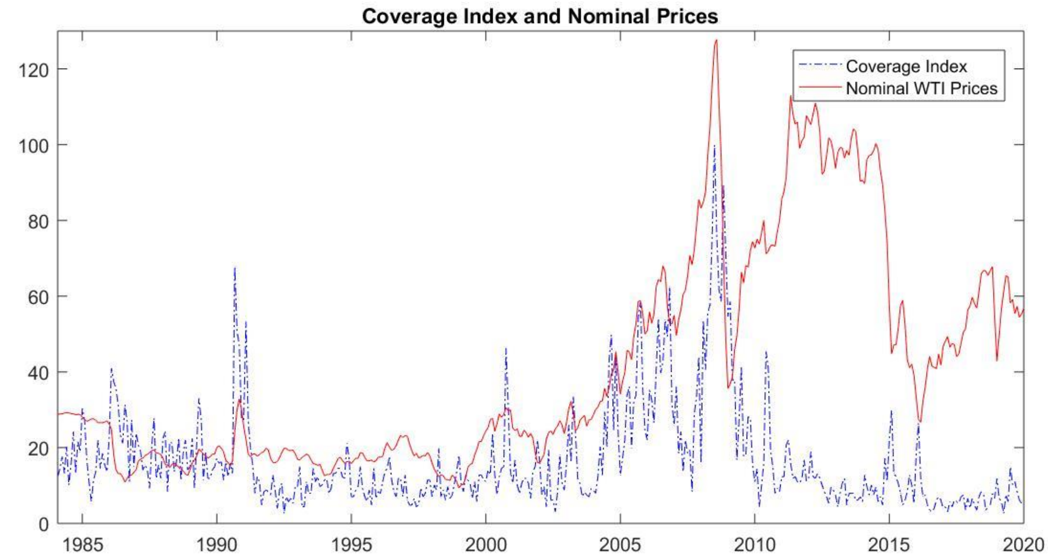


Figure 1.7: Media coverage index and nominal WTI prices between 1984 and 2020. Before 2008, media coverage tend to be positively correlated with the crude oil prices. During 2014-2016, we media tend to cover more when there is a large drop in crude oil prices.

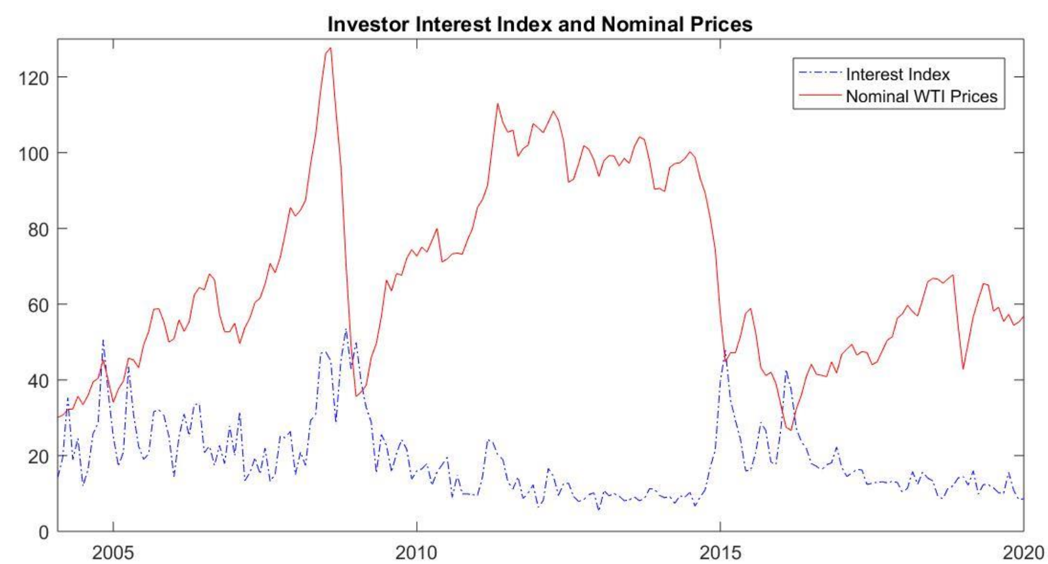


Figure 1.8: Investor interest index and nominal WTI prices between 2004 and 2020. Investor interest in the crude oil market increase with significant decreases and increases in crude oil prices.

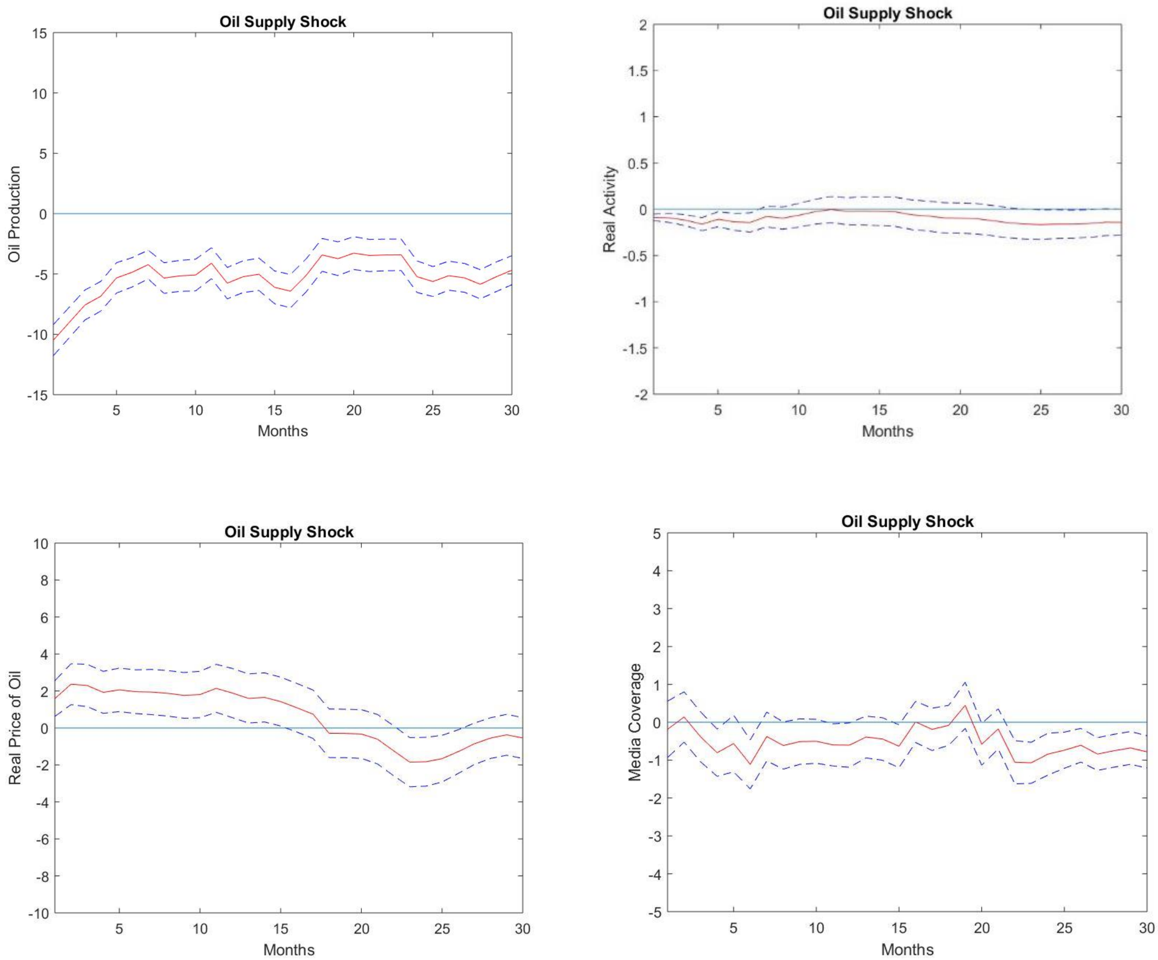


Figure 1.9: IRFs of supply shocks on oil price, oil production, economic activity and media coverage. Supply shocks are scaled to have one-standard-deviation positive effects on oil prices. Supply shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation supply shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

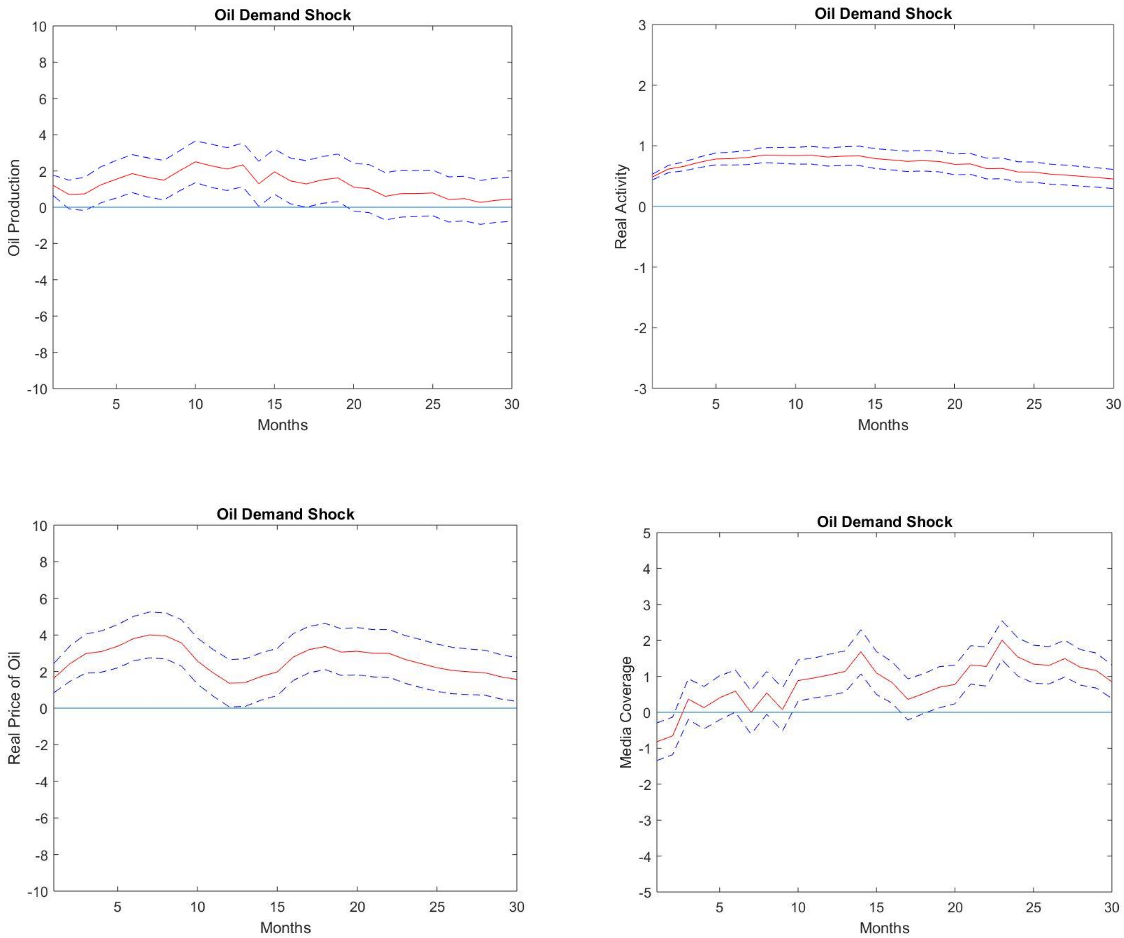


Figure 1.10: IRFs of demand shocks on oil price, oil production, economic activity and media coverage. Demand shocks are scaled to have one-standard-deviation positive effects on oil prices. Demand shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation demand shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

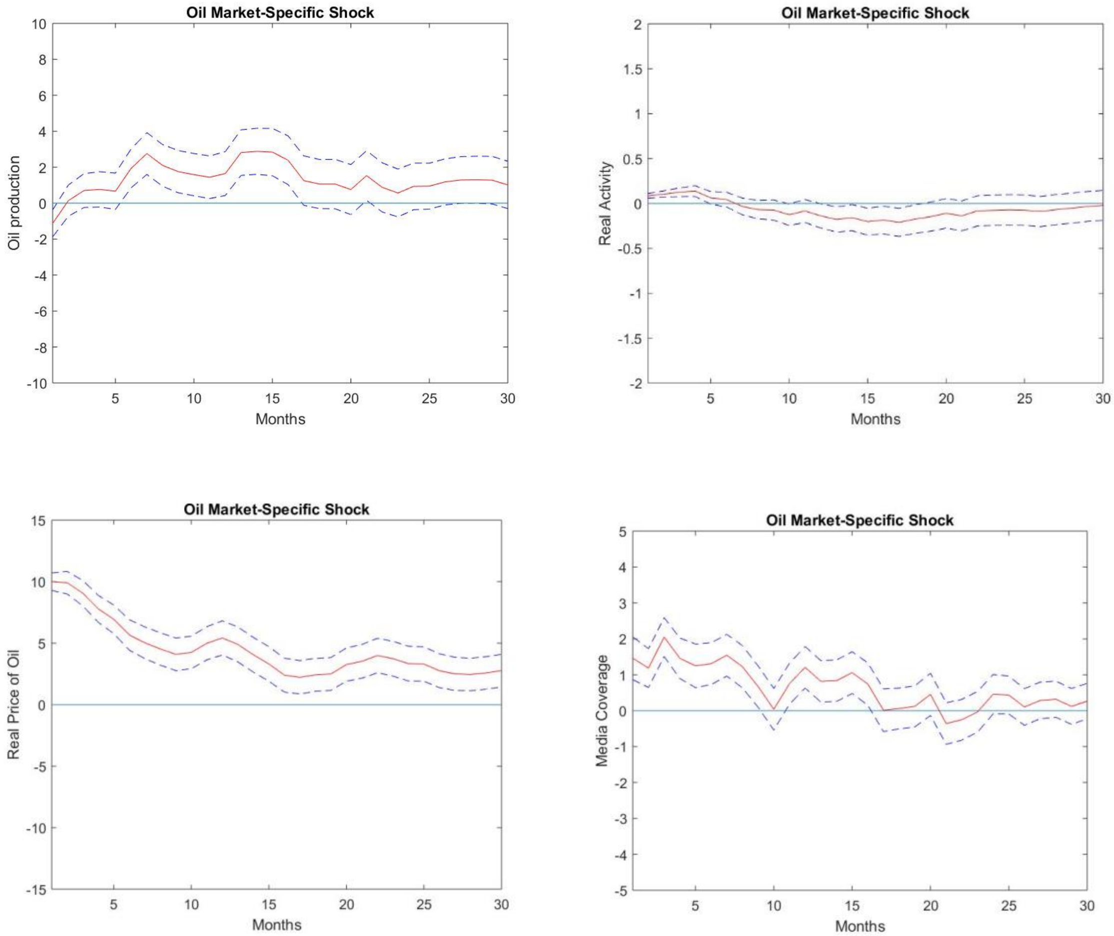


Figure 1.11: IRFs of oil market-specific shocks on oil price, oil production, economic activity and media coverage. Oil market-specific shocks are scaled to have one-standard-deviation positive effects on oil prices. Oil market-specific shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation oil market-specific shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

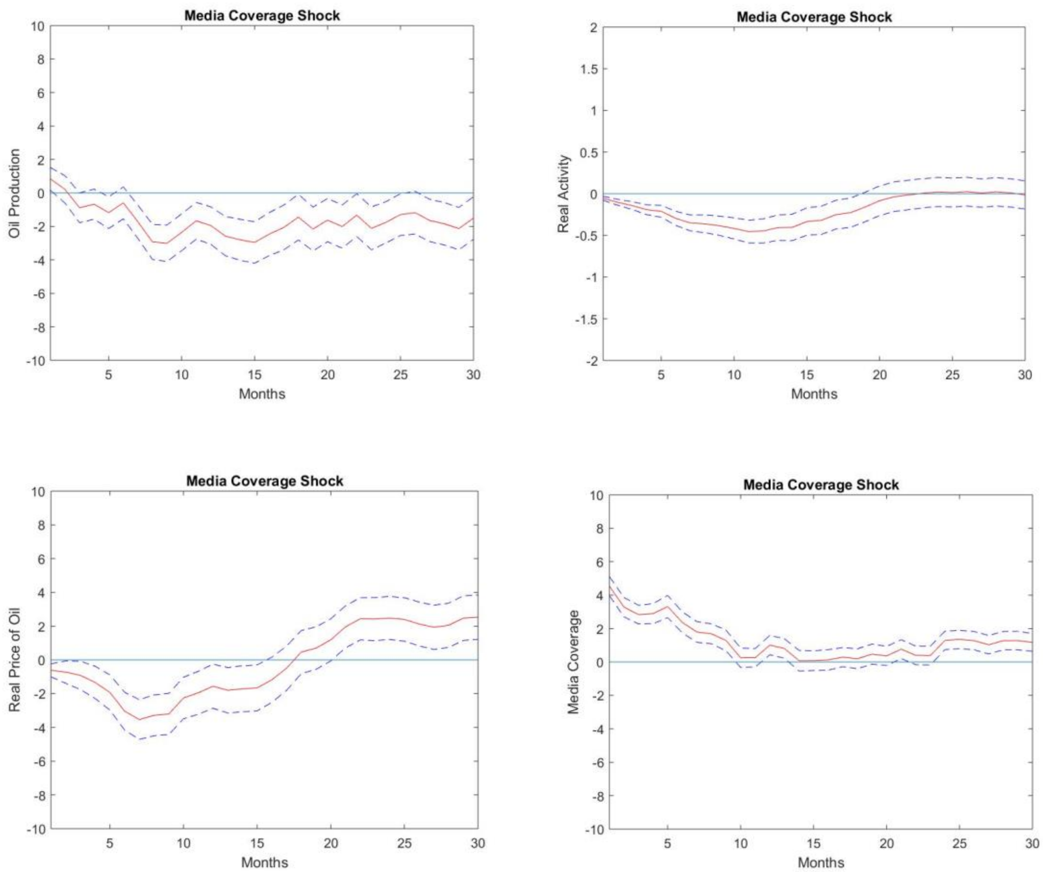


Figure 1.12: IRFs of media coverage shocks on oil price, oil production, economic activity and media coverage. Media coverage shocks are scaled to have one-standard-deviation negative effects on oil prices. Media coverage shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation media coverage shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

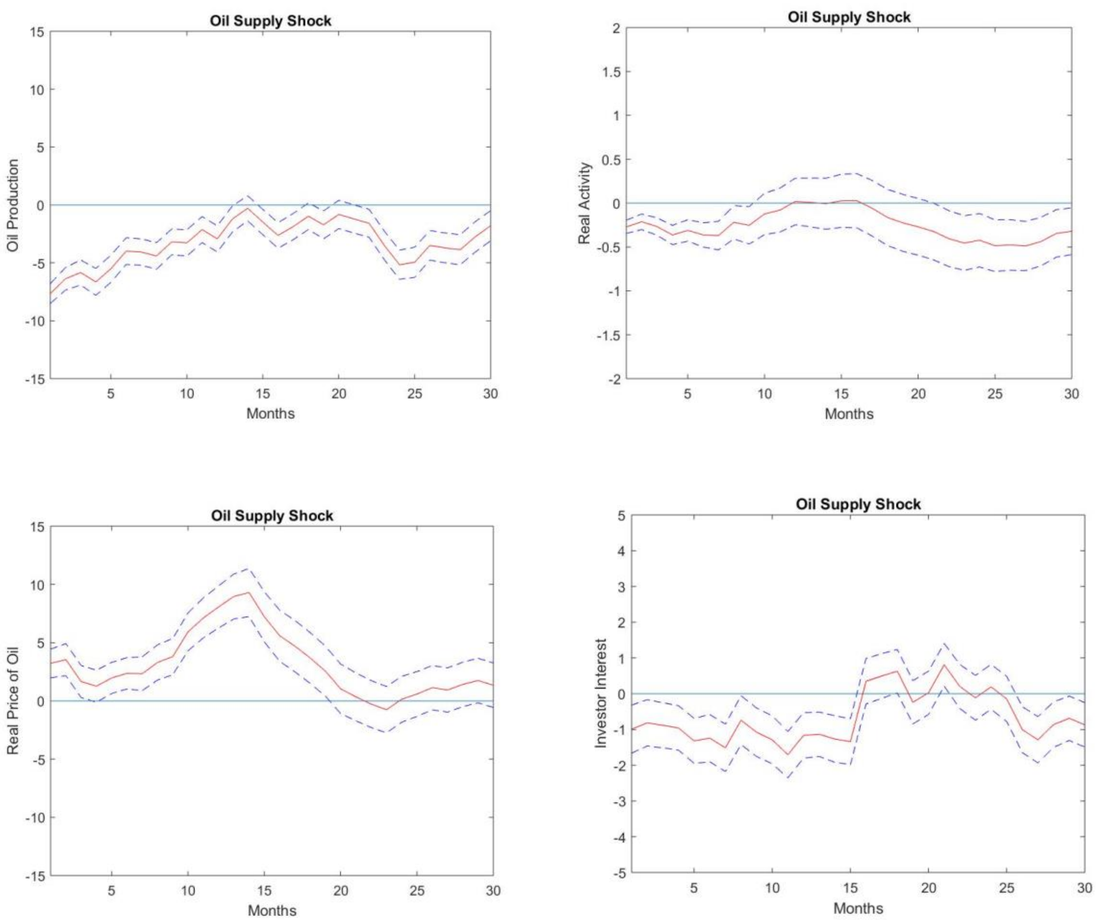


Figure 1.13: IRFs of supply shocks on oil price, oil production, economic activity and investor interest. Supply shocks are scaled to have one-standard-deviation positive effects on oil prices. Supply shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation supply shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

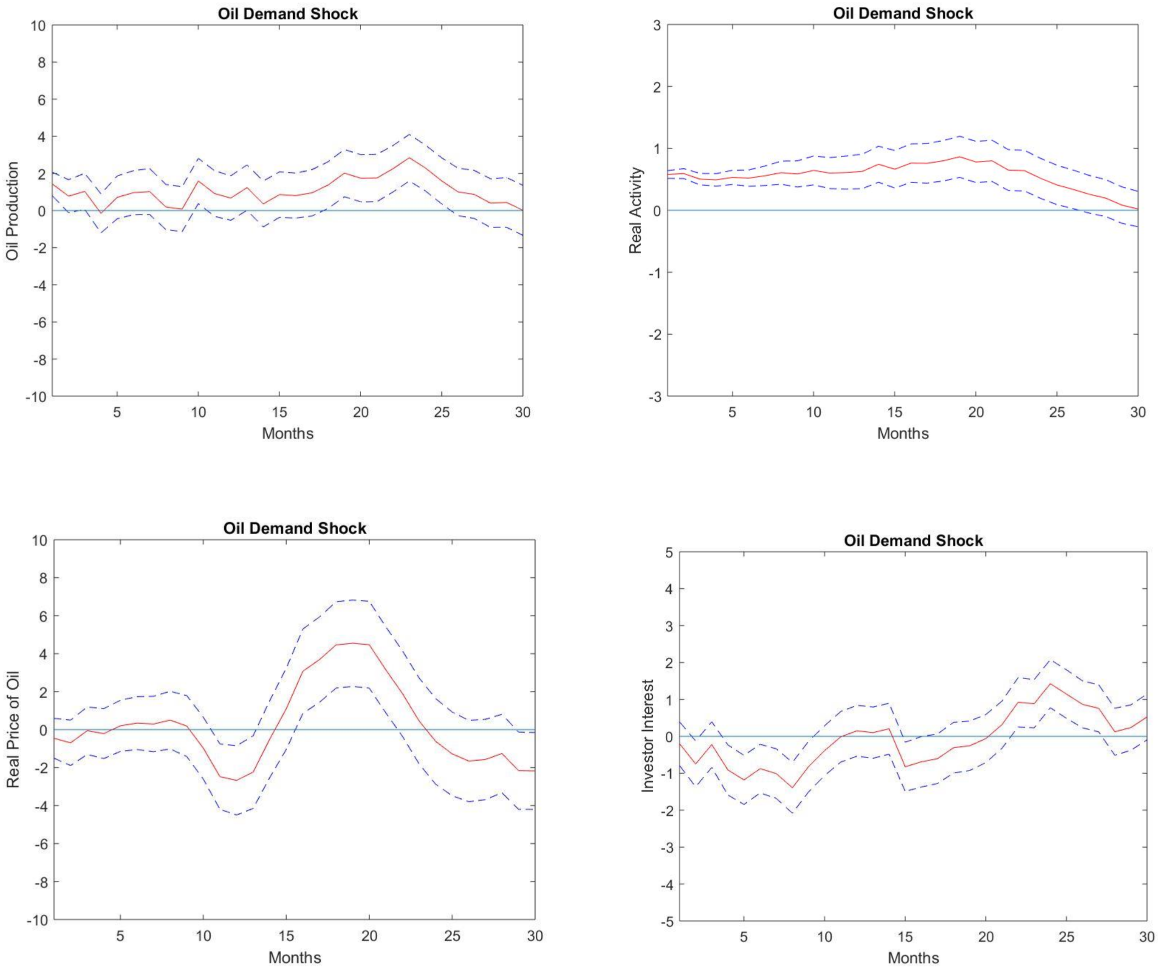


Figure 1.14: IRFs of demand shocks on oil price, oil production, economic activity and investor interest. Demand shocks are scaled to have one-standard-deviation positive effects on oil prices. Demand shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation demand shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

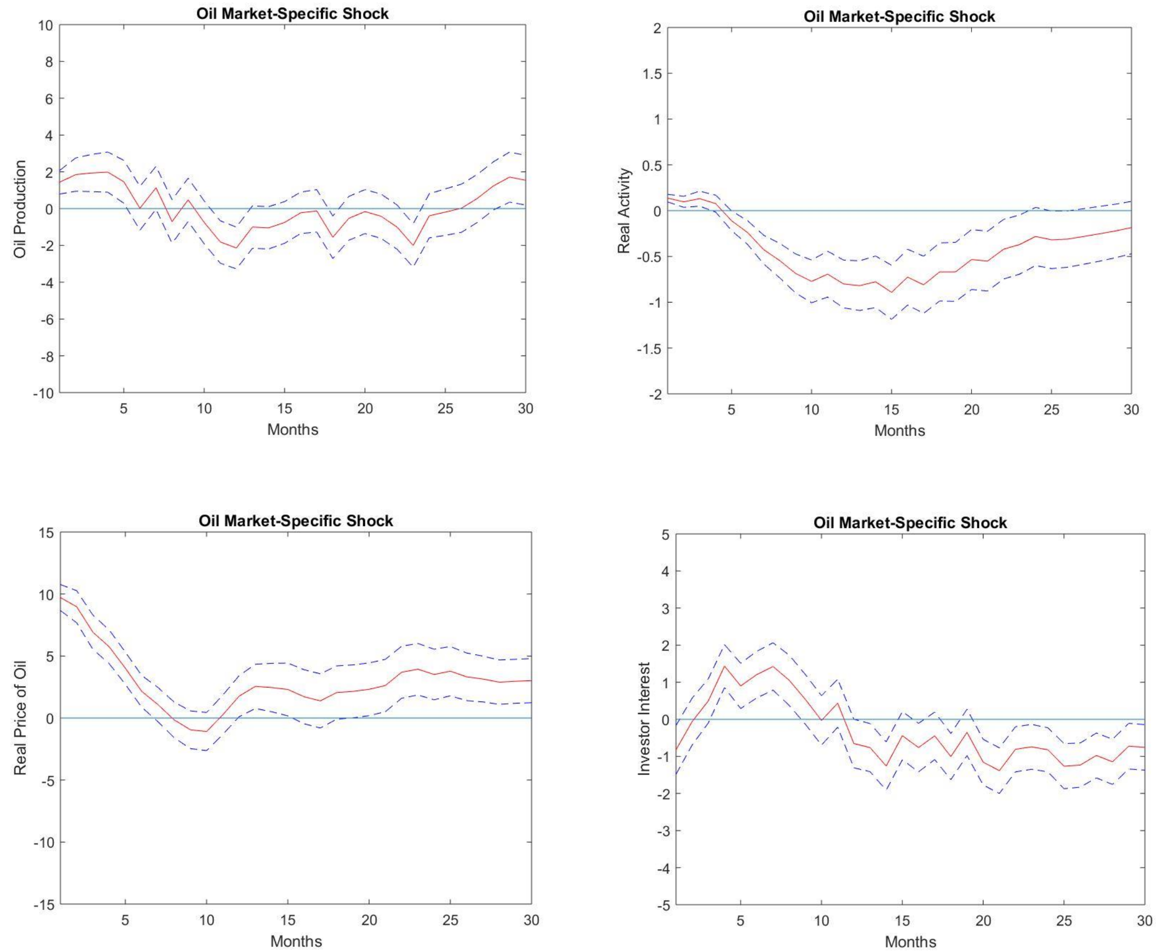


Figure 1.15: IRFs of oil market-specific shocks on oil price, oil production, economic activity and investor interest. Oil market-specific shocks are scaled to have one-standard-deviation positive effects on oil prices. Oil market-specific shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation oil market-specific shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

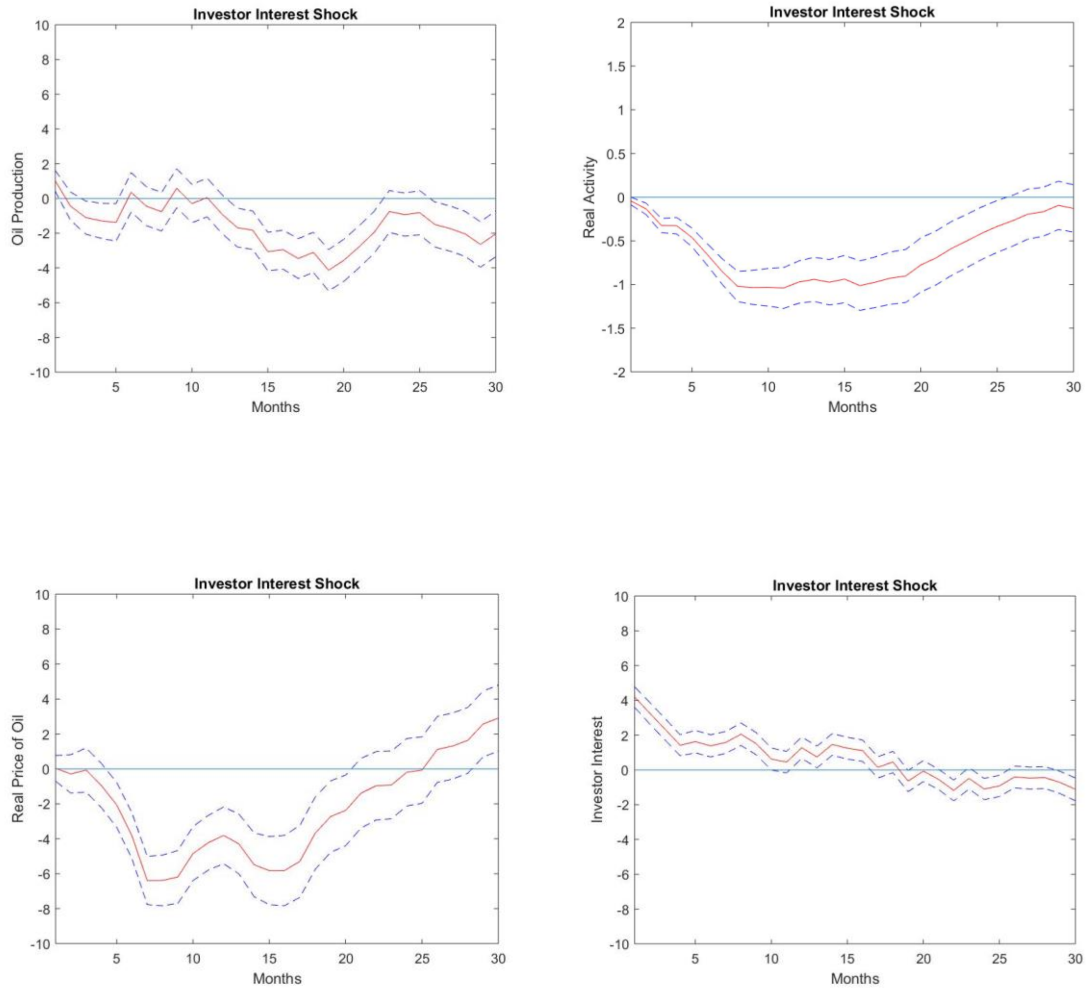


Figure 1.16: IRFs of investor interest shocks on oil price, oil production, economic activity and investor interest. Investor interest shocks are scaled to have one-standard-deviation negative effects on oil prices. Investor interest shocks are identified by imposing recursive ordering restrictions. Solid line represents the effects of one-standard-deviation investor interest shock on crude oil market variables, and dashed lines represent one-standard-error band around the shock effects constructed using bootstrap method with 2000 replications.

Crude Oil	Crude Oil Demand	Crude Oil Supply
Crude Oil Price	Crude Oil Invest	Crude Oil Investing
Crude Oil Future	Crude Oil Futures	Crude Oil ETFs
Crude Oil Movement	Crude Oil Disruptions	WTI Crude Oil

Table 1.1: Twelve crude oil market related search terms considered to construct the investor interest index.

Media Coverage Index			
	Lags	P value	Impact
Non-Commercial	4	0.0019	(-)*
Commercial	4	0.0002	(+)*
Non-Reported	4	0.0291	(-)*

Table 1.2: Effects of media coverage index on net futures positions of non-commercial, commercial, and non-reported traders. The effects on non-commercial and non-reported traders are negative and significant. The effects on commercial traders are positive and significant.

Investor Interest Index			
	Lags	P value	Impact
Non-Commercial	2	0.0373	(-)*
Commercial	1	0.2476	(+)
Non-Reported	1	0.0239	(-)*

Table 1.3: Effects of investor interest index on net futures positions of non-commercial, commercial, and non-reported traders. The effects on non-commercial and non-reported traders are negative and significant. The effects on commercial traders are positive but insignificant.

Non-Commercial Traders			
	Lags	P value	Impact
Investor Interest	2	0.2262	(-)
Media Coverage	4	0.6575	(-)

Table 1.4: Reverse effects of non-commercial traders' net futures positions on investor interest and media coverage. The effects are insignificant.

Commercial Traders			
	Lags	P value	Impact
Investor Interest	1	0.7713	(+)
Media Coverage	4	0.3200	(+)

Table 1.5: Reverse effects of commercial traders' net futures positions on investor interest and media coverage. The effects are insignificant.

Non-Reported Traders			
	Lags	P value	Impact
Investor Interest	1	0.4563	(-)
Media Coverage	4	0.8246	(-)

Table 1.6: Reverse effects of non-reported traders' net futures positions on investor interest and media coverage. The effects are insignificant.

Chapter 2

Expectation Shocks in the Crude Oil Market

2.1 Introduction

The primary purpose of this paper is to revisit the credibility of the Kilian Index as a proxy measure for the real global economic activities and extend the model to include expectation shocks in the crude oil market. Before 2009, the mainstream literature focuses on the supply side of crude oil price shocks to explain the effects of crude oil price changes. While they consider the responses of macroeconomic aggregates and monetary policies, the demand side of the crude oil price shocks was often neglected. In Kilian's 2009 paper, he argues crude oil price shocks should be separated into both crude oil supply shocks and crude oil demand shocks. The results conducted by Kilian (2009) are significant. According to Kilian, most of the crude oil price shocks come from unexpected aggregate demand shocks and oil market-specific shocks. This conclusion is very different from results concluded by previous papers in the literature, which show that crude oil supply shocks have substantial effects on crude oil price changes. To separate and estimate the aggregate demand shock, Kilian proposes the use of the later called "Kilian Index"-- a proxy measure for the global real economic activities based on the voyage freight shipping costs of a set of commodity goods. Since then, dozens of papers adopt the Kilian Index for considering crude oil demand shocks and for the use in related areas.

However, in a recent article by Hamilton (2018), he criticizes the credibility of the Kilian Index as a proxy measure for real global economics activities. Hamilton points out that the normalization method of the Kilian Index is inaccurate, and thus fail to capture real global economic activities. In the same article, Hamilton also provides an alternative proxy measure based on the OECD industrial production levels. In response to Hamilton's article, Kilian acknowledges the mistake and proposes a correction method to the original index. However, in Kilian's response, he does not explain how the corrected index would affect the results of his original paper. With this question, the first section of part one of this paper intends to replicate the Kilian (2009) results using the corrected index with the correction method proposed by Kilian, comparing the results to those of Kilian's original paper.

The main focus of the second section is to consider the argument Hamilton (2018) proposes, while estimate the crude oil price shocks by using the OECD industrial production index as a replacement for the Kilian index. The third section of this paper focuses on the consideration of changes in crude oil price shocks when the global crude oil markets are more integrated. The Kilian Index is extended to 2018 to include the effects of two major crude oil market events: the US fracking boom, and the lift of the US crude oil export ban.

The purpose of the second part of this paper is to extend the Kilian (2009) model by including expectation shocks. The first section considers improving the estimation results of the crude oil price shocks by using ETFs that track crude oil future contracts as the price value. The results are compared to previous results using spot prices as commonly used in the literature.

The second section, in the second part, considers extending the Kilian model by examining the effects of crude oil supply and demand expectation shocks. The conventional way is to use changes in OECD crude oil inventory reported by EIA as a proxy measure for crude oil future supply expectation, and changes in professional GDP growth rate forecast for future crude oil demand expectation. Most of the literature in the field with the same topic implemented that way. This section, however, will use a more direct measure of OPEC monthly report supply forecast and changes in OECD crude oil inventories as a proxy of crude oil supply forecast, and OPEC global demand forecast as a proxy measure of future crude oil demand expectation. The final section, in the second part considers the possible shock effects of political and unanticipated events in crude oil market.

Part I

2.2 Kilian Index: Possible Issues and Correction Method

Kilian (2009) proposes a proxy measure for real global economic activities to decompose the crude oil price shocks into crude oil supply shocks and crude oil demand shocks. The Kilian Index is constructed based on the voyage ocean freight rates of a list of commodity goods. The validity of the index as a proxy measure for real global activities based on the arguments proposed by Stopford (1997). In the short run and intermediate run, when there are low levels of freight volumes, the supply curve is relatively flat. On the other hand, when shipping demand increases due to expansions in real global economic activities, the supply curve becomes steeper, and the freight rates increase. With this argument, increases in freight rates may be an indicator of strong economic activities. Kilian (2009) gives a more detailed argument for the index.

When constructing the index, Kilian (2009) calculates period-to-period growth rates of each commodity's freight rates, and take equally weighted averages of the log growth rates across all the commodity goods in the sample. In the original Kilian index calculation method, Kilian then deflates the series and linearly detrends the series to obtains the Kilian Index as in equation (1).

$$\log(x_t)\text{-}\log(CPI_t)=\alpha+\beta t+\epsilon_t \tag{1}$$

Where x_t=Equal weighted average of the natural logarithm of a set of different growth rates of freight rates, and the residuals ϵ_t is the Kilian Index.

Hamilton (2018) criticizes the credibility and construction method of the original index. Kilian (2019), in response to Hamilton's criticism, suggests the problem was generated based on the double logarithm transformation on the growth rates of the freight rates. He proposes a correction method, as in equation (2).

$$x_t\text{-}\log(CPI_t)=\alpha+\beta t+\epsilon_t \tag{2}$$

The corrected version of the Kilian Index is constructed based on the regression model above. Figure 2.1 plots the original Kilian Index as well as the Kilian Index with correction. As demonstrates in Figure 2.1, the original Kilian Index tends to underestimate the real global activities compare to the corrected Kilian Index.

2.2.1 Estimation Model

The model in this paper follows the same structural vector autoregression model as in Kilian's 2009 paper. This structural VAR model aims to decompose the crude oil price shocks into crude oil supply shocks, aggregate demand shocks, as well as crude oil market-specific shocks. The three corresponding variables are percent changes in global crude oil production, Kilian Index, and real crude oil prices. Both Kilian Index and crude oil prices are in log form X_t = ($\Delta Production_t$,$real_t$,$Price_t$).

$$X_t = \alpha + B(L)X_{t-1} + S\varepsilon_t \tag{3}$$

$$B(L) = \sum_{i=1}^{16} B_i\, L^{i-1}$$

$$S\varepsilon_t = \begin{bmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Supply\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Specific-demand\ Shock} \end{pmatrix}$$

I've imposed recursive ordering restrictions onto the model. The model assumes crude oil production levels are not affected by current month unexpected aggregate demand shocks and unexpected oil specific-demand shocks. Due to the high costs of adjusting production levels and the uncertainty of the crude oil market, producers are unlikely to adjust their production levels during the current month of the shocks.

The model also assumes that real global economic activities react to the supply shocks in the current month but not to shocks that are oil market-specific. Finally, crude oil prices react to both crude oil supply shocks and unexpected aggregate demand shocks in the current month. I choose 16 lags to estimate the model based on the AIC test. The lag value in the original paper is 24. To obtain the impulse response functions, I use monthly data from February 1973 to December 2018 to estimate the B matrix and the residual matrix. I use the Cholesky decomposition method to obtain the S matrix. All shocks in this model are normalized to be one standard deviation.

2.2.2 Results

Figure 2.2 demonstrates the result comparisons:

In the section for a supply shock, crude oil supply shocks associated with a small reduction in real economic activities and a small increase in real crude oil prices. Comparing the results between using the original Kilian Index and the corrected Kilian Index, the results are mainly the same between the cases.

In the section of an unanticipated aggregate demand shock, the effects on both real global economic activities and real crude oil prices are positive and persistent. The results between the original index and the corrected index stay the same for the effects on real crude oil prices, whereas the main differences come from the effects on real global economic activities. As comparing the two impulse response functions, the effects in the corrected index case are more than two times larger than in the original index case. The differences, in this case, signal possible substantial underestimations of the responses of the real economic activities in both the original Kilian paper and papers that adopt the original Kilian Index.

In the results for crude oil market-specific shocks, the positive effects on real crude oil prices stayed the same between the original Kilian Index and corrected Kilian Index. However, the positive effects on real economic activities are again much more significant in the case with the corrected Kilian index.

In conclusion, with the correction to the Kilian Index, the main results of the Kilian (2009) conclusion stay mostly valid, where crude oil price shocks are mainly from both unexpected aggregate demand shocks and oil market-specific shocks. However, with the original index, the results largely underestimate the responses of real global economic activities on both unexpected aggregate demand shocks and crude oil market-specific shocks. This difference is essential and can affect the results of papers that adopted the original Kilian index. Those papers are possibly facing the same underestimation problem.

2.3 OECD Industrial Production Level for Proxy Measure

In Hamilton (2008), he criticizes the credibility of the Kilian index as a proxy measure for real global economic activities. Instead, he proposes that a better proxy measure would be the OECD country's industrial production level. This section intends to figure out the differences between the two measures and which one would possibly be a better representation of real global economic activities. The model is adjusted to apply the proxy measure constructed using the OECD industrial production level. The results are compared to the one with the Kilian Index. As proposed by Hamilton (2018), in this case, the proxy measure is constructed by getting the cyclical part with taking a two-year difference. In contrast, the Kilian Index is calculated by applying the linear detrending method and using the residuals as the index. The model here follows the original Kilian (2009) model, and the only difference is that the OECD industrial production index replaces the Kilian index.

Figure 2.3 demonstrates the results. Comparing the results between using the Kilian Index and using the OECD industrial production index, we see that the differences between the two results are minimal. Focusing on the effects of shocks on crude oil prices, we see that in the section of crude oil production shocks, the effects stay the same in both cases. On the other hand, the results are also very similar in the crude oil market-specific shocks. The only difference, in this case, is the effects on aggregate demand price shocks. Where in the Kilian Index case, we have permanent increasing positive effects, but in the Hamilton case, we have permanent but stable positive effects on crude oil prices. In summary, though the two proxy variables in both cases are constructed differently, and we have different results on the effects of aggregate demand shocks. Nevertheless, the conclusion of Kilian's 2009 paper stays valid with both Kilian Index and the OECD industrial production index.

2.4 Comparing the Results to 2018

The two major events in the crude oil market that took place between 2007 and 2018 are the US fracking boom and the lift of the US crude oil export ban. The two events, in theory, led to the US crude oil market and the global oil market to become more integrated. This section examines whether the crude oil market integration changed the effects of the crude oil price shocks from 2007 to 2018.

In both scenarios, with the original Kilian Index and with the corrected Kilian Index, the results show that the effects of crude oil supply shocks are small on both real global economic activities and real crude oil prices. Kilian (2009) proposes an argument that helps explain the small effects of crude oil supply shocks, where supply disruptions in one location can be compensated by increases in crude oil production in other locations.

On the other hand, expectations for future crude oil production disruptions are associated with precautionary demand shocks, which are represented by the oil market-specific shocks in the model. This section intends to investigate whether the two major events-- US fracking boom and the lift of the crude oil export ban, have diminished the effects of both supply shocks and oil market-specific shocks on global economic activities and crude oil prices.

The initial assumption is that with the US crude oil market and the global crude oil market became more integrated, crude oil production locations are easier to compensate each other for any production disruptions. As a result, it would lower the effects of crude oil supply shocks. From the perspective of precautionary demand shocks, with the crude oil market became more integrated, the concerns for future crude oil disruption decrease, and therefore lowers the effects of precautionary demand shocks, as well as oil market-specific shocks.

Figure 2.4 shows the results contradict the initial assumptions. Considering the effects of crude oil supply shocks, in the 2018 case, the effects on real oil prices are the same at the initial periods, but become much more negative in later periods. There are no significant changes in the effects on real global economic activities. Now consider the effects of oil market-specific shocks. Comparing to the 2007 case, effects on real crude oil prices are more significant in the 2018 case for the first eight months, while effects on real economic activities are also larger in the 2018 case for the first five months. Both of the results contradict the initial assumptions.

One possible explanation for this observation is the decreasing global crude oil spare capacity. Even though the global crude oil markets are more integrated than before with the US fracking boom and lift of the US crude oil export ban, the global crude oil production spare capacity has decreased dramatically as well, due to OPEC's decision of increasing production in competition with the US shale producers. The lowering in spare production capacity makes it harder for crude oil-producing countries to compensate for crude oil production disruptions. On the other hand, the reduction in crude oil production capacity results in increased effects of precautionary demand shocks.

Another explanation would be the limitations of crude oil transportation pipelines. It is still hard for US shale producers to export inland crude oil productions for-- most of the exports are still from offshore productions. With the two possible explanations, it makes sense for observing increases in both crude oil supply shocks and oil market-specific shocks. Another main observation in this section is for the unexpected aggregate demand shocks on real economic activities and real crude oil prices. Both effects are larger in the initial periods of the 2018 case than of the 2007 case.

Part II

2.5 Extension

Part two of this paper serves as an extension to Kilian's 2009 paper. The improved model includes estimation of future supply and future demand shocks, which focuses on petroleum data releases and news reports. In Kilian's original paper, he decomposes the crude oil price shocks into three shocks, aggregate demand shock, supply shock, and oil market-specific shock. However, the paper is not clear on the specific components of the oil market-specific shock. As pointed out by Davig et al. (2015), the aggregated demand and supply shocks suggests by the original Kilian (2009) model fail to explain the substantial decline in oil prices from mid-2014 to 2016. Thus, it is crucial to decompose the oil market-specific shocks for further explanations. This part contributes to the literature by introducing the expectation shocks on future supply and demand, considering the information from news reports and data releases, as well as implementing crude oil future contract ETFs as price variable.

2.5.1 Spot Price vs. ETFs

Kilian (2009) and most of the papers with extensions to the model use spot crude oil prices when constructing crude oil shocks. Though spot prices can capture some of the investors' expectations on the crude oil market, more of the expectations are reflected in the changes of crude oil future contract prices. However, both the values of the futures contracts and the price spread between them can be challenging to track. In this section, to solve this problem, an ETF (OIL) is implemented to track both WTI and Brent futures contracts as a price indicator.

2.5.2 Explanation of ETF Choice

The selection of implementing ETFs is crucial as it impacts the model accuracy. There are three factors considered in selecting an appropriate ETF: trading volume, whether the ETF tracks only crude oil future contracts, and multiplier in tracking the crude oil future contracts. Based on the average monthly trading volumes, the five most traded crude oil ETFs are UCO, OIL, UWT, USO, and BNO. Of these five ETFs, USO and BNO track both crude oil future contracts and S&P 500 index, and OIL, UCO, UWT tracks only crude oil future contracts. Furthermore, comparing the three ETFs that track only crude oil future contract market, OIL tracks with one percent to one percent ratio, UCO tracks with two percent to one percent, and UWT tracks with three percent to one percent. For this paper, OIL is selected as an ETF proxy measure for the crude oil future contracts to keep the price volatility of the ETF proxy measure aligns with the crude oil future contracts.

2.6 Supply and Demand Expectation Shocks

The idea of including future supply shocks first appears in Davig et al. (2015), and later the model is extended by Fueki et al. (2018). In both papers, changes in OCED crude oil inventories are used as a proxy variable for expectation on future crude oil supply. Fueki et al. (2018) further extend the model by including the adjustments in professional GDP growth forecasts as a proxy variable for future crude oil demand. While the idea is inspiring, the chosen proxy variables have some inherent weaknesses in capturing expectations. This section intends to introduce possibly better proxy variables for future supply and demand expectations: the information from petroleum data releases.

2.6.1 Expectation on Future Supply

Using changes in OECD crude oil inventories as a proxy variable for expectation on crude oil supply is with some flaws. First of all, Davig et al. (2015) and Fueki et al. (2018) obtain OECD crude oil inventories data from EIA (US Energy Information Administration). EIA reports OECD crude oil inventories data with four months lag, which means it is possible the OECD inventory values obtained from the EIA are being reported to investors four months later. There is no explicit discussion in both papers about this issue. One possible solution to this issue could be implementing the OECD crude oil inventories data reported in the OPEC monthly reports, and match the stated month as the month the value being reported. Moreover, the predicted Non-OPEC crude oil supply forecasts in OPEC monthly reports serve as a more direct proxy variable for future crude oil supply. This section uses the following proxy variables for expected future crude oil: Non-OPEC supply expectation value in the monthly report and OPEC reported OECD crude oil inventories.

2.6.2 Expectation on Future Demand

In Fueki et al. (2018), adjustments in professional forecasts of global GDP growth is used as a proxy variable for future demand expectations. Though an increase in global GDP is a valid indicator of increasing economic activities and crude oil consumption, there are better and more direct proxy variables investors consider for future crude oil demand forecast. This section will introduce a more direct proxy variable --the global crude oil demand forecast in the OPEC monthly report.

2.6.3 Models and Methods

The first model in this section follows the similar structural vector autoregression model, as in Kilian's 2009 paper. Different from Kilian (2009), in this model, the proxy variable for real economic activities is replaced with an index calculated using the OECD country industrial production index. Moreover, the price variable in crude oil prices of the original model is replaced with ETF(OIL) prices. The purpose of this model is to compare the differences in effects of oil market-specific shocks between spot crude oil prices and ETF prices.

X_t= ($\Delta Production_t$,$real_t$,$Spot\ Price_t$); X_t= ($\Delta Production_t$,$real_t$,$ETF\ Price_t$).

$$X_t = \alpha + B(L)X_{t-1} + S\varepsilon_t \tag{4}$$

$$B(L) = \sum_{i=1}^{12} B_i\, L^{i-1}$$

$$S\varepsilon_t = \begin{bmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Supply\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Specific-demand\ Shock} \end{pmatrix}$$

The second model in this section includes future supply shocks and future demand shocks. To measure the two shocks, the original VAR model is extended with two proxy variables for future supply and expectations. The purpose of this model is to investigate the effects of future demand shocks and future supply shocks.

X_t= ($\Delta Production_t$,$real_t$, $\Delta Demand\ Forecast_t$, $\Delta Supply\ Forest_t$ $ETF\ Price_t$).

$$X_t = \alpha + B(L)X_{t-1} + S\varepsilon_t \tag{5}$$

$$B(L) = \sum_{i=1}^{12} B_i\, L^{i-1}$$

$$S\varepsilon_t = \begin{bmatrix} s_{11} & 0 & 0 & 0 & 0 \\ s_{21} & s_{22} & 0 & 0 & 0 \\ s_{31} & s_{32} & s_{33} & 0 & 0 \\ s_{41} & s_{42} & s_{43} & s_{44} & 0 \\ s_{51} & s_{52} & s_{53} & s_{54} & s_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Supply\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Future\ Demand\ Shcok} \\ \varepsilon_t^{Future\ Supply\ Shock} \\ \varepsilon_t^{Oil\ Market-Specific\ Shock} \end{pmatrix}$$

2.6.4 Results

2.6.4.1 Comparing the Effects of Oil Market-Specific Shocks Between Spot Prices and ETF Prices

Figure 2.5 demonstrates the comparison:

The Impulse response functions are similar in both cases since the ETF considered, in this case, tracks crude oil future contracts with one percent to one ratio. However, the results comparing the effects of oil market-specific shocks between crude oil spot prices and EFT prices have confirmed my assumption. The initial effect on the ETF is larger than the effects on crude oil spot prices. Based on the results, ETF that tracks crude oil futures contracts captures more expectation effects than spot prices capture. The results are robust by using the Kilian Index as a proxy variable for real economic activities.

2.6.4.2 Results on Future Supply and Demand Shocks using OPEC Demand and Supply Forecast

In this section, the proxy variable used for future supply is the changes in OPEC crude oil supply forecast. The proxy variable used for future demand is the changes in OPEC global crude oil demand forecast. Focusing on the shock effects on ETF prices (Figure 2.6), the effects of supply shocks and aggregate demand shocks stay the same as before. However, there are slightly positive effects coming from future demand shocks and substantial significant future supply shocks during the initial periods. At the same time, there is a significant decrease in the initial effects for oil market-specific shocks. Considering the results, in this case, we can see that a portion of the previous oil market-specific shocks is now explained by both the future demand shocks and future supply shocks. The next section will consider the OECD crude oil inventories reported by the OPEC monthly report, to see if the results still hold.

2.6.4.3 Results Using the OECD Change in Crude Oil Inventories Reported by the OPEC Monthly Report

This section improves the results already in the literature that implement changes in OECD crude oil inventories as a proxy variable for future crude oil supply. Unlike in the Fueki et al. (2018), which uses changes in OECD crude oil inventories reported by EIA, this section will use the changes in OECD crude oil inventories reported by OPEC monthly report as a proxy variable for future crude oil supply. Figure 2.7 demonstrates the results. Similar to the case with non-OPEC crude oil supply, in this case, we again observe a small positive crude oil demand expectation effects and substantial negative supply expectation effects in the initial periods. We can also observe a significant decrease in the effects of crude oil market-specific shocks.

The results shown above with the petroleum data from OPEC monthly report indicates that some of the oil market-specific effects can contribute to the expectation of the future crude oil supply and demand.

2.6.4.4 Shock Effects on Related Variables

With the results of shock effects on crude oil future ETF prices, it is also crucial to consider shock effects on the other four related variables. Figure 2.8 demonstrates the corresponding results. First, all five shocks have minimal effects on changes in crude oil demand forecast. The fact that OPEC only makes small changes in their demand forecast from month to month helps explain this observation. In contrast, other variables are more volatile from month to month. The second observation is that future supply shocks have positive effects on crude oil production; however, the effects only last for two periods. The results might seem counter-intuitive at first since the results suggest that OPEC's forecasting power in future crude oil production is weak. The results observed here can be explained by two arguments; First is suggested by Kilian (2009, 2014). Changes in crude oil production in one location are responded by increase or decrease production in other locations accordingly. On the other hand, OPEC tends to change its production level according to Non-OPEC crude oil supply levels to stabilize global crude oil prices.

Finally, the shock effects on future supply forecasts are also trivial. During OPEC's global crude oil supply forecasting process, the five variables we considered in this paper are not the main inputs variables and thus carry less weight. This argument helps explain the observation.

2.6.4.5 Robustness Check

As for the robustness check for the obtained results in this part, it is essential to check the recursive ordering assumed in the model. As we mentioned and discussed in the first part of this paper, crude oil production and real global economic activities are the slow variables. They are not likely to be affected by OPEC monthly reports, the crude oil price, or the ETF prices in the current month. However, changing the ordering of demand forecast, supply forecast, and crude oil prices are needed to check for the robustness of the results. First, changing the ordering of the supply forecast and demand forecast does not affect the results, and the impulse response functions stay the same as in Figure 2.9. Second, by changing the ordering of the price variable and supply and demand forecast variable, the results again show that the changes in the impulse response functions are minimal (Shown in Figure 2.10). Based on the results of the robustness check, the results in part two of this paper are robust to changes, and the recursive ordering assumption of the model is valid.

2.6.4.6 Political and Unanticipated Events

After controlling for the crude oil supply expectation shocks and crude oil demand expectation shocks, other possible shocks in the crude oil market are shocks from political and unanticipated events. This section will consider the effects of political events and unanticipated events in the crude oil market by using the instrumental variable regression method. In this model, the residual values of variables of interest are obtained using the VAR model in equation (5), which capture the parts of the variables of interest that are not explained by the VAR model. Then the residuals are regressed on political and unanticipated event indicators. Table 2.1 demonstrates the results. First, we see significant positive effects on crude oil ETF prices in the current period and the period after. The results confirm the assumption since most events considered in this section led to disruption in crude oil production and an increase in crude oil prices. Moreover, the further effects of the political and unanticipated events that are not captured in the VAR model led to a crude oil price increase in the second period. On the other hand, we see that the aggregate effects on crude oil production are negative. More importantly, there tend to have substantial decreases in crude oil supply forecast in the first period after political events took place. Since political events might happened around or after the monthly reports are released in a current month, the changes in supply forecast are likely to be reflected in the next month's report. Finally, the effects of political and anticipated events have negative but minimal effects on the crude oil demand forecast. The results follow the argument that most of the events led to changes in crude oil production but not to changes in crude oil demand directly. The results in this section demonstrate the possibility of political and unanticipated event shocks as components of the oil market-specific shocks.

2.7 Conclusion

The first part of this paper has shown that results from the original Kilian (2009) paper have changed by applying the corrected Kilian index and the index constructed from OECD industrial production levels. However, different from Hamilton's claim, although the magnitudes of the price shock effects have changed, the conclusions of the Kilian 2009 paper stay valid. At the end of the first part, the data has been extended into 2018 to include the two main events of the global crude oil market: the lift of the US crude oil export ban and the US fracking boom. The results contradict the assumption that a more integrated market would lead to smaller effects of both crude oil supply shocks and crude oil market-specific shocks. Instead, the results can be explained by the decrease in global crude oil spare capacity.

The second part of this paper focuses on extending the original Kilian model to decompose the oil market-specific effects into supply expectation and demand expectation shocks. The first section concludes with the introduction of using ETF prices as the price variable instead of spot price. Doing so, we would observe an increase in the effects of the crude oil market-specific shocks, which are also the precautionary demand shocks. The second section decomposes the oil market-specific shocks into crude oil demand expectation and crude oil supply expectation shocks by applying the crude oil supply and demand forecast provided the OPEC monthly reports. The results have shown significant effects for crude oil supply expectation shock and trivial effects for demand expectation shock. Moreover, we see that after controlling for supply and demand forecast shocks, there is a substantial decrease in the effects in the oil market-specific shocks. Finally, political and unanticipated events in the crude oil market also have significant effects on crude oil prices, which are captured in the oil market-specific shocks.

2.8 Figures and Tables

Figure 2.1: Comparison of original Kilian (2009) Index and corrected Kilian Index from 1973 to 2009.

Original 2007 ***Corrected 2007***

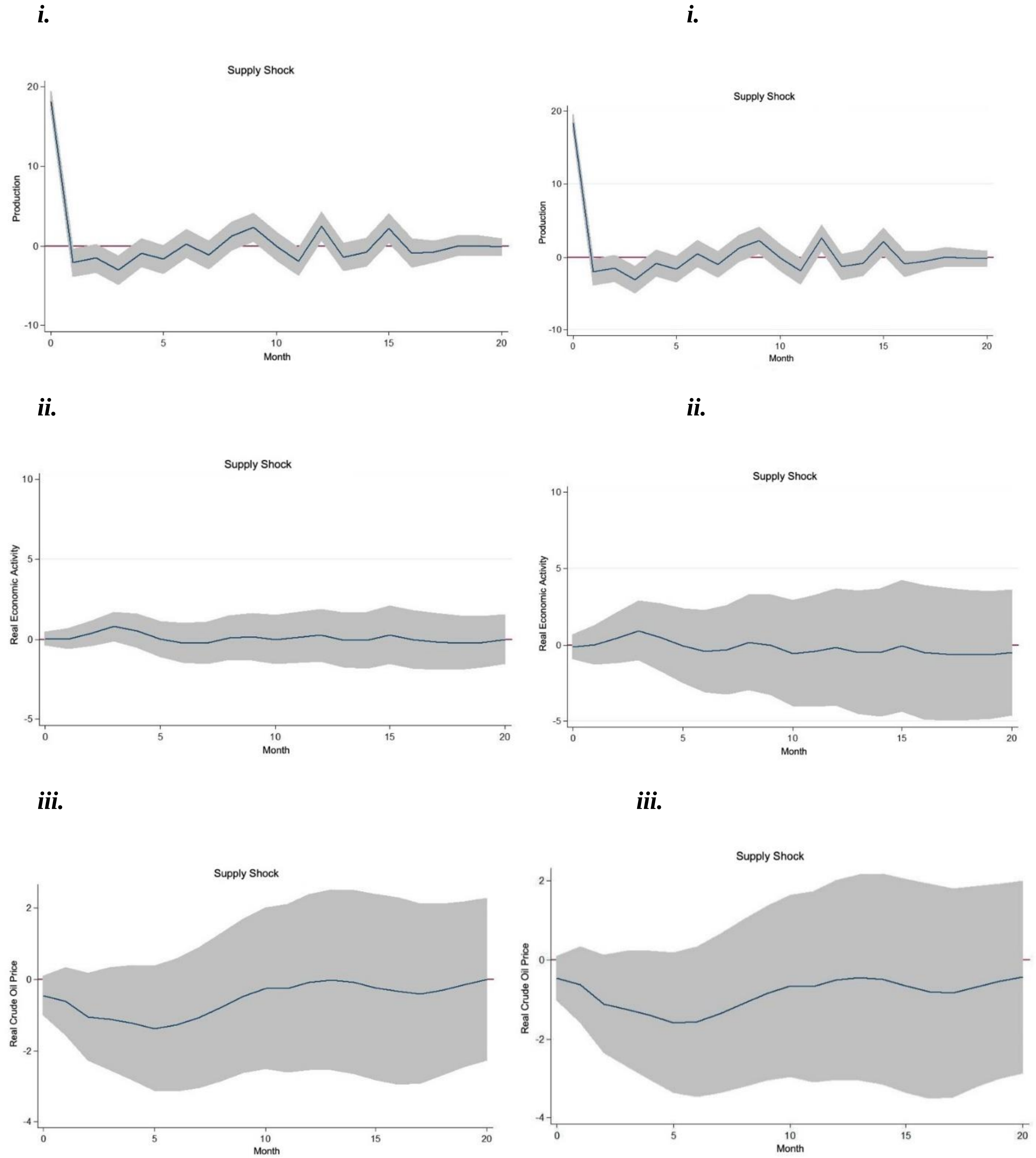
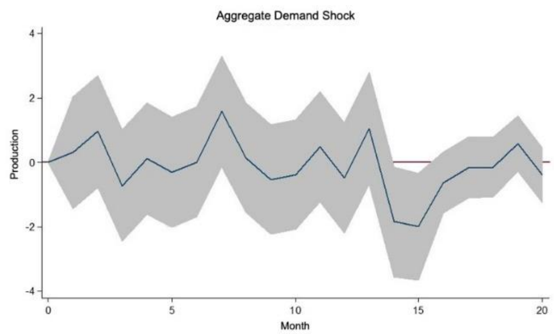


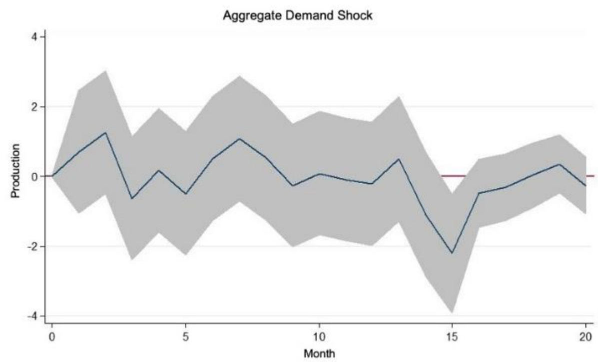
Figure 2.2a: Comparison of 2007 data with original and corrected Kilian Index. IRFs of supply shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Original 2007 ***Corrected 2007***

i.



i.



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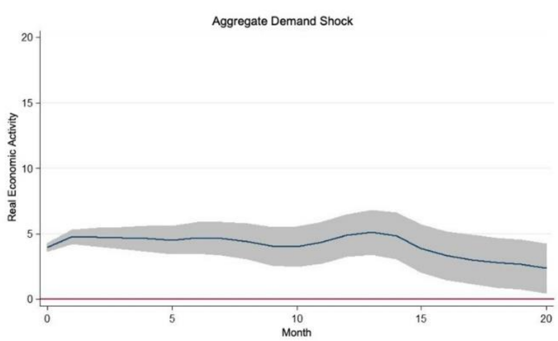

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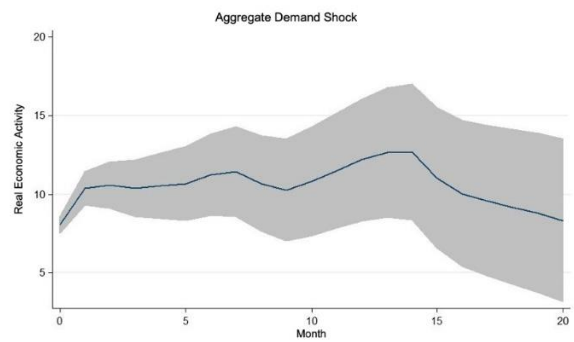

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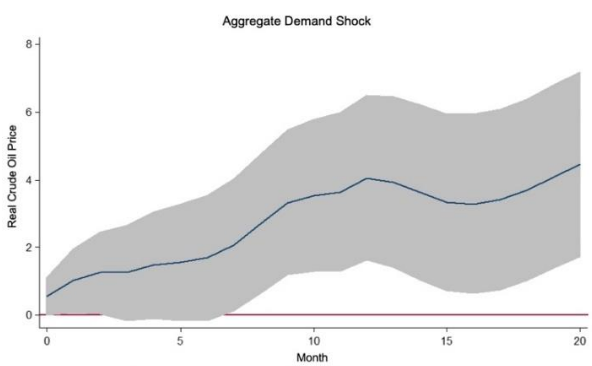

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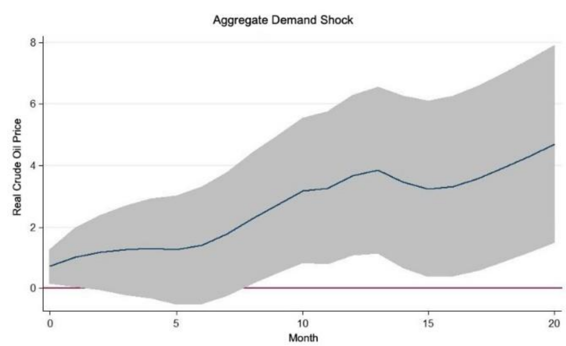
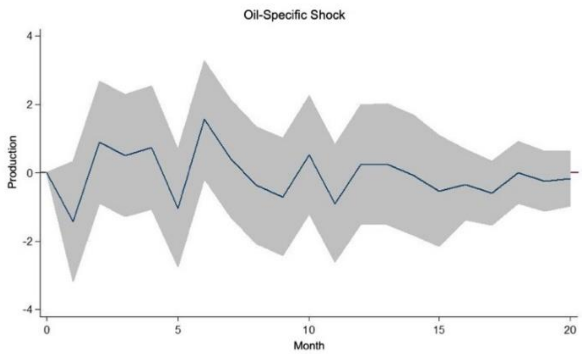


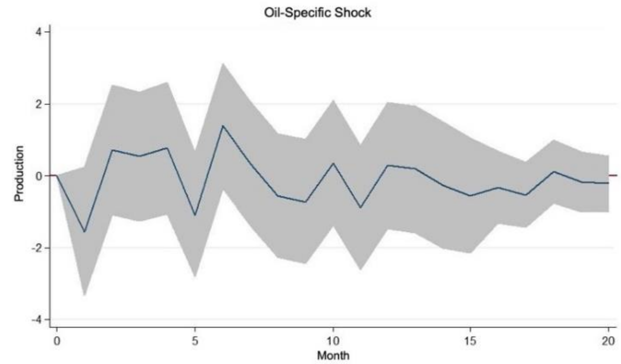
Figure 2.2b: Comparison of 2007 data with original and corrected Kilian Index. IRFs of aggregate demand shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Original 2007 ***Corrected 2007***

i.



i.



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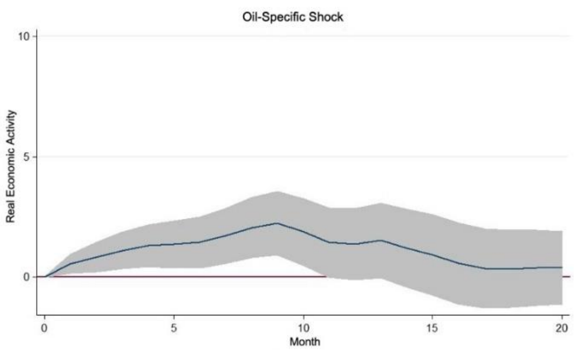

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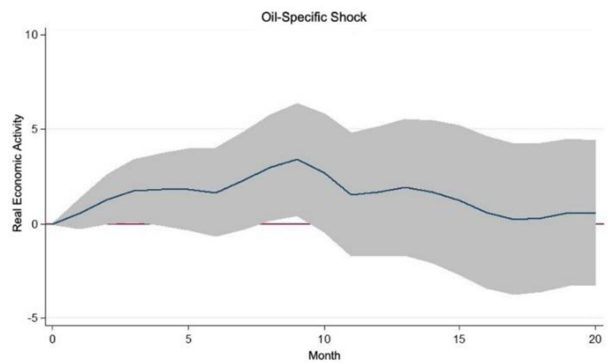

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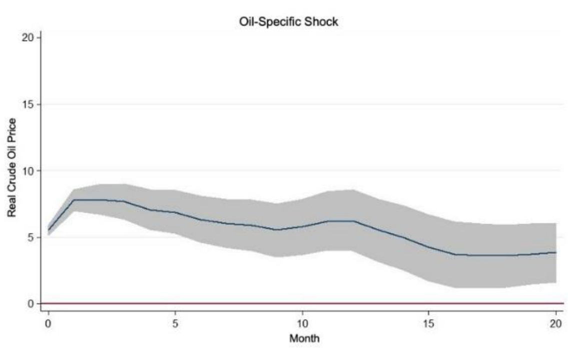

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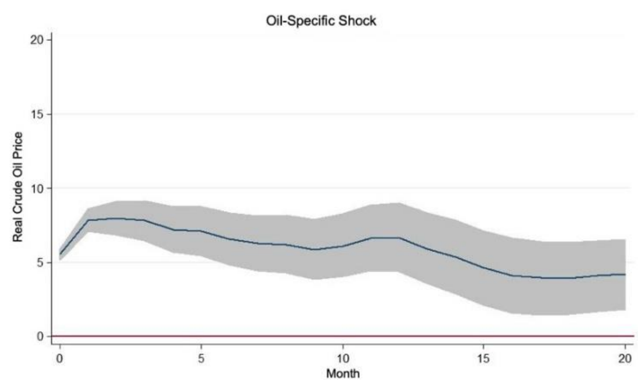


Figure 2.2c: Comparison of 2007 data with original and corrected Kilian Index. IRFs of oil-specific shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

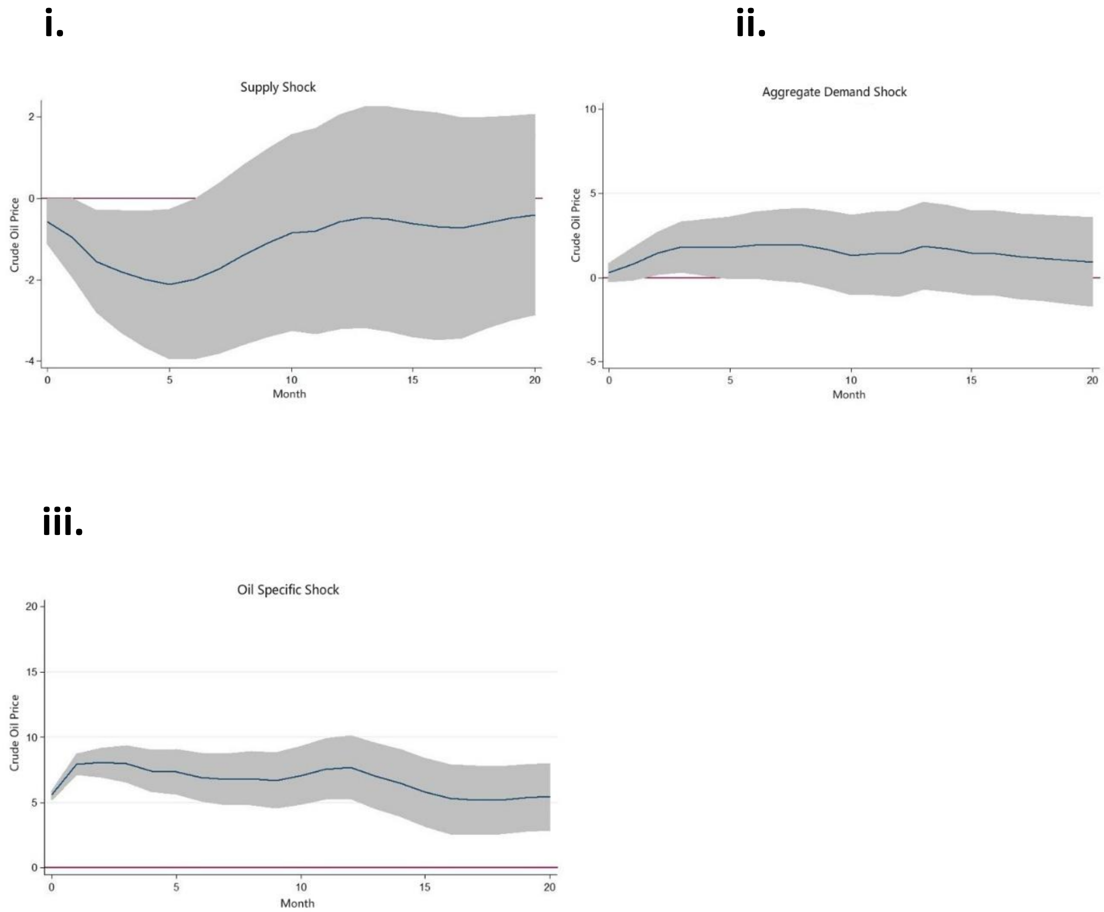
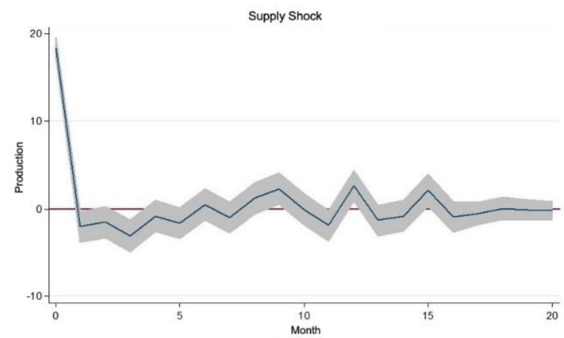


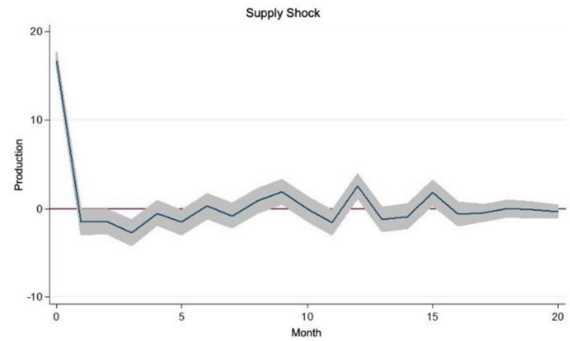
Figure 2.3: IRFs with OECD industrial production index as real economic activity. IRFs of supply, aggregate demand, and oil-specific shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Corrected 2007 ***Corrected 2018***

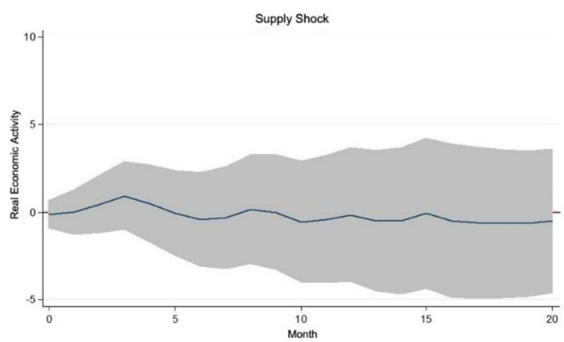
i.



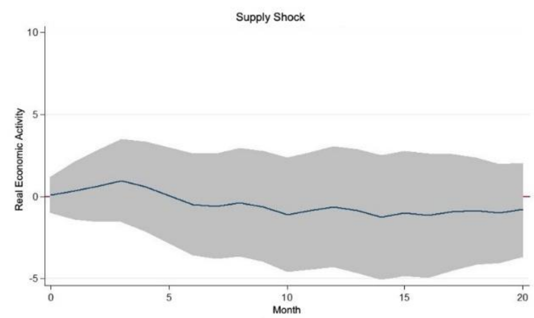
i.



ii.



ii.



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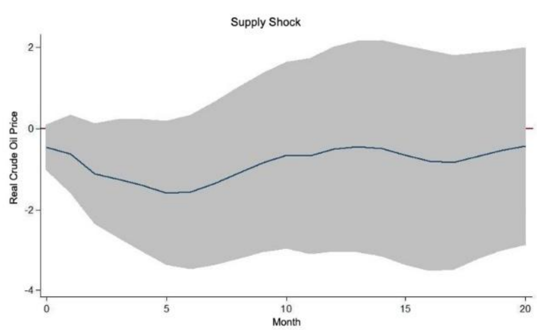

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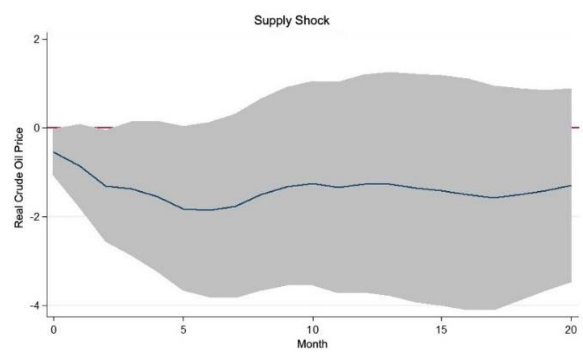


Figure 2.4a: Comparison of 2007 and 2018 data with corrected Kilian Index. IRFs of supply shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Corrected 2007 ***Corrected 2018***

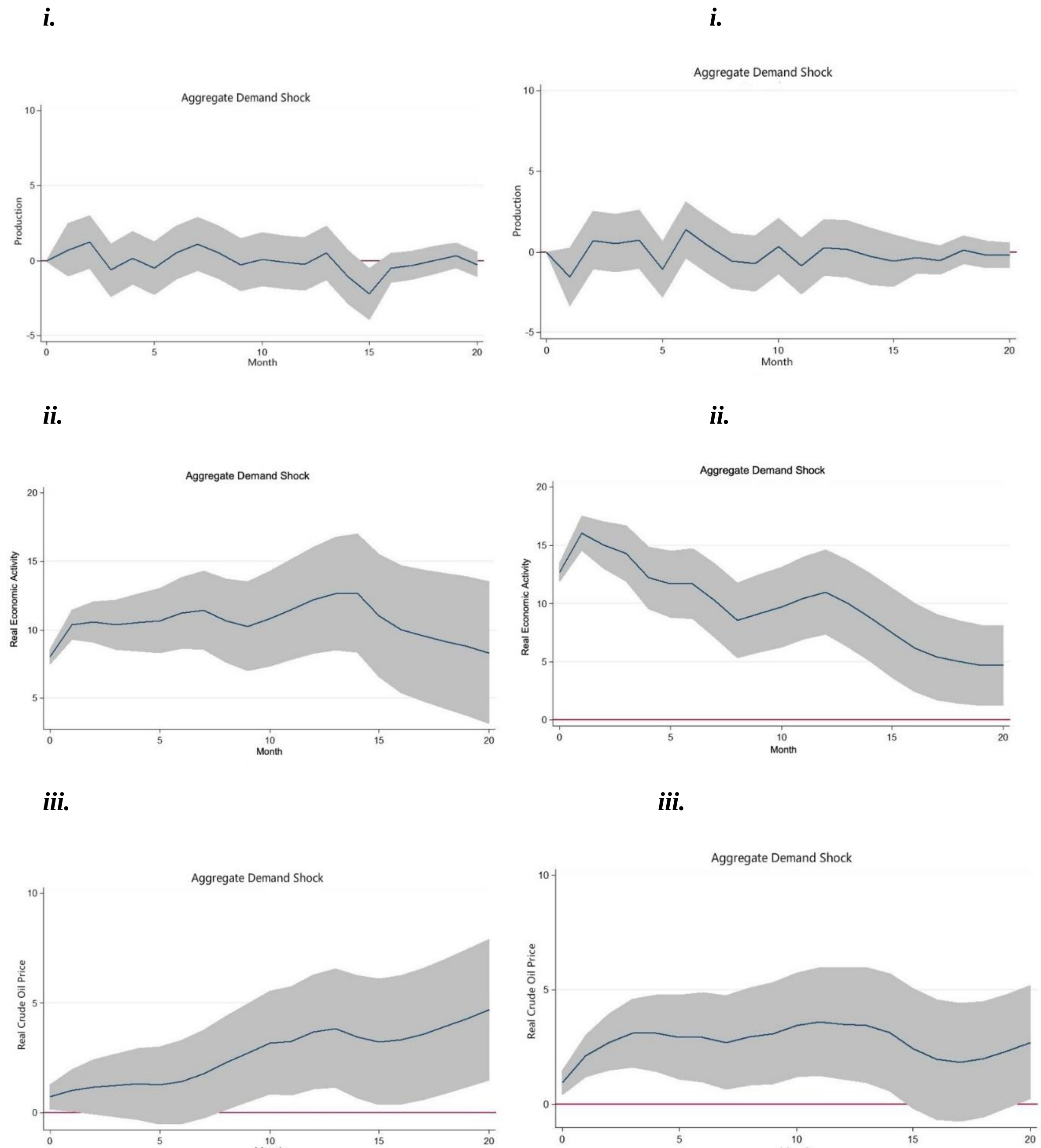
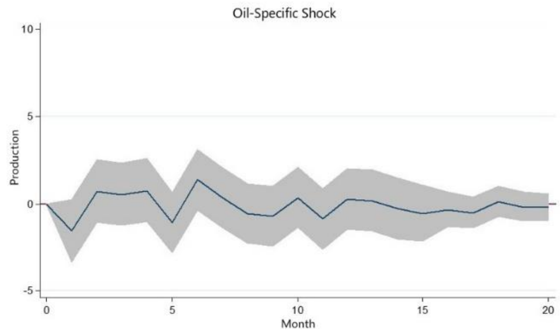


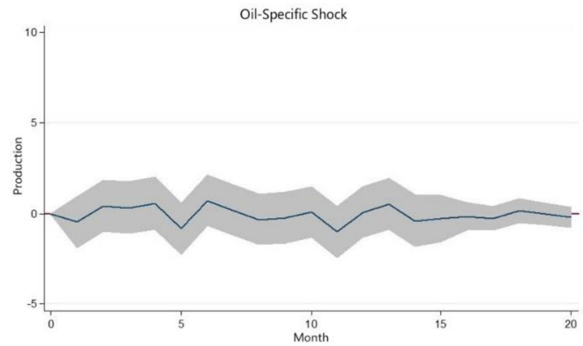
Figure 2.4b: Comparison of 2007 and 2018 data with corrected Kilian Index. IRFs of aggregate demand shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Corrected 2007 ***Corrected 2018***

i.



i.



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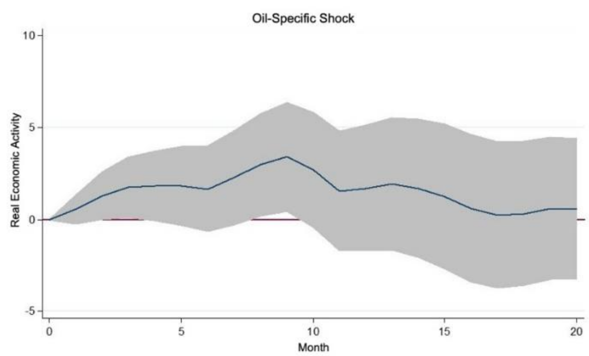

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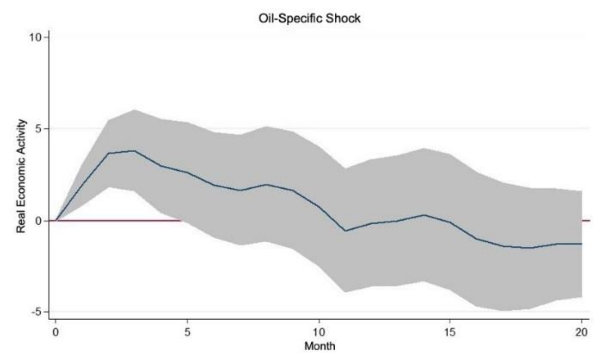

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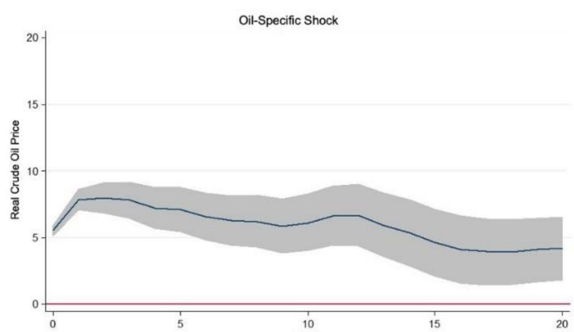

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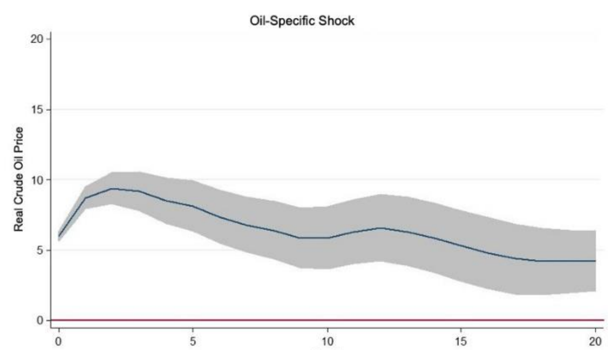


Figure 2.4c: Comparison of 2007 and 2018 data with corrected Kilian Index. IRFs of oil-specific shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

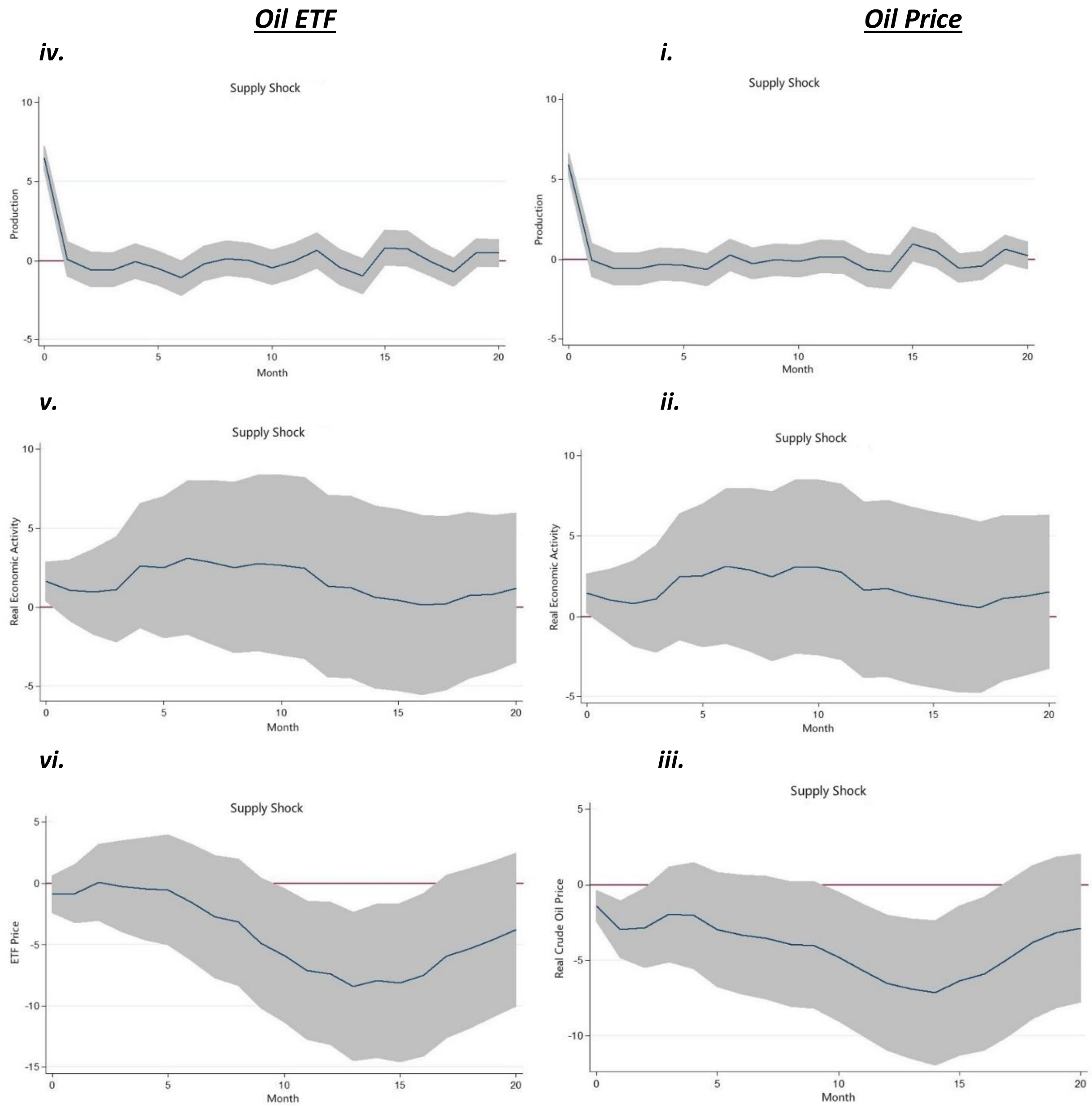


Figure 2.5a: Comparison of crude oil spot price and crude oil ETF. IRFs of supply shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

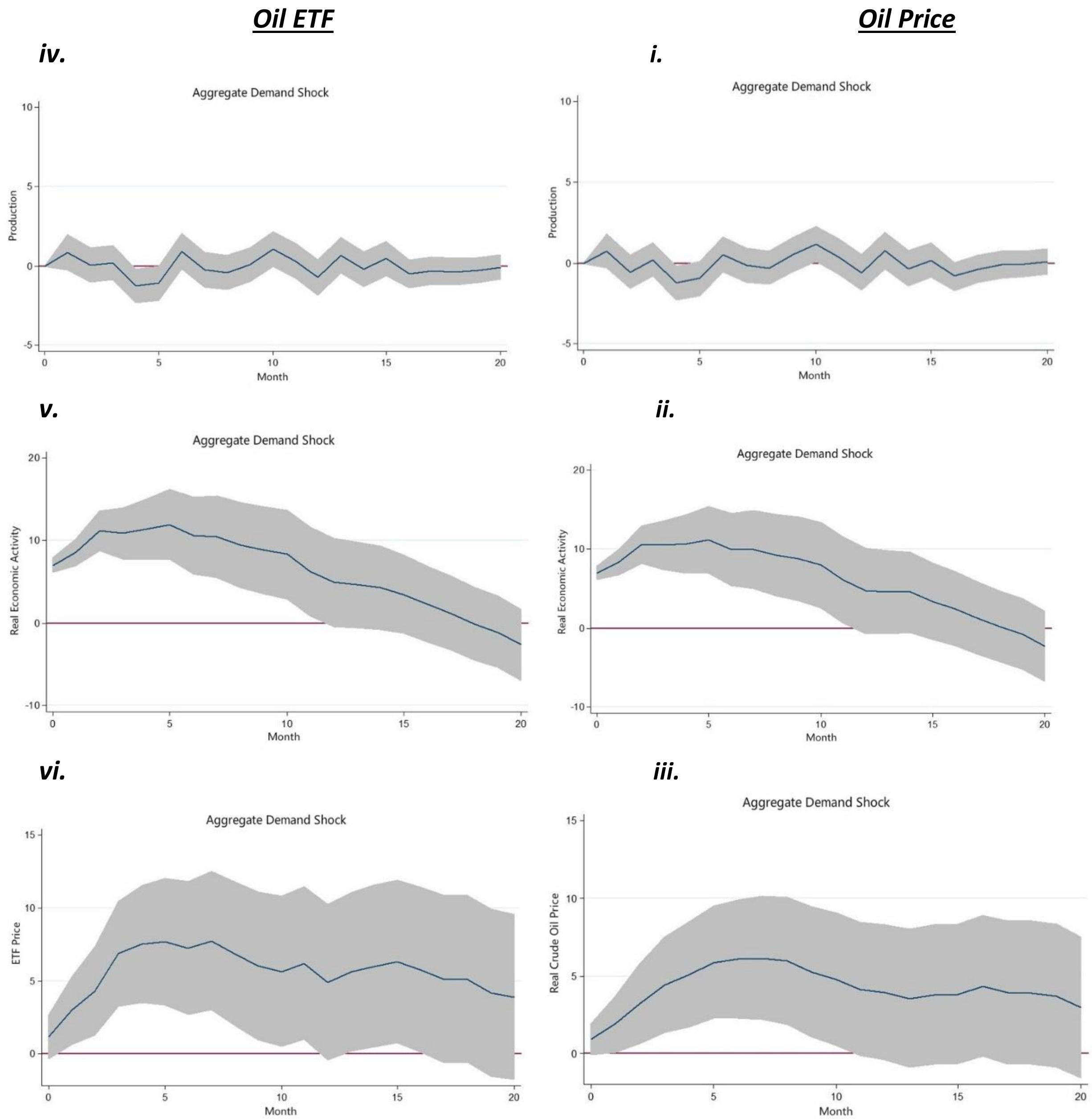


Figure 2.5b: Comparison of crude oil spot price and crude oil ETF. IRFs of aggregate demand shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

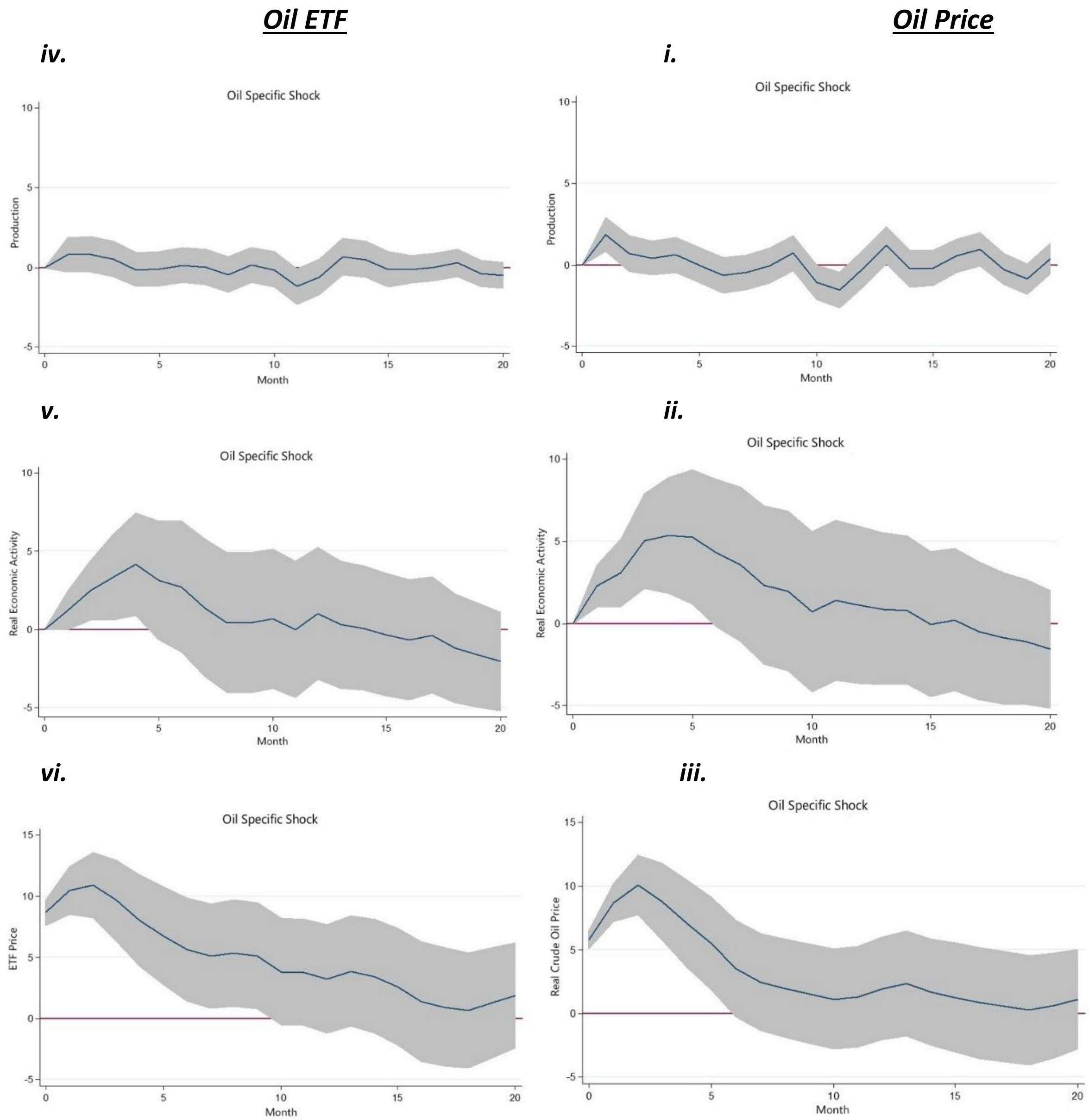
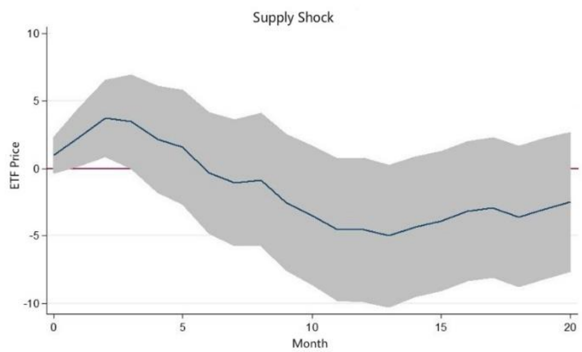


Figure 2.5c: Comparison of crude oil spot price and crude oil ETF. IRFs of oil-specific shocks on oil price, oil production and real economic activity. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

i.



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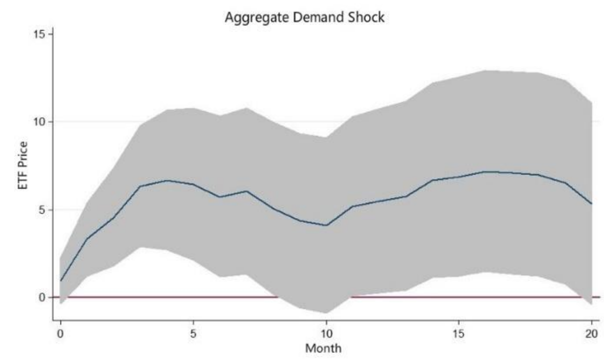
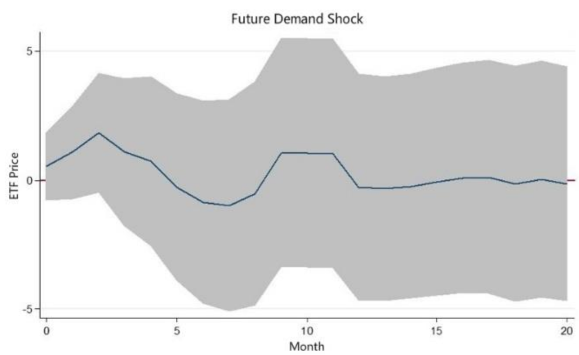
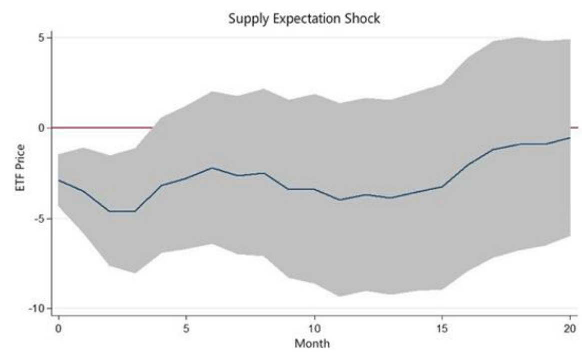


iii.



iv.



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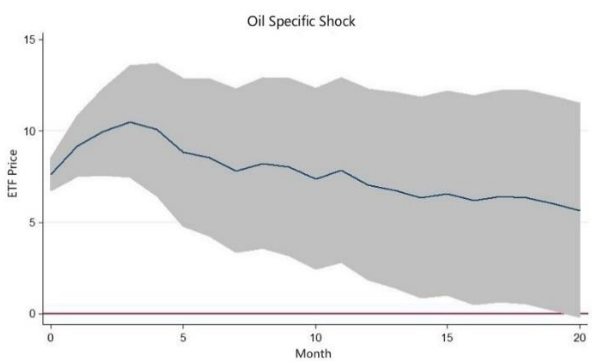


Figure 2.6: IRFs with OPEC crude oil supply forecast. IRFs of supply, aggregate demand, oil-specific, supply expectation, and demand expectation shocks. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

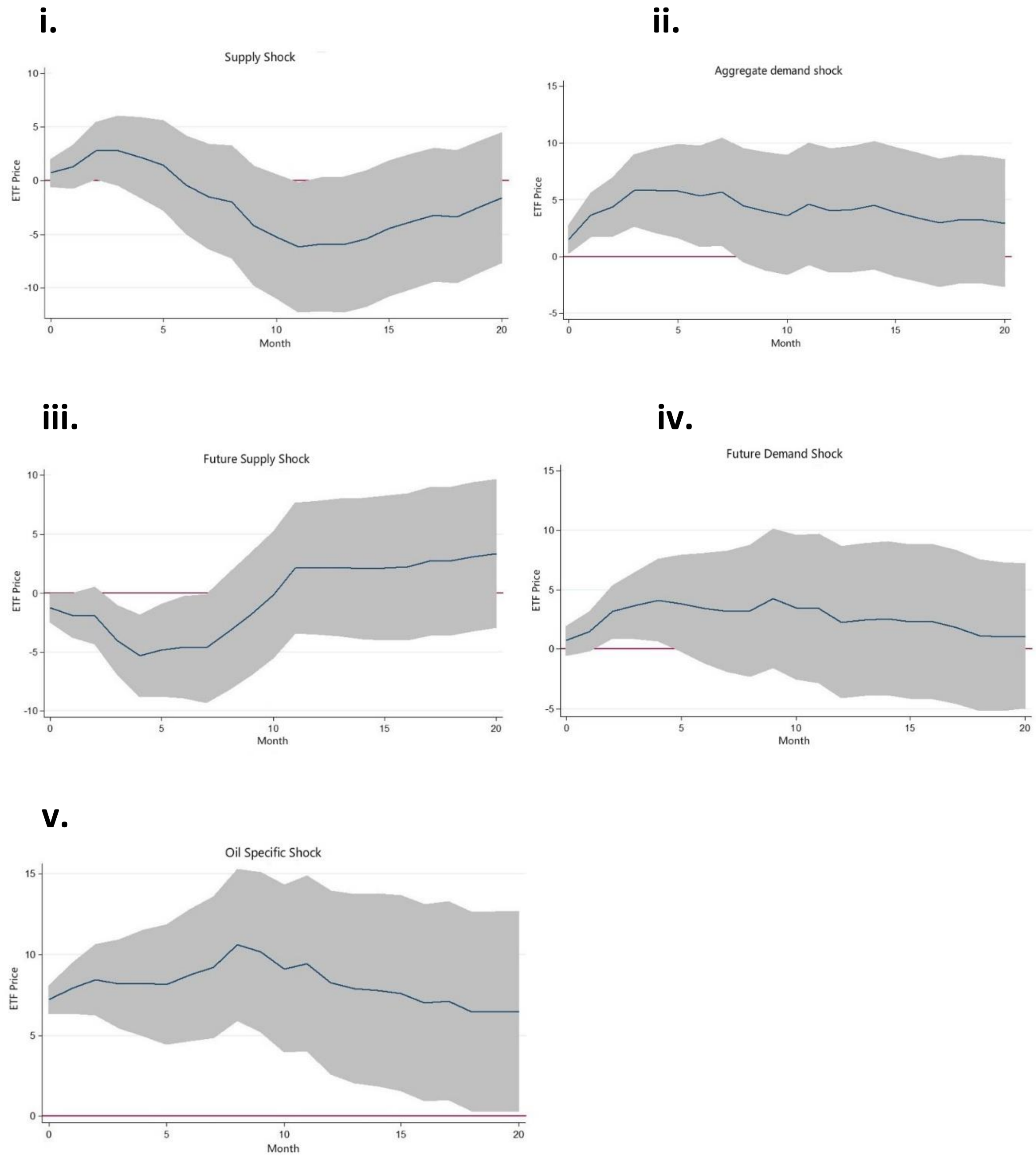


Figure 2.7: IRFs with OECD crude oil inventories. IRFs of supply, aggregate demand, oil-specific, supply expectation, and demand expectation shocks. Solid line represents the effects of one-standard-deviation shock on crude oil market variables, and shaded areas represent one-standard-error band around the shock effects.

Figure 2.8: IRFs panel with OPEC crude oil supply forecast

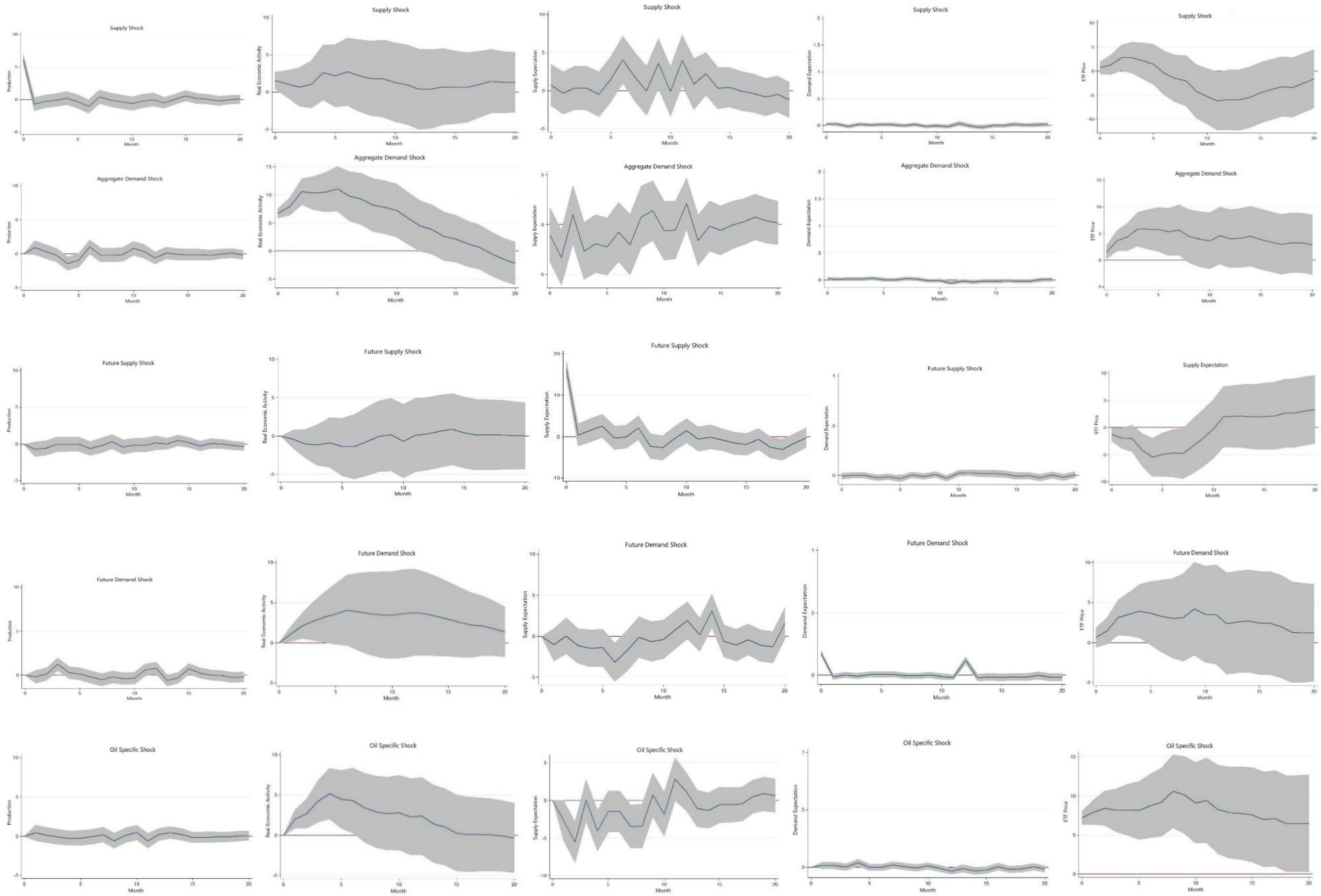


Figure 2.9: IRFs panel for recursive ordering assumption robustness check

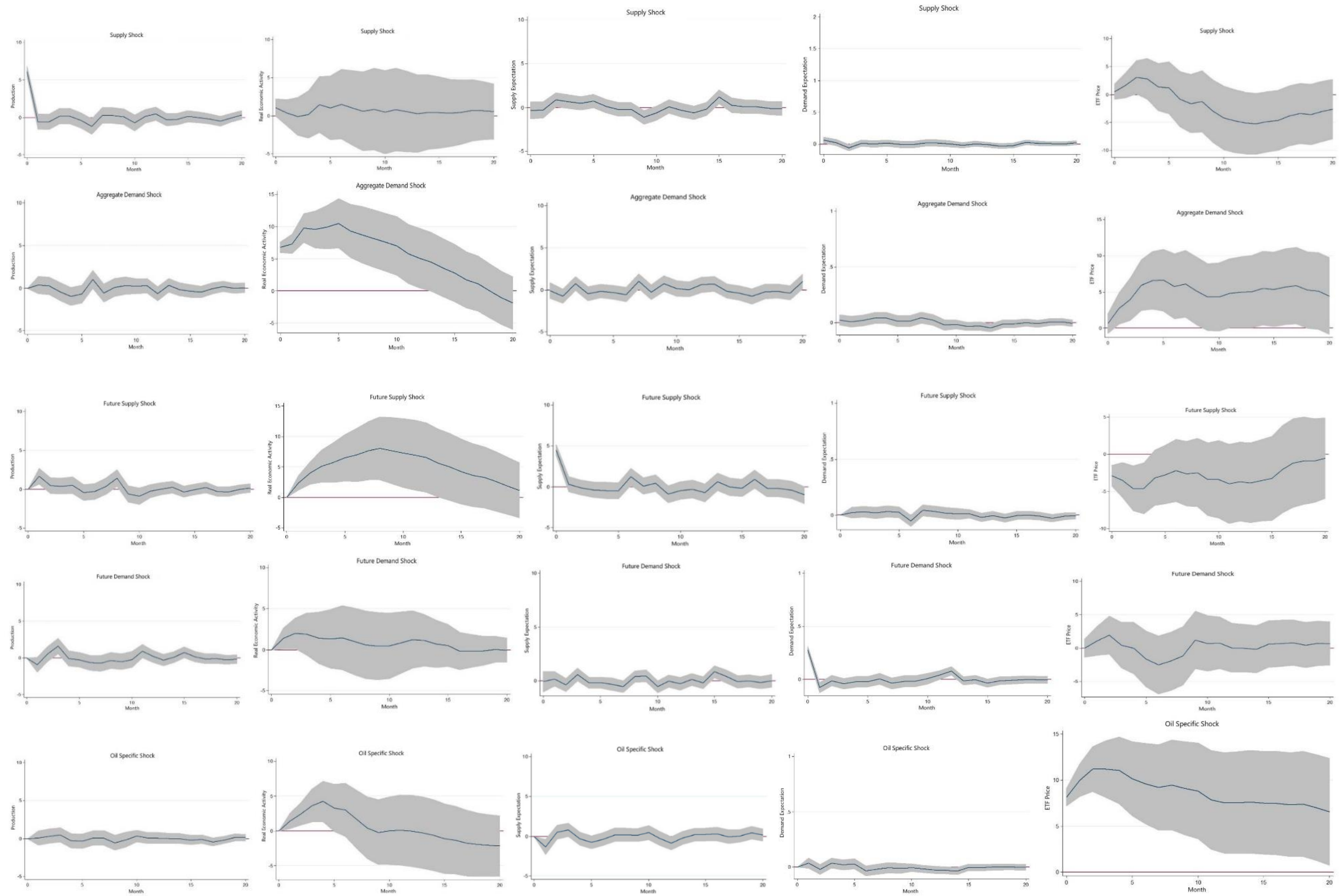
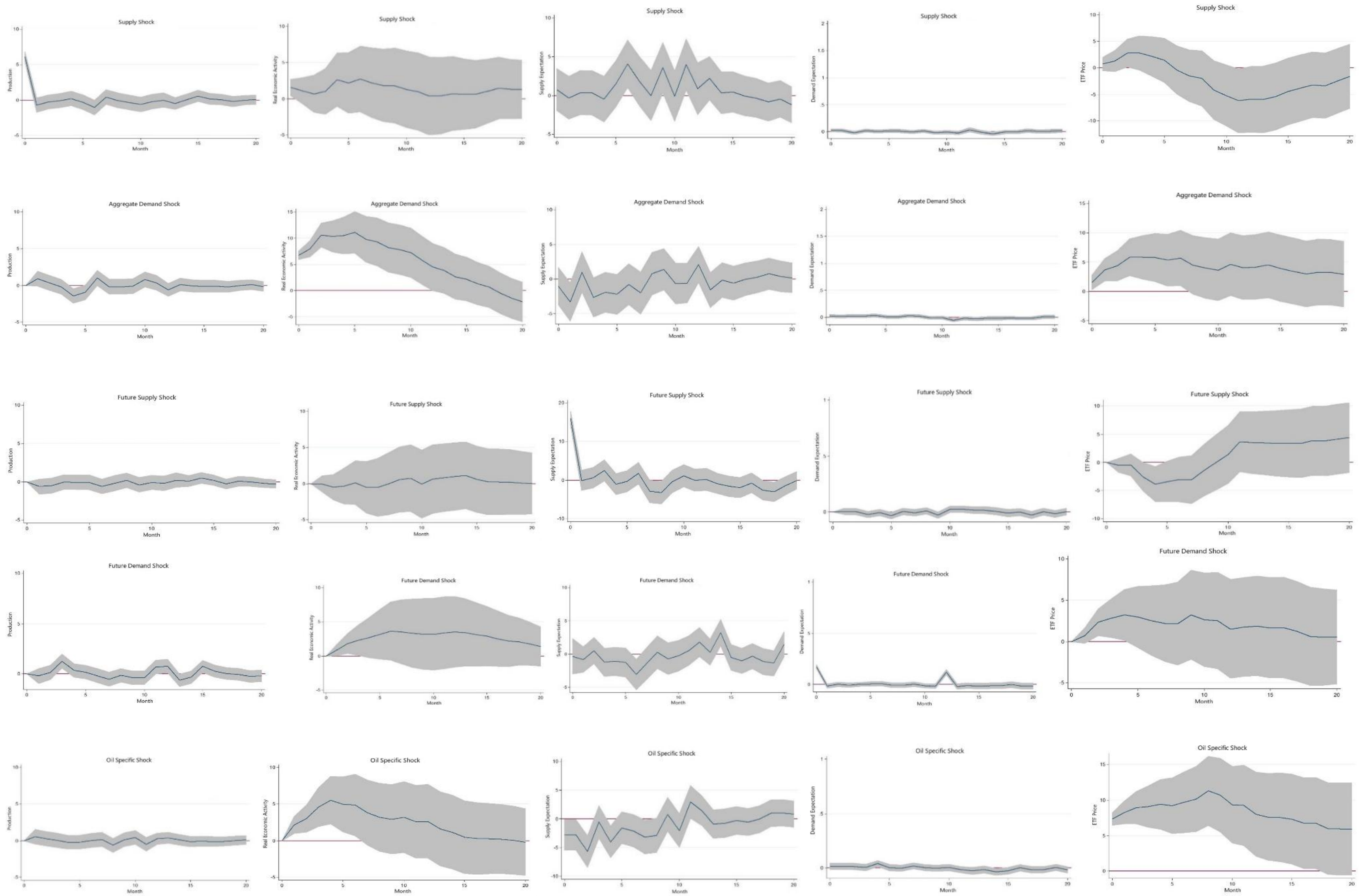


Figure 2.10: IRFs panel for recursive ordering assumption robustness check



Price:

	Coefficient	Standard Error	T-stats
Period 1	5.814663	1.810184	3.21
Period 2	2.95335	2.919505	1.01
Period 3	.1661668	.1750665	0.95

Production:

	Coefficient	Standard Error	T-stats
Period 1	-1.70209	2.368202	-0.72
Period 2	-2.251595	1.878228	-1.20
Period 3	.9489518	2.701444	0.35

Supply Forecast:

	Coefficient	Standard Error	T-stats
Period 1	.1390328	4.464366	0.03
Period 2	-5.777231	4.127545	-1.40
Period 3	-.1623299	.1659405	-0.98

Demand Forecast:

	Coefficient	Standard Error	T-stats
Period 1	-.0422047	.1190607	-0.35
Period 2	.0901733	.0693181	1.30
Period 3	-.1146634	.1082233	-1.06

Table 2.1: Residual regression on political and unanticipated event indicators

Chapter 3

US Crude Oil Prices: Fracking Boom and Export Ban

3.1. Introduction

Two main events that happened in the U.S. crude oil market since 2000 are the U.S. fracking boom and the lifting of the U.S. crude oil export ban. In late 2008, the U.S. crude oil producers started to adopt the hydraulic fracturing production method, also known as fracking. With the adaptation of the new technology, U.S. crude oil production picked up quickly in early 2011 and have kept increasing since then to all-time highs (Figure 3.1). In December 2015, Congress voted to lift the 40-year crude oil export ban, which was put in place to insulate the U.S. from the volatile and unpredictable global crude markets.

The effects of government policies and technology improvements on the global crude oil market are important for both policymakers and financial investors. In Killian's (2016, 2017) analysis of the effects of the U.S. fracking boom on U.S. crude oil and gasoline prices, he shows the U.S. fracking boom led to an increase in the price spread between West Texas Intermediate (WTI) crude and Brent crude. In this paper, I extend his analysis and consider the effects of the lifting of the

U.S. crude oil export ban on the WTI-Brent price spread. To further extend Killian's analysis on the U.S. fracking boom and following the analysis by Choi et al. (2018) that considers the crude oil pass-through effects on domestic inflation of 72 developed and developing countries from 1970 to 2017, I investigate the pass-through effects on U.S. domestic inflation and the difference in effects before and after the U.S. fracking boom. Finally, I further consider the effects of lifting the crude oil export ban by considering the difference in investors' reactions to weekly U.S. government petroleum data reports and OPEC monthly data reports before and after the lifting of the ban.

The rest of the paper procees as follows. In Section 3.2, I provide some historical background of the U.S. fracking boom and U.S. crude oil export ban and also examine the WTI-Brent price spread before and after the U.S. fracking boom started and before and after the lifting of the crude oil export ban. Section 3.3 investigates the crude oil price pass through effects on U.S. domestic inflation and 8 other crude oil importing countries. Section 3.4 explores crude oil investors' reactions to the U.S. government weekly petroleum data reports and OPEC monthly petroleum data reports. Section 3.5 concludes.

3.2. Background

3.2.1 History of U.S. Fracking Boom and Crude Oil Export Ban

The United States' crude oil production started to decrease around 1985 (Figure 3.1). After two decades of shrinkage, U.S. crude oil production dropped to as low as 3.8 million barrels per day in mid-2008. Such decline in yield was mainly due to the high cost of crude oil production in the U.S. compared to those in OPEC countries and Russia. In order to reduce production cost and improve productivity, in late 2008, U.S. crude oil producers began to adopt the hydraulic fracturing production method, also known as fracking (Maugeri, 2012). This new crude oil production method allowed U.S. shale producers to highly increase their output while keeping production costs low; oil production picked up quickly in early 2011. In late 2011 U.S. crude oil production level hit 6.2 million barrels per day and has kept increasing since then.

In 1973, the Arab oil embargo agitated United States' crude oil and gasoline markets. To insulate the U.S. from volatile and unpredictable global crude markets, President Ford signed the Energy Policy and Conservation Act in December 1975, which put a ban on U.S. crude oil exports. This ban prohibited most of the country's crude oil export with a few exemptions, such as exports to Canada. After 40 years, with the increase in crude oil production in the U.S. starting from 2011, prices of U.S.-produced WTI crude significantly decreased. Some crude oil production companies and politicians argued that the crude oil export ban had limited the growth of the U.S. oil industry and the possibility of the nation's energy independence. In December 2015, Congress voted to lift the 40-year crude oil export ban.

3.2.2 Brent-WTI Spread

Price spreads between Brent crude and WTI crude were largely affected by the U.S. fracking boom and the lift of the U.S. crude oil export ban. Both Brent and WTI are global crude oil indexes. Brent price is the benchmark price for African, European and Middle Eastern oil. WTI is the benchmark price for crude oil produced in North America and stored in Cushing, Oklahoma. Brent crude and WTI crude are both considered “sweet” crude, i.e. with sulfur content less than 0.42%. Petroleum product that contains over 0.42% sulfur is considered “sour”. Brent consists of 0.37% sulfur, whereas WTI has only 0.24% in its composition; a higher level of sulfur in Brent indicates that Brent crude is less “sweet” compared to WTI crude and, consequently, more expensive to refine into gasoline. In theory, Brent crude should trade at discount compared to WTI. However, most of WTI crude is produced inland that requires pipeline and rail to ship out for sale and refinement. Because of high transportation costs, in recent years Brent crude trades at premium to WTI.

As demonstrated in Figure 3.2, prior to 2011, the price spread between WTI and Brent stayed within -4 to 4 dollars. After the U.S. fracking boom started in 2011, with the large increase in U.S. crude oil production and limitation to export, WTI crude price was pushed down a great extent, which boosted price spread to as high as 28 dollars in mid-2011. The price spread had lowered since it hit the highest point. The results are the same to those in Kilian’s analysis (2016 and 2017) on U.S. fracking boom. At around late 2015, a period of lower price spread was observed in the market, which coincides with the time when the crude oil export ban was removed. The fall in the price spread maybe be attributable to the integration of WTI crude and Brent crude markets. The price spread started to increase again in mid-2017 due to the limitation of transportation pipeline in U.S. and led to increase in transportation costs for shipping WTI Crude.

3.2.3 Brent-WTI Return Volatilities

In addition to examining price spread, this research also investigated the volatilities in return of Brent and WTI crude regarding the U.S. fracking boom and the crude oil export ban. As shown in Table 3.1, in the period before the U.S. fracking boom started (2000-2011) , volatilities for Brent and WTI were 9.49 percent and 9.64 percent, respectively. In the period after the fracking boom started (2011-2015), volatilities in return for Brent and WTI were 8.02 percent and 8.44 percent, respectively. Comparing these two sets of figures, volatilities in return for both Brent crude and WTI crude were higher in the period before the U.S. fracking boom started. One possible source of the high volatility before the fracking boom started may have been the 2008 recession. To address this problem, data for the years of 2007, 2008, and 2009 was disregarded. Excluding three-year data, volatility dropped to 8.91 percent for Brent and 8.87 percent for WTI, but the statistics were still higher before the U.S. fracking boom started. On the other hand, unlike the variance in volatilities along the fracking boom, volatilities remained nearly constant before and after the crude oil export ban was lifted.

3.2.4 Events Led to Large Price Changes

In order to investigate the pass-through effects of crude oil prices on U.S. domestic inflation and effects on crude oil investors' reactions on petroleum products repot releases, it's important to consider events that led to large changes in crude oil prices besides the normal market speculation events and market fundamental changes.

Of the 1980 WTI trading days between January 2011 and August 2018, 12 of the trading days ended with 6 percent or more changes in daily oil prices (Table 3.2). The situations behind such prominent price movement fell into four categories. The first and most influential category of events were the OPEC bi-annual meetings, in which OPEC announced its production plans for the future, a year or half a year ahead. OPEC announcements often differed from market forecasts and delivered surprise to investors, whom must adjust their forecasts immediately and as a result, drove large changes in price. OPEC semi-annual meetings were associated with 6.10 percent to 10.09 percent of changes in WTI daily prices. Iran, being the second largest OPEC producer, was one of the most crucial crude oil suppliers. The next determining event in line was the United States' decisions on sanctioning Iran, bringing between 7.10 percent to 8.30 percent of changes in crude oil price. The third category of causes were the pipeline outages due to militant attacks in Libya and Nigeria. These events led to decreases in production outputs and drove up crude oil prices. In this case, crude oil prices hiked between 6.80 percent to 9.10 percent. Finally, the U.S. crude oil worker strike on February 3rd, 2015 also invoked a 6.54 percent surge in prices. These events should be taken into account in the study of pass-through effects and the effects of petroleum product data reports.

3.3. Crude Oil Pass Through Effects

This section will discuss the pass-through effects of crude oil prices to U.S. domestic inflation. The analysis of the crude oil pass through effects in the U.S. involves monthly CPI data from January 1990 to November 2018. To test if the effects are similar to the effects of other countries, I considered a panel of 8 crude oil importing countries (Japan, India, Korea, Netherlands, Germany, Italy, Spain, France). In this case, due to data availability, yearly CPI data from 1970 to 2017 was utilized. Finally, the research separated the U.S. CPI data into two sub samples to examine whether the effects were different before and during the U.S. fracking boom.

3.3.1 Econometric Model

To test the pass-through effects on U.S. domestic inflation, this research ran a time series model looking at the effects on domestic inflation with 2 lag periods of past inflation(l=2), current crude oil price change, and 2 lag periods of past crude oil price changes(k=2). In this model, the coefficients of interest are the values of β_0, β_1 and β_2 that captured the effects at the initial period, second period, and third period.

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_t \tag{1}$$

For the eight crude oil importing countries, the model was the same as above but with panel data and fixed effects model. β_0, β_1 and β_2 coefficient values were still the aim of this investigation.

$$\pi_{i,t} = \alpha_i \ + \nu_t \ + \sum_{j=1}^{l} \gamma_j \ \pi_{i,t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_{i,t} \tag{2}$$

One potential concern with the above model is that there might be an endogeneity problem, where crude oil prices and domestic inflation simultaneously affect each other and lead to reverse causality effects. In principle, changes in crude oil prices affect inflation, but at the same time changes in overall inflation can also affect crude oil prices and lead to a reverse causality effect. However, crude oil prices tend to have much larger changes (8.9 percent monthly volatility) than changes inflation (0.25 percent monthly volatility); therefore, the potential reverse causality effect in the model is small. Moreover, the implementation of the panel data model also reduces the problem here. With panel data, each country's economy except the U.S. is small compared to the global economy and it is unlikely changes in inflation level for a particular country would affect global oil prices. As a further check on the potential endogeneity problem, I will also consider an instrumental variable regression below, using the dates in Table 3.2 as an instrument.

3.3.2 Results

The first section studied the pass-through effects from January 1990 to November 2018. As illustrated in Figure 3.3 and Table 3.3, the pass-through effect was significant in the initial period. A 10 percent increase in crude oil prices was associated with a 0.136 percent increase in domestic inflation. In the second period of the crude oil price shock, the effect dropped to 0.011 percent and became insignificant. For comparison, the weight of gasoline in the U.S. CPI is 3.6 percent. This would imply a pass-through effect of 0.36 percent increase in domestic inflation per 10 percent increase in crude oil prices. The estimates in Figure 3.3 and Table 3.3 are smaller than this, probably because of crude oil price changes and gasoline price changes are not one to one, with gasoline prices include markup portions from the refinery industry.

To compare the results with those in other countries, a panel data fixed effect regression model was employed to analyze data of eight other crude oil importing countries. As shown in Figure 3.4 and Table 3.4, the effects of the eight crude oil importing countries was larger than the effects in the U.S., where a 10 percent increase in the eight countries' crude oil prices was associated with a

0.207 percent increase in domestic inflation. Moreover, the pass-through effect remained significant in the second period with a 0.189 percent increase in domestic inflation with 10 percent increase in crude oil prices. The effects became insignificant starting from the third period. The result here are somewhat smaller than those in Choi et al's (2018) analysis of 72 developed and developing countries, where they find the initial effect to be a 10 percent increase in crude oil prices is associated with a 0.4 percent increase in domestic inflation. The differences can be explained by developing countries' higher CPI shares in transportation and developing countries' less stable monetary policy systems compared to developed countries. (Choi et al, 2018). The smaller pass-through effects in the results of this paper can be explained by the eight crude oil importing countries considered in this paper being developed countries with more stable monetary policies compared to the countries considered in Choi et al's analysis.

The next step was to test whether the pass-through effects were different before and during the U.S. fracking boom. Here, the data set was separated into two sub sample sets: the first sub set contains data before the U.S. fracking boom started from 1990 to 2010, and the second sub set contains data during the U.S. fracking boom from 2011 to 2018. The hypothesis is that the pass-through effects were the same before and during the fracking boom. The reason for the hypothesis is that increase in crude oil production in the U.S. should have no effects on how changes in crude oil prices pass through to the U.S. domestic inflation.

As shown in Figure 3.5 and Table 3.5, in the period before the U.S. fracking boom started, the pass-through effect was faster than the effects after the fracking boom started. A 10 percent increase in crude oil prices was associated with a 0.143 percent increase in domestic inflation before the U.S. fracking boom, but was only associated with a 0.112 percent increase in domestic inflation after the boom started. The difference between the two initial effects was significant at the 1 percent significance level. In addition, before the fracking boom started, the pass-through effects became insignificant after the initial period, but the effects lasted one more period during the U.S. fracking boom. The results here indicated that the difference before and after the U.S. fracking boom started was significant, which contradicted this research's hypothesis.

This section takes into account the events that led to significant changes in crude oil prices while testing the difference in the pass-through effects. To capture the effects of the events, I use the instrumental variable approach by including a new variable that takes value 1(-1) if there is a 6 percent or more increase(decrease) in daily prices, and 0 otherwise. To test the validity of this instrumental variable, I consider both the relevance and exogeneity conditions. For relevance, I examine the first stage regression results with crude oil prices and the instrumental variable. The coefficient on the price change instrumental variable is significant with the coefficient value of 7.65 and standard error of 2.72. The adjusted-R squared for the model is 0.345(Table 3.6). For exogeneity condition, as listed in Table 3.2, the 12 events are mostly political and OPEC events that are unlikely to be related to U.S. domestic inflation in anyway other than through oil prices. With both relevance and exogeneity conditions satisfied, the instrumental variable is valid for further regression analysis. As shown in Table 3.7, the initial pass-through effect in the IV regression case for both the period before the U.S. fracking boom and the period during the U.S. fracking boom are similar to those in Table 3.5. In the period before (during) the fracking boom, the initial effect with the instrumental variables is a 0.115 (0.087) percent increase in domestic inflation, associated with a 1 percent increase in crude oil prices, whereas in the previous model without the instrumental variables, it was a 0.143 (0.112) percent increase in domestic inflation. The results indicate that the endogeneity problem in the model might not be sever.

3.4. WTI Price Changes on Petroleum Data Report Releases

In this section of the paper, I will investigate how crude oil prices react to weekly and monthly petroleum data report releases. For weekly data releases, I will employ the following three reports in my analysis: American Petroleum Institute (API) weekly industry report, U.S. Energy Information Administration (EIA) weekly official report, and Baker Hughes weekly rig count report. For monthly data releases, the monthly data report from the Organization of the Petroleum Exporting Countries (OPEC) will be considered. In addition, I will explore whether the reactions of the crude oil prices were different before and after the lift of crude oil export ban.

3.4.1 Weekly Government Official Report

In this section, I will study crude oil prices' reactions towards weekly EIA government official reports. The three most reported variables in the financial news report each week were U.S. crude oil inventory, U.S. gasoline inventory, and U.S. crude oil production. Since these three variables were most frequently exposed to investors, they are expected to have the most prominent effects on crude oil price changes. With this assumption, I will take these three variables into account in my regression analysis.

As shown in column 1 of Table 3.8, all variables in the regression were insignificant with the exception of gasoline inventory, which was significant and positive. The sign of this variable was unexpected, as gasoline inventory usually correlates negatively with crude oil prices, i.e. increase in gasoline inventory would lead to decrease in crude oil prices. More importantly, when EIA released their weekly data reports, these variables were widely discussed in financial news; therefore, investors were expected to react to the changes in these variables. In fact, we did observe large price fluctuations on EIA weekly report days.

To explain this phenomenon, my hypothesis is that investors did not react to the EIA report itself, but rather reacted to the difference between the EIA report and their expected values developed by consulting market forecast and industry forecast values. Each week around Monday, financial agencies such as Bloomberg, and financial websites such as investing.com would gather predictions from market economists and analysts about changes in petroleum products. Together, these predictions provided investors forecasted values of petroleum products' weekly changes. On the other hand, on Tuesday each week, American Petroleum Institute would also release the industry estimate of the week's changes in petroleum product level. The two forecasts and their estimated values are assumed to have served as a base prediction for investors before them receiving government official report on Wednesday.

To test my hypothesis above, I added two new variables to the regression. The first variable captured the difference in crude oil inventory variations between market forecasts and government official values. The second variable captured the difference in inventory variations between API industry forecasts and government reports. Column 2 of Table 3.8 demonstrates the result of this new regression. In the new regression, the coefficients of the two variables were significant. For the first variable regarding difference between market forecasts and government reports, each one-million more barrels in market forecast was associated with a 0.45 percent decrease in crude oil prices. For the second variable regarding difference between API industry forecasts and government reports, each one-million more barrels in API estimates was associated with a 0.27 percent decrease in crude oil prices. Moreover, the coefficient on crude oil inventory change variable is significant, with positive effect. The sign is unexpected, since with crude oil inventory change, crude oil prices should decrease in response. However, the aggregate effect of the three significant variables was still negative.

3.4.2 Other Relevant Variables in EIA reports

This section investigates variables that were on EIA weekly reports, but not frequently reported by financial news agencies. These variables were separated into three groups. The first group consists of crude oil export and import amounts revealed in EIA weekly reports. These values were important, because they directly related to crude oil inventory changes. The second group of variables was weekly refinery inputs of crude oil. The amount of refinery input was crucial, as it presented the direct relationship between changes in crude oil inventory and changes in gasoline inventory. The last group of variables indicated whether the weekly reports were released in summer driving season from mid-May to mid-September. A dummy variable was created for summer driving season. I also included two cross dummy variables to examine if an increase in crude oil inventory happened in summer driving season, and if an increase in gasoline inventory happened in summer driving season. The rationale to include these variables was that during summer driving season, investors were less likely to expect builds in both crude oil and gasoline inventories than in non-summer season. The rationale also suggested that a build in inventories during summer driving season were expected to have more negative effects than those during non-summer driving season. These variables, in theory, should be very important; however as shown in Table 3.9, all the variables were insignificant. One explanation for the insignificant result is that often these variables were not reported in financial news, hence investors focused more on variables that were indeed reported.

3.4.3 Effect Difference Before and After the Lift of the Export Ban

This section considers EIA reports' effect on crude oil prices, particularly the difference before and after the removal of U.S. crude oil export ban. The hypothesis here is that after the export ban was lifted, WTI and global crude oil markets had became more integrated; therefore, WTI prices should be less influenced by U.S. government's petroleum data, but more by global oil market factors.

To test my hypothesis, I separated my regression data previously analyzed in setion 3.4.1 into two subsets: one set included data before lifting crude oil export ban from 2011 to 2015, and another set of data from 2016 to 2018, after the export ban was abolished. The results here are shown in Table 3.10. For the variable regarding differences between market forecasts and government data, each one-million more barrels in market forecast was associated with a 0.62 percent of decrease in crude oil prices when the export ban was implemented, but dropped to a 0.42 percent of decrease in prices after the export ban being lifted. The variable regarding differences between API forecasts and government report exhibited a similar diminishing pattern, where each one-million more barrels in API estimates correlated to a 0.42 percent of increase in oil prices when the export ban existed, but the effect reduced to a 0.27 percent of increase after the ban was terminated. The difference is significant at the 1 percent significant level. The results here align with my hypothesis that WTI prices are less influenced by the U.S. government's petroleum data after the lift of the crude oil export ban.

3.4.4 Baker Hughes Weekly Rig Count Report

In this last section about weekly report, I will analyze the weekly Friday rig count report by Baker Hughes. Rig count number could signal future crude oil production and should be an important factor for investors to forecast future production level. However, as shown in Table 3.11, rig count numbers and changes in rig count numbers were both insignificant. In fact, crude oil price change in a typical trading day was 1.402 percent, whereas the price change on a rig count report day was only slightly higher at 1.74 percent. The result here demonstrated that investors focused more on the current production level than the production level forecasted by rig count numbers.

3.4.5 OPEC Monthly Report

This section investigates the effect of monthly OPEC reports on crude oil prices. OPEC releases its monthly petroleum data reports on around 15th of each month. In this analysis, I will consider 3 variables that are widely reported by financial news agencies when OPEC releases it's monthly reports. The three variables are: OPEC countries' production level, one-year-ahead world demand forecast, and one-year-ahead non-OPEC production forecast.

As shown in Table 3.12, the results are insignificant for the three variables, except for the variable for non-OPEC production forecast before the lift of the U.S. crude oil export ban. The results are unexpected since OPEC monthly report are influential among the crude oil investors and are widely reported by financial news agencies. To explain the unexpected results, we can observe that changes in world demand forecast and non-OPEC supply forecast values are often in small increments and doesn't have large effects on crude oil prices. On the other hand, most of the OPEC crude oil production values are already forecasted and reported by the news agencies like Reuters. Forecast values from these news agencies tend to be accurate, since most of them obtained their data from firms that track with shipments from OPEC countries monthly to have estimate on their production level.

3.5. Conclusion

I examine the impact of the U.S. fracking boom and the lifting of the crude oil export ban on crude oil price spreads, pass-through effects on U.S. domestic inflation, and crude oil investors' reactions on petroleum data report releases. I find that the price spread between WTI and Brent became wider after the U.S. fracking boom started. With the large increase in U.S. crude oil production and limitation to export, WTI crude price was pushed down a great extent. Around late 2015, a period of lower price spreads was observed, which coincides with the time when the crude oil export ban was removed.

In the section investigating the pass-through effects from oil prices to U.S. domestic inflation, I find the pass-through effects are significant in the first month, then become insignificant after the first month. I also find that the pass-through effects are slower after the U.S. fracking boom started.

Moreover, I consider crude oil investors' reactions to weekly U.S. government petroleum data reports and OPEC monthly petroleum data reports. For weekly reports, I find investors react to the differences between market forecasts with government reports and the differences between industry estimates with government reports. Moreover, with the lift of the crude oil export ban, WTI crude is more integrated with the global oil market, the effects of the U.S. government weekly reports become smaller since WTI prices are now more dependent on the global oil market factors than just the U.S. petroleum data. Finally, I find that crude oil investors are less sensitive to the monthly OPEC reports.

3.6 Figures and Tables

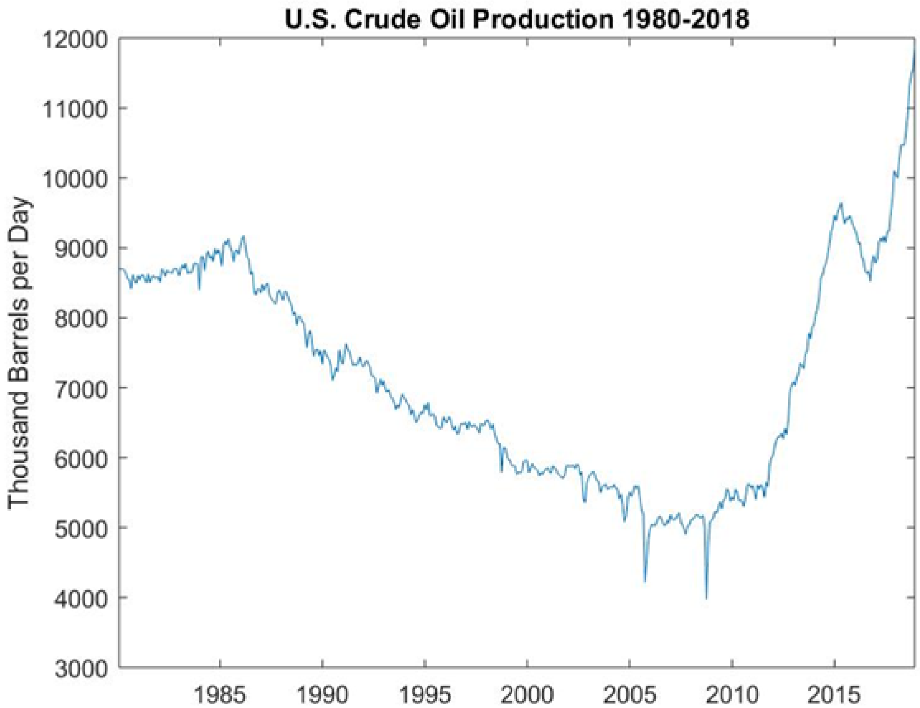


Figure 3.1: U.S. crude oil production started to decrease around 1985 and picked up quickly in early 2011.

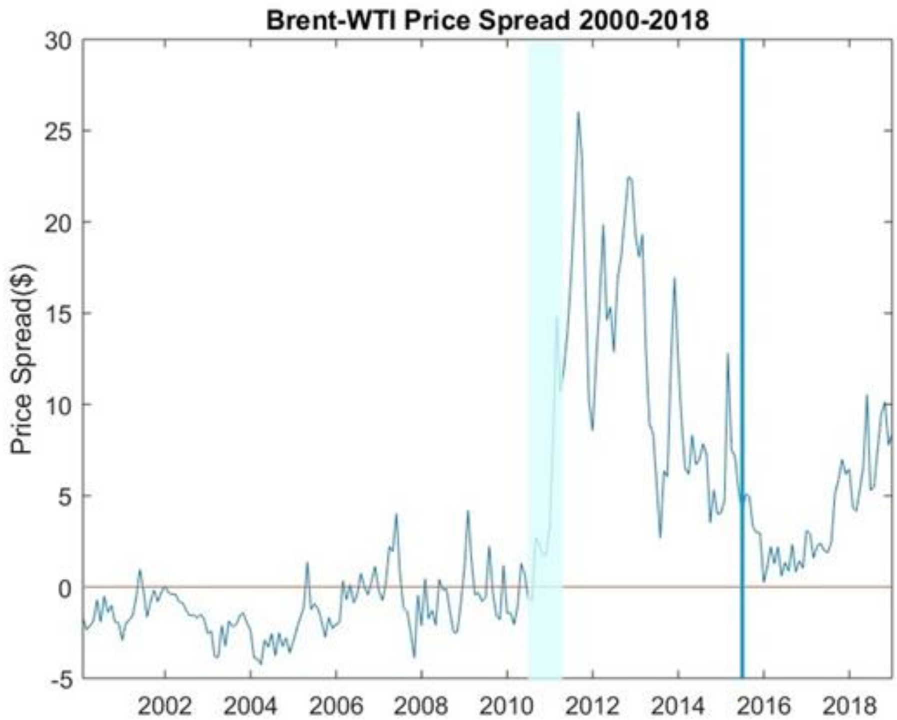


Figure 3.2: WTI-Brent price spread started to increase in early 2011 with increases in U.S. crude oil production (denoted by shaded region). Price spread narrower after the lift of U.S. crude oil export ban in late 2015(denoted by vertical line)

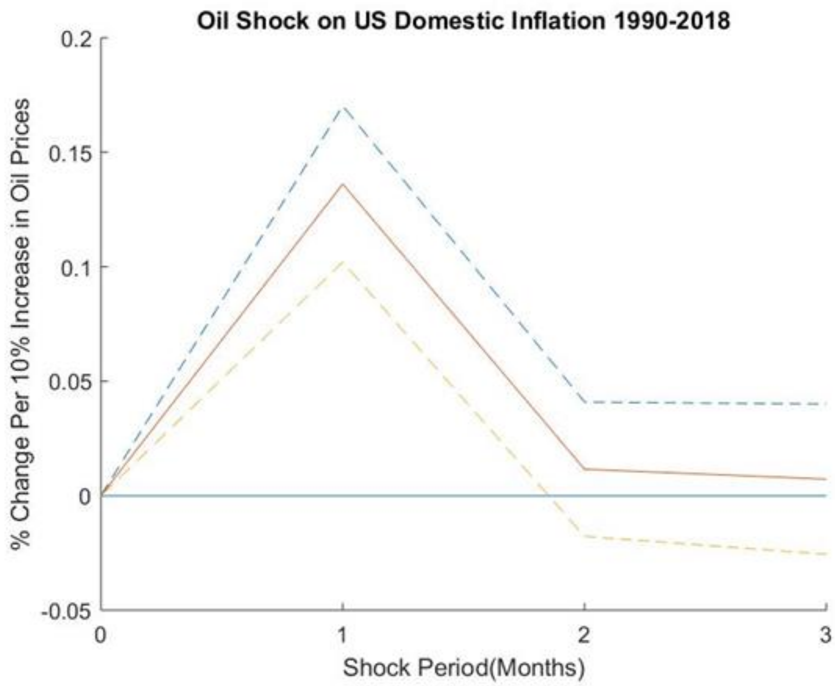


Figure 3.3:

Regression Model:

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_t$$

Figure above plots the β coefficients up to 3 periods.

Pass-through effect was significant at the initial period; 10 percent increase in crude oil prices was associated with 0.136 percent in domestic inflation. Effects become insignificant in the second period.

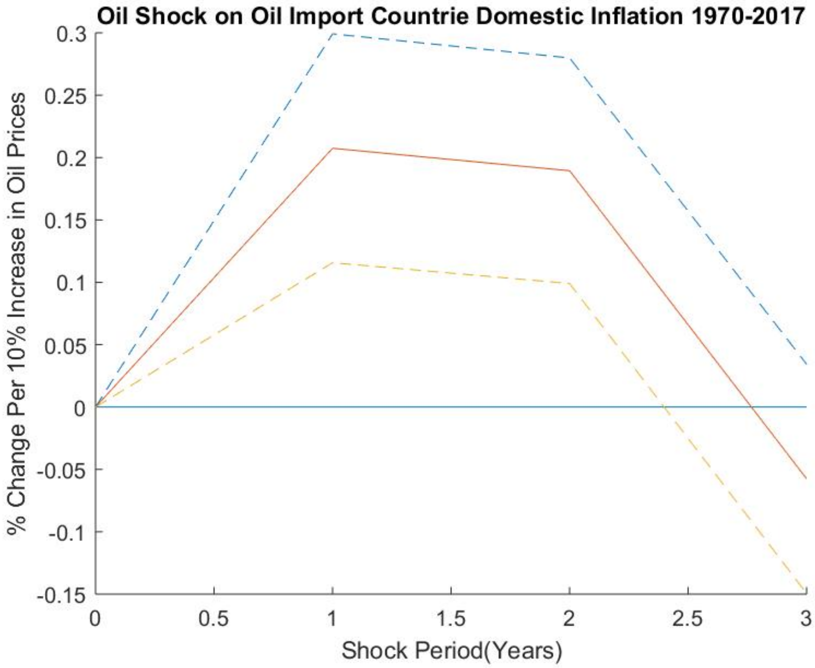


Figure 3.4:

Regression Model:

$$\pi_{i,t} = \alpha_i + \nu_t + \sum_{j=1}^{l} \gamma_j \, \pi_{i,t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_{i,t}$$

Figure above plots the β coefficients up to 3 periods.

Pass-through effect was significant in the initial period; 10 percent increase in crude oil prices was associated with 0.207 percent in domestic inflation. Effects stay significant in the second period; 10 percent increase in oil prices associated with 0.189 percent in domestic inflation.

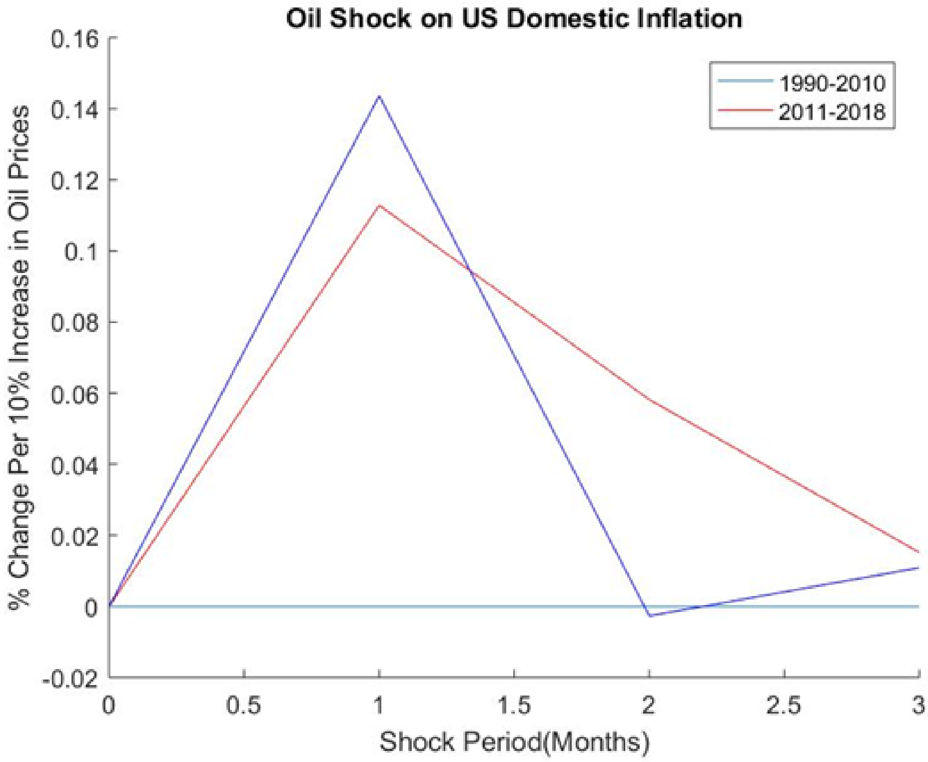


Figure 3.5:

Regression Model:

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_t$$

Figure above plots the β coefficients up to 3 periods for both 1990-2010 and 2011-2018

The pass-through effect was faster than the effects after the fracking boom started. The difference between two initial effects was significant at the 1 percent significance level.

	BRENT		WTI	
	Monthly Average Return	Monthly Volatility	Monthly Average Return	Monthly Volatility
2000-2011(Before Fracking Boom)	1.472%	9.492%	1.441%	9.642%
2000-2011(Exclude ‘2008’ Recession)	1.533%	8.906%	1.452%	8.87%
2011-2015(After Fracking Boom)	-1.219%	8.02%	-1.137%	8.435%
2016-2018(After Lift of Export Ban)	1.354%	8.159%	0.926%	8.496%

Table 3.1: Brent-WTI Average Return and Volatility 2000-2018**.** Data Source: U.S. Energy Information Administration

Date	Percentage Change	Comment
November 28th 2014	-10.00%	OPEC meeting-Decision on no production
August 31th 2015	9.33%	OPEC Special Meeting on decreasing crude oil prices-recommendation for production cut in December 2015 regular meeting
November 30th 2016	9.28%	OPEC Meeting-Decision of 1.2 million barrels per day production cut
August 27th 2015	9.24%	News reports on outages in Nigerians pipeline
June 29th 2012	8.28%	Iran Economic Sanctions and crude oil export limitation took effect
May 5th 2011	-8.26%	No Special event except large jump in dollar index
January 22nd 2016	7.88%	Libyan Storage Attacked by Islamic State
February 12th 2016	7.84%	OPEC Minister Comments-OPEC countries are ready on production cut
February 3rd 2015	6.55%	U.S. Oil worker strike
January 20th 2016	-6.28%	Iran Economic Sanctions lifted-Iran crude oil product might increase
December 7th 2015	-6.11%	OPEC Meeting-Decision of no product cut
January 6th 2016	-6.11%	News reports on Iran Saudi conflict-possibilities of product cuts decrease

Table 3.2: Events associated with 6 percent or more crude oil price changes from Jan 2011 to Aug 2018. Data Source: Wall Street Journal Archive and Bloomberg

	Coefficients	95% Confidence Interval		P Values
β_1	0.0136	0.0102	0.017	0.000
β_2	0.0011	-0.0017	0.004	0.439
β_3	0.0007	-0.0025	0.004	0.665

Table 3.3: Crude oil price pass-through effects on U.S. domestic inflation

Regression Model:

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_t$$

Note: Effect significant at the initial period, then become insignificant

	Coefficients	95% Confidence Interval		P Values
β_1	0.0207	0.0115	0.0299	0.000
β_2	0.0189	0.0099	0.0279	0.001
β_3	-0.0057	-0.0149	0.0034	0.219

Table 3.4: Pass-through effects on crude oil importing countries' domestic inflation

Regression Model:

$$\pi_{i,t} = \alpha_i \ + \nu_t \ + \sum\nolimits_{j=1}^{l} \gamma_j \ \pi_{i,t-j} + \sum\nolimits_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_{i,t}$$

Note: Effects are significant at both initial and second period

	Coefficients	95% Confidence Interval		P Values
β_1	0.0143	0.0102	0.0184	0.000
β_2	-0.0002	-0.0037	0.0032	0.88
β_3	0.001	-0.0031	0.0053	0.51

1990-2010 (Before US Fracking Boom)

	Coefficients	95% Confidence Interval		P Values
β_1	0.0112	0.0056	0.0168	0.000
β_2	0.0058	0.0002	0.0114	0.042
β_3	0.0015	-0.0035	0.0065	0.553

2011-2018 (During US Fracking Boom)

Table 3.5: Differences in pass-through effects before and during U.S. fracking boom

Regression Model:

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + \epsilon_t$$

Note: Pass-through effect was faster before the U.S. fracking boom started

	Coefficient	Standard Error	P Value
β	7.65	2.72	0.006

Table 3.6: First-stage instrumental variable regression

Regression Model:

$$\pi_t^{oil} = C \quad + IV_t + \epsilon_t$$

Instrumental variable relevance condition is satisfied

	Coefficients (1990-2010)	Standard Errors	Coefficients (2011-2018)	Standard Errors
β_1	0.0115	0.00183	0.0087	0.00243
β_2	0.0002	0.00241	0.0063	0.00231
β_3	0.0022	0.00234	0.0009	0.00254

Table 3.7: Pass-through effects with instrumental variable

Regression Model:

$$\pi_t = C \quad + \sum_{j=1}^{l} \gamma_j \ \pi_{t-j} + \sum_{j=0}^{k} \beta_j \pi_{t-j}^{oil} + IV_t + \epsilon_t$$

Effects become smaller with instrumental variable approach

EIA Reports On Crude Oil Prices		
	(1)	(2)
	Price %Δ	Price %Δ
Crude Oil Inventory	-0.000042	-0.0000418
	(-1.07)	(-0.96)
Crude Oil Inventory Δ	0.0000445	0.00406***
	(0.11)	(3.37)
Crude Oil Production	0.000111	0.000416
	(0.53)	(0.88)
Crude Oil Production Δ	0.000847	-0.000197
	(0.63)	(-0.12)
Gasonline Inventory	0.000363*	0.000278
	(2.24)	(1.16)
Gasoline Inventory Δ	0.000122	-0.000498
	(1.6)	(-0.56)
Crude Oil Inventory Market Forecast Difference		-0.00449***
		(-3.64)
Crude Oil Inventory Difference From API		-0.00273**
		(-3.30)
Constant	-0.0728*	-0.0732
	(-2.32)	(-1.64)
N	399	242
Note: t statistics in parentheses; *p<0.05, **p<0.01, ***p<0.001		

Table 3.8: Regression results on weekly EIA and API reports

EIA Reports Other Factors (Percentage to Level)			
	(1)	(2)	(3)
	Price %Δ	Price %Δ	Price %Δ
Crude Oil Inventory	-0.0000359	-3.71E-05	-0.0000447
	(-0.81)	(-0.85)	(-1.01)
Crude Oil Inventory Δ	0.00400**	0.00406***	0.00344*
	(3.22)	(3.36)	(2.52)
Crude Oil Production	0.000426	0.000443	0.000385
	(0.9)	(0.94)	(0.81)
Crude Oil Production Δ	0.00032	0.000502	-0.000301
	(0.15)	(0.25)	(-0.19)
Gasonline Inventory	0.000252	0.000255	0.000294
	(1.03)	(1.04)	(1.23)
Gasoline Inventory Δ	-0.000394	-0.000491	-0.000704
	(-0.44)	(-0.55)	(-0.67)
Crude Oil Inventory Forecast Difference	-0.00418**	-0.00455**	-0.00404**
	(-2.62)	(-3.72)	(-3.05)
Crude Oil Inventory Difference From API	-0.00265**	-0.00274**	-0.00271**
	(-3.15)	(-3.31)	(-3.21)
Crude Oil Consumption Change	-0.000403		
	(-0.41)		
Import Change	-0.000534		
	(-0.72)		
Export Change	0.000356		
	(0.35)		
Refinery Input		-0.000676	
		(-0.69)	
Summer Driving Season			-0.00574
			(-0.70)
Oil Inventory Increase During Summer			0.00308
			(0.33)
Gasonline Inventory Increase During Summer			-0.000979
			(-0.12)
Constant	-0.0705	-0.0717	-0.0716
	(-1.57)	(-1.60)	(-1.60)
N	242	242	242
Note: t statistics in parentheses; *p<0.05, **p<0.01, ***p<0.001			

Table 3.9: Regression results on relevant variables in weekly EIA reports

EIA Weekly Reports		
	2011-2015	2016-2018
	Price %Δ	Price %Δ
Difference from Market Forecast	-0.0062642 **	-0.0041509 **
	(-2.97)	(-2.56)
Difference from API	-0.0043916 **	-0.0026712 **
	(-3.15)	(-2.41)
Crude Oil Inventory Change	0.0053342 *	0.0038418 *
	(2.75)	(2.54)

Table 3.10: Differences in effects of EIA reports before and after lift of crude oil export ban: WTI prices are less influenced by EIA report after lift of the crude oil export ban

WTI with Rig Counts		
	(1)	(2)
	Price %Δ	Price %Δ
RigCh	-0.0000455	
	(-0.46)	
LnRigChange		-0.0212
		(-0.11)
Constant	0.000404	0.000395
	(0.43)	(0.42)
N	398	398
Note: t statistics in parentheses; *p<0.05, **p<0.01, ***p<0.001		

Table 3.11: Effects of weekly Baker Hughes rig count reports: Rig count numbers are insignificant to the oil price changes

OPEC Monthly Reports On Crude Oil Prices		
	2011-2015	2016-2018
	Price %Δ	Price %Δ
NonOPECSupply	-2.359*	3.179
	(-2.11)	(1.27)
WorldDemand	2.26	-1.686
	(1.37)	(-0.84)
OPECProduction	1.555	0.439
	(1.71)	(0.34)
Constant	-0.635	-0.108
	(-1.81)	(-0.28)
N	60	32
Note: t statistics in parentheses; *p<0.05, **p<0.01, ***p<0.001		

Table 3.12: Effects of OPEC monthly reports: OPEC monthly report variables are mostly insignificant except for non-OPEC supply forecast

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