

Essays on Saudi oil production, world oil production, and the response of the Saudi
macroeconomy to oil shocks

By

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AN ABSTRACT OF A DISSERTATION

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Department of Economics
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Abstract

This three-chapter dissertation examined the effect of Saudi Arabia's oil supply shocks on non-OPEC and non-Saudi OPEC oil production and the effect of oil price shocks on the Saudi economy.

The first chapter predicted how non-OPEC and non-Saudi OPEC oil supplies respond to Saudi oil supply shocks using a Bayesian structural vector autoregression (BSVAR) model on monthly data from 1993 to 2020. The examination of three different prior distributions using prior information found that the response to a Saudi oil shock depends heavily on the identification restrictions.

The second chapter also used the BSVAR model to explore whether the CPI response to an oil price shock is offset by Saudi Arabia's monetary policy. Based on monthly data from 1980 to 2014, the results confirmed that Saudi Arabia's monetary policy is effective. Following Bernanke et al.'s (1997) methodology, we found that conducting an experiment that reduced the Saudi central bank's response to an oil shock resulted in a much larger response of Saudi inflation to that oil shock.

Finally, the third chapter predicts the effect of the structural oil market shocks on sectoral inflation rates in Saudi Arabia using Kilian's (2009) methodology to help Saudi Arabia's policymakers overcome inflation rates. As Saudi Arabia's policymakers seek to overcome the inflation rates, it is useful for them to know how to react in the face of oil market shocks (i.e., the source of oil price increases) to control the inflation rate as sector. The examination found that the effect of oil market shocks on the CPI differs by sector, with oil-specific demand shocks having the largest impact in most sectors compared to other structural oil market shocks.

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Dedication

I dedicate this work to all my family members for their love, relentless support, and encouragement to pursue my dream.

Chapter 1 - The Non-OPEC and Non-Saudi OPEC Response to the Saudi Oil Supply Shock

1.1 Introduction

OPEC is a critical player in the world oil market, and OPEC production decision announcements frequently have a profound impact on the price of oil (Kaenzig, 2021). However, as a group of independent oil-producing countries, there is no mechanism to force individual member countries to follow through with their agreed values of oil production. In particular, there may be an incentive for individual countries to gain revenue by exceeding their quotas. Moreover, it is impossible for OPEC to foresee many of the shocks that hit world oil markets when setting production targets, so it may not be optimal to follow through on their announced strategies.

This essay uses a Bayesian structural vector autoregressive (BSVAR) model to study the response of production decisions by OPEC producers, non-OPEC producers, and Saudi Arabia to world oil market shocks. As OPEC's largest oil producer, and with one-fourth of the world's oil reserves (Nakov & Nuno, 2013), Saudi Arabia plays a special role. It has the ability to offset shocks to both OPEC and non-OPEC production levels. In addition, it may have an incentive to adjust oil production levels strategically in the name of international relations. We investigate the responses of all three groups to oil production shocks from any of the other groups. We follow the approach of Baumeister and Hamilton (2018). This allows us to incorporate a wider range of identifying information than in the traditional structural VAR literature, resulting in greater credibility of our findings compared with identification through coefficient restrictions

Our motivation for this essay is that Saudi Arabia oil production has some advantages. Saudi Arabia has a low-cost advantage when producing oil as well as a larger spare capacity than other producers. Indeed, Saudi oil production capacity is equivalent to more than one-tenth of the

world's entire oil production, and its reserves are equivalent to one-fourth of the world's reserves according to Nakov and Nuno (2013). Clearly, this capacity makes Saudi Arabia critical in the oil market. Saudi Arabia responds by using its ability to react quickly to any decrease or increase in exporting countries' production. In other words, Saudi Arabia's production responds rapidly to other countries' production decisions, and Saudi Arabia has a high capability to absorb shocks, either by decreasing or increasing its own production depending on the type of shock due to its high flexibility in oil production. Nakov and Nuno (2013) further indicated that Saudi Arabia has a higher production share than other producers inside or outside OPEC, despite the fluctuations in its production. The contribution of our paper is that it studies the three oil supply shocks separately, motivated by non-OPEC, non-Saudi OPEC, and Saudi oil suppliers. All play different roles, and their shocks require different identification. Due to Saudi Arabia's role in the world oil market, the effects of the other shocks might be different.

In this essay, we ask whether non-Saudi OPEC producers and non-OPEC producers react to Saudi oil production shocks and, if so, how. The answers depend on the empirical strategy used to identify the shocks. A natural starting point is to look at the impulse response functions in a recursive system (i.e., when using a Cholesky decomposition for identification). Despite its popularity in the literature, the Cholesky decomposition requires strong assumptions. We check the robustness of the identified impulse response functions to changes in the identifying assumption, finding that they change dramatically with changes in the identification restriction we impose.

Baumeister and Hamilton (2015) argued in favor of a Bayesian approach to identification. Their approach allows for the identification of impulse response functions using a greater range of information. Of particular importance is that their approach allows researchers to account for

uncertainty about the identifying restrictions. Returning to the previously discussed Cholesky decomposition, as it can be hard to make the case that a particular coefficient is exactly equal to zero, it is reasonable to allow for the possibility that the value is in the vicinity of zero but not exactly equal to zero. We apply the Bayesian approach considering alternative identification strategies. The first alternative is to impose identifying restrictions that are the average values of the short-term price elasticity of oil supply, short-term oil price elasticity of global demand, short-term price elasticity of oil demand, and income elasticity identified in the literature. In our model, we have three oil supply elasticities and three oil demand elasticities of non-OPEC producers, non-Saudi OPEC producers, and Saudi Arabia. Using this baseline, we find that Saudi supply shocks cause a moderate decrease in both non-OPEC and non-Saudi OPEC oil production as well as these producers' oil GDP in the short run.

In the second and third prior distributions, we impose progressively weaker and more plausible restrictions. In the second prior distribution, we impose sign restrictions —namely, the sign restriction of the negative effect of Saudi oil production on non-OPEC and non-Saudi OPEC producers' oil production. We find that Saudi oil supply shocks have a larger negative effect on non-OPEC and non-Saudi OPEC producers' oil production and their oil GDP (oil rents are a share of the GDP) compared to the first prior distribution (i.e., baseline). In the third prior distribution, which is much weaker than either of the previous two prior distribution, we impose the sign restriction of the negative effect of non-OPEC and non-Saudi OPEC producers' oil production on Saudi oil production. We find that Saudi oil supply shocks have a negative effect on only non-Saudi OPEC producers' oil production and their oil GDP in the short run.

The current essay is organized accordingly. The next section introduces the Saudi's oil production policies and its objectives. Section 1.3 reviews the existing literature, and Section 1.4

introduces the data set. Section 1.5 discusses the model and methodology. Section 1.6 summarizes the pretest result and the impulse response function result. Finally, conclusions are offered in Section 1.8.

1.2 Saudi Arabia's Oil Production Policies and Objectives

Saudi Arabia continually updates its oil production policies based on changes in the oil market; decisions are not fixed, but instead change according to the changes taking place in the oil market. Fattouh (2021) demonstrated that Saudi Arabia has adopted several different policies that allow it to intervene rapidly when imbalances in the oil market occur. For example, its tit-for-tat policy uses the remuneration method for countries that comply with production decisions related to quotas for each product whereas producers who seek to increase their production at a rate greater than the agreed-upon quotas are punished, resulting in prices being greatly affected. Meanwhile, its Cournot policy enables producers to choose the quantities that will achieve profits for them while considering the quantities competitors produce to achieve a balance in the oil market. However, Saudi Arabia prefers not to apply the Cournot policy and instead chooses to use other policies to achieve a balance in the oil market. The Cournot policy is applied when producers produce more than their agreed-upon quotas; Saudi Arabia reacts by increasing its production so that other producers return to the level of Cournot profits. According to Griffin and Neilson (1994), Saudi Arabia's Cournot strategy is defined as:

$$Q^{\text{World}}(P^C) = R^{\text{SA}}(P^C) - R^{\text{Non-OPEC}}(P^C) - R^{\text{Non-Saudi OPEC}}(P^C) \quad (1.1)$$

where Q^{World} is the best response of the world demand function as a function of price, R^{SA} is Saudi Arabia's best response function, $R^{\text{Non-OPEC}}$ is the sum of the non-OPEC countries' best-response

functions, $R^{\text{Non-Saudi OPEC}}$ is the non-Saudi OPEC countries' best-response function, and P^C indicates the Cournot equilibrium price.

Finally, it uses its swing policy to compensate for shortages in global production at the same or slightly higher prices. As a result, Saudi Arabia generates more profits through its swing policy than its Cournot policy. According to Griffin and Neilson (1994), Saudi Arabia's swing production is defined as:

$$Q^{\text{SA}}(P) = Q^{\text{World}}(P) - Q^{\text{Non-OPEC}}(P) - Q^{\text{Non-Saudi OPEC}}(P) \quad (1.2)$$

where Q^{SA} denotes the output of Saudi Arabia, Q^{World} denotes the world demand for oil at price P , $Q^{\text{Non-OPEC}}$ denotes the output of non-OPEC countries, $Q^{\text{Non-Saudi OPEC}}$ denotes the output of non-Saudi OPEC countries, and P is the price specified by OPEC producers

Saudi Arabia meets with competing OPEC and non-OPEC oil producers to determine production quotas; the price of oil is determined after identifying the global demand for oil. OPEC shares three objectives with Saudi Arabia: balancing the oil market, maximizing its profits, and maintaining market shares (Fattouh, 2021). Yet Saudi Arabia's objectives periodically differ. Non-OPEC countries also seek to maximize profits and will increase their production beyond the agreed-upon quotas. When certain producers believe that the quotas do not enable them to meet the objective of maximizing profits, they can create an increase in the oil supply by increasing their production, which affects the other producers' quotas and can lead to a problem for OPEC.

1.3 Literature Review

In recent years, numerous studies have investigated the effect of an oil market shock as typically having only one oil supply shock on crude oil production, global industrial production, and oil prices. Kilian (2009a) studied the response of world oil production, world economic activity, and oil prices to oil market shocks using SVAR. He found that all oil market shocks cause an increase in oil prices, although the oil supply shock plays a smaller role in oil price variations than both oil demand shocks. In addition, he found that both oil supply and demand shocks affected U.S. economic variables. Kilian and Murphy (2012) examined the response of real oil prices to oil demand and oil supply shocks by imposing sign restrictions using BSVAR. Their results indicated that using only sign restrictions was insufficient for demonstrating the effect of oil demand and oil supply shocks. They subsequently added sign restrictions with prior information about the short-run supply elasticity, which was close to zero; this result was consistent with their result using a Cholesky decomposition (2009). Meanwhile, Baumeister and Peersman (2013a) estimated the effect of oil market shocks on oil price volatility using a Bayesian VAR with time-varying coefficients (TVC) and stochastic volatility. They observed a significant decrease in the price elasticity of oil demand and oil supply in the short run, which had a large effect on oil price volatility but little effect on oil production volatility. They concluded that, because of the inelasticity in demand and supply curves, any change in the oil market will cause a higher volatility in oil prices. Caldara et al. (2019) investigated the effect of oil supply and demand shocks on the oil market, including demand elasticity and supply elasticity, using the structural VAR model. They found that demand and supply shocks clearly explain oil price fluctuations. Supply shocks caused a rise in oil prices, thereby generating a positive effect on the industrial production of a developing economy but a negative effect on the industrial production of a developed economy.

Other studies have included crude oil inventories to represent speculative shocks. Kilian and Murphy (2014) developed their previous model by adding speculative demand shock to study the response of oil prices to market shocks. They found that oil supply shocks play a major role in explaining oil prices. Baumeister and Hamilton (2018) investigated the effect of oil supply and oil demand shocks on oil prices by including crude oil inventory as a representing speculative shock using BSVAR. They also added the prior information of all elasticities with sign restrictions. Their result showed that global economic activity is affected by supply shocks whereas demand shocks have no effect. Kaenzig (2019) examined the effect of oil supply shock resulting from expectations about future oil prices and U.S. macroeconomic variables using global oil demand forecasts. He found that oil supply shock causes a significant increase in the price of oil whereas its effect on U.S. macroeconomic variables is very small.

Other studies have considered different shocks. For example, Lippi and Nobili (2012) investigated the effect of five shocks-oil supply shock, U.S. supply shock, non-U.S oil supply shock, U.S. demand shock, and non-U.S. oil demand shock-on the price of oil using sign restrictions. Their results indicated that both non-U.S. oil supply and non-U.S. oil demand shocks led to increased oil prices. In addition, non-U.S oil supply shock explained a large part of the fluctuations in oil prices. Rebei and Sbia (2020) examined the effect of transitory demand and supply shocks, permanent demand and supply shocks, and speculative shocks. Their results indicated that permanent oil demand shock had a negative effect on oil production and there was a difference in the effect of transitory and permanent shocks on oil prices. Furthermore, most of the movement in oil prices was affected by permanent shock supply whereas speculative shock played a small role.

Additional studies considered published papers related to oil market shocks to compare their models. Kilian and Zhou (2020) reviewed recent studies on oil market models and how their models were developed to identify assumptions and methods of inference on oil demand and oil supply shocks using the VAR model. They concluded that the reason for the inaccuracy of some studies' results was due to how they measured oil demand and supply shocks. De Michelis et al. (2019) investigated the effect of oil prices on the consumption of oil across 55 exporter and importer countries. Their results indicated that it takes time for consumption to respond to oil prices. However, consumption in oil-importer countries responds positively to oil price decreases whereas in oil-exporter countries it responds negatively. Both oil-exporter and -importer countries show negative consumption responses to oil price increases.

However, the existing literature considers just one oil supply shock. As we believe that not all oil shocks have the same effect, we consider in our model three different supply shocks separately motivated by non-OPEC, non-Saudi OPEC, and Saudi Arabia oil supplies, where they play different roles and their shocks require different identifications. Due to Saudi Arabia's role in the world oil market, the effects of the other shocks will be different.

1.4 Data

To conduct an empirical analysis, this study applies the monthly time series data from January 1993 through May 2020. This data includes crude oil production of Saudi Arabia (COP_{SA}), crude oil production of non-OPEC countries ($COP_{Non-OPEC}$), crude oil production of non-Saudi OPEC countries ($COP_{non-Saudi OPEC}$), crude oil price of West Texas Intermediate (OP), and the index of global real economic activity known as industrial production (IP). The crude oil productions statistics were taken from the U.S. Energy Information Administration. The OP data was obtained from the Federal Reserve Bank of St. Louis. The global real economic activity monthly data was taken from the Federal Reserve Bank of Dallas. For the data, we took the log of all variables except global real economic activity.

1.5 The Structural Vector Autoregression Model

The existing literatures considers just one oil supply shock, which leads us to question whether all oil shocks have the same effect. We consider in our model three different supply shocks that may have different effects: shocks motivated by non-OPEC, non-Saudi OPEC, and Saudi oil suppliers. All three play different roles, and their shocks require different identifications. We build our model, which includes five shocks: non-OPEC oil supply shock, non-Saudi OPEC oil supply shock, Saudi oil supply shock, aggregate demand shock, and oil price shock. The first model uses a recursive structure as a baseline for comparison with more sophisticated identification strategies. Consider this VAR model:

$$AZ_t = \alpha + \sum_{t-i}^p A_i Z_{t-i} + \varepsilon_t \quad (1.3)$$

where A is the matrix of the coefficient that captures the contemporaneous relationships of endogenous variables, Z_t is the vector of endogenous variables, and ε_t is the vector of the structural error terms.

$$Z_t = [\text{COP}_{\text{non-OPEC}}, \text{COP}_{\text{non-Saudi OPEC}}, \text{COP}_{\text{SA}}, \text{IP}, \text{OP}] \quad (1.4)$$

where $\text{COP}_{\text{non-OPEC}}$ indicates crude oil production of non-OPEC countries, $\text{COP}_{\text{non-Saudi OPEC}}$ indicates crude oil production of non-Saudi OPEC countries, COP_{SA} indicates crude oil production of Saudi Arabia, IP indicates industrial production, and OP indicates oil price.

We can then rewrite the model from Equation 1.3 as follows:

$$Z_t = A^* + \sum_{t-i}^p A_i^* Z_{t-i} + e_t \quad (1.5)$$

where $A_i^* = A^{-1}A_i$, $e_t = A^{-1}\varepsilon_t$

$$\begin{pmatrix} e_{\text{non-OPEC COP}} \\ e_{\text{non-Saudi OPEC COP}} \\ e_{\text{SA cop}} \\ e_{\text{IP}} \\ e_{\text{OP}} \end{pmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & 0 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \begin{pmatrix} \varepsilon_{\text{non-OPEC COP}} \\ \varepsilon_{\text{non-Saudi OPEC COP}} \\ \varepsilon_{\text{SA cop}} \\ \varepsilon_{\text{IP}} \\ \varepsilon_{\text{OP}} \end{pmatrix} \quad (1.6)$$

The restrictions for our model following non-Saudi OPEC, Saudi crude oil production, industrial production, and oil price have no contemporaneous effect on non-OPEC countries' oil production, where $\alpha_{12} = \alpha_{13} = \alpha_{14} = \alpha_{15} = 0$. Also, $\alpha_{23} = \alpha_{24} = \alpha_{25} = 0$, meaning that Saudi crude oil production, industrial production, and oil price have no contemporaneous effects on non-Saudi OPEC crude oil production. Furthermore, $\alpha_{34} = \alpha_{35} = 0$, which suggests that industrial production and oil price have no contemporaneous effect on Saudi crude oil production. Finally, $\alpha_{45} = 0$, which indicates that oil price has no contemporaneous effect on industrial production.

The reason we introduced the recursive model is to compare it with the Bayesian approach and to show the effect of each variable on the next variable in the order of Equation 1.6. In fact, according to Kilian and Zhou (2020), the recursive model has limitations in that it does not seem credible. It assumes that the world's oil production does not respond to other shocks contemporaneously; consequently, it imposes a short-run price elasticity of oil supply equal to zero. Finally, it assumes that real economic activity does not respond to oil-specific demand shocks contemporaneously, which means that the short-run oil price elasticity of global demand is equal to zero.

Due to these shortcomings, we use a more credible Bayesian Structural Vector Autoregression to assign the coefficients a prior distribution, which means we do not need to make recursiveness assumptions or impose specific numerical values for the coefficients. Applying a prior distribution suggests that the less information available, the more uncertain the impulse response functions will be.

1.5.1 Bayesian Structural Vector Autoregression

As we choose not to rely on the recursive model introduced in Section 1.5 due to the reasons detailed above, we apply a Bayesian approach that allows for using sign restrictions as prior information. According to the structural Bayesian vector autoregression model:

$$AY = BX + U \quad U \sim N(0, D) \quad (1.7)$$

where Y represents a matrix of endogenous variables ($n \times T$), and X represents a matrix containing lags of the endogenous variables ($K \times T$). Further, A represents a matrix that contains prior information and the sign restriction ($n \times n$), while B is a matrix that contains lags of structural coefficients ($n \times K$). In addition, U represents a matrix of structural innovations ($n \times T$) and has the diagonal covariance matrix of U , which is D ($n \times n$). N represents the number of endogenous variables, which are 5 in our model; T represents the number of observations, which are 329; and $K = nL + 1$, which is $K = (5 \times 8) + 1 = 41$.

Therefore, once we have the prior information about matrix A , we assume the prior information about other parameters represented by parametric distributions. To calculate the Bayesian posterior distribution, the prior information about D conditional on A is represented by the following equation:

$$p(D|A) = \prod_{i=1}^n p(d_{ii} | A) \quad (1.8)$$

where d_{ii} indicates the row and column i of D .

The posterior distribution of B is given by the following equation:

$$p(B|D, A) = \prod_{i=1}^n p(b_i | D, A) \quad (1.9)$$

For equation (i)

$$b_i | D, A \sim N(m_i A, d_{ii} M_i) \quad (1.10)$$

where $b_i | D, A$ indicates the conditional Gaussian distribution and b_i is row i of matrix B .

Baumeister and Hamilton (2017) treated u_t as a Gaussian random variable. They used the Metropolis Hastings algorithm to take draws of the parameters from posterior distribution by generating different draws of α^ℓ , d_{ii}^ℓ , and b_i^ℓ and then increasing ℓ by one and having many draws up to the total number of iterations.

1.5.1.a. The Bayesian Structural Vector Autoregression with Zero Restrictions

The zero restrictions of the recursive model in Section 1.5 can also be represented as a prior distribution for the Bayesian model. The prior distribution imposes that the coefficients of A are as follows, with variance of each of the elements above the diagonal equal to zero.

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & 0 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \quad (1.11)$$

No prior information is imposed on the distribution of any of the coefficients below the diagonal. Following Baumeister and Hamilton, we used student t-distribution with location parameter C= 0, scale $\sigma = 100$, and V= 3 degree of freedom.

In our model, we impose certain coefficients from the literature, meaning we do not assume them to equal zero, like in a recursive model. Therefore, we examine what would happen if we changed our assumption by changing the coefficients to determine how the estimate IRF changes.

1.5.1.b. Bayesian Structural Vector Autoregression with Other Types of Prior Information

Having imposed zero restrictions in the previous section, in this section we impose both the sign restriction and prior information, as shown in the following three prior distributions. For

sign restrictions, we follow the work of Kilian and Murphy (2012) and Baumeister and Hamilton (2017). The shifting oil supply curve is the result of world events and wars, such as the Iraqi invasion of Kuwait in 1990. When an oil supply shock occurs, the sign restriction of oil production and oil price would have different responses whereas the industrial production will follow the response of the oil production, so the positive oil supply shock on non-OPEC will negatively affect non-Saudi OPEC and Saudi crude oil production and cause a decrease in oil prices and an increase in industrial production. However, the positive oil supply shock on non-Saudi OPEC will negatively affect non-OPEC and Saudi crude oil production, which also causes oil prices to decrease and industrial production to increase. Furthermore, the positive oil supply shock on Saudi Arabia will negatively affect non-OPEC and non-Saudi OPEC crude oil production, causing a decrease in oil prices and an increase in industrial production. The shifting oil demand curve is due to oil demand shocks that result from economic growth.

For aggregate demand shocks, the sign restriction of oil production, industrial production, and oil price have the same response. The positive aggregate demand shock causes an increase in oil production (non-OPEC, non-Saudi OPEC, and Saudi Arabia), industrial production, and oil prices. For oil price shocks resulting from the news about the future, the sign restriction of oil production and oil price have the same response while industrial production responds differently. The positive oil price shock causes oil production and the oil price to increase while causing the industrial production to decrease as shown below.

$$\begin{pmatrix} COP_{non-OPEC} \\ COP_{non-Saudi OPEC} \\ COP_{SA} \\ IP_t \\ OP_t \end{pmatrix} \begin{bmatrix} \text{non-OPEC supply shock} & \text{non-Saudi OPEC supply shock} & \text{Saudi supply shock} & \text{aggregate demand shock} & \text{oil price shock} \\ + & - & - & + & + \\ - & + & - & + & + \\ - & - & + & + & + \\ + & + & + & + & - \\ - & - & - & + & + \end{bmatrix} \quad (1.12)$$

We consider three different prior distributions. The first prior distribution follows Kilian and Murphy (2012) by imposing the price elasticity from previous literature on oil supply, oil price elasticity of global demand, price elasticity of oil demand, and income elasticity of oil demand. It then follows Baumeister and Hamilton (2017) by adding more prior information to achieve certainty in our impulse response function, as explained in the following prior distribution. The second prior distribution adds more prior information based on historical events in which Saudi Arabia's oil production negatively affected both non-OPEC and non-Saudi OPEC oil production. The final prior distribution adds still more prior information, that Saudi Arabia's oil production negatively responded to non-OPEC and non-Saudi OPEC oil production.

1.5.1.b.1 Prior Distribution I

This prior distribution is the baseline upon which we impose coefficients with specific values for the short-term price elasticity of oil supply, short-term oil price elasticity of global demand, short-term price elasticity of oil demand, and income elasticity of oil demand. The traditional approach in the literature imposes certain coefficients restrictions. To do so, we impose the average estimate of the coefficients shown in Table 1.1, where α_{15} represents the short-term supply elasticity of non-OPEC countries, which is equal to 0.32 (Golombek et al., 2018); α_{25} represents the short-term supply elasticity of OPEC countries, which is equal to 0.19 (Golombek et al., 2018); and α_{35} represents the short-term supply elasticity of Saudi Arabia, which is equal to 1.036 (Dagoumas et al., 2017). Meanwhile, α_{45} represents the short-term oil price elasticity of global demand, which is equal to -0.05 according to Baumeister, and Hamilton (2018). Further, α_{51} represents the short-term price elasticity of oil demand for non-OPEC, which is equal to -0.01 according to Boroumand (2014); α_{52} represents the short-term price elasticity of oil demand for

OPEC, which is equal to -0.01 according to Boroumand (2014); and α_{53} represents the short-term price elasticity of oil demand for Saudi Arabia, which is equal to -0.05 according to Metwally and Arab (1987). Finally, α_{54} represents the income elasticity of oil demand, which is equal to 1.0 according to Baumeister, and Hamilton (2018), as the income elasticity of an oil-exporting country is close to one. Also, according to Sillah and Al-Sheikh (2012), the income elasticity for oil-exporting countries is between 0.7 and 1.0.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & \alpha_{15} \\ 0 & 1 & 0 & 0 & \alpha_{25} \\ 0 & 0 & 1 & 0 & \alpha_{35} \\ 0 & 0 & 0 & 1 & \alpha_{45} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \quad (1.13)$$

As previously explained, we use a structural t-distribution with the location of the prior information ($\alpha_{15}=0.32$, $\alpha_{25}=0.19$, $\alpha_{35}=1.036$, $\alpha_{45}=-0.05$, $\alpha_{51}=-0.01$, $\alpha_{52}=0.01$, $\alpha_{53}=-0.05$, $\alpha_{54}=1.0$), scale parameter $\sigma = 0.2$, and degrees of freedom $v=3$.

Table 1.1 Summarizing the Short-run Elasticities.

Elasticity	Average values of elasticities	Citation
Short-term supply elasticity of non-OPEC countries	0.32	Golombek et al. (2018)
Short-term supply elasticity of OPEC countries	0.19	Golombek et al. (2018)
Short-term supply elasticity of Saudi Arabia	1.036	Dagoumas et al. (2017)
Short-term oil price elasticity of global demand	-0.05	Baumeister, and Hamilton (2018)
Short-term price elasticity of oil demand for non-OPEC countries	-0.01	Boroumand (2014)
Short-term price elasticity of oil demand for OPEC countries	0.01	Boroumand (2014)
Short-term price elasticity of oil demand for Saudi Arabia	-0.05	Metwally and Arab (1987)
Income elasticity of oil demand	1.0	Baumeister, and Hamilton (2018)

1.5.1.b.2 Prior Distribution II

In this prior distribution, we relax our restrictions in the first prior distribution by imposing a negative effect of Saudi oil production on non-OPEC countries' oil production and non-Saudi OPEC countries' oil production. Therefore, the restrictions we impose are that α_{31} and α_{32} are negative. In this prior distribution, we also use student t-distribution with the location of the prior $c_{31}^{\alpha} = c_{32}^{\alpha} = -0.02$, a scale parameter $\sigma = 0.2$, and degrees of freedom $v=3$.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & \alpha_{15} \\ 0 & 1 & 0 & 0 & \alpha_{25} \\ \alpha_{31} & \alpha_{32} & 1 & 0 & \alpha_{35} \\ 0 & 0 & 0 & 1 & \alpha_{45} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \quad (1.14)$$

1.5.1.b.3 Prior Distribution III

This prior distribution is a more informative prior. We keep all restrictions from both prior distributions and add two additional restrictions. We impose a negative effect of non-OPEC countries' oil production and non-Saudi OPEC countries' oil production on Saudi Arabia's oil production to prevent prices from declining and balancing the market. Thus, the restrictions we impose are that α_{13} and α_{23} are negative. In this prior distribution, we also use student t-distribution with the location of the prior $c_{13}^\alpha = c_{23}^\alpha = -$, a scale parameter $\sigma = 0.2$, and degrees of freedom $v=3$.

$$\begin{bmatrix} 1 & 0 & \alpha_{13} & 0 & \alpha_{15} \\ 0 & 1 & \alpha_{23} & 0 & \alpha_{25} \\ \alpha_{31} & \alpha_{32} & 1 & 0 & \alpha_{35} \\ 0 & 0 & 0 & 1 & \alpha_{45} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \quad (1.15)$$

Thus, we estimated the BSVAR and computed the impulse response function¹ to examine the effect of Saudi Arabia's oil supply shock on non-OPEC and non-Saudi OPEC' crude oil production.

¹ The estimates for IRF of BSVAR were done by using R(version 3.0.1) and using function BH-BSVAR.

1.6 Results and Discussions

1.6.1 Test for Unit Root

It is common to investigate the stochastic properties for macroeconomic variables by using an empirical analysis to consider their order of integration and applying Augmented Dickey-Fuller (1979), Philips and Perron (1988), and Kwiatkowski-Phillips-Schmidt-Shin (1992). These results are summarized in Tables 1.2 and 1.3. The results confirm the nonstationary of the our variables in their levels and stationarity when the first differences are taken.

Table 1.2 Augmented Dickey Fuller (1979) Unit Root Test.

	Level Data			First Difference Data		
	None	Drift	Trend	None	Drift	Trend
non-OPEC COP	0.97	-1.74	-3.79	-9.55	-9.60	-9.58
non-Saudi OPEC COP	0.22	-1.98	-0.65	-14.64	-14.63	-14.90
SACOP	0.20	-2.13	-3.78	-12.59	-12.57	-12.53
IP	-3.23	-3.22	-3.37	-12.33	-12.32	-12.32
OP	-0.102	-1.93	-2.15	-11.75	-11.74	-11.75

Note: The 5% critical values for ADF test are: None=-1.95, Drift=-2.87, and Trend=-3.42

Table 1.3 Philips and Perron (1988) and Kwiatkowski et al (1992) Unit Root Test.

	Philips and Perron (1988)				Kwiatkowski-Phillips-Schmidt-Shin (1992)			
	Level		First Difference		Level		First Difference	
	Constant	Trend	Constant	Trend	Constant	Trend	Constant	Trend
non-OPEC COP	-1.72	-3.78	-13.28	-13.28	5.18	0.37	0.10	0.04
non-Saudi OPEC COP	-1.93	-0.13	-17.46	-17.69	4.19	0.70	0.49	0.09
SACOP	-2.43	-4.43	-19.12	-19.07	4.20	0.22	0.05	0.04
IP	-2.68	-2.84	-13.09	-13.08	0.86	0.68	0.06	0.02
OP	-1.76	-1.52	-13.35	-13.34	3.85	0.84	0.16	0.06

Note: The 5% critical values for pp test: Constant=-2.882684, and Trend=-3.427043; for KPSS test: Constant=0.463, and Trend=0.146

1.6.2 The Impulse Response Function

To understand the relative contribution of Saudi oil supply shocks in explaining the movements of non-OPEC and non-Saudi OPEC oil production over time, SVAR, Bayesian Structural VAR (BSVAR) with zero restrictions, and BSVAR with sign restriction for different prior distributions of prior information are used. Figures A.1 and B.2. in the Appendix illustrate the IRF over a 24-months horizon for both the SVAR and BSVAR with zero restrictions. However, the Choleski decomposition and BSVAR with zero restrictions almost showed the same response. Figures 1.1-1.3 are plots of the impulse response functions and show that the structural Saudi oil supply shock is a considerable source of non-OPEC and non-Saudi OPEC oil production fluctuations over time. The full results for the three prior distributions are presented in Figures A.3 – A.5 in the Appendix. However, these results also show that the response of non-OPEC and non-Saudi OPEC oil production movements to Saudi Arabia's oil supply shock decreases in most of our prior distributions.

Figure 1.1 displays the IRF of the first prior distribution using the following restrictions: short-run supply elasticities, short-run oil price elasticity of the aggregate, short-run price elasticities of oil demand, and income elasticity. The results indicate that the response of non-OPEC and non-Saudi OPEC crude oil production immediately and negatively reacts to Saudi oil supply shocks and continues for more than two months before turning positive until the end of the period. In addition, their responses to Saudi oil supply shocks are initially significant. However, this result indicates that, when Saudi Arabia increases its production, the production of non-OPEC countries decreases by 0.15% while non-Saudi OPEC countries' production decreases by almost 0.1%, resulting in small reductions in their oil GDP. Saudi oil supply shocks produce a moderate reduction on both OPEC and non-OPEC oil production and their oil GDP in the short run.

Figure 1.2 displays the IRF of the second prior distribution using the restrictions of the first prior distribution and adding two more restrictions. The results show that the response of non-OPEC and non-Saudi OPEC crude oil production to Saudi oil supply shocks is negative over the time horizon. Furthermore, the response of non-OPEC crude oil production to Saudi oil supply shocks is significant for five months, while the response of non-Saudi OPEC crude oil production is significant for more than two months. This result indicates that, when Saudi Arabia increases its production, the production of non-OPEC countries decreases by about 5% to 10% while that of non-Saudi OPEC countries decreases by about 10% to 20%, thereby decreasing their oil GDP. Saudi oil supply shocks have a larger effect compared with the first prior distribution on both OPEC and non-OPEC countries' oil production and oil GDP.

Figure 1.3 displays the IRF of the last prior distribution, using the restrictions of the first and second prior distribution and adding two more restrictions. The results show that the non-OPEC crude oil production's response to Saudi oil supply shocks is positive and insignificant at all horizons; meanwhile, the non-Saudi OPEC crude oil production's response is negative for all horizons and significant for more than two months. These results are expected due to existing agreements and quotas among OPEC members. The result in this prior distribution, which is a much weaker assumption, indicates that increasing Saudi Arabia's oil production has no effect on non-OPEC production while the non-Saudi OPEC oil production decreases by about 10% to 20% in the short run, thereby reducing the GDP as well. Saudi Arabia's oil supply shocks affect only non-Saudi OPEC oil production and oil GDP in this prior distribution.

Overall, the conclusion inferred from the impulse response function shows that Saudi oil supply shocks lead to a decrease in non-OPEC and non-Saudi OPEC crude oil production. The result of the first prior distribution, which is the baseline, indicates that Saudi supply shocks led to

a moderate decrease in world production as well as oil GDP. The result of the second prior distribution indicates that Saudi supply shocks led to a higher decrease in world production as well as oil GDP when we add more information. Finally, the result of the last prior distribution, which is a much weaker assumption, indicates that Saudi supply shocks led to a decrease in the production and oil GDP of only non-Saudi OPEC producers. These results were evident during some periods, such as during the Covid-19 pandemic in February 2021. Saudi Arabia was planning to reduce its oil production by one million barrels per day because of the Covid-19 crisis. It asked OPEC and non-OPEC producers to reduce their oil productions to prevent oil prices from going even lower due to the decrease in global demand. However, OPEC and non-OPEC producers continued to increase their oil productions, causing a huge decrease in the price of oil. When Saudi Arabia saw no cooperation, it reacted by increasing its own oil production so the other producers reduced their productions.

Finally, in our model we impose certain coefficients from the literature, meaning we do not assume them to equal zero, like in a recursive model. Therefore, we want to examine what would happen if we changed our assumption by changing one of the coefficients to see how the estimate IRF changes. To this end, we changed one oil supply elasticity α_{15} to different values, which led to changes in the response of both non-OPEC and non-Saudi OPEC oil production. Figure 1.4 indicates the changes in the impulse response function for non-OPEC oil production responses to Saudi oil supply shocks. Figure 1.5 indicates the changes in the impulse response function for non-Saudi OPEC oil production responses to Saudi oil supply shocks. As Figure 1.4 demonstrates, when we assume the coefficient to be zero, the IRF decreases by 1.8%; when we assume the coefficient to be one, the IRF decreases by 4.8%. Figure 1.5 shows that, when we assume the coefficient to be zero, the IRF decreases by 2.2% ; when we assume the coefficient to

be one, the IRF decreases by 6.8%. Therefore, our result shows that the IRF changes as we change the coefficient, indicating that the IRF heavily depends on the identity assumption. Thus, we should not rely on Cholesky decomposition as the result is not robust at all; indeed, the difference affects the percentage of how Saudi Arabia production affects the world as our results show that increasing Saudi oil production affects the production of both OPEC and non-OPEC producers and their oil GDP.

Figure 1.1: Impulse response function for non-OPEC and non-Saudi OPEC oil production responses to Saudi oil supply shocks using the sign restriction from the first prior distribution.

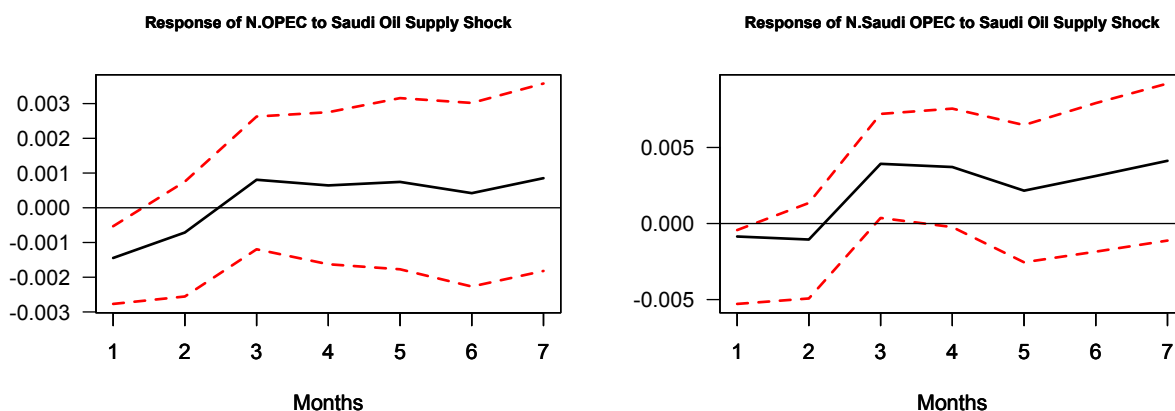


Figure 1.2: Impulse response function for non-OPEC and non-Saudi OPEC oil production responses to Saudi oil supply shocks using the sign restriction of the second prior distribution.

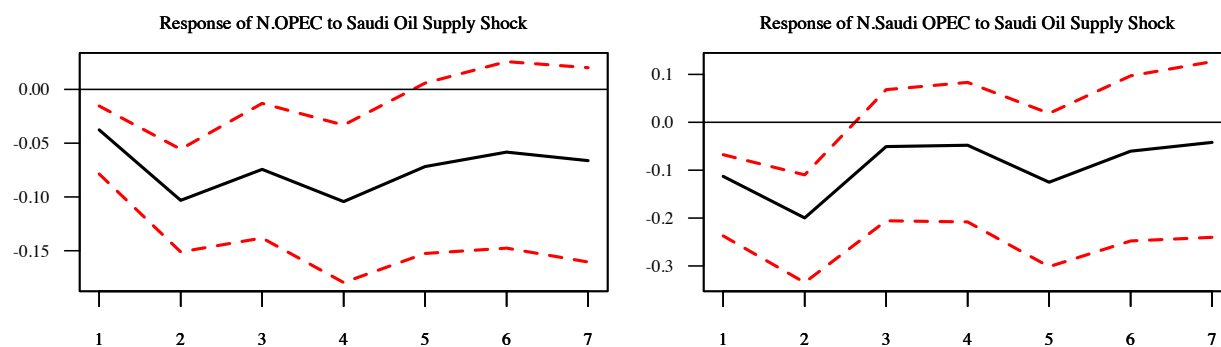


Figure 1.3: Impulse response function for non-OPEC and non-Saudi OPEC oil production responses to Saudi oil supply shocks using sign restriction of the last prior distribution.

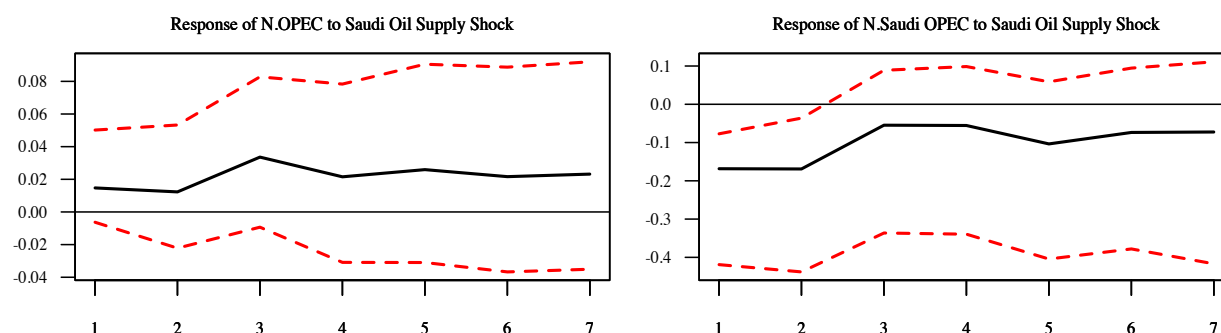


Figure 1.4: The first impulse response function for non-OPEC oil production responses to Saudi oil supply shocks after changing one oil supply elasticity α_{15} to different values.

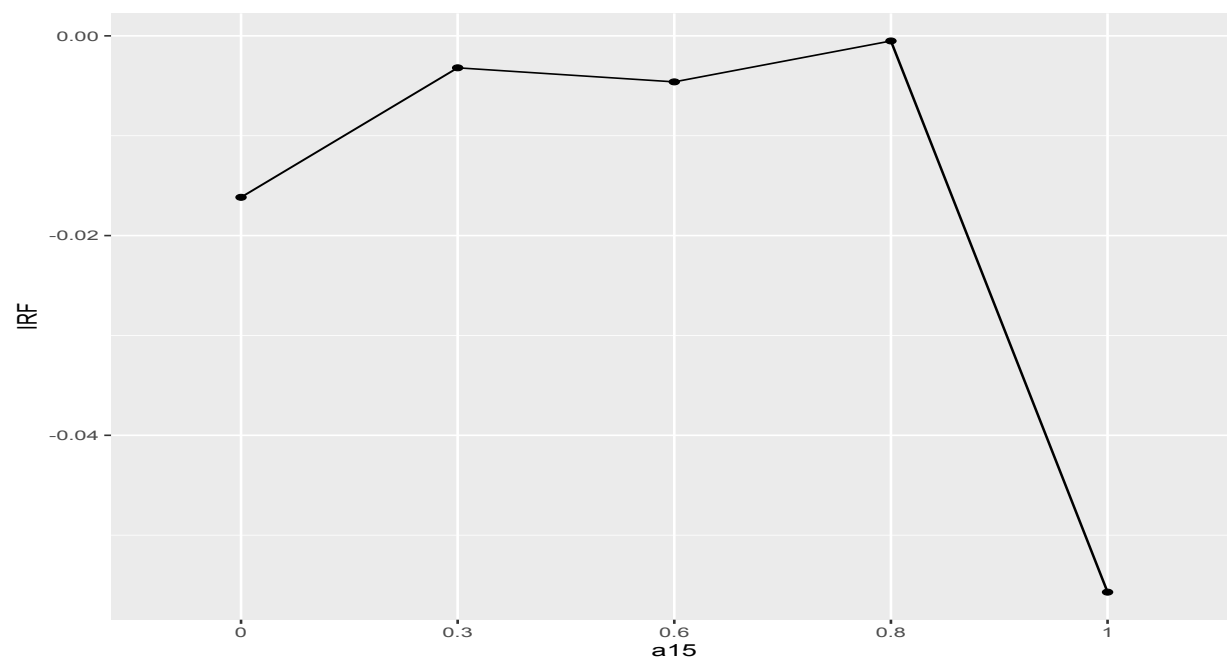
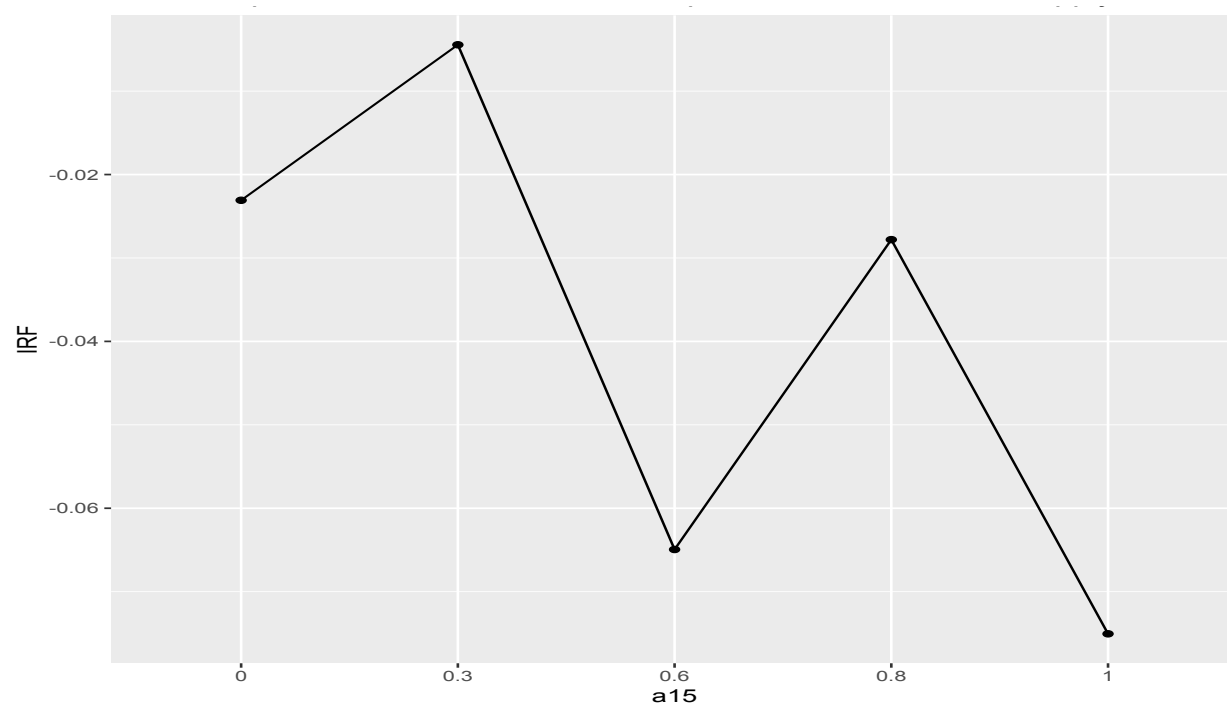


Figure 1.5: The first impulse response function for non-Saudi OPEC oil production responses to Saudi oil supply shocks after changing one oil supply elasticity α_{15} to different values.



1.7 Conclusions

Saudi Arabia is the largest oil exporter and, thus, plays an important leadership role in OPEC. It uses different policies to protect its interests and achieve its goals, but its production-related decisions also affect OPEC and non-OPEC producers. In addition to Saudi Arabia's ability to make up for any shortfalls in oil supplies, making it a very important player in the oil market, it has the advantage of lower-cost production and higher-standby capacity than other producers. As its production fluctuates due to its rapid responses to any shortages in global production, it has implemented policies to prevent other producers from exceeding the specified production quotas to ensure market balances and maintain prices.

In this paper, we have investigated the response of the exporter countries to Saudi Arabia's production shocks. We have considered three supply shocks-non-OPEC supply shock, non-Saudi OPEC supply shock, and Saudi supply shock-using BSVAR with sign restrictions and prior information with different prior distributions. Our results demonstrate that non-OPEC and non-Saudi OPEC producers' responses to Saudi Arabia's oil supply shocks are negative in most prior distributions. In this essay, we explicated how Saudi oil production shocks affect all other oil exporter countries. We demonstrated that Saudi oil production shocks cause a negative impact on both non-OPEC and non-Saudi OPEC oil production and their oil GDP. However, future studies could look at the effect of each of oil supply shock (i.e., non-OPEC, non-Saudi OPEC, and Saudi oil production shocks) on the price of oil.

Chapter 2 – The Monetary Policy Authority’s Reaction to Prevent Inflation in Saudi Arabia.

2.1 Introduction

Inflationary effects of oil shocks have long been a concern for macroeconomists (Darby, 1982). The literature that grew out of the oil shocks of the 1970s has often treated oil shocks as shocks to aggregate supply; oil shocks are expected to be inflationary. Two factors imply that the relationship between oil price shocks and inflation is different in Saudi Arabia compared to the United States. First, as an oil exporting country, the primary effect on inflation comes through the changes in aggregate demand resulting from the change in the price of oil. This relationship is ambiguous because the price of oil is correlated with the production of oil, meaning that a higher oil price can lead to higher or lower aggregate Saudi income. The sign of the relationship is an empirical question. Second, the Saudi economy is heavily dependent on the imports of goods and services. Variations in Saudi Arabia’s inflation rate are driven by variations in the exchange rate.

Due to concerns about exchange rate fluctuations causing inflation, the Saudi Arabian Monetary Agency pegs the riyal to the US dollar. This essay asks whether such a policy reduces the inflationary effect of an oil price shock. To answer this question, we ask whether the CPI response to oil price shock depends on the current exchange rate policy. To our knowledge, no paper has investigated the effectiveness of the Saudi exchange rate policy at stabilizing the inflation rate in the presence of oil price shocks. In other words, we are interested in quantifying what would happen if the Saudi Arabian Monetary Agency responded less forcefully to oil price shocks.

To this end, we follow the methodology of Bernanke et al. (1997). We first estimate an identified structural VAR model, which includes a trade-weighted exchange rate index, to understand the Saudi CPI’s response to an oil shock. We then change the estimated VAR model

coefficients so that the exchange rate index shows a weaker response to oil price shocks. When we do that, the corresponding impulse response functions for the CPI to an oil price shock increase dramatically. Although the Monetary Authority fixes the riyal to the US dollar, the effect of such a policy should stabilize the trade-weighted exchange rate index. Thus, the alternative policy in the empirical analysis is one in which the exchange rate against the dollar is stabilized but no longer fixed. We conclude that the current policy is successful at stabilizing the Saudi inflation rate.

Section 2.2 describes the background of Saudi Arabia's monetary policy. Section 2.3 reviews the literature relevant to our paper. Section 2.4 summarizes the data. In Section 2.5, we describe our methodology. Section 2.6, presents our results.

2.2 Background of the Saudi Arabia's Monetary Policy

Over time, Saudi Arabia has followed different regimes for exchange rates, which affected inflation levels in different ways depending on the regime. In 1973, the Saudi Arabian Monetary Agency linked the riyal to special drawing rights (SDR), which pegged the Saudi currency with the IMF's SDR basket of currencies. According to Alkhareif and Qualls (2016), the peg to the SDR was discontinued in May 1981, as the SDR system had limited flexibility in monetary policy and a limited ability to adapt to shocks. Since 1986, the Saudi Arabian Monetary Agency has pegged the riyal to the dollar (Aljasser, & Banafe, 1999). According to Alkhareif and Qualls (2016), from 1974 to 1976, when the Saudi monetary policy adopted SDR, the inflation rate was higher than 30% as it was being affected by the increasing oil prices; when the Saudi monetary policy adopted the fixed exchange rate in 1986, the non-oil inflation was 3.1%.

The Saudi Arabian Monetary Agency has played an important role in money management, and its role has evolved along with the development of the Saudi economy. According to Ramady (2005), the Saudi Arabian Monetary Agency performs several roles, including issuing currency, serving as a bank for the government, supervising banks, advising the government on debt, and managing foreign exchange reserves. It is also responsible for managing the monetary policy through the use of various tools introduced to the agency in an effort to control the liquidity in the economy and avoid monetary policy turbulence. These tools include the minimum legal reserve ratio, the legal liquidity ratio, reposessions, reverse reposessions, foreign currency swaps, foreign currency interventions, and the investment of public funds. In addition, the Saudi Arabian Monetary Agency uses the publication of prudential guidelines (Ramady, 2010).

The three potential objectives of monetary policy are the free movement of capital, a fixed exchange rate, and an independent monetary policy. As it is difficult for Saudi Arabia to achieve the three objectives at the same time, the Saudi Arabian Monetary Agency seeks to achieve the free movement of capital without capital controls and a fixed exchange rate, but it cannot achieve independent monetary policy (SAMA, 2016). The Saudi policy fixes the currency against the dollar, which will, hopefully, also stabilize it compared to other major currencies. Pegging the riyal to the dollar offers several advantages, including the stabilization of the value of the riyal both internally and externally, promotion of the government's desire to encourage foreign investments, and attempts to prevent capital flows outside the country through currency stability.

Furthermore, adherence to the fixed exchange rate policy achieves a balance in both domestic prices and payments and seeks to achieve stability in market prices. Thus, it reduces inflation related to the devaluation of the currency. However, the success of the peg in Saudi Arabia is due to exports as a whole, as well as most imports, being priced in dollars (Ramady, 2005). Al-

Jasser and Banafa (2003, p. 204) explained that Article 1 of the Saudi Arabian Monetary Charter states that “the objective of the Saudi Arabian Monetary Agency is to issue the Saudi currency, strengthen it, and stabilize its internal and external value.” However, the linkage prevents the monetary policy from being independent, and it quickly picks up on external influences, especially in light of economic openness. Moreover, the fixed exchange rate due to the linkage does not respond to external shocks whereas the interest rate does. As a result, speculators follow the fixed exchange rate to achieve profits (Ramady, 2005).

Sometimes the Saudi Arabian Monetary Agency resorts to foreign currency interventions to achieve stability because of the speculation² that taking advantage of the differences between interest rates can negatively affect foreign exchange reserves in Saudi Arabia (Ramady, 2009). If the interest rates of the Saudi riyal do not track those of the dollar while staying less than those of the dollar, speculators seek to borrow from Saudi Arabia, where interest rates are low, and invest in the U.S., where interest rates are high. However, borrowing in riyals and investing in dollars leads to an increase in the demand for borrowing and then an increase in the printing of riyals, thereby decreasing the value of the currency while also leading to inflation (Ramady, 2005). Therefore, the Saudi Arabian Monetary Agency was forced to intervene in two ways: adjusting interest rates in riyals to track interest rates in dollars and trying to influence foreign currency outflows by discouraging them (Ramady, 2005).

Saudi Arabia has faced several imbalances in foreign reserves. For example, when the government uses its foreign currencies to make the payments for which it is responsible, such as import payments, it does not benefit because the money leaves the system (Ramady, 2005). Furthermore, many leaks out of Saudi Arabia have occurred due to huge remittances for labor

² Speculators follow the exchange rate policy to achieve investment by borrowing in a currency with a low interest rate and investing in a currency with a high interest rate according to (Ramady, 2005).

between 1970 and 2008; these leaks have totaled 1,229 billion riyals (Ramady, 2010). The Saudi Arabian Monetary Agency has worked to reduce such remittances, which affect both the money supply and the Saudi economy (Ramady, 2005).

To preserve the economy from these fluctuations, the Saudi Arabian Monetary Agency pegged the riyal to the dollar in an attempt to keep expenditures fixed despite fluctuations in oil revenues. Saudi oil exports are priced in dollars in global markets so they are not affected by changes in the exchange rate. To promote both stability and confidence in the riyal, it is linked to the dollar, as not having a fixed exchange rate leads to fluctuations in the exchange rate and causes a lack of confidence in the cost of import prices. Saudi Arabia is an importer of all commodities except oil. American imports account for 20% of all Saudi imports, except when the dollar's currency rises, at which point Saudi Arabia tends to import from other countries priced in non-dollars to save costs. For example, from 2003 to 2004, oil prices rose; at the same time, the value of the U.S. dollar declined (between 2002 and 2004), which led to a decrease in the value of the Saudi riyal and significant impacts on Saudi imports. Pricing imports from other countries in dollars helped further reduce the decline in the value of the Saudi riyal while the rise in oil prices helped reduce the impact of the decline in the currency by increasing the foreign exchange reserve to support the local currency. However, the decrease in the value of the riyal did not lead to an increase in Saudi exports. This may have been due to the fact that all Saudi exports are from the oil sector, as well as its commitment to meeting quotas with members of OPEC (Ramady, 2005).

The Saudi Arabian Monetary Agency does not have any flexibility in setting monetary policy, which follows the policy of the Federal Reserve as well as U.S. interest rates. When the government receives oil revenues in dollars, it deposits the revenues in the Saudi Arabian Monetary Agency, which keeps all government funds in dollars and enters these dollars into

foreign exchange reserves. When the government wants to use its revenues, the agency converts this foreign money into local liquidity by depositing an equivalent amount in Saudi riyals into the account of the Ministry of Finance; consequently, there is no immediate impact on domestic liquidity or money supply (SAMA, 2016). By keeping the dollar currency, the Saudi Arabian Monetary Agency supports the local currency; it also meets the private sector's dollar needs by selling the dollars and adjusting the reserves as necessary to maintain a balance between the sources of oil revenues and the economy's requirements. Such adjustments usually occur through large expenditures on infrastructure due to increases in economic activity. For example, in February 1980, the agency adjusted the reserves after obtaining permission from the Ministry of Finance; no adjustments have been made to the reserves since then (Aljasser, & Banafe, 1999).

Currency stability has also played an important role in capital inflows. Within Saudi Arabia, capital flows have maintained the money supply without effect because the government revenue flows are automatically sterilized. As these revenues do not affect the money supply directly, the money supply remains unaffected unless the government pumps part (or all) of its foreign revenues into the economy. Meanwhile, capital outflows are not sterilized and, thus, they affect the money supply (Akikina & Al-Hoshan, 2003). The Saudi Arabian Monetary Agency uses interest rates to control the money supply to the greatest extent possible. Although such controls are not the best solution, it is better to put such necessary economic reforms in place to reduce the risks of the capital flows. Changes in oil revenue flows due to fluctuating oil prices prevents the monetary policy from dealing with these changes effectively through exchange rates because of the dollar peg; in such a situation, fiscal policy plays a different role as the government applies a countercyclical fiscal policy by adjusting government spending to stabilize the economy. Thus, when oil revenues were increasing and growth was getting out of control, the government adopted

a fiscal policy to curb the economy by reducing government spending and vice versa (Al-Jasser & Banafe, 2008).

In 1973, the price of oil increased due to the Arab oil embargo, affecting economies around the world, including that of the U.S., and causing a recession (Hamilton, 1983). The economy of Saudi Arabia, being completely dependent on oil revenues, was significantly affected by the price of oil. As oil prices increased, Saudi Arabia's inflation rose to its highest level ever in 1970s, surpassing 30% (Ramady, 2005). As a result, the Saudi government took steps to achieve stability through different policies. Most recently, in April 2016, they focused on their Vision 2030 to develop the kingdom's economy to reduce its dependence on oil revenues. The different levels of inflation between countries due to their different policies have become evident.

It is widely believed that exchange rate fluctuations affect inflation rates (Caselli & Roitman, 2016; McCarthy, 2000). For example, if the multilateral trade-weighted value of a country's currency falls, the imported goods for that country will be more expensive, thereby causing prices of local goods to rise. Countries have followed different economic policies, such as a free-floating exchange rate, a managed floating exchange rate, and a fixed exchange rate policy, according to what suits their economic goals. As a result, differences in the nature of relationships between the exchange rate and inflation have emerged (Reinhart & Rogoff, 2002). Rogoff et al. (2005) found that developing countries that adopt a fixed exchange rate have a low inflation rate. According to IMF Report No. 19/290 (2019), if Saudi Arabia used the flexible exchange rate system, it would have support of its fiscal revenues in riyals while also achieving development in its non-oil sector. As a result, the Saudi Arabian Monetary Agency has the ability to adopt an independent monetary policy, thereby enabling the kingdom's real exchange rate to move with the terms of trade. On the other hand, there are disadvantages to moving away from the fixed exchange

rate system, including a lack of confidence in the local currency and instability in its economy. Thus, the Saudi Arabian Monetary Agency linked the Saudi riyal to the US dollar (Alkhareif & Qualls, 2016). In some other countries, central banks combat inflation by tightening monetary policy, such as by increasing interest rates, which makes borrowing expensive. This approach in turn affects consumption and investment until inflation rates decline, at which point the policy is eased for the continuity of developing their economies.

2.3 Literature Review

Economists have examined how inflation change due to different exogenous effects by looking in three directions. Some have looked at the passthrough of exchange rate changes, as shown below, while others have explored the oil price effect on exchange rate and inflation. The difference between our study and previous studies is that we are studying the behavior of the exchange rate in a counterfactual experiment where the Saudi Arabian Monetary Authority reacts less strongly to stabilize the exchange rate when the price of oil changes. First, many empirical studies have focused on the pass-through of exchange rates into inflation; confirming that the pass-through in many countries is incomplete. For example, McCarthy (2000) estimated the effect of exchange rate and import price on consumer price index (CPI). He found that the pass-through of the exchange rate to CPI has a small effect while import price has a large effect on the pass-through to CPI. Takhtamanova (2008) demonstrated that the pass-through of the exchange rate to prices decreased from the 1980s to the 1990s in a sample that included 14 countries from the Organization for Economic Cooperation and Development (OECD). Rahimov et al. (2017) used a vector autoregression (VAR) model to find that even an incomplete pass-through was significant for three exporting countries (i.e., Azerbaijan, Kazakhstan, and Russia) from Q2:2003 to Q1:2016. In addition, Modenesi et al. (2017) examined the exchange rate pass-through to CPI using structural

vector autoregression (SVAR) models and found an asymmetry in the fluctuation of the exchange rate to CPI. Finally, Caselli and Roitman (2016) found non-linear and asymmetrical relationships between exchange rate movements and consumer prices for 28 emerging countries.

Economists' second directions was to study the effect of oil price shocks on exchange rates. Many of the papers focused on long-term relationships. Amano and Norden (1998) examined the effect of oil price shocks on the U.S. exchange rate using a cointegration and causality test. They found a cointegration relationship and causality from oil prices to exchange rates, but not vice versa. Habib and Kalamova (2007) evaluated the impact of oil prices on exchange rates by focusing on export countries and identified a long-term relationship between oil prices and exchange rates for Russia, but not for Saudi Arabia or Norway. Benassy-Quere et al. (2007) also identified a long-term relationship between oil prices and exchange rates between 1974 and 2004 and noted the existence of causality from oil prices to exchange rates using both the dollar's real effective exchange rate and the real exchange rate against the euro. Other papers, such as Huang and Feng (2007), used SVAR to study the effect of oil price shocks on the movements of the Chinese exchange rate. The results showed that shocks in oil prices led to an appreciation of the exchange rate. Basher et al. (2012) also used SVAR to examine the relationship between oil prices and the U.S. exchange rate and found that a positive oil price shock led to a decreased U.S. exchange rate. Hameed et al. (2021) used forecast error variance decompositions from VARs to estimate the spillover effect of oil prices on exchange rates for oil-importing countries (i.e., Pakistan, India, China, Japan, and Germany) and oil-exporting countries (i.e., UAE, Canada, Iraq, Russia, and Saudi Arabia), finding that the volatility spillover of oil prices has a different magnitude effect on the exchange rates of oil-exporting countries compared to oil-importing countries. Beckmann and Czudaj (2013) used a Markov-switching vector error correction model with a group of 12

economists and noticed that the results did not differ not only between oil-exporting and oil-importing countries, but also within the same groups. Furthermore, fluctuations in the price of oil led to changes in the exchange rates. These authors also demonstrated the existence of an inverse causal relationship from the exchange rate to the price of oil in some countries. From a theoretical perspective, Backmann et al. (2020) focused on the theoretical effect on the relationship between the price of oil and exchange rates, claiming that using a specific part of the data leads to different results, as does dependence on a particular method and country chosen for the study.

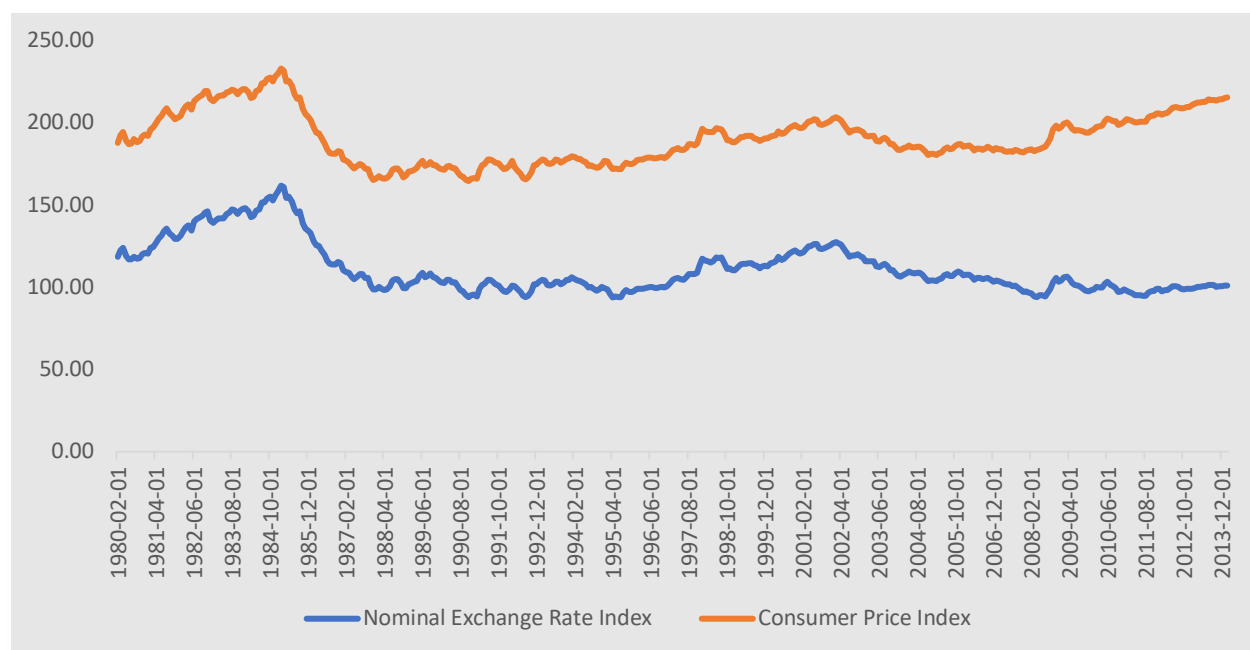
The third directions of the economists' work looked at the relationship between oil prices and inflation. Hooker (2002) estimated the effect of oil price shocks on U.S. inflation and found a structural break: Oil shocks contributed to core inflation until 1981, but not after that. Kiptui (2009) examined the effect of oil price shocks on Kenya's inflation, identifying a significant effect with incomplete pass-through in both the short and long term. Chou and Tseng (2011) estimated the influence of oil shocks on inflation in 12 Asian countries; they found a significant impact in most of these countries in the long term. Sek et al. (2015) used the autoregressive distributed lag (ARDL) model and the pass-through equation to study the effects of oil price shocks and other shocks, such as real exchange rates, on inflation in different groups of countries. They concluded that oil prices had a direct effect on inflation in countries with a low dependency on oil whereas countries with a high dependency showed an indirect effect. Due to economists' concern about the impact of exchange rates' volatility resulting from the volatility of oil prices on the rate of inflation, we find that some economists studied the direct relationship between the exchange rate and inflation whereas others studied the impact of the oil price shock on exchange rates or inflation rates. With regard to Saudi Arabia, which uses a fixed exchange rate policy, we would like to determine if this policy is considered successful in maintaining the stability of the inflation level or not.

In this essay, we follow the work of Bernanke et al. (1997), who investigated the role of monetary policy in the U.S. recessions that followed oil shocks. They sought to determine whether the recessions were directly caused by the change in the price of oil or were instead caused by a tightening of monetary policy in response to higher oil prices. They estimated an SVAR model of the U.S. economy. One of the equations captured the Federal Reserve's monetary policy reaction function, including the response to a change in the price of oil. They compared the impulse response function for U.S. output that they estimated in the data against a counterfactual impulse response function. The counterfactual impulse response function was computed after changing the coefficients on the oil shock to zero in the Federal Reserve's reaction function. The difference in impulse response functions was interpreted as the part of the economy's response to an oil shock that can be attributed to the monetary policy's response. We followed Bernanke et al.'s (1997) approach to determine if Saudi Arabia's exchange rate policy prevents inflation following an oil shock, with one important difference. Whereas Bernanke, et al changed the coefficients on oil price shocks in the monetary policy reaction function to zero, we reduce the coefficient on oil price shocks in the equation for the exchange rate index by 20%. This has the benefit of allowing the study of a counterfactual policy rule with a moderate change in policy, reducing concerns about the Lucas critique.

2.4 Data

To achieve our goal in this essay, we used the price of oil and nominal effective exchange rate index, which is an unadjusted weighted average rate of Saudi Arabia's currency exchanges for multiple foreign currencies and consumer price index that is used as the measure of the monthly change in prices. Both indexes are shown in Figure 2.1 as the nominal effective exchange rate index and consumer price index in Saudi Arabia. Finally, industrial production measures the real output in the manufacturing, electric, and gas industries. We used the monthly data from February 1980 to February 2014. The OP data were acquired from the Federal Reserve Bank of St. Louis. The NER, CPI, and IP data were obtained from International Financial Statistics. Hereinafter, OP, NEER, CPI, IP denote the oil price, nominal effective exchange rate index, consumer price index, and industrial production at time t , respectively.

Figure 2.1 The Nominal effective exchange rate index and the consumer price index for February 1980 to February 2014



2.5 Methodology

To determine whether Saudi Arabia's exchange rate policy prevents inflation following an oil shock, we followed Bernanke et al.'s (1997) approach which investigated the role of monetary policy in the U.S. recessions that followed oil shocks. They compared the impulse response function for U.S. output they estimated from the data against a counterfactual impulse response function. The counterfactual impulse response function was computed after changing the coefficients of the oil shock to zero in the Federal Reserve's reaction function.

However, our paper offers one important difference where the large change in policy adopted by the paper by Bernanke does lead to questions about the reliability of the results (Hamilton & Herrera, 2004). The Lucas critique is a concern when there is a drastic change in policy. For that reason, we multiply the monetary policy coefficients on the oil price shock by 0.8 rather than by 0, which reduces the size of the change in monetary policy. Rather than a change in the policy regime from a strong reaction to oil shocks to no reaction at all, as in Bernanke et al, we check the consequences of weakening the monetary policy reaction just a bit.

In other words, we investigated whether a Saudi policy reduces the inflationary effect of an oil price shock to estimate a BSVAR model for the Saudi economy where one of the equations is the nominal exchange rate response to the oil price shock controlled by the Saudi monetary authority. We compare the impulse response function for inflation's response to that oil price shock that we estimated in our data against a counterfactual impulse response function. We then computed the counterfactual impulse response function after multiplying the coefficient in the nominal exchange rate equation by 0.8. That means we moved from a fixed exchange rate to a limited floating exchange rate.

To do that, we use the Bayesian Structural Vector Autorepression model (BSVAR), written as follows:

$$A Y_t = B X_{t-1} + u_t \quad (2.1)$$

where Y_t is an $(n \times T)$ matrix of endogenous variables ($Y_t = OP_t, NER_t, CPI_t, IP_t$) which are the price of oil, the nominal exchange rate, the consumer price index, and industrial production. A is an $(n \times n)$ matrix of prior information or the structural relationship between the selected endogenous variables. X_{t-1} is an $(k \times T)$ matrix of lagged endogenous variables, B is an $(n \times k)$ matrix of lagged structural coefficient, u_t is an $(n \times T)$ matrix of structural errors, and D is an $(n \times n)$ diagonal covariance matrix of errors. Further, n is the number of variables included in our model, T is the number of observations, and k is determined by using the equation $k = n l + 1$. Baumeister and Hamilton (2017) treated u_t as a Gaussian random variable. Therefore, once we have the prior information about A , their approach assumes the prior information about other parameters are represented by parametric distributions. To calculate the Bayesian posterior distribution, Baumeister and Hamilton (2017) assume the prior information about D conditional on A as in the following equation:

$$p(D|A) = \prod_{i=1}^n p(d_{ii} | A) \quad (2.2)$$

where d_{ii} indicates the raw and column i of D .

The prior information for B becomes the structural coefficients as shown in the following equation:

$$p(B|D, A) = \prod_{i=1}^n p(b_i | D, A) \quad (2.3)$$

For equation (i)

$$b_i | D, A \sim N(m_i A, d_{ii} M_i) \quad (2.4)$$

where $b_i | D, A$ indicates the conditional Gaussian distribution, and b_i indicates the raw i of B matrix. Baumeister and Hamilton (2017) used the Metropolis Hastings algorithm to get different

draws of the parameters from posterior distribution by generating different draws of α^ℓ , d_{ii}^ℓ , and b_i^ℓ and then increasing ℓ by 1 and having many draws up to the total number of iterations.

To check the consequences of weakening the monetary policy reaction, we first obtain the impulse response function for inflation's response to oil price shocks from the data. To do so, once we get the posterior distribution of the $\tilde{A}$ matrix, $\tilde{B}$ matrix, and $\tilde{D}$ matrix by generating different draws, and we convert the BSVAR into the reduced form BSVAR as shown in the following equations.

$$(I - \tilde{A}) y_t = \tilde{B} y_{t-1} + \tilde{D}_t \quad (2.5)$$

$$y_t = (I - \tilde{A})^{-1} \tilde{B} y_{t-1} + (I - \tilde{A})^{-1} \tilde{D}_t \quad (2.6)$$

Thus, we can rewrite our model as:

$$Z_t = F Z_{t-1} + (I - \tilde{A})^{-1} E_t \quad (2.7)$$

where $Z_t = y_t$, $F = (I - \tilde{A})^{-1} \tilde{B}$, and $E_t = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$. We impose the shock of oil price, which is

one non-zero element, in E_t . We then calculate the IRF of the CPI to the oil price shock as follows:

$$IRF_k = F^k (I - \tilde{A})^{-1} E_t \quad (2.8)$$

We then obtain the counterfactual impulse response function by multiplying the first coefficient of the second equation, which is the direct effect of oil price shock on the exchange rate that is controlled by the Saudi monetary authority, by 0.8 in both the contemporaneous relationship matrix A in element α_{21} and the coefficients for matrix B in element B_{21} as shown below.

$$\hat{A} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.8 \alpha_{21} & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 0 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 0 \end{bmatrix} \quad \hat{B} = \begin{bmatrix} \hat{B}_{11} & \hat{B}_{12} & \hat{B}_{13} & \hat{B}_{14} \\ \hat{B}_{21} & \hat{B}_{22} & \hat{B}_{23} & \hat{B}_{24} \\ \hat{B}_{31} & \hat{B}_{32} & \hat{B}_{33} & \hat{B}_{34} \\ \hat{B}_{41} & \hat{B}_{42} & \hat{B}_{43} & \hat{B}_{44} \end{bmatrix} \quad (2.9)$$

$\hat{A}$ indicates the new A matrix after multiplying α_{21} by 0.8, and $\hat{B}$ indicates the new B matrix after multiplying $\hat{B}_{21}$ by 0.8.

We then recalculate the reduced form BSVAR as follows:

$$(I - \hat{A}) y_t = \hat{B} y_{t-1} + \tilde{D}_t \quad (2.10)$$

$$y_t = (I - \hat{A})^{-1} \hat{B} y_{t-1} + (I - \hat{A})^{-1} \tilde{D}_t \quad (2.11)$$

We can then rewrite our model as:

$$Z_t = \hat{F} Z_{t-1} + (I - \hat{A})^{-1} E_t \quad (2.12)$$

where $Z_t = y_t$, $F = (I - \hat{A})^{-1} \hat{B}$, and $E_t = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$. We impose a one unit shock to the oil price,

which is one non-zero element, in E_t . We then calculate the IRF of CPI to oil price shock as shown in the following equation:

$$IRF_k = \hat{F}^k (I - \hat{A})^{-1} E_t \quad (2.13)$$

However, once we have the impulse response function both for the data and for the counterfactual experiment, we can determine whether the Saudi policy which is the fixed exchange rate reduces the inflationary effect of an oil price shock or does not.

2.6 Results and Discussions

2.6.1 Unit Root Tests

It is common to investigate the stochastic properties for macroeconomic variables by using an empirical analysis to consider their order of integration by applying the Augmented Dickey-Fuller (1979) and Kwiatkowski (1992) tests. The results of these tests, as presented in Tables 1.1 and 1.2, confirm the nonstationary of the data in their levels while the series is stationary when the first differences are taken.

Table2.1 Augmented Dickey Fuller (1979) Unit Root Test.

	Level Data			First Difference Data		
	None	Drift	Trend	None	Drift	Trend
OP	0.22	-1.29	-2.64	-12.43	-12.4	-12.48
NER	-0.54	-1.69	-1.96	-12.99	-12.99	-12.98
CPI	3.95	3.48	0.78	-11.168	-11.78	-12.49
IP	-0.22	-2.39	-3.33	-14.46	-14.45	-14.45
Note: The 5% critical values for the ADF test are: None=-1.95, Drift=-2.87, and Trend=-3.42						

Table 2.2 Kwiatkowski et al (1992) Unit Root Test.

	Kwiatkowski-Phillips-Schmidt-Shin (1992)			
	Level		First Difference	
	Constant	Trend	Constant	Trend
OP	3.95	1.39	0.16	0.02
NER	2.30	0.58	0.08	0.08
CPI	4.75	1.03	0.43	0.11
IP	2.65	0.31	0.31	0.05
Note: The 5% critical values for the KPSS test: Constant=0.463, and Trend=0.146				

2.6.2 The Impulse Response Function

Figures 2.2 and 2.3 present the impulse responses with one standard deviation bands for the Bayesian structural VAR (BSVAR) and reduced form BSVAR. Clearly, inflation's response to an oil price shock differs before and after we change the exchange rate policy, indicating that Saudi Arabia's monetary policy is helpful for controlling inflation.

Figure 2.2 shows that the exchange rate's response to oil price shocks on BSVAR depreciates for seven months. The exchange rate appreciates over the remaining time horizon in response to oil price shocks and is significant only for the first 5 months. However, this result is contrary to economic theory regarding exporter countries. In theory, for oil-exporting countries, there is a positive relationship between oil price and exchange rate that shows a positive impact after 7 months that continues until the end of the horizon. However, the depreciations in the exchange rate are due to how Saudi Arabia's monetary policy is set for its own exchange rate, which is a fixed exchange rate. Figure 2.2 also illustrates inflation's response to oil price shocks, where the increase of inflation is associated with oil price shocks and insignificant for the entire horizon. Finally, the full results of the BSVAR is shown in Figure A.6 in the Appendix.

Figure 2.3 illustrates the reduced-form BSVAR of inflation's response to oil price shocks using different exchange rate policies before and after reducing the policy. Inflation's response to oil price shocks seems to differ under the current policy, which is the actual response, and under the reduced policy, which is the counterfactual inflation response. If inflation is initially 5% and the oil price increases by 1%, the actual response is 5.01% while the counterfactual response is 5.1%. In other words, when we move from a fixed exchange rate policy to the counterfactual limited floating exchange rate policy, inflation's response to oil price shocks changes, indicating

that the current exchange rate policy stabilizes inflation in the aftermath of oil shocks. For example, during the Iraq War in 2003, which caused a 19% increase in oil prices, the actual inflation rate was 0.6% (the World Bank, 2022) while the counterfactual inflation rate would have been 2.5%. The price of oil significantly increased by 38% in the first half of 2008; the actual inflation rate was 10% (Ramady, 2010) while the counterfactual inflation rate would have been 13.8%.

Overall, the results indicate that the effect of the exchange rate policy is important to explain inflation's response to oil price shocks in Saudi Arabia. Inflation has been noticeably lower since Saudi Arabia's adoption of a fixed exchange rate in 1986. According to Alkhareif and Qualls (2016), from 1974 to 1976, when the Saudi monetary policy adopted SDR, the non-oil inflation rate was higher than 30% as it was being affected by the increasing oil prices; when the Saudi monetary policy adopted the fixed exchange rate in 1986, the non-oil inflation rate was 3.1%. Thus, the fixed exchange rate policy has played an important role in the stabilization of Saudi Arabia's inflation rate.

Figure 2.2 The Responses of NER and CPI to Oil Price Shocks

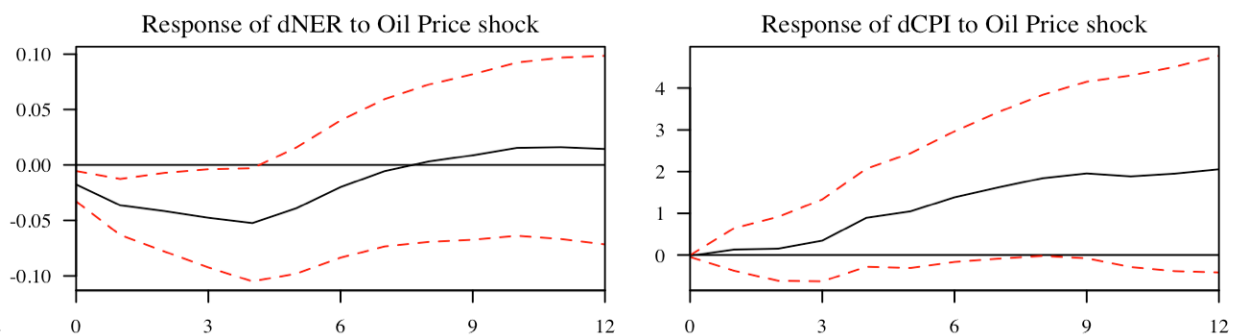
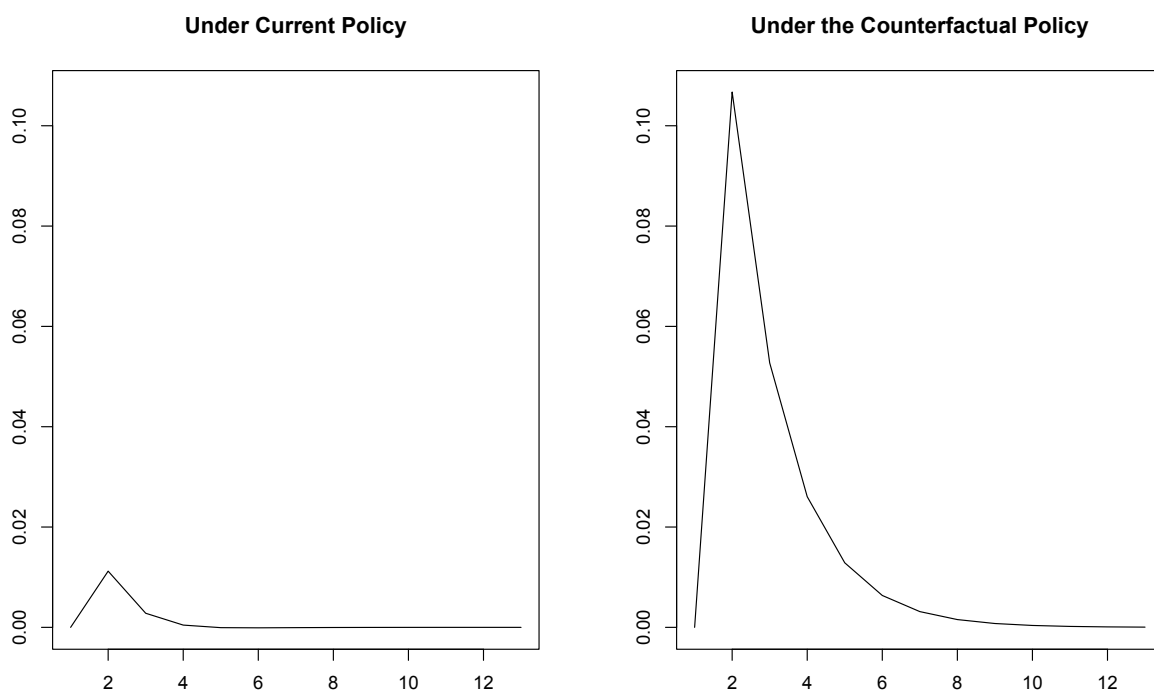


Figure 2.3 The Responses of CPI to Oil Price Shocks



2.7 Conclusion

Due to the Saudi economy's dependence on oil revenue and the fact that it is heavily dependent on imports of non-oil goods, fluctuations in oil prices affect its economy. Therefore, Saudi Arabia was keen to implement policies that would promote stability. In 1973, it adopted the special drawing rights and then adopted the fixed exchange rate in 1986. The level of inflation changed significantly between these two policies, surpassing 30% in the former but being only 3.1% during the latter. In this essay, we have investigated whether the fixed exchange rate policy played a role in lowering inflation levels. Following Bernanke et al.'s (1997) methodology, we found that the current exchange rate policy plays an important role in the response of inflation to oil price shocks. This essay aimed to show the Saudi Arabian Monetary Authority how effective its policy of pegging the Saudi riyal to the U.S. dollar is. Our results show that linking the riyal to dollar led to a decrease in the inflation rate whereas a limited floating exchange rate led to an increase in the inflation rate. Future studies should study how the inflation rate would change if the riyal were linked to another currency, such as the Chinese yuan or a European currency.

Chapter 3: How Should Saudi Arabia's Policy Makers View Oil Market Shocks if They are Concerned about Inflation?

3.1 Introduction

Since the 1970s, economists have studied whether increasing oil prices have any relationship with inflation, and they have found that the inflation rate differs by both countries and periods. Specifically, the inflation rate in developed countries was 0.3% while in developing countries it was 2.7% in 2015 according to Ha et al. (2019). Meanwhile, in terms of the time period, in Saudi Arabia, the highest level of inflation was 30% between 1974 and 1976, while the lowest level of inflation was 0.6% in 2002 (Ramady, 2005). The policies in Saudi Arabia sought to achieve stability in domestic prices, especially after the high levels of inflation that occurred in the 1970s. Inflation is still a source of concern, as the level of inflation rose from 1% in 2005 to 10% in 2008 in response to oil price increases (Ramady, 2010). Although both fiscal and monetary policy are used, fiscal policy is dominant because the government tries to maintain steady government spending to deal with any fluctuations in oil revenues. They have adopted countercyclical fiscal policy.

Internal factors affecting inflation include government spending and the money supply. In Saudi Arabia, both are affected by oil prices. The exchange rate is an important determinant of inflation because of the kingdom's heavy reliance on imports of many goods. As a result, trading partners' inflation is transmitted to Saudi Arabia's economy through the import channel. According to Ramady (2005), the government spends 6 billion riyals annually on subsidies for goods and services to keep prices stable. If prices of these commodities continue to rise, the government faces a choice: continue to increase the related subsidies or make them adapt to the rise in prices.

Kilian (2009) identified different sources that cause the price of oil to increase, thereby generating different responses in the U.S. inflation rate. Most economies following Kilian's (2009) method have shown that increasing the price of oil causes different responses in the inflation rate. As Saudi Arabia's policymakers seek to control inflation, it is useful for them to know how to react in the face of oil market shocks (i.e., the source of oil price increases) to control the inflation rates in different sectors. Saudi Arabia's policymakers are looking to stabilize certain sectors over others by paying subsidies. Thus, the government spends 6 billion riyals annually on subsidies for some sectors, namely the housing, water, electricity, gas, and other fuels sector and also the food and beverages sector in order to try and keep prices stable (Ramady, 2005). In this essay, we explore how much Saudi Arabia's inflation sectors change due to oil market shocks, including world oil supply shocks, world aggregate demand shocks, and oil-specific demand shocks. The goal is to provide information that can be used by Saudi Arabia's monetary and fiscal authorities when setting policy.

To the best of our knowledge, this is the first paper to consider the effect of these global shocks on the consumer price indexes in Saudi Arabia. Our results show that the effect of oil market shocks on the consumer price index differs according to sectors, and the oil-specific demand shocks have the largest impact in most of the sectors compared to other structural oil market shocks. As a result, Saudi Arabian authorities may need to take the necessary actions to combat inflation, especially if the increase in oil prices is caused by an oil-specific demand shock.

The remainder of this essay is organized as follows. The next section details subsidies that Saudi Arabia provides to stabilize consumer price indexes in certain inflation sectors. Section 3.3 reviews the relevant literature. Section 3.4 presents the data, and Section 3.5 describes the methodology. Section 3.6 discusses the results. Finally, Section 3.7 offers conclusions.

3.2 Saudi Arabian Subsidies to Stabilize Consumer Price Indexes in Certain Inflation Sectors

The Saudi government provides subsidies to specific sectors, such as food and beverages, and housing, and also water, electricity, gas, and other fuels. According to Ramady (2005), the government spends 6 billion riyals annually on subsidies for goods and services to keep their prices stable. If the prices of these commodities continue to rise, the government faces a choice: either continue to increase the subsidies for these commodities or make the sectors adapt to the rise in prices. In terms of fuel and electricity prices, in Saudi Arabia, high oil prices lead to increased prices in the oil sector industries; consequently, fuel and electricity prices increase. Thus, in 2015, Saudi Arabia enacted a lifting of subsidies for energy and water prices to curb individuals' increased consumption, which also contributed to increasing their prices. Several support programs also contributed to help individuals face higher consumer price indexes. The government implemented several policies to control inflation, such as entering a citizen account in December 2017 where energy subsidies could provide different amounts to 3.5 million families. The civil service also carried out wage reforms by giving civil and military employees 1,000- riyals cost-of-living allowances between January 2018 and the end of 2019, resulting in the government spending 70 billion riyals for this particular subsidy.

Increasing oil prices also caused housing costs to rise. Therefore, a mortgage program was introduced in 2016 to help Saudi families who were applying for mortgage loans, and the government offered homes at reasonable prices. According to IMF Report No. 19/290 (2019), the government encouraged construction through financing to increase the housing supply and provided support to developers and subsidized loans worth 120 billion riyals as of February 2018. In these ways, the public and private sectors worked together to monitor financial stability in the

real estate market. According to IMF Report No. 19/291 (2019), a 25% tax on undeveloped lands was announced in 2016 and was implemented in March 2017. The tax revenues from unused land amounted to one billion riyals in 2018 to encourage more investment in these lands.

The increase in oil prices also led to a global increase in food prices. Rice was particularly affected due to the restrictions imposed on its export when the domestic supply decreased. Rice and wheat producers also had started relying on biofuels and renewable energy, which further increased prices. According to Ramady (2010), Saudi Arabia tried to control these prices to reduce inflation and provided rice subsidies and social welfare payments and raised wages by 15%. The government also reduced customs duties for many foods and other commodities by 5% to 20% from 2008 to 2009.

3.3 Literature Review

First, we review some important studies of the U.S., which is one of the developed countries highlighted by researchers such as Hooker (2002), who studied the effect of changes in oil prices on inflation in the U.S. using Phillips curve models. Hooker found that the oil price shocks before 1981 led to a rise in inflation, while inflation did not appear after that. Bachmeier and Cha (2011) examined the effect of oil price shocks on U.S. inflation rates using bivariate models and demonstrated that oil price shocks do not have the same effect on inflation, as changes in the response of the consumer price index to oil shocks vary according to the time period. In 1970, the consumer price index's response to the oil price shock was great, while whereas after 1986 it was weak.

Barsky and Kilian (2002) studied the impact of the fluctuation of oil prices on inflation. They found that oil price shocks played a major role in increasing inflation, especially between 1973 and 1974 and between 1979 and 1980 as a result of rises in oil prices. Kilian (2009) explored the response of the U.S. economy to oil supply and demand shocks using a structural VAR and found that different oil shocks affected the U.S. economy differently. Kilian and Park (2009) studied the impact of global oil market shocks on real stock returns in the U.S. and found that U.S. stock returns responded differently to different types of oil price shocks. Kilian and Zhou (2021) examined the fluctuations in oil and gasoline price shocks on inflation and inflation expectations using a structural VAR. They noted that the impact of oil price scenarios on headline inflation and core inflation differed; the monthly effects were greater and disappeared quickly compared to the annual effects.

Some studies have focused on developed and developing countries, such as Choi et al.'s (2018) research on the effect of oil price changes on domestic inflation in 72 developed and

developing countries. They highlighted the differences in the impact of oil price shocks across advanced and developing countries using a structural VAR and asymmetry oil price shocks. They found that global price inflation leads to an increase in domestic inflation, but this effect disappears over time of period while similarities occurred between advance and developing economies. The asymmetry of oil price shocks indicated that positive shocks have a greater effect than negative shocks. Sarmah and Bal (2021) studied the effect of oil price on inflation and economic growth in India by using the structural VAR and nonlinear and asymmetric autoregressive distribution lag. They found that oil price negatively affects economic growth but positively affects inflation. Using asymmetric autoregressive distribution lag, they found the same result for the positive side of oil prices on inflation and economic growth, while the negative side showed an effect on economic growth.

A limited number of studies have examined the effects of inflation in Saudi Arabia. Hasan and Alogoskoufis (2008) explored the external factors of inflation and included the local factors on GCC countries using cointegration tests and VEC model estimates. They found that inflation in Saudi Arabia is driven by trading partners, while domestic factors have little effect in the short term. Kandil and Morsy (2009) found that external factors have a greater impact on inflation in the GCC, including Saudi Arabia, than local factors based on the results of cointegration tests and estimated impulse response functions. According to Ramady (2009), which emphasized the effect of external and local variables on inflation by using correlation tests and a linear model with OLS, the depreciation of the riyal in conjunction with the depreciation of the dollar led to an increase in imported inflation in Saudi Arabia. Nazer (2016) considered several variables-namely, trading partner, oil price, U.S. interest rate, money supply and real GDP- by using cointegration, causality tests, and the linear model with OLS and found that the main cause of inflation in Saudi Arabia is

trading partner and the money supply. Osman et al. (2019) examined the cause of inflation effects on Saudi Arabia's economy using an impulse response and variance decomposition test. They showed that certain factors (i.e., money supply, oil price, real GDP, and world inflation rate) have a positive effect on inflation. In contrast, the stock price index showed a negative impact on inflation, while the exchange rate had no effect on inflation.

Table 3.1 Summary of the Literature Review

Citation	Purpose	Method	Conclusions
Hooker (2002)	identifies a structural break in core U.S. inflation	basic Phillips curve models	The results indicated that oil price shocks before 1981 led to a rise in inflation, but inflation did not appear after that.
Bachmeier and Cha (2011)	investigated the effect of oil price shocks on U.S. inflation rates	bivariate models	The results of this study demonstrated that oil price shocks do not have the same effect on inflation, as changes in the response of the consumer price index to oil shocks vary according to the time period. In 1970, the consumer price index's response to the oil price shock was great whereas after 1986 it was weak.
Barsky and Kilian (2002)	used oil prices shocks as an endogenous variable to study their effect on the U.S. economy	classic resource extraction model	Oil price shocks played a major role in increasing inflation, especially between 1973 and 1974 and between 1979 and 1980 as a result of rises in oil prices.
Kilian (2009)	examined how oil price shocks affect the U.S. economy	SVAR model	Oil shocks affected the U.S. economy differently.
Kilian and Park (2009)	examined the effect of global oil market shocks on real stock returns in the U.S.	SVAR model	U.S. stock returns responded differently to different types of oil price shocks.
Kilian and Zhou (2021)	investigated the fluctuations in oil and gasoline price shocks on inflation and inflation expectations	SVAR model	The impact of oil price scenarios on headline inflation and core inflation differed; the monthly effects were greater and disappeared more quickly compared to the annual effects.
Choi et al.'s (2018)	researched the effect of oil price changes on domestic	SVAR model and asymmetry oil price shocks	The authors found that global price inflation leads to an increase in domestic inflation, but this effect disappears over

	inflation in 72 developed and developing countries		time; meanwhile, similarities occurred between developed and developing economies. The asymmetry of oil price shocks indicated that positive shocks have a greater effect than negative shocks.
Sarmah and Bal (2021)	studied the effect of oil price on inflation and economic growth in India	SVAR model and nonlinear and asymmetric autoregressive distribution lag	The authors found that oil price negatively affects economic growth but positively affects inflation. Using asymmetric autoregressive distribution lag, they found the same result for the positive side of oil prices on inflation and economic growth, while the negative side showed an effect on economic growth.
Hasan and Alogeel (2008)	explored the external factors of inflation and included the local factors on GCC countries	cointegration tests and VEC model estimates	The authors found that inflation in Saudi Arabia is driven by trading partners, while domestic factors have little effect in the short term.
Kandil and Morsy (2009)	explored the external factors of inflation and included the local factors on GCC countries	cointegration tests and impulse response functions	The results indicated that external factors have a greater impact on inflation in the GCC, including Saudi Arabia, than local factors.
Ramady (2009)	emphasized the effect of external and local variables on inflation	correlation tests and a linear model with OLS	The depreciation of the riyal in conjunction with the depreciation of the dollar led to an increase in imported inflation in Saudi Arabia.
Nazer (2016)	explored causes of inflation in Saudi Arabia	cointegration, causality tests, and the linear model with OLS	The authors concluded that the main causes of inflation in Saudi Arabia are the trading partner and the money supply.
Osman et al. (2019)	examined the cause of inflation effects on Saudi Arabia's economy	impulse response and variance decomposition test	The results showed that certain factors (i.e., money supply, oil price, real GDP, and world inflation rate) have a positive effect on inflation. In contrast, the stock price index showed a negative impact on inflation, and the exchange rate had no effect on inflation.

3.4 Data

This study applied monthly time series data from Kilian's (2009) corrected data from January 1973 through February 2020. The data included world crude oil production (COP), global real economic activity (IP), and U.S. crude oil by refiners (OP). To determine world crude oil production, we considered the percentage change when crude oil is deflated by CPIAUCSL. In addition, we used the consumer price index as a sector for Saudi Arabia from January 2011 through December 2021. The world crude oil production and crude oil prices were collected from the U.S. Energy Information Administration. The U.S. consumer price index was accessed from the Federal Reserve Bank of St. Louis. Global real economic activity came from the Federal Reserve Bank of Dallas. The Saudi Arabian consumer price index as a sector was acquired from the International Monetary Fund.

3.5 Methodology

We used Kilian's (2009) model to estimate the structural VAR model using our monthly data as follows:

$$A_0 Y_t = \alpha + \sum_{i=1}^q A_i Y_{t-i} + \varepsilon_t \quad (3.1)$$

where the vector Y_t is global oil production, global real economic activity, and real price of crude oil. In addition, the lag length q is chosen according to AIC, which is equal to five lags. Also, the vector of ε_t denotes the uncorrelated error. We can rewrite Equation 1 as follows:

$$Y_t = \alpha A_0^{-1} + \sum_{i=1}^q A^* Y_{t-i} + e_t \quad (3.2)$$

where $Y_t = (\Delta \text{prod}_t, \text{rea}_t, \text{rpo}_t)$, $A^* = A_0^{-1} A_i$ and $e_t = A_0^{-1} \varepsilon_t$

To identify our shocks using recursive identification, we assumed that global oil production does not contemporaneously respond to both global real economic activity and the real price of crude oil. In addition, the global real economic activity does not respond contemporaneously to the real price of crude oil. The first block of Kilian's (2009) model focused on oil supply and demand shocks.

$$e_t = \begin{bmatrix} e_{1t}^{\text{global oil production}} \\ e_{2t}^{\text{global real economic activity}} \\ e_{3t}^{\text{real price of oil}} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t}^{\text{oil supply shock}} \\ \varepsilon_{2t}^{\text{Aggregate demand shock}} \\ \varepsilon_{3t}^{\text{oil-specific demand shock}} \end{bmatrix} \quad (3.3)$$

where ε_{1t} denotes the oil supply shock, ε_{2t} captures the aggregate demand shock, and ε_{3t} denotes the oil-specific demand shock. In the second block, we study the impact of these structural shocks on the SACPI sectors. After we determine the above shocks, CPI sectors will respond to these shocks based on the following regression

$$CPI_{ST} = \alpha_j + \sum_{i=0}^{12} \beta_{ji} \hat{\varepsilon}_{j,t-i} + U_{jt} \quad j = 1,2,3 \quad (3.4)$$

where U_{jt} is the error, β_{ji} is the impulse response coefficient at horizon 12, and $\hat{\varepsilon}_{j,t-i}$ for $j = 1, 2, 3$ represents the structural shocks.

3.6 Results and Discussions

3.6.1 Unit Root Tests

The first step of our analysis was ascertaining the stationarity of economic variables. we used the standard root test, the Augmented Dickey-Fuller test (1979) and Kwiatkowski-Phillips-Schmidt-Shin tests. The results are presented in Tables 3.2 and 3.3 show that both tests confirmed the nonstationary of our selected variables in their level but not in their first differences except for crude oil production which was stationary in its level.

Table 3.2 Augmented Dickey-Fuller and Kwiatkowski et al Unit Root Tests in The
Level

	Augmented Dickey-Fuller test (1979) Test		Kwiatkowski-Phillips-Schmidt-Shin (1992) Test	
	Constant	Trend	Constant	Trend
COP	-18.57	-18.55	0.03	0.02
IP	-4.27	-4.27	0.37	0.39
OP	-3.06	-3.08	1.07	0.94
	Augmented Dickey-Fuller test (1979) Test		Kwiatkowski-Phillips-Schmidt-Shin (1992) Test	
	Constant	Trend	Constant	Trend
CPI Index:				
Food and Beverages	-0.056	-1.125	2.210	0.392
Tobacco	-0.812	-2.155	2.639	0.250
Clothing and Footwear	-1.273	-1.775	0.871	0.390
Housing, Water, Electricity, Gas, and Other Fuels	-1.833	-1.148	0.800	0.654
Furnishings, Household Equipment	-1.237	-2.314	1.935	0.269
Health	-1.919	-3.538	2.670	0.396
Transport	-0.448	-3.442	2.545	0.198
Communication	-0.303	-1.256	1.127	0.314
Recreation and Culture	-2.542	-2.514	0.733	0.254
Education	-1.686	-1.648	1.903	0.457
Restaurants and Hotels	-0.024	-2.057	2.522	0.408
Miscellaneous Goods and Services	-1.814	-2.829	1.981	0.207
Note: The 5% critical values for ADF test: Drift=-2.88, and Trend=-3.43; for KPSS test: Constant=0.463, and Trend=0.146				

Table 3.3 Augmented Dickey-Fuller and Kwiatkowski et al Unit Root Tests in
First Difference

Augmented Dickey-Fuller test (1979) Test		Kwiatkowski-Phillips-Schmidt-Shin (1992) Test		
	Constant	Trend	Constant	Trend
COP	-28.62	-28.59	0.01	0.01
IP	-15.18	-15.16	0.05	0.05
OP	-12.55	-12.54	0.05	0.05
Augmented Dickey-Fuller test (1979) Test		Kwiatkowski-Phillips-Schmidt-Shin (1992) Test		
	Constant	Trend	Constant	Trend
CPI Index:				
Food and Beverages	-7.62	-7.59	0.16	0.13
Tobacco	-8.36	-8.34	0.07	0.07
Clothing and Footwear	-7.32	-7.36	0.20	0.13
Housing , Water, Electricity, Gas, and Other Fels	-5.75	-6.51	0.98	0.09
Furnishings, Household Equipment	-8.51	-8.48	0.08	0.08
Health	-8.48	-8.62	0.18	0.02
Transport	-8.58	-8.57	0.06	0.03
Communication	-8.23	-8.32	0.20	0.07
Recreation and Culture	-8.05	-8.05	0.11	0.07
Education	-7.94	-7.98	0.13	0.05
Restaurants and Hotels	-8.17	-8.17	0.10	0.05
Miscellaneous Goods and Services	-7.45	-7.43	0.13	0.12
Note: The 5% critical values for ADF test: Drift=-2.88, and Trend=-3.43; for KPSS test: Constant=0.463, and Trend=0.146.				

3.6.2 Impulse Response Functions

Figures 3.1-3.6 present the impulse responses with a one-standard deviation bands for all consumer price index areas. The response of the consumer price index to structural oil market shocks differs depending on the source of the shocks.

The food and beverages sectors are represented in Figure 3.1.A, tobacco is represented in Figure 3.1.B, furnishings and household equipment are represented in Figure 3.3.A, health is represented in Figure 3.3.B, transport is represented in Figure 3.4.A, and restaurants and hotels are represented in Figure 3.6.A. The plotted impulse responses for health, as well as restaurants and hotels indicate positive responses for the three oil market shocks, which means there is only a difference in the magnitude. The plotted impulse responses for the food and beverages, tobacco, furnishings and household equipment, and transport sectors indicate positive responses over time due to aggregate demand shocks and oil-specific demand shocks, while the effect of oil supply shocks fluctuated between positive and negative for these sectors. Thus, structural oil market shocks produce different responses for these sectors.

The clothing and footwear sector is represented in Figure 3.2.A, while the housing, water, electricity, gas, and other fuels sector is represented in Figure 3.2.B. The plotted impulse response for clothing and footwear was negative to aggregate demand shocks and oil-specific demand shocks while the effect of oil supply shocks fluctuated between positive and negative in this sector. On the contrary, the plotted impulse response for the housing, water, electricity, gas, and other fuels sector was positive due to oil supply shocks and aggregate demand shocks while the effect of oil-specific demand shocks fluctuated between positive and negative for this sector. These sectors also show different responses to oil market shocks.

The education sector is represented in Figure 3.5.B, while the miscellaneous goods and services sector is represented in Figure 3.6.B. The plotted impulse responses indicate that the positive responses are associated with aggregate demand shocks and oil-specific demand shocks, while the effect of oil supply shocks fluctuated between positive and negative in these sectors. In addition, the communication sector is represented in Figure 3.4.B, and the recreation and culture sector is represented in Figure 3.5.A. The plotted impulse response for communication showed a negative response due to oil supply shocks and a positive response due to oil-specific demand shocks; the aggregate demand shocks produced no responses. The communication sector showed clearly differing responses in oil price shocks. The plotted impulse response for the recreation and culture sector seems to have different response to oil supply and oil-specific demand shocks where it responds negative to oil supply shock and positive to oil-specific demand shock whereas the sector responds negatively to aggregate demand shocks.

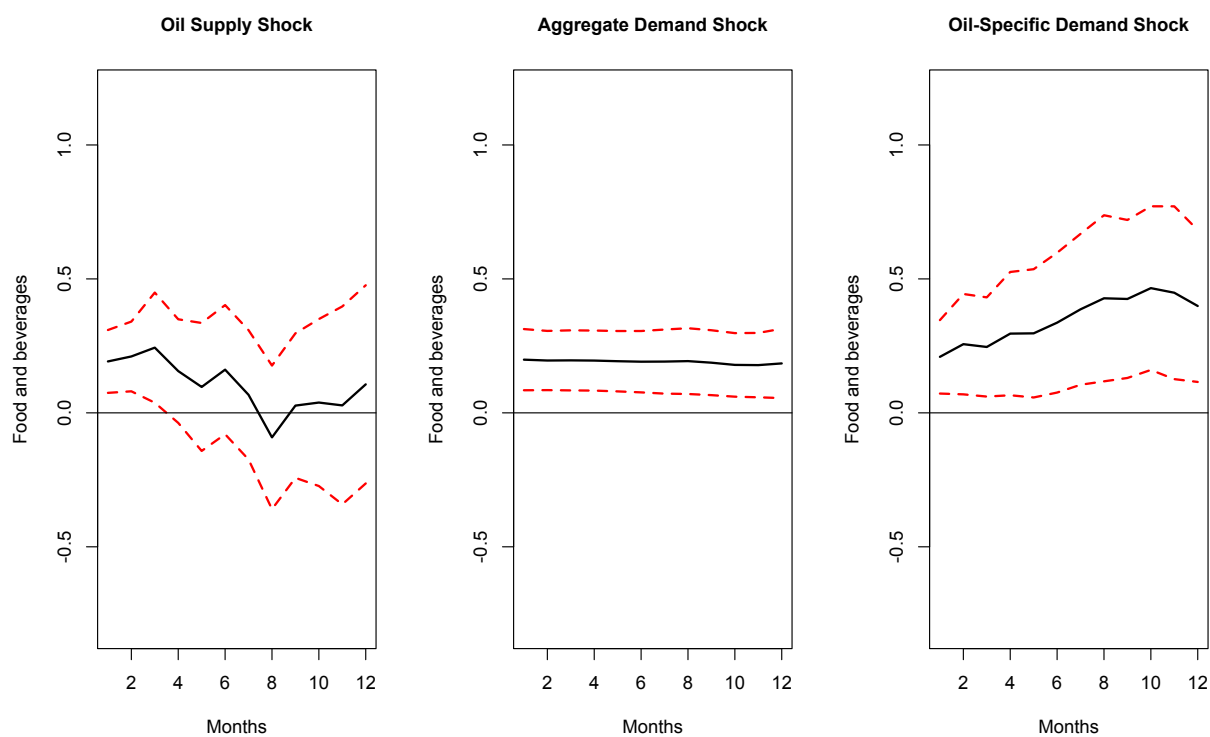
One of the reasons inflation sectors respond differently is that the government spends 6 billion riyals annually on subsidies for some sectors, such as goods and services, to keep prices stable (Ramady, 2005). From our results, we can conclude that the tobacco sector has a strong response to oil price shocks because the government does not support any sector harmful to the population's health. The housing, water, electricity, gas, and other fuels sector also has a strong response to oil price shocks, although the government has implemented several policies to address consumer price indexes. For example, in December 2017, citizen accounts were established so the government could provide subsidies to the energy sector by giving different amounts to a large number (nearly 3.5 million) of families. Moreover, a mortgage program was introduced in 2016 to support Saudi families in applying for mortgage loans, and the government offered homes at reasonable prices. According to IMF Report No. 19/290 (2019), the government encouraged

construction through financing to increase the housing supply and by providing support to developers and subsidized loans worth 120 billion riyals in February 2018. The food and beverages sector also has a strong response to oil price shocks, although the government carried out wage reforms by giving civil and military employees 1,000- riyals cost-of-living allowances, which cost the government 70 billion riyals. In addition, according to Ramady (2010), Saudi Arabia tried to control prices to reduce inflation by providing rice subsidies. Finally, the health, restaurants and hotels sectors have a limited responses to oil price shocks.

In sum, our results help provide insights for policymakers as they respond to oil price shocks. By knowing the impact of each shock on inflation in various sectors, they can help the central bank when they set monetary policy or fiscal policy. Sectors that have a strong response to oil price shocks, such as the housing, water, electricity, gas, and other fuels sector and the food and beverages sector, should be targeted more by fiscal policy than others that have a limited response after different oil shocks. In addition, our results show that the oil-specific demand shocks have a larger impact than other shocks on most sectors, as shown in Figures A.7–A.18 in the Appendix. Fiscal policy affects the economy through government spending while imposing taxes, such as the value-added tax in 2018. The ministry tries to maintain steady government spending to deal with any fluctuations in oil revenues by adopting counter-cyclical policies. At the same time, the Saudi Arabian Monetary Agency oversees monetary policy by contributing to the management of both liquidity and interest rates.

Figure 3.1 The Responses of food and beverages sector and tobacco sector to structural oil shocks

A- Food and Beverages



B- Tobacco

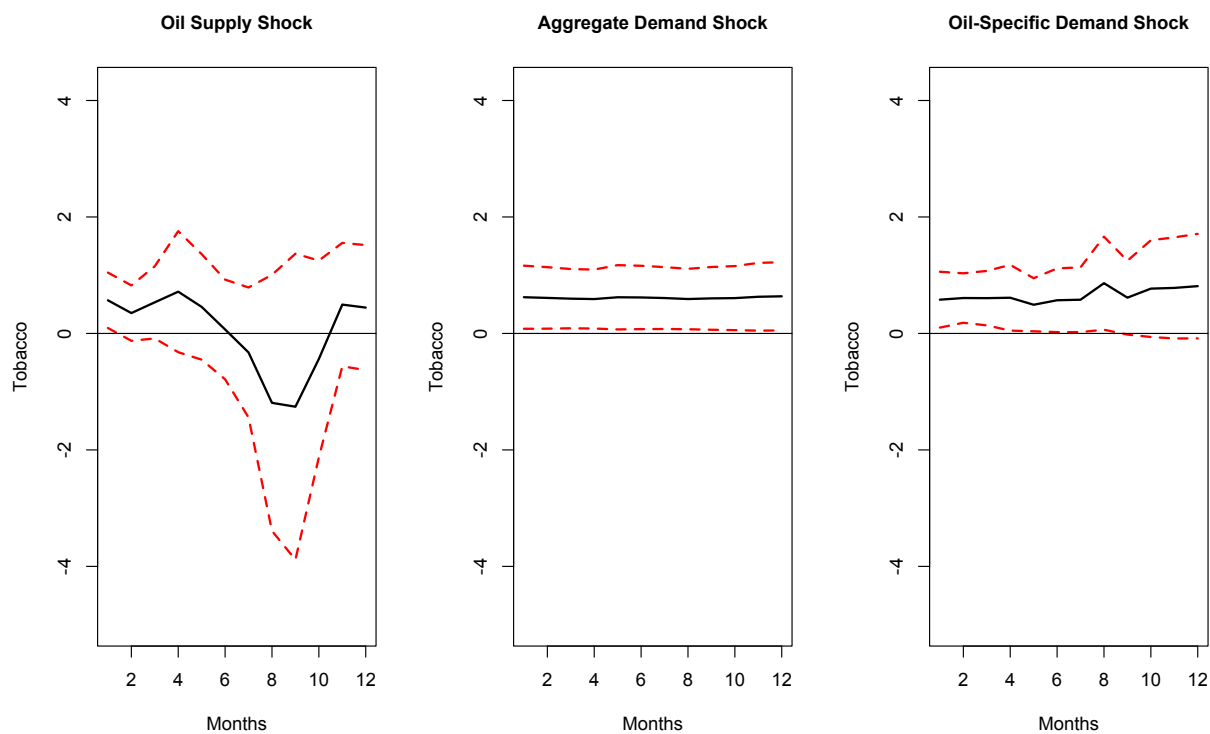
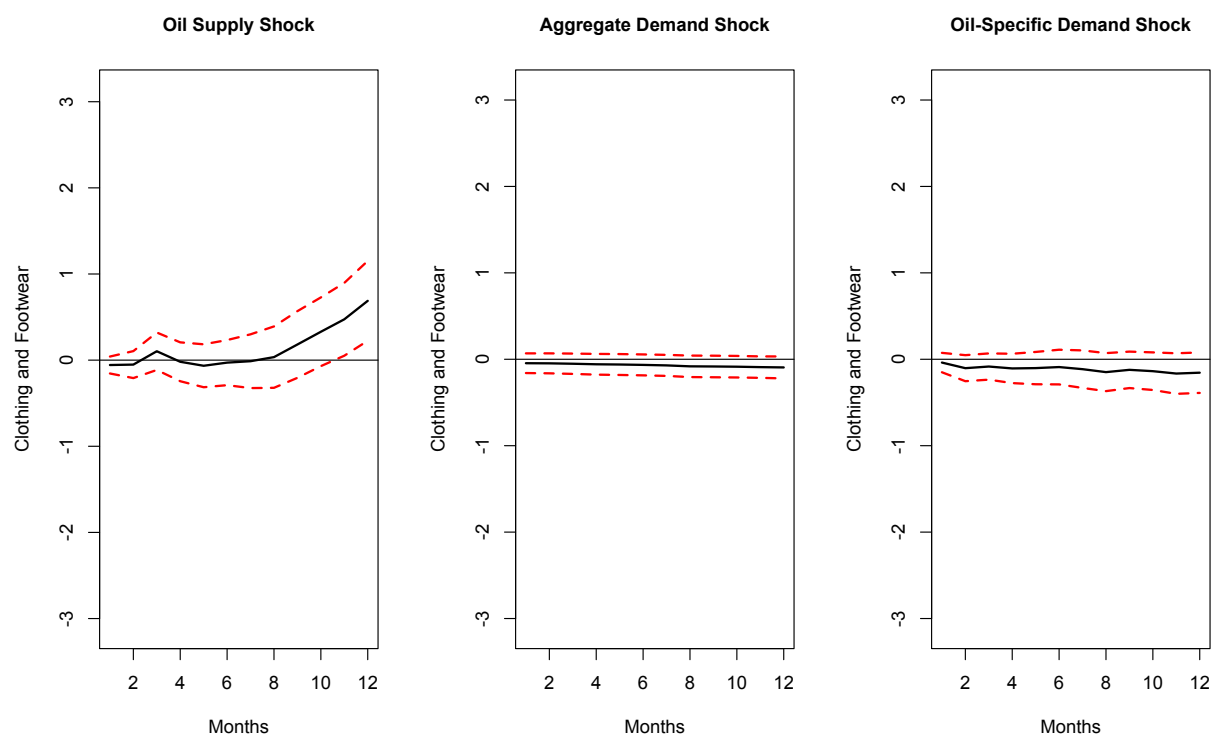


Figure 3.2 The Responses of clothing and footwear sector and housing, water, electricity, gas, and other fuels sector to structural oil shocks

A- Clothing and Footwear



B- Housing, Water, Electricity, Gas, and Other Fuels

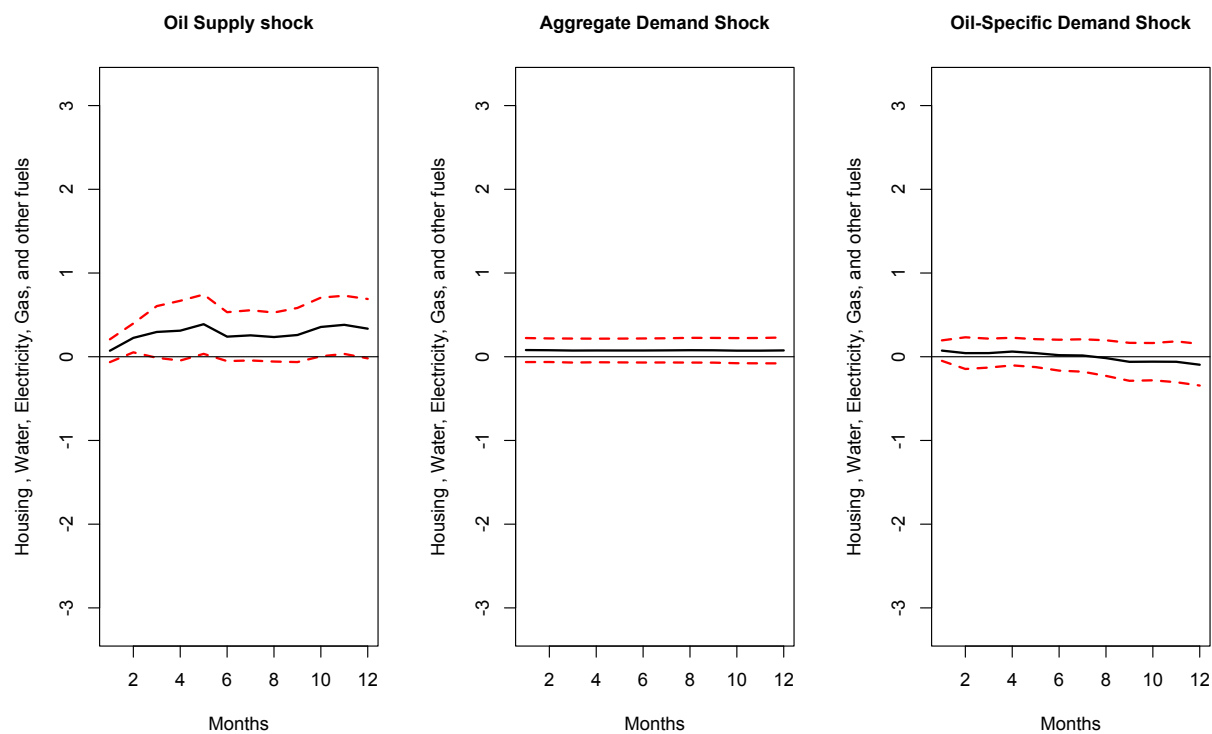
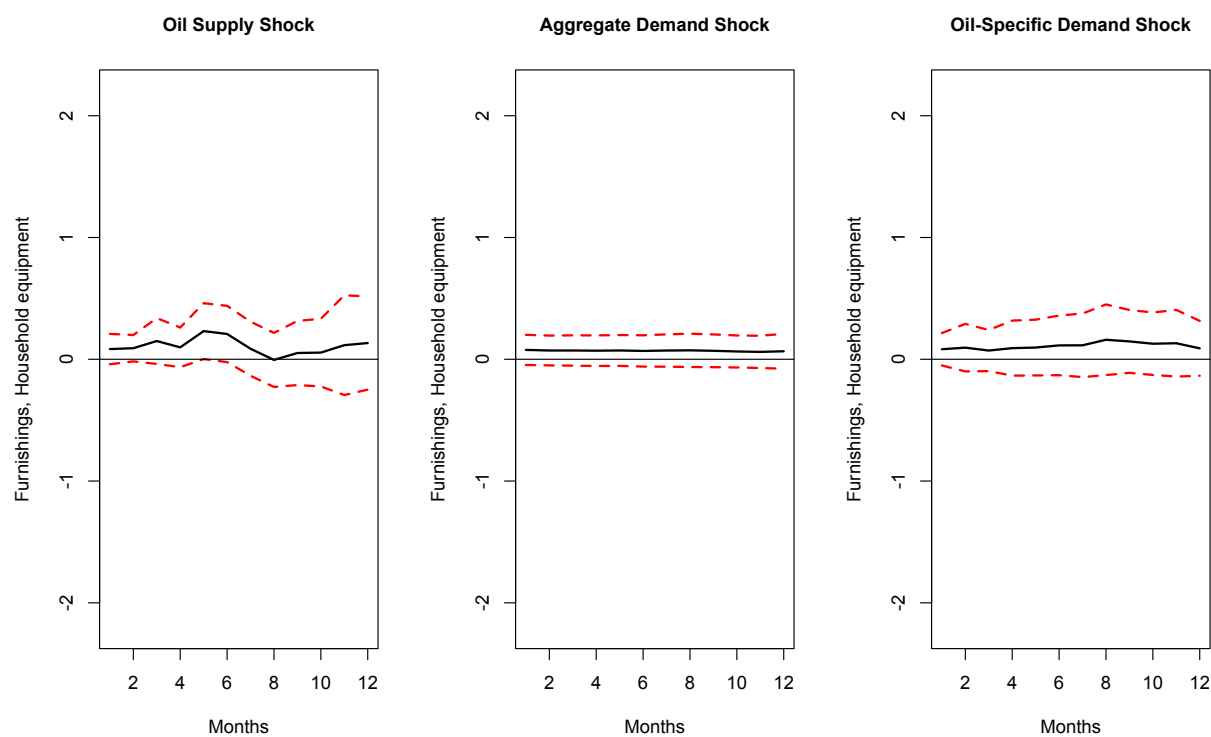


Figure 3.3 The Responses of furnishings and household equipment sector and health sector to structural oil shocks

A- Furnishings and Household Equipment



B- Health

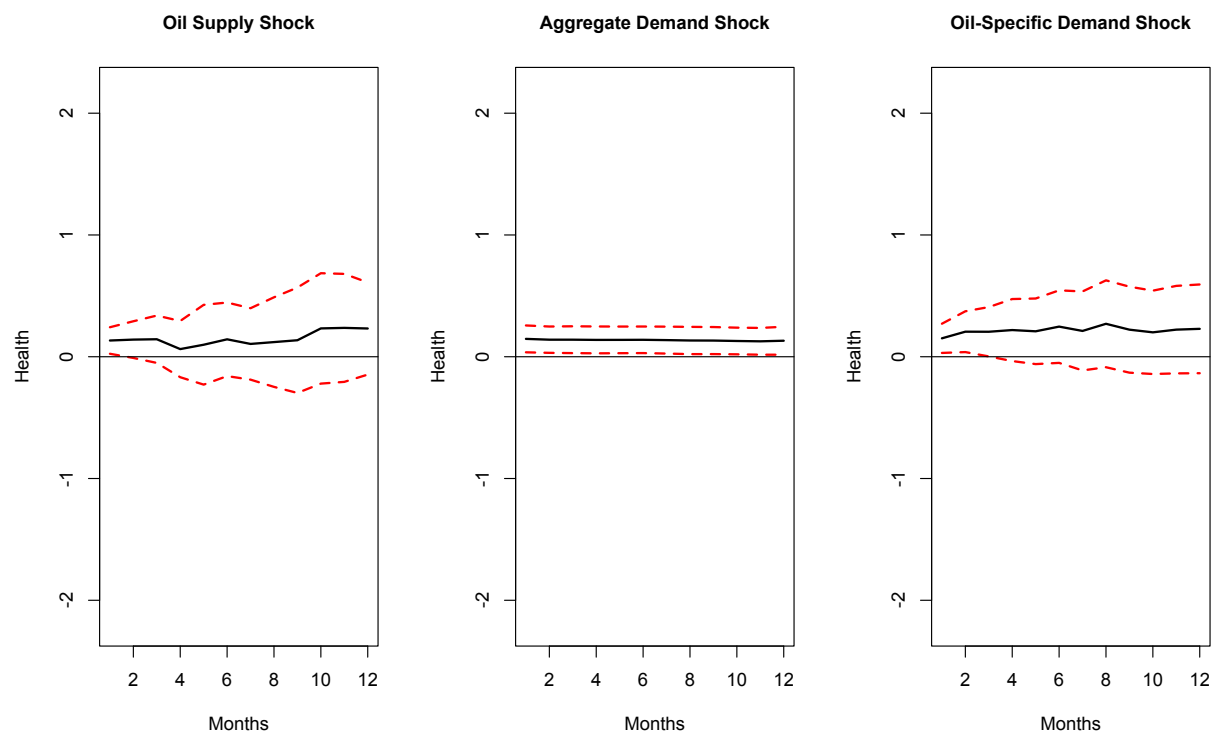
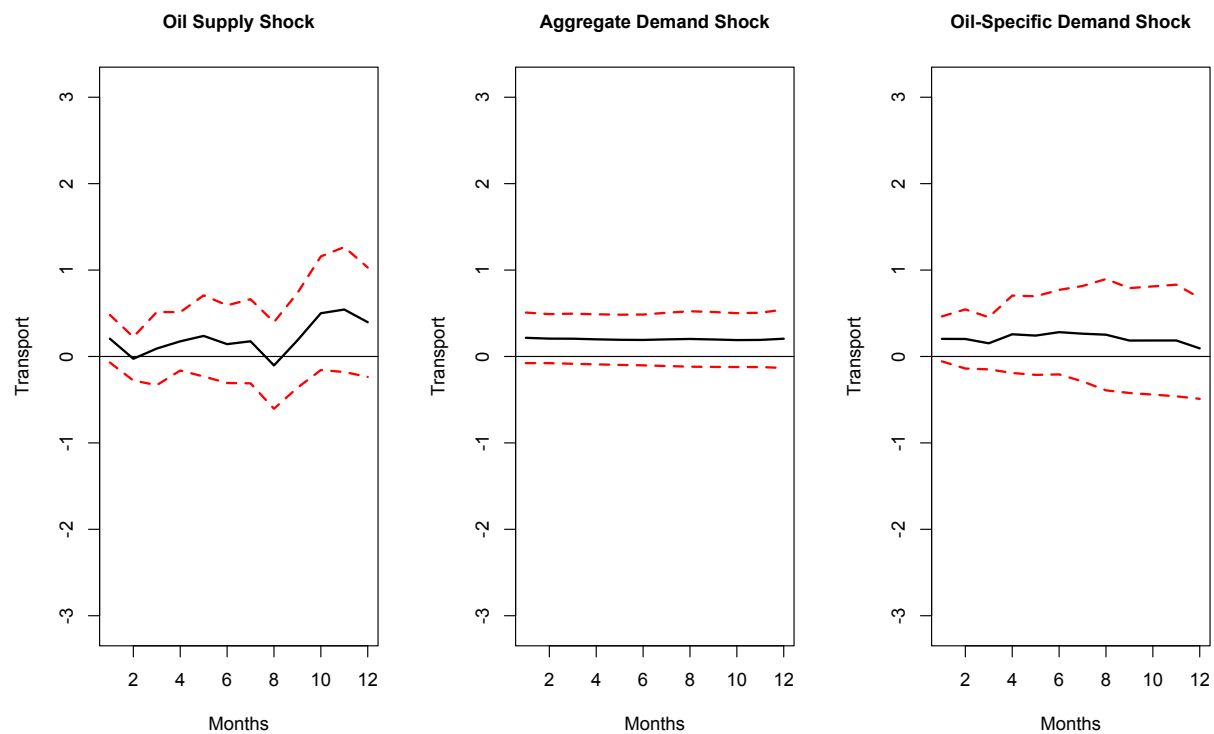


Figure 3.4 The Responses of transport sector and communication sector to structural oil shocks
A- Transport



B- Communication

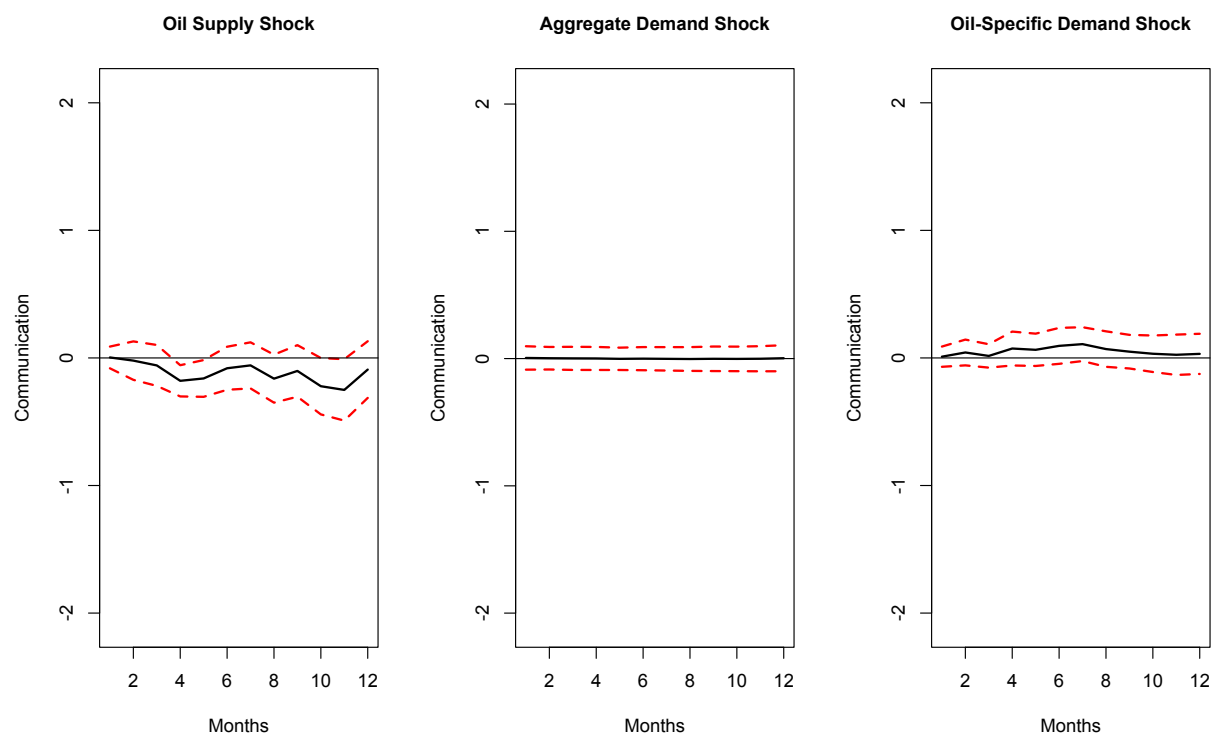
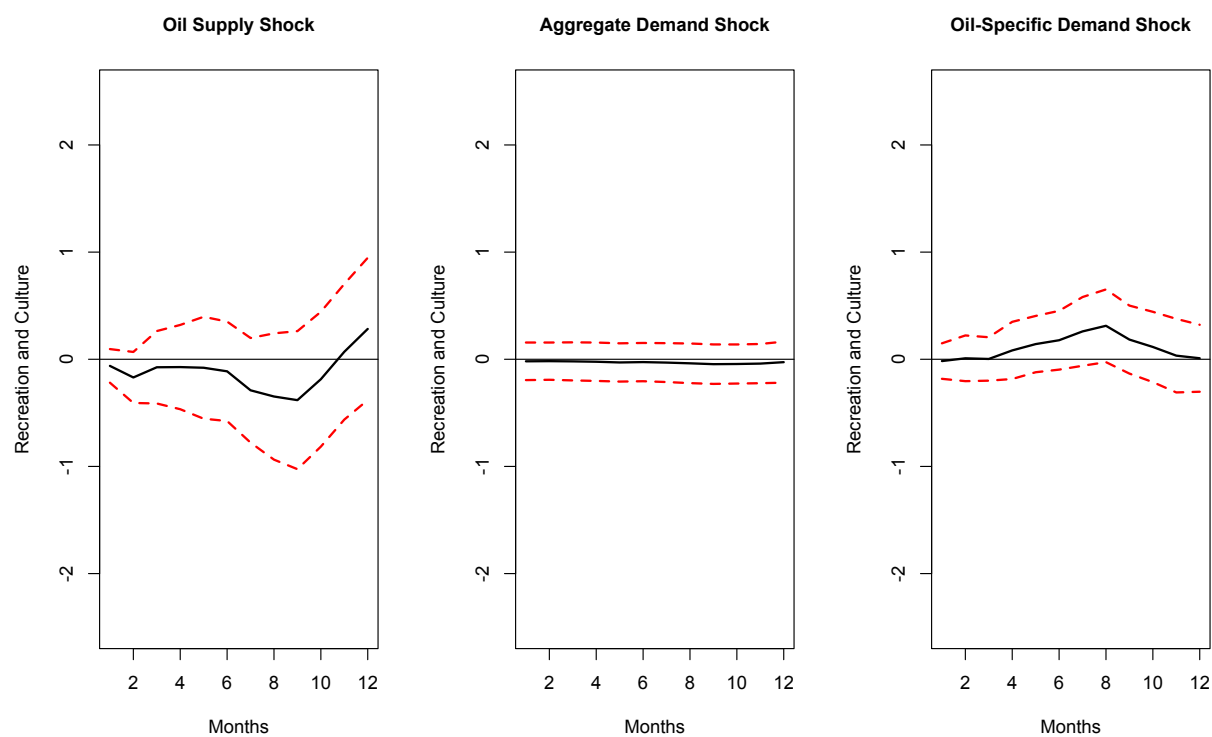


Figure 3.5 The Responses of recreation and culture sector and education sector to structural oil shocks

A- Recreation and Culture



B- Education

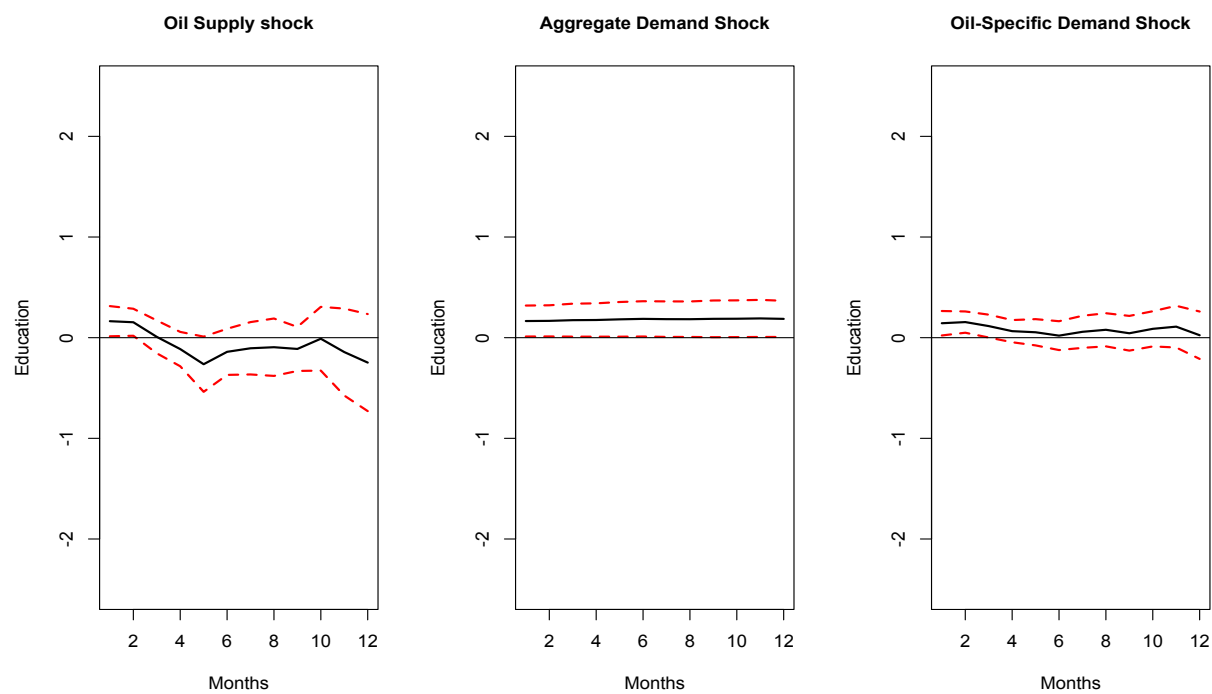
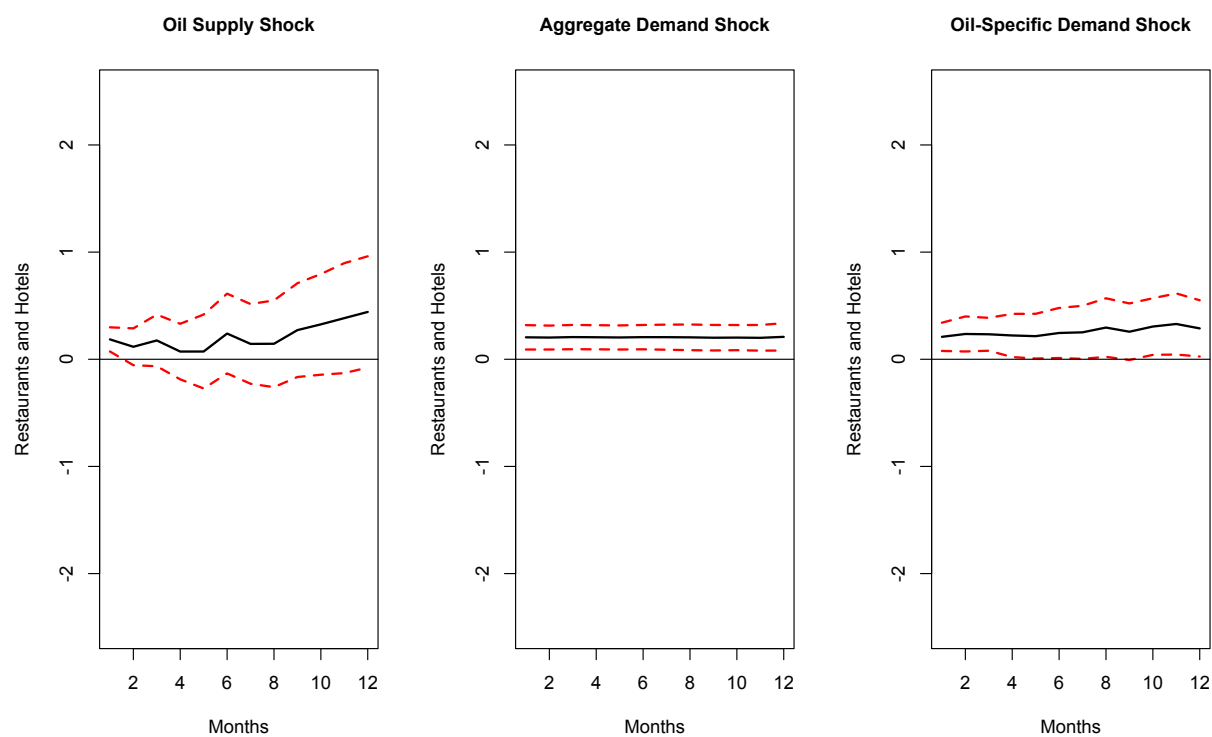
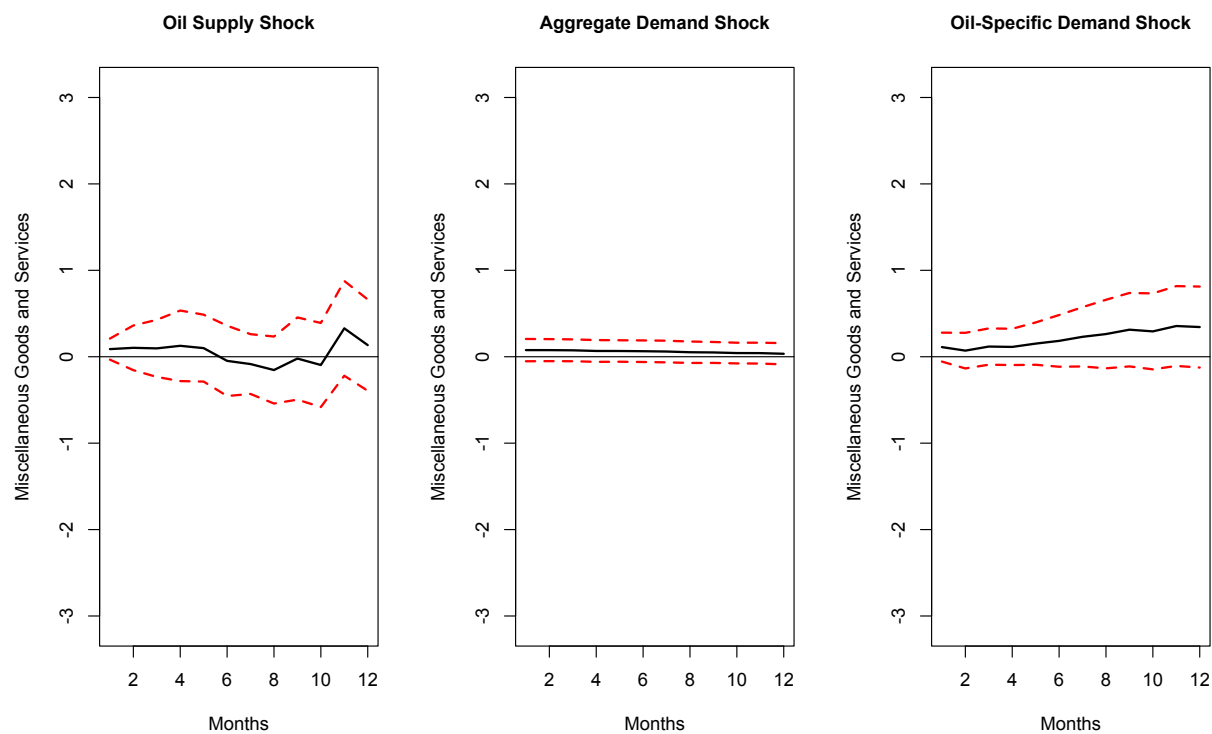


Figure 3.6 The Responses of restaurants and hotels sector and miscellaneous goods and services sector to structural oil shocks

A- Restaurants and Hotels



B- Miscellaneous Goods and Services



3.7 Conclusion

We found that, in some periods, high oil prices have had a very large impact on the level of Saudi inflation in certain sectors; in other periods, although the oil price was high its impact on inflation was considered weak. Kilian (2009) found that such differences are due to the fact that oil prices have several sources, including shocks in demands and others in supply. To achieve our goal in helping policy makers deal with different oil shocks to control inflation rates, we applied Kilian's method to see if these shocks have a different impact on the inflation sectors.

We concluded that the inflation sectors' responses to different oil shocks vary. In addition, the oil-specific demand shocks have the biggest impact in most sectors compared to other structural oil market shocks. In this essay, we highlight for policymakers how each of the structural shocks affect the inflation as sectors. Based on our results, some sectors, including the tobacco, housing, water, electricity, gas and other fuels, and food and beverages sectors, have a strong response to oil price shocks. Other sectors showed a limited response. These different responses are due to some sectors receiving government subsidies. In addition, our results show that oil-specific demand shocks have a larger impact on most of the sectors than other shocks.

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Appendix

Figures A.1-A.5 relate to Chapter 1. Figure A.1 represents the full results of the impulse response function for our five variables (i.e., non-OPEC, non-Saudi OPEC, Saudi oil production, industrial production, and the price of oil) using SVAR while Figure A.2 uses BSVAR with zero restrictions. Figures A.3-A.5 present the full results of the impulse response function using BSVAR with the three different scenarios.

Figures A.1 Impulse Response Function for Five Variables Sets Identified using SVAR.

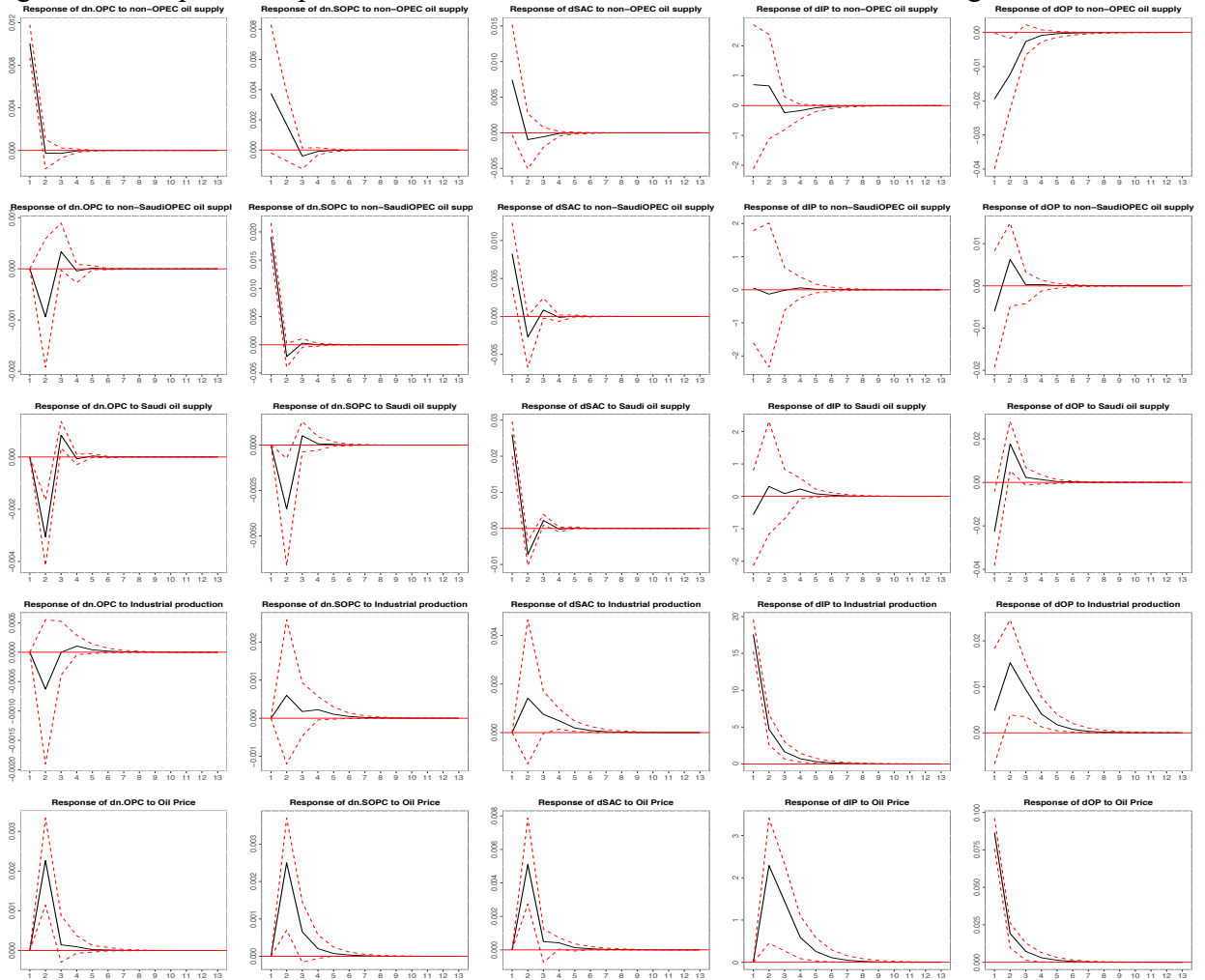


Figure A.2 Impulse Response Function for Five Variables Sets Identified by using Zero Restriction.

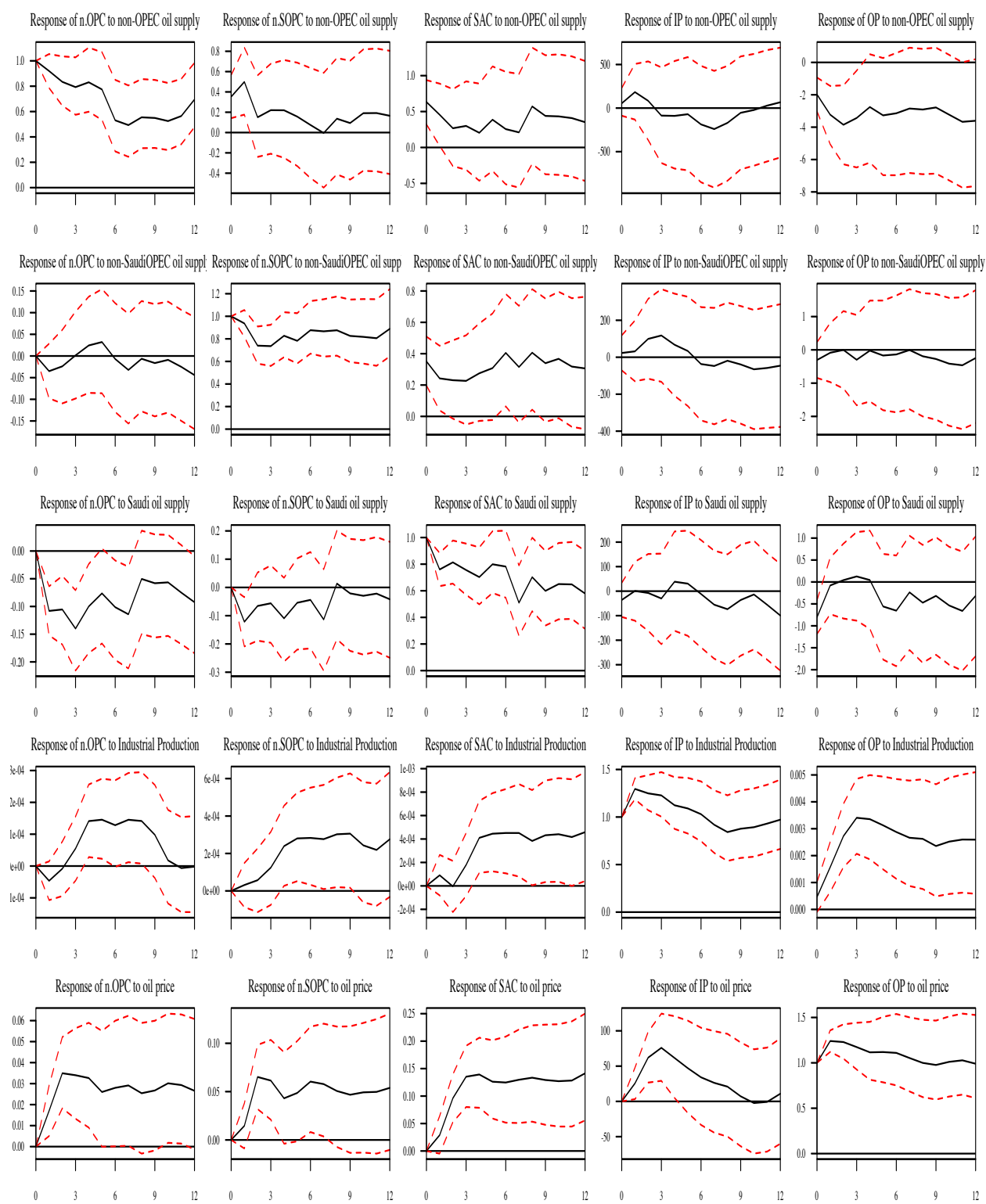


Figure A.3 Impulse Response Function for Five Variables Sets Identified by using the First Prior Distribution.

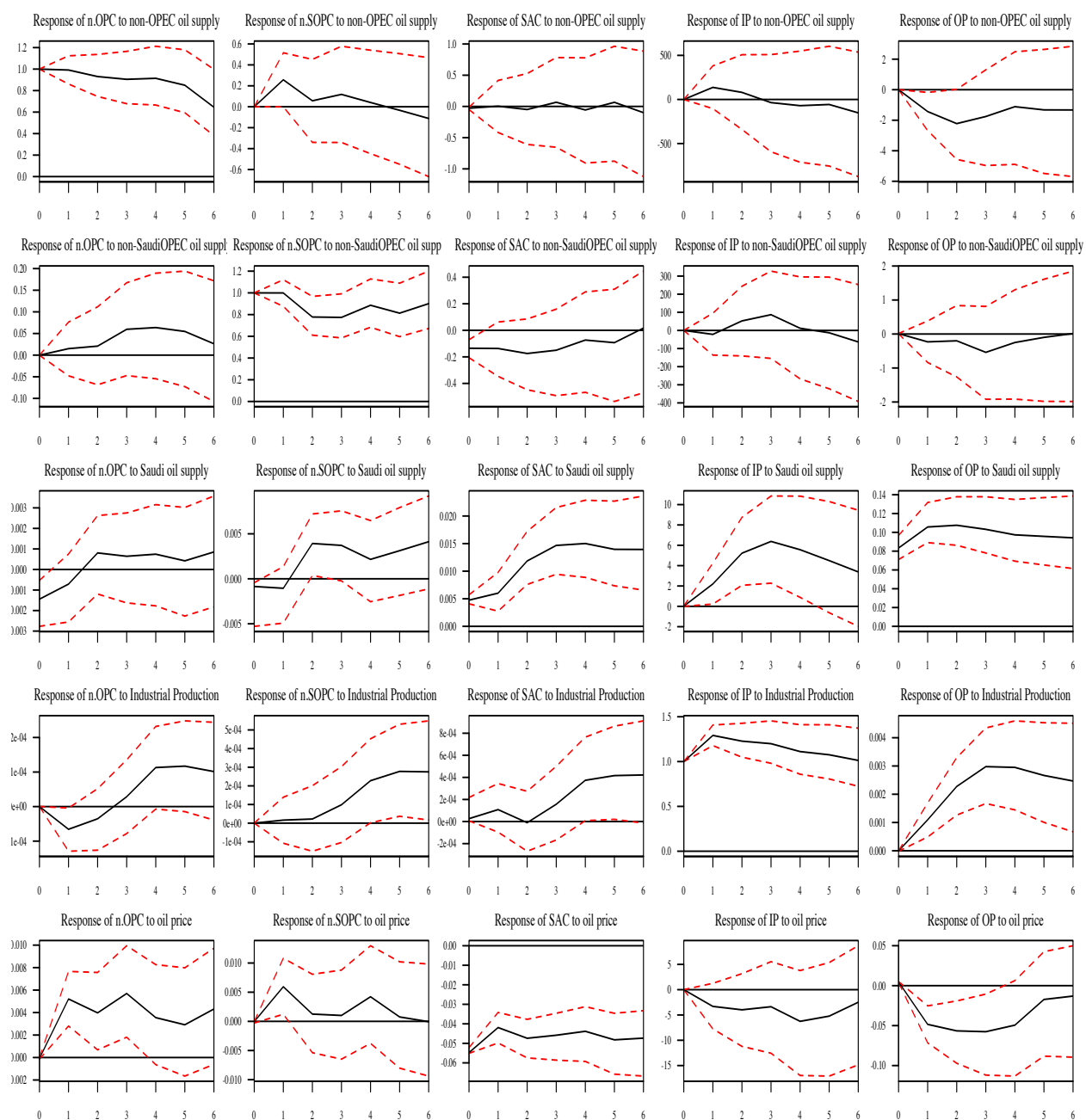


Figure A.4 Impulse Response Function for Five Variable Sets Identified by using the Second Prior Distribution.

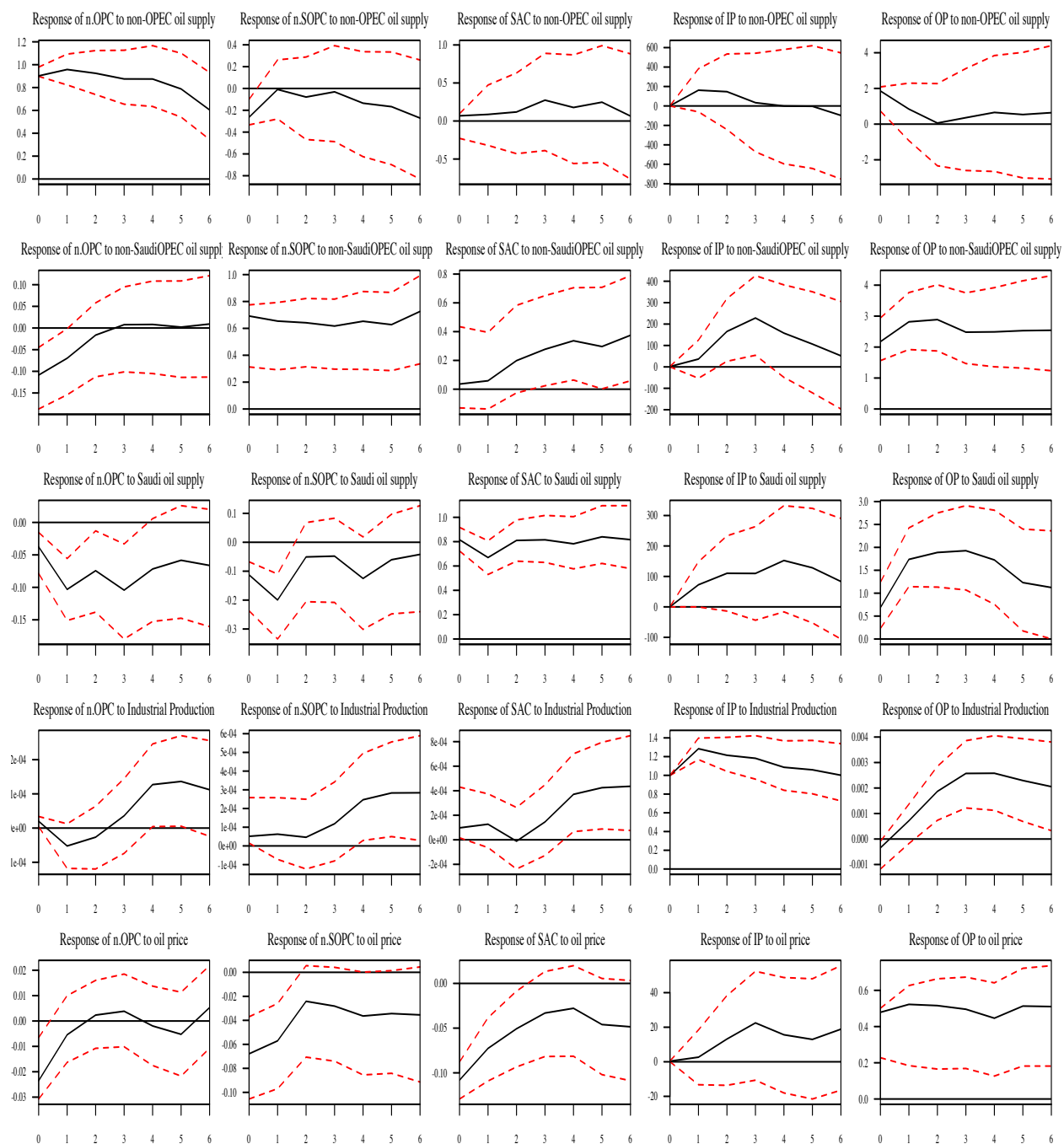
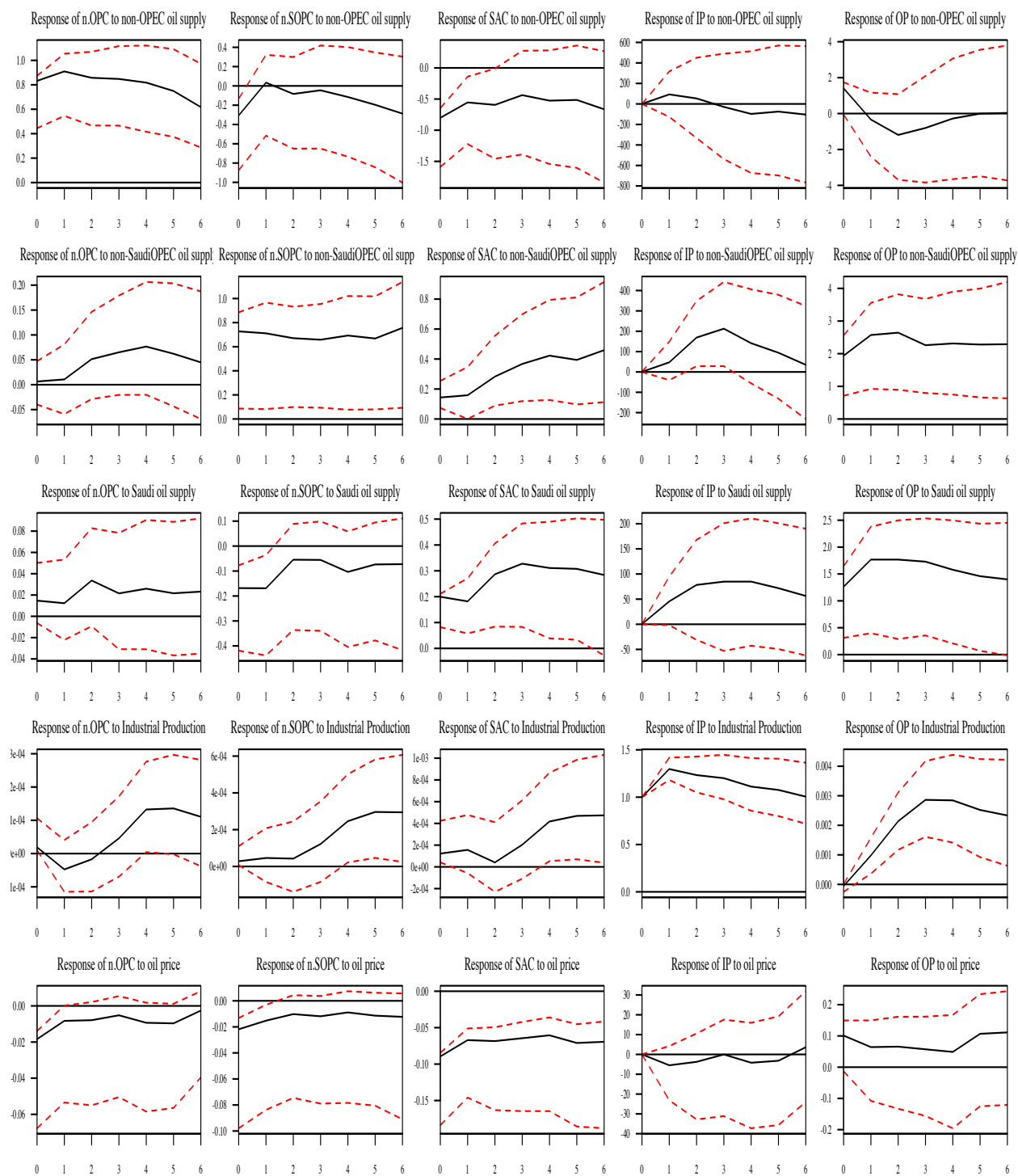
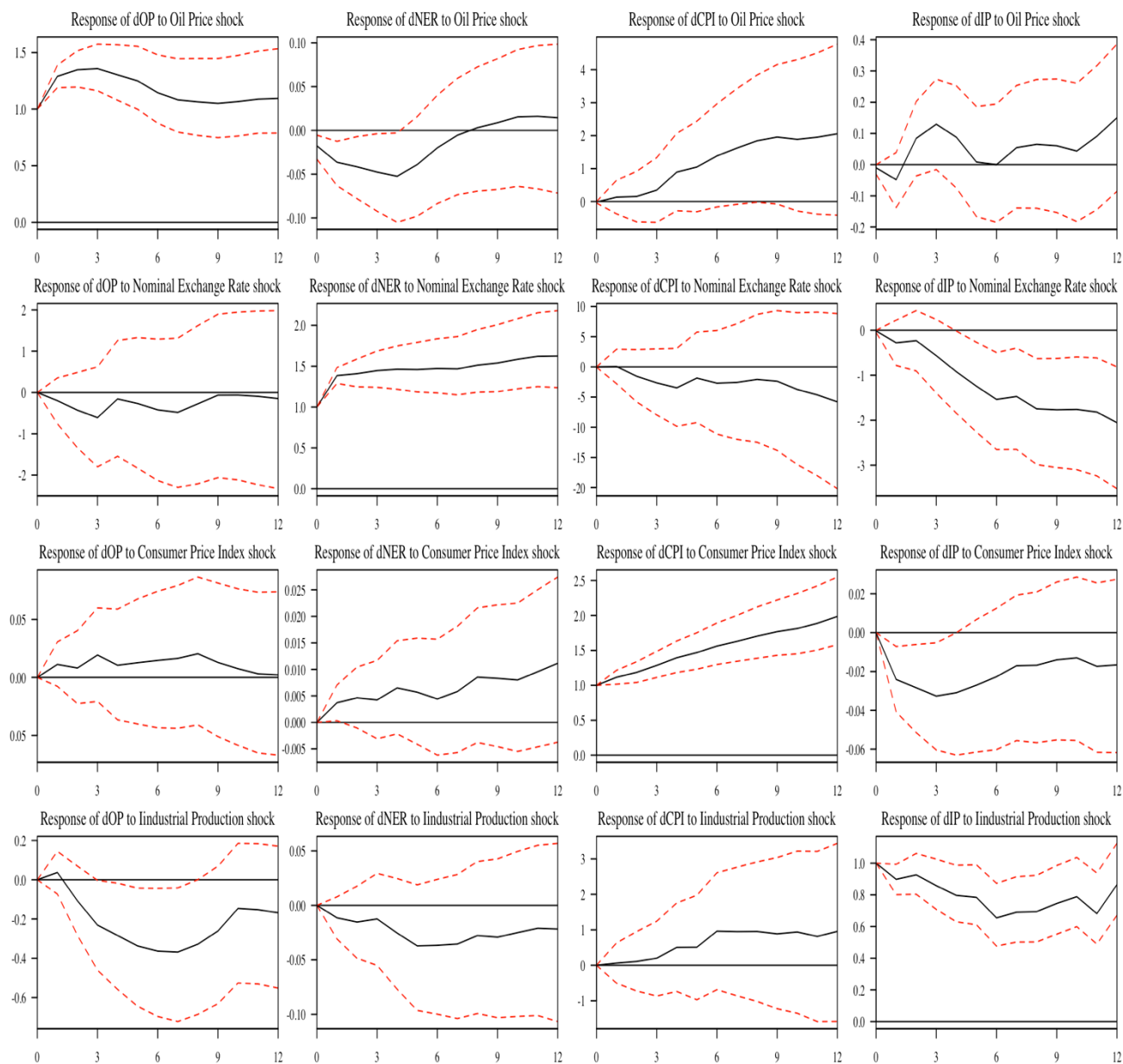


Figure A.5 Impulse Response Function for Five Variables Sets Identified by using the Last Prior Distribution.



The following figure relate to Chapter 2, which represents the full results of the response of the Saudi economy to oil price shocks.

Figure A.6 The Response of Saudi economy to Oil Price Shocks



Figures A.7–A.18 relate to Chapter 3. These figures present the combined responses of all 12 sectors to structural oil shocks (i.e., oil supply shocks, aggregate demand shocks, and oil-specific demand shocks). Figures A.7–A.18 cover the food and beverages, tobacco, clothing and footwear, housing, water, electricity, gas, and other fuels, furnishings and household equipment, health, transport, communication, recreation and culture, education, restaurants and hotels, and miscellaneous goods and services sectors.

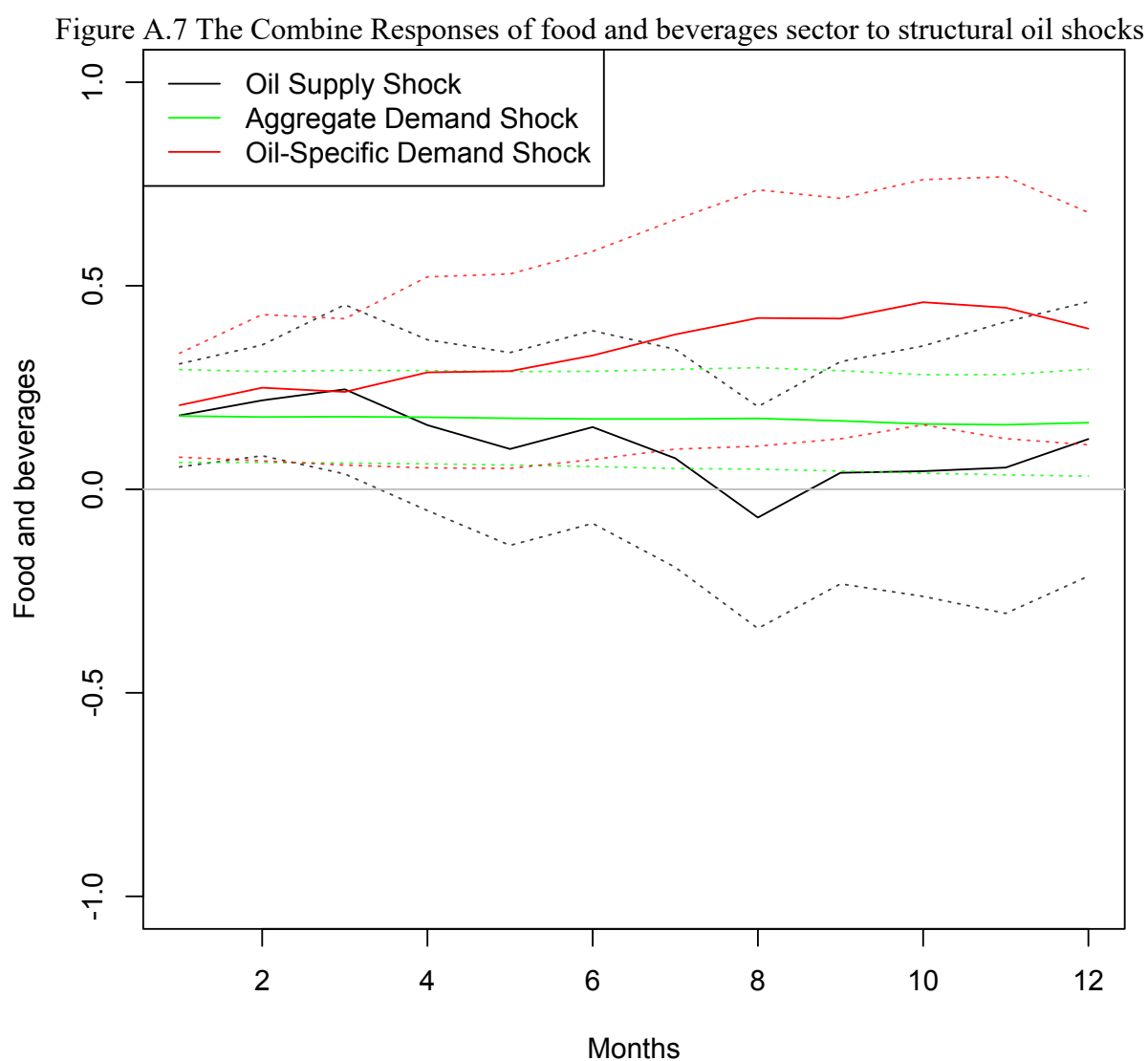


Figure A.8 The Combine Responses of Tobacco sector to structural oil shocks

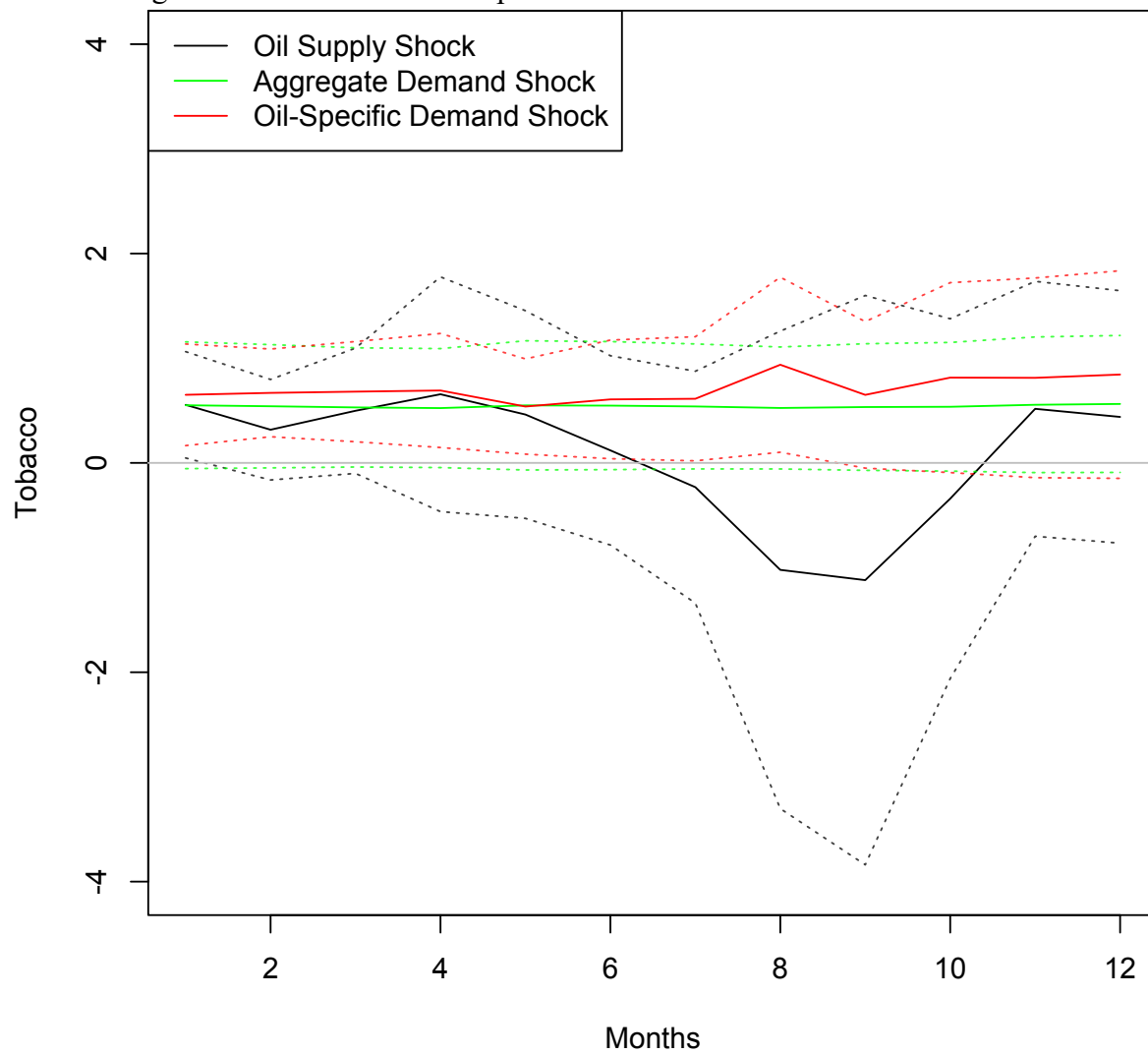


Figure A.9 The Combine Responses of clothing and footwear sector to structural oil shocks

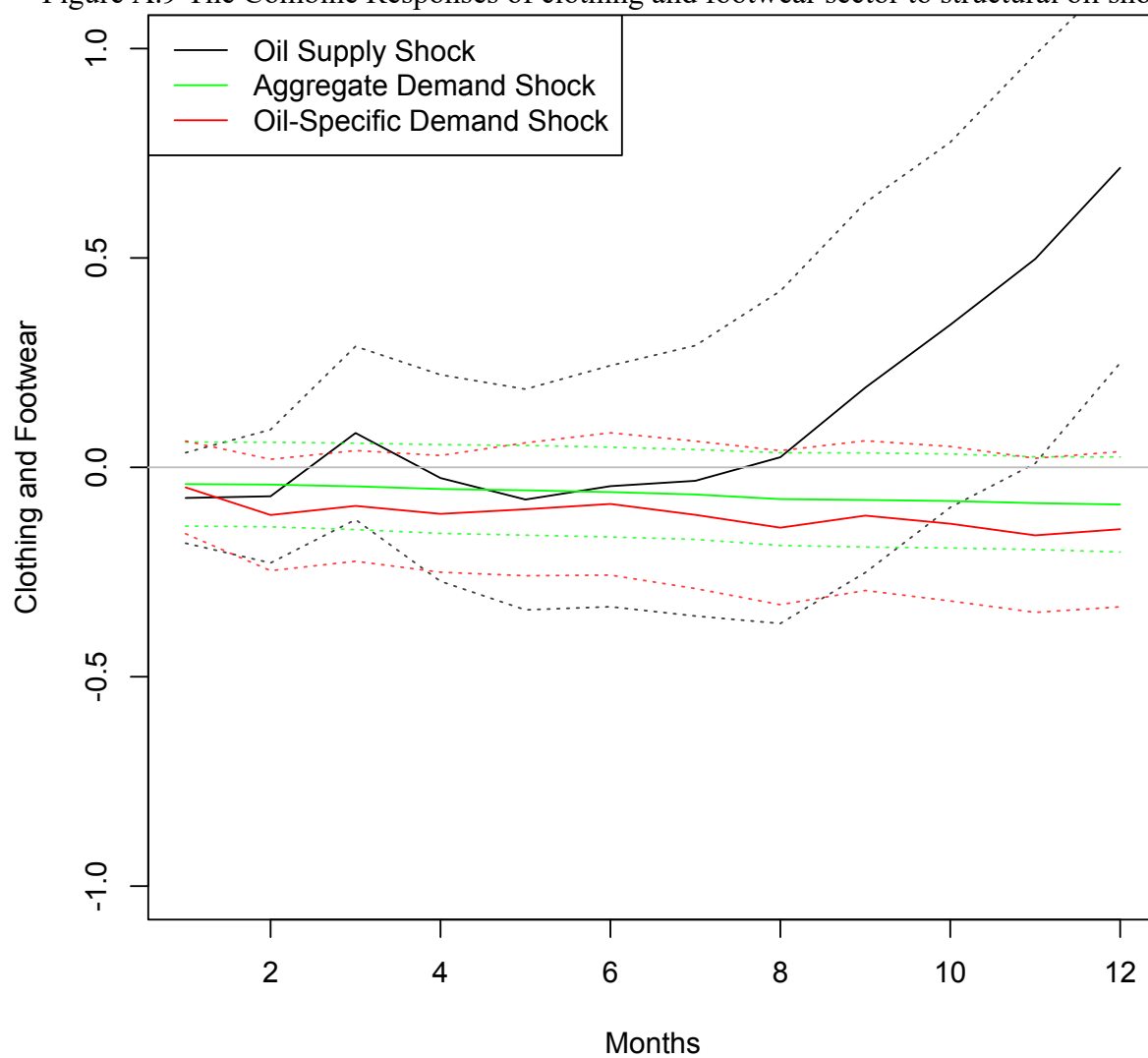


Figure A.10 The Combine Responses of housing, water, electricity, gas, and other fuels sector to structural oil shocks

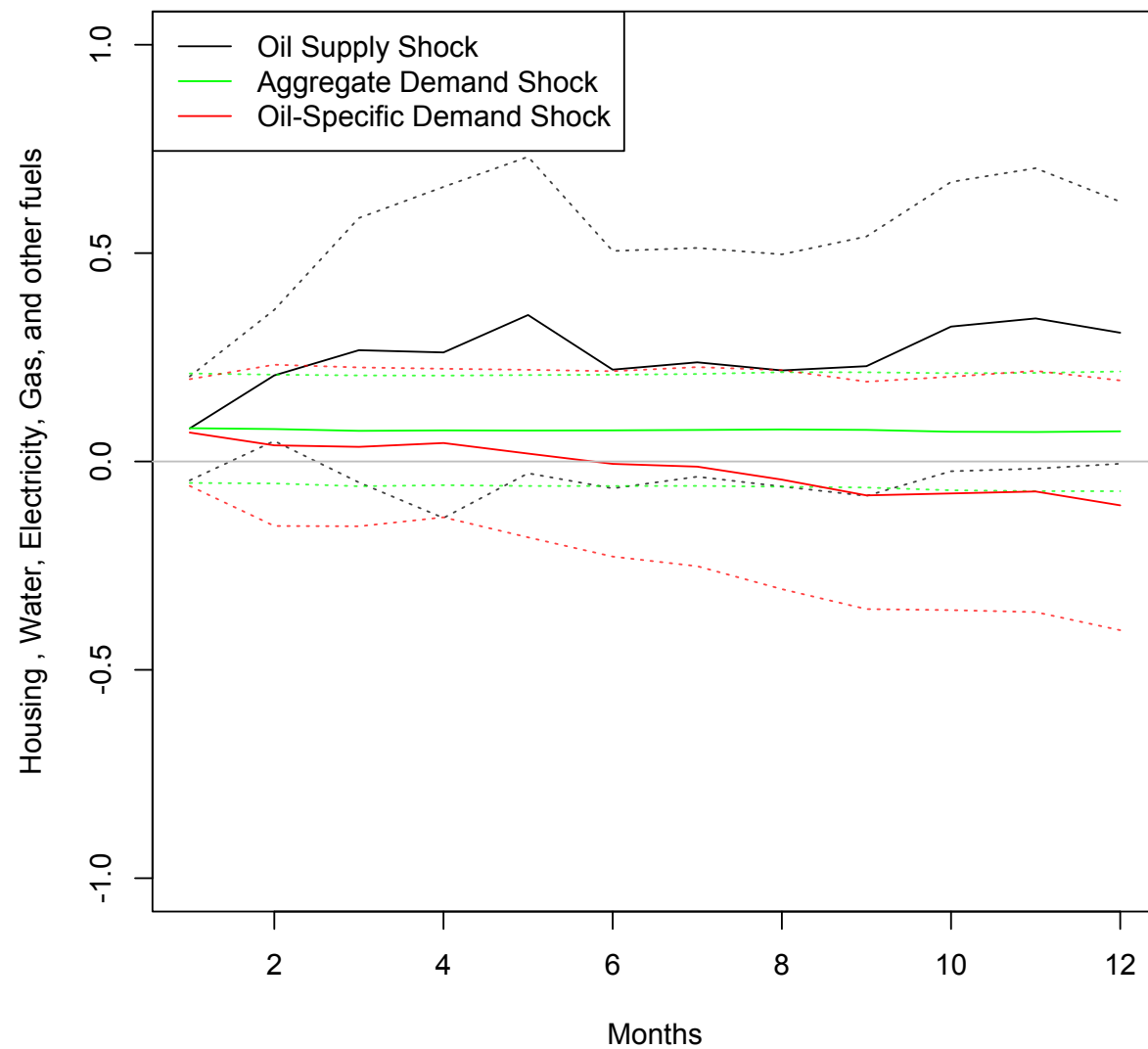


Figure A.11 The Combine Responses of furnishings and household equipment sector to structural oil shocks

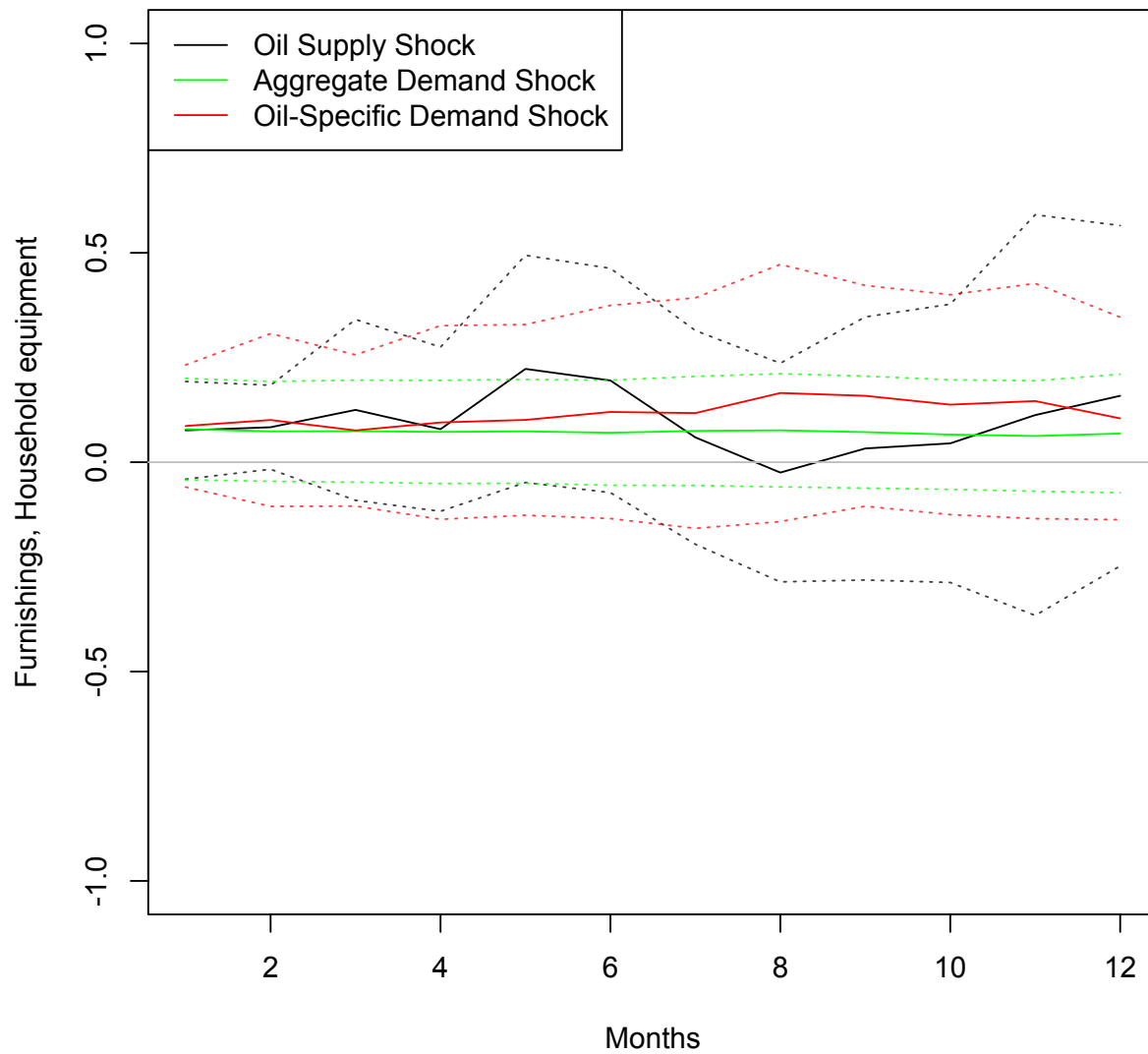


Figure A.12 The Combine Responses of health sector to structural oil shocks

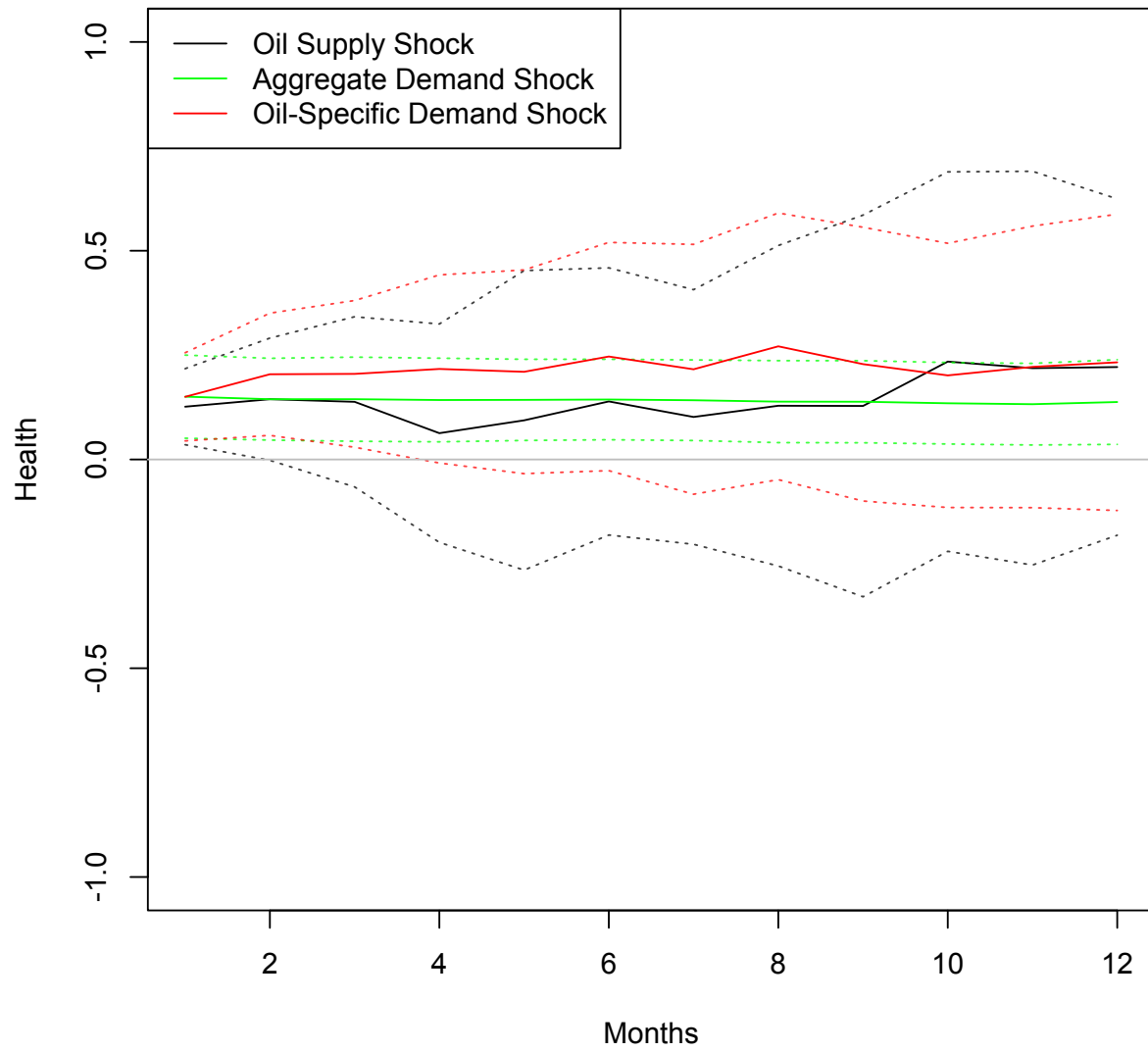


Figure A.13 The Combine Responses of transport sector to structural oil shocks

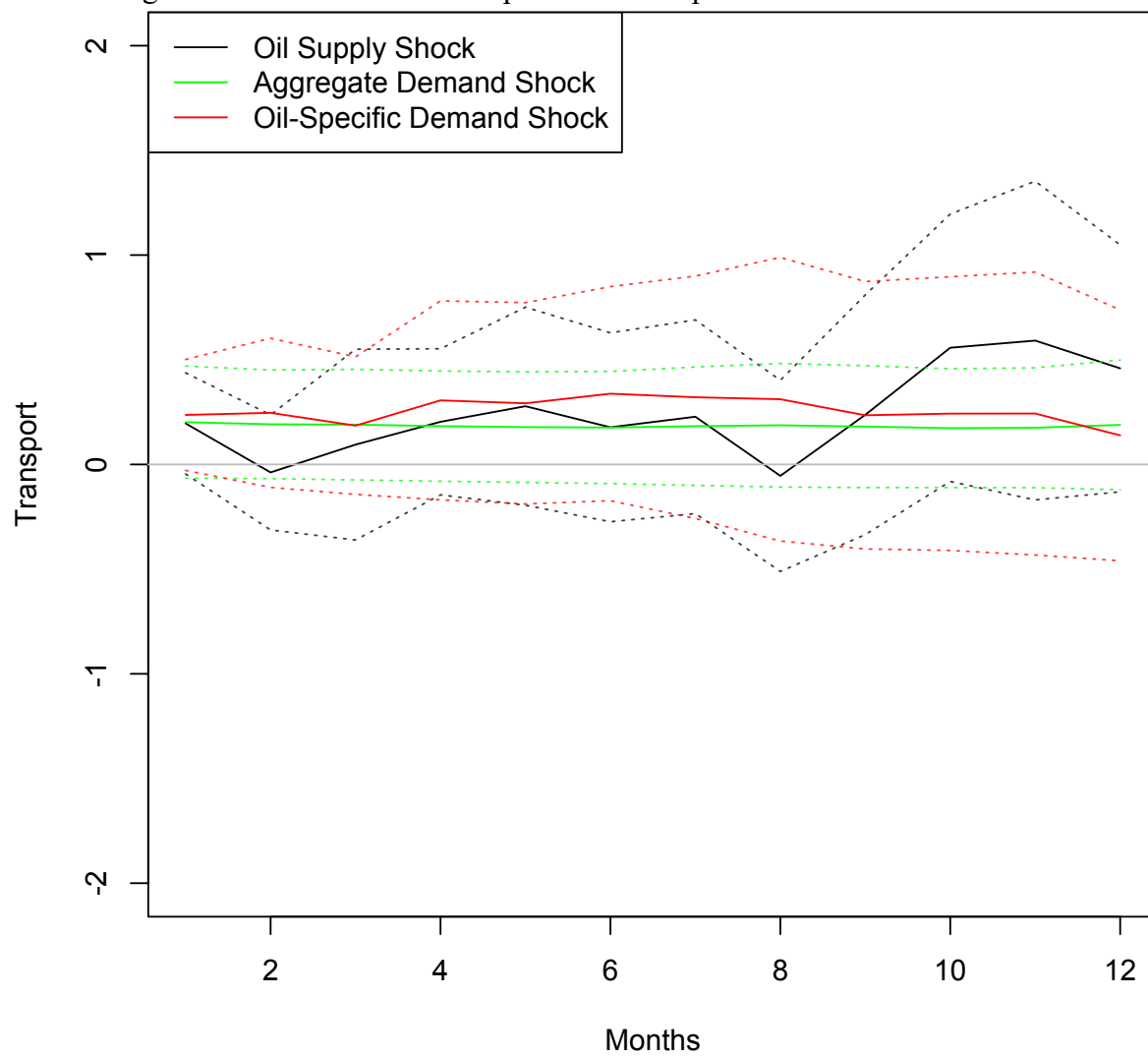


Figure A.14 The Combine Responses of communication sector to structural oil shocks

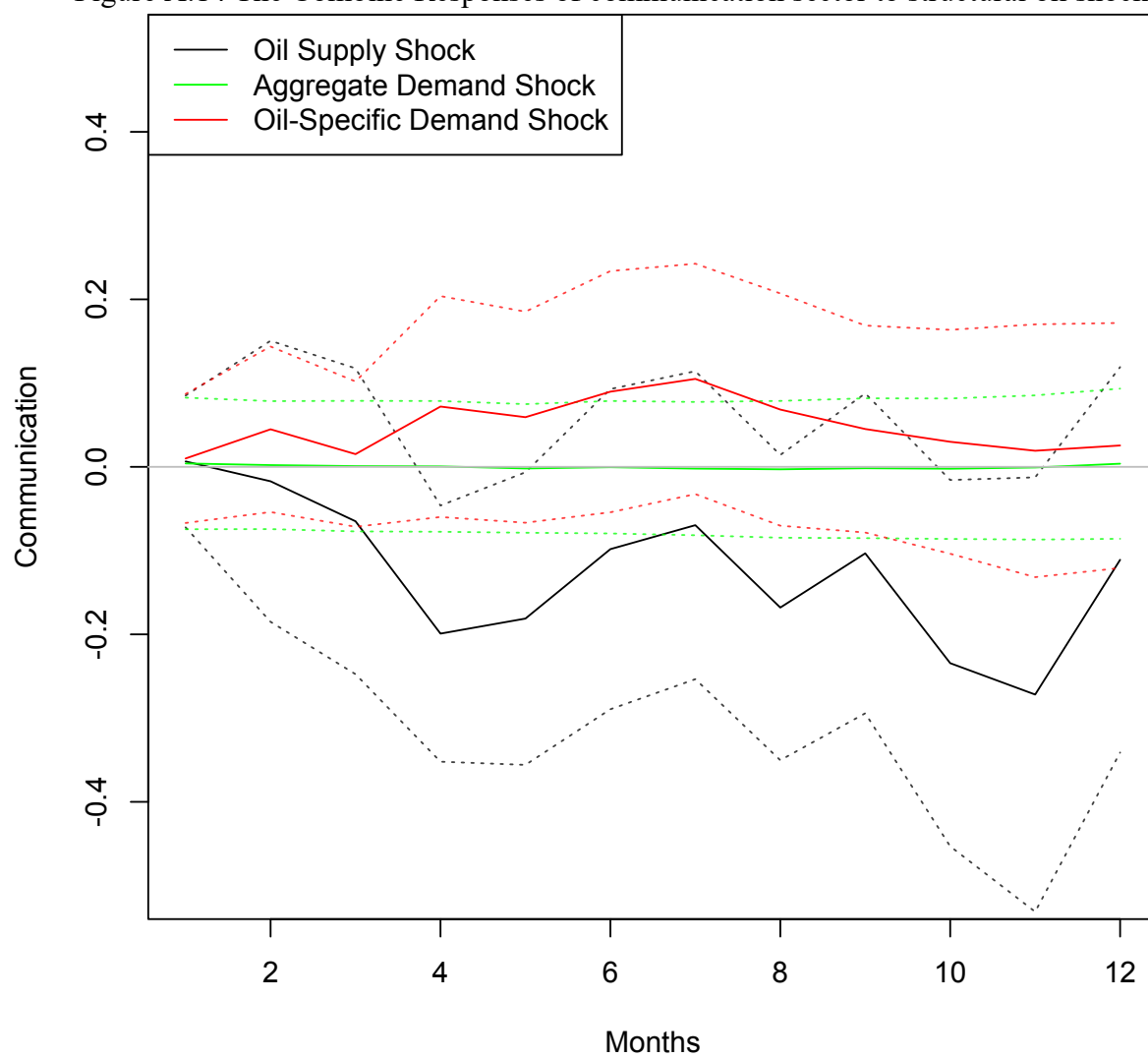


Figure A.15 The Combine Responses of recreation and culture sector to structural oil shocks

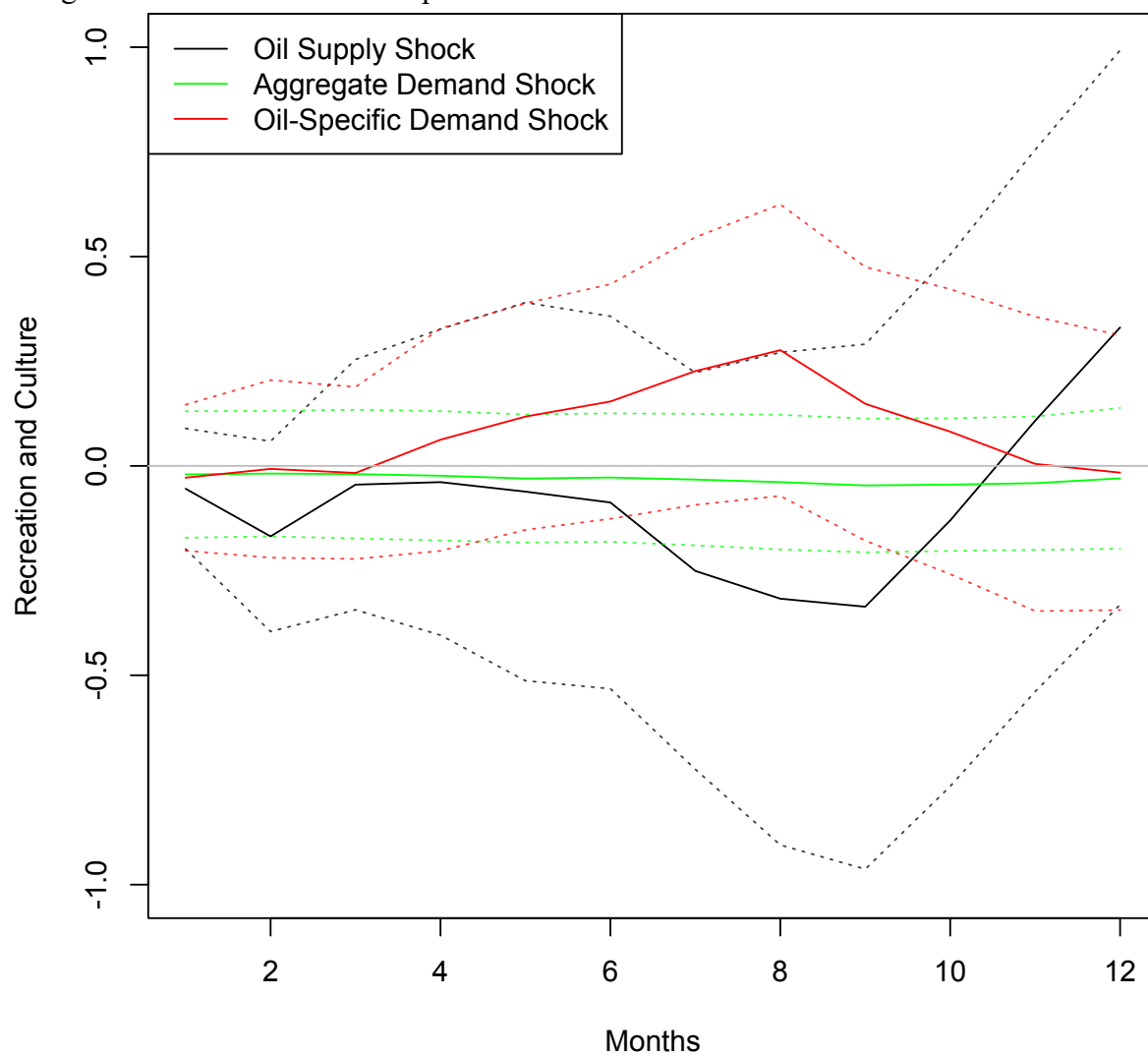


Figure A.16 The Combine Responses of education sector to structural oil shocks

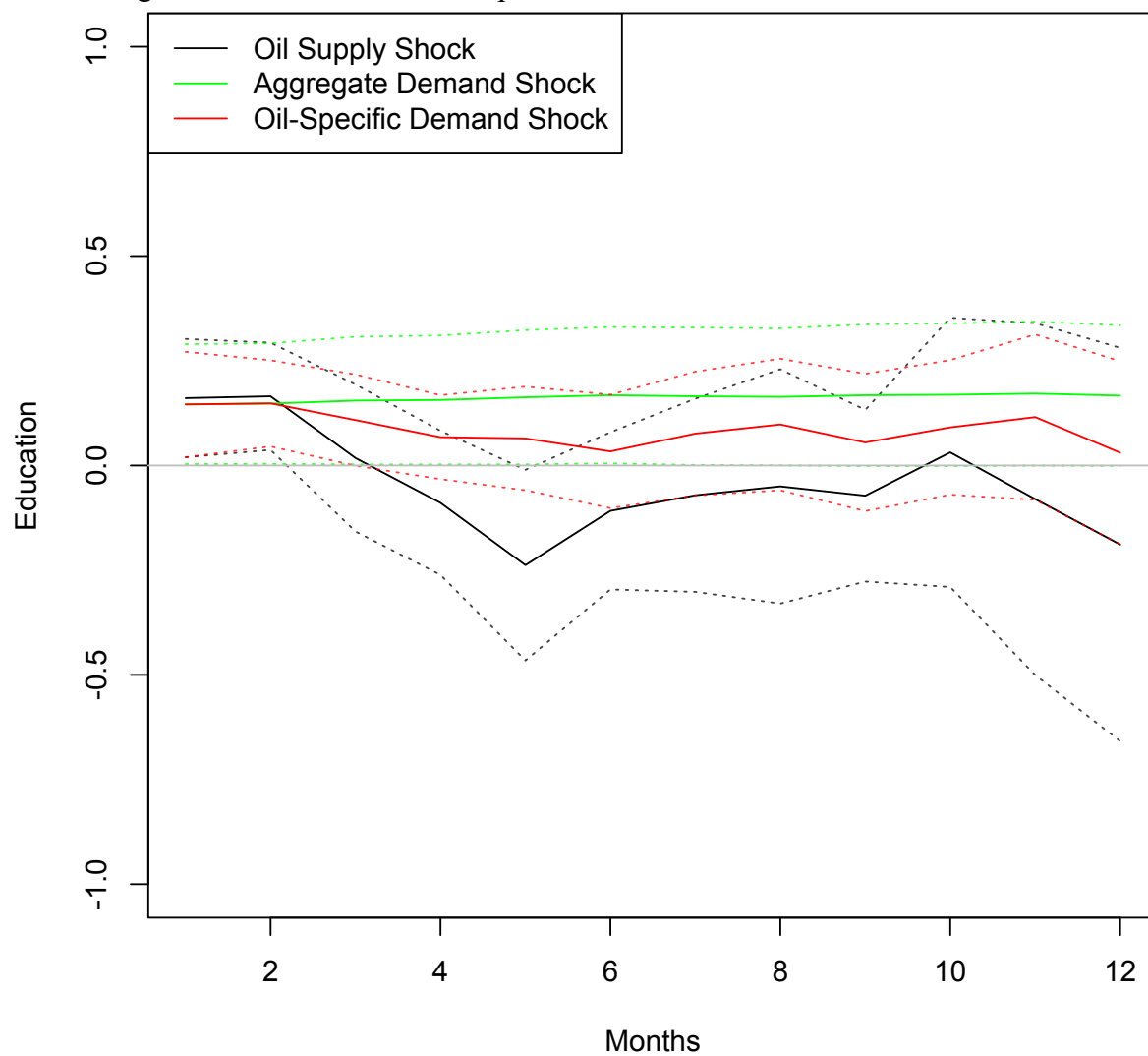


Figure A.17 The Combine Responses of restaurants and hotels sector to structural oil shocks

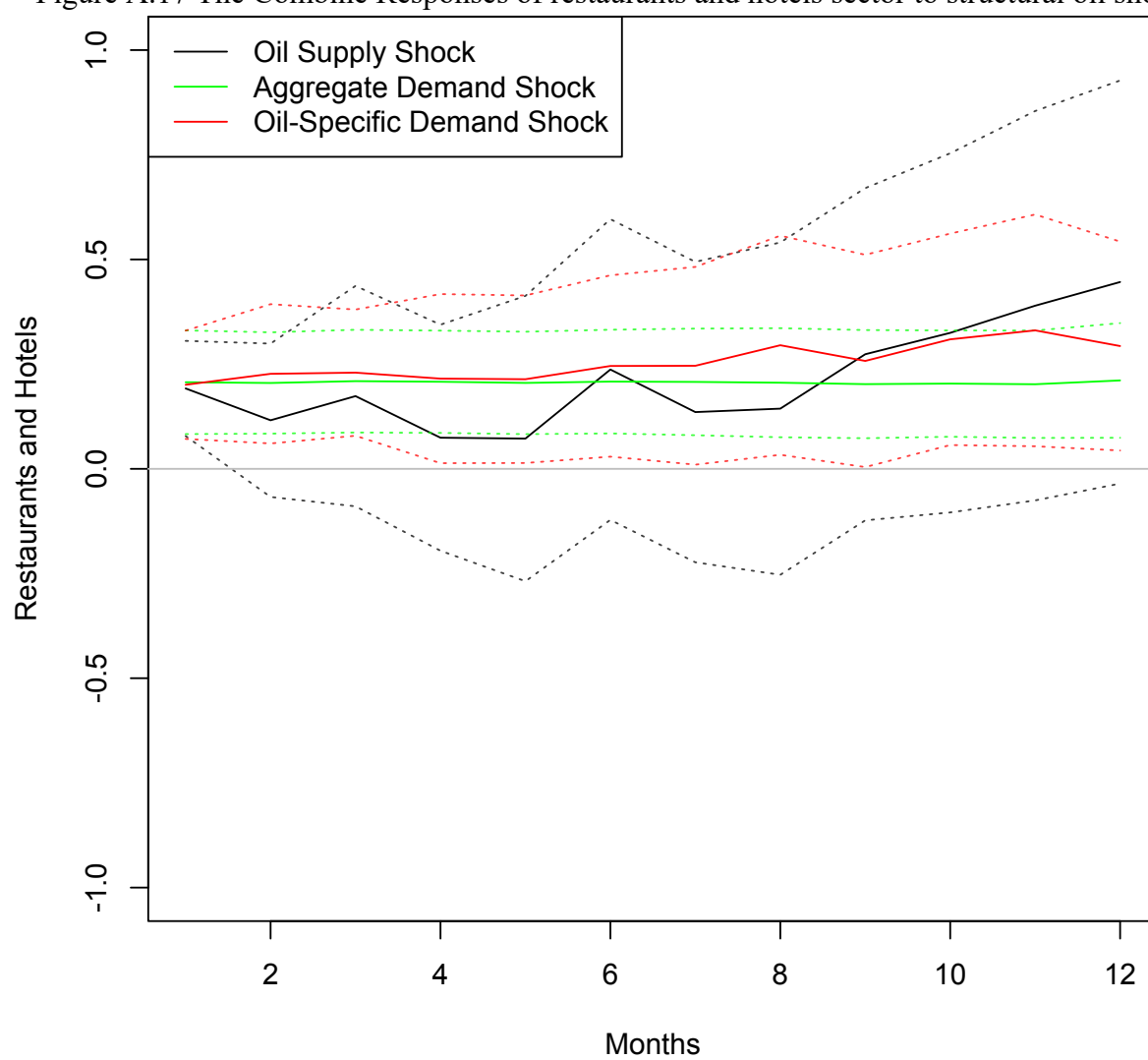


Figure A.18 The Combine Responses of miscellaneous goods and services sector to structural oil shocks

