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Investigating effects of oil price changes on the US, the UK and Japan

Yasunori Yoshizaki
Graduate School of Economics, Kobe University

Abstract

Based on the structural VAR model of the global crude oil market proposed by Kilian(2009), this article investigates the causes for wild fluctuations in oil prices since the mid-2000s. A main contribution of the study is to compare the effects of changes in oil price on three major economies, the US, the UK, and Japan. I find oil-specific demand shocks as well as aggregate demand shocks played an important role in the rise in the real price of oil since early 2002 and the subsequent sharp drops after the failure of Lehman Brothers Holdings Inc.. Moreover I have found that oil-specific demand shocks increase real GDP in Japan, which is very different from the US and the UK where oil-specific demand shocks lead to reduction in real GDP. This difference possibly comes from the oil efficiency of Japanese products.

I am grateful for helpful comments of the editor and an anonymous reviewer.

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1. Introduction

This paper investigates the causes for wild fluctuations in oil prices since the mid-2000s. It also assesses, empirically, the effects of oil price shocks on the real economic activity and price development of three industrialized countries; the US, the UK, and Japan. In order to pursue my study, I have used the structural VAR model of the global crude oil market proposed by Kilian (2009).

The price of oil is one of the most familiar economic indicators for many people as it is closely related to daily life. We are sensitive to changes in the price of gasoline or that of gas for example. Therefore, changes in the price of oil and their causes have been an interesting issue for economists. Early works reported that recessions in the US economy were related to exogenous political events in OPEC countries and subsequent rises in the price of oil. For example, Hamilton (1983, 1996) and Hooker (1996) show that most of the US recessions were preceded by increases in oil price[1]. The effect of the oil shock on the US economy has been studied by many economists from other aspects as well. For instance, Bernanke, Gertler, and Watson (1997) studied oil price shocks in terms of monetary policy. Finn (2000) investigated the role of exogenous oil price variation as a source of the US economic cycle.

However, the writers of early literatures generally assumed exogeneity of oil shocks in studying the response of macroeconomic aggregates, when there may be reverse causality from the global economy through oil demand prices. This may bring inappropriate implications to policy makers. For example, a central bank would unambiguously raise interest rates in response to an endogenous demand-driven increase in the price of oil, but may face a difficult tradeoff between inflation and output when deciding policy against an exogenous cost-push, oil supply-shock. This point is closely related to the ongoing debate over whether it was oil supply shocks or contractionary monetary policy that caused the US recession in the late 1970s and 1980s, e.g. Bernanke, Gertler and Watson (1997), Barsky and Kilian (2002, 2004)[2], and Hamilton and Herrera (2004). Developing the works of Barsky and Kilian (2002, 2004), Kilian (2009) established the structural VAR model of the global oil market in order to identify three underlying shocks in the global oil market: (1) oil supply shocks; shocks to the physical ability to produce oil, (2) aggregate demand shocks; shocks to the current demand for all industrial commodities which are determined by global macroeconomic conditions and (3) oil-specific demand shocks; shocks which cannot be explained based on oil supply shocks or aggregate demand shocks. Oil-specific demand shocks may for example, reflect precautionary demand[3], which stems from an uncertainty

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1 Hamilton (1996) use “net oil price increase” as an oil price variables while Hooker (1996b), in his reply to Hamilton (1996), casts doubt on the theoretical and empirical validity of using “net oil price increase” to represent oil price shocks to the macro economy.

2 Barsky and Kilian (2004) reports five recessions of the US which followed surges in the price of oil: the recessions of November 1973, January 1980, July 1981, July 1990 and March 2001.

3 Alquist and Kilian (2007) conduct formal analysis on precautionary shocks. It is stated that precautionary demand varies depending on whether there is good access to inventory holdings of oil that

about possible future shortfalls of oil. Based on this identification of structural shocks, Kilian concludes that a rise in oil price may affect the real economy differently, depending on the underlying cause of the increase in the real price of oil. Today, it is widely understood that the price of oil has been endogenous to global macroeconomic conditions and cannot be treated as exogenous.

As seen in the previous studies above, most literatures have mainly focused on the effects of changes in oil price on the US economy. In contrast, a relatively small number of studies have been done for other major economies, such as Japan. Much remains unknown about the response of those economies associated with oil price fluctuations. To the best of my knowledge, this article is the first study to make a comparison of the effects of changes in oil price on three major economies, the US, the UK, and Japan, taking the endogeneity of oil price into consideration. The main findings of this paper are as follows: First, the historical decomposition analysis allows me to conclude that oil-specific demand shocks as well as aggregate demand shocks played an important role in the rise in the real price of oil since early 2002 and the subsequent sharp drops after the failure of Lehman Brothers Holdings Inc.. Second, Kilian's finding, the way oil price changes affect economy is different depending on where the changes fundamentally come from, is found not to be specific to US economy. It is also true for two other big industrialized economies; Japan and the UK. Third, I have found that oil-specific demand shocks increase real GDP in Japan, which is very different from the US and the UK where oil-specific demand shocks lead to reduction in real GDP. This difference possibly comes from the oil efficiency of Japanese products.

The remainder of the paper is organized as follows: Section 2 provides a detailed description of the data. Section 3 describes the econometric models used in this paper. Section 4 summarizes the empirical results, such as historical decomposition and measures the impact of the shocks on three economies by regressing three structural shocks on the growth of real GDP and CPI. Section 5 proposes a conclusion.

2. Data Description

Following Kilian (2009), I will consider the following three shocks as structural innovations to the global oil market; oil supply shocks, aggregate demand shocks and oil-specific demand shocks. Correspondingly, the variables which I will use are as follows: world crude oil production; world industrial production[4]; and West Texas Intermediate spot crude oil prices[5]. Details about the data such as its sources are described in the Table 1.

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may act like an insurance against a disturbance in oil supplies.

[4] The index of world industrial production is weighted sum of the industrial production of each OECD countries plus major six non-member economies; Brazil, China, India, Indonesia, the Russian Federation, and South Africa. The weight is calculated based on purchasing-power-parity valuation of each country.

[5] As for the oil price, the US refiner acquisition cost of imported crude oil deflated by the US CPI is used in Kilian (2009). Instead of this series, I use WTI because besides the fact that WTI is considered one of the most popular international oil price index.

Table 1 Data description and sources

Variable	Description	Data source
World Production of Oil (prod)	Original Series.	Oil and Gas Journal
World Industrial Production (IIP)	Seasonally adjusted. Gap from linear trend.	Organisation for Economic Co-operation and Development
Real oil price (p)	Original Series of WTI deflated by the US CPI.	Federal Reserve Bank
Japanese Real GDP	Seasonally adjusted.	Cabinet Office of Japan
The US Real GDP		Bureau of Economic Analysis
The UK Real GDP		Office for National Statistics
Japanese CPI		Organisation for Economic Co-operation and Development
The UK CPI		
The US CPI		

The major differences described by Kilian (2009) are a choice of variable which represents global real economic activity and the length of the sample period. For the index of global real economic activity, Kilian (2009) constructs his original series based on dry cargo freight rates. To some extent, the fluctuations in freight rates captures the cycle of macroeconomic conditions. However, it possibly reflects some irrelevant information to real economic activity which is specific to the ship-freight market, such as weather condition and a demurrage. Therefore, I will use the index of world industrial production instead, taking the difference from its time trend to capture the development of global real economic activity well. As for the sample period, this paper covers 1973.1-2010.12 which is the updated series of Kilian (2009), 1973.1-2006.10. This allows me to reveal the underlying cause of the hike in oil price in summer 2008 and the subsequent sharp drop.

3. Methodology

Similar to Kilian (2009), I will take the following two steps in my analytical framework. As a first step, the structural VAR model of the global crude oil market will be estimated in order to obtain a series of identified shocks. Secondly, by using these structural shocks obtained from the SVAR model, regression models will be estimated to assess the macroeconomic implication of the identified shocks for each country.

3.1 The Structural VAR model: Decomposing the Real Price of Oil

Consider a restricted VAR model with 24 lags[6] based on monthly data described in the

[6] Although the lag length indicated by AIC is 7, based on the fact that I use monthly series in model, I have decided to take 24 lags as Kilian (2009) does. We can avoid the problem of dynamic misspecification by taking 24 lags. The results based on 7 lags and 12 lags are very similar to the result based on 24 lags.

previous section. The restricted VAR is represented as

$$X_t = \alpha + \sum_{i=1}^{24} \beta_i X_{t-i} + e_t \tag{1}$$

where $X_t = (\Delta prod_t, IIP_t, P_t)'$ and $e_t = (e_t\Delta^{prod}{}_t, e_t^{IIP}, e_t^{P})'$. $\Delta prod_t$ is the percentage change in global crude oil production and all variables are expressed in the natural log[7].

Then, the structural VAR is represented as

$$A_0 X_t = A_0 \alpha + \sum_{i=1}^{24} A_i \beta_i X_{t-i} + u_t \tag{2}$$

In order to identify the structural shocks u_t, it is assumed that A_0^{-1} takes a specific form so that the reduced form errors e_t and the structural errors u_t have the relationship as below.

$$e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{IIP} \\ e_t^{P} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} u_t^{\text{oil supply shock}} \\ u_t^{\text{aggregate demand shock}} \\ u_t^{\text{oil-specific demand shock}} \end{pmatrix} = A_0^{-1} u_t \tag{3}$$

The assumptions on A_0^{-1} are motivated as follows: First, oil supply shocks are innovations to oil production that are assumed not to respond to innovations to the demand for oil within the same month. i.e., the model postulates a vertical short-run supply curve of crude oil. Second, aggregate demand shocks are innovations to world industrial production that oil supply shocks cannot explain. With aggregate demand shocks, it is assumed that a rise in oil price, driven by shocks which are specific to the oil market, will not lower global world industrial production with a delay of at least a month. Lastly oil-specific demand shocks are innovations to the oil price that can be accounted for by neither the oil supply shocks nor aggregate demand shocks. Oil-specific demand shocks are, for example, supposed to reflect changes in precautionary demand, which come from uncertainty about future oil supply shortage. They are also supposed to reflect changes caused by speculative demand for oil.

3.2. Regression Model

Next I will explain how the structural innovations in model (3) affect the CPI and real GDP growth in the US, the UK, and Japan. One complication that must be addressed is caused by the fact that real GDP is not available at monthly frequency. In addition, the series other than real GDP which are given at a monthly frequency cannot be aggregated to a quarterly frequency because at that frequency, the identifying assumptions used in estimating model (3) would no longer be credible[8]. In order to deal with the frequency not being consistent, I firstly average the monthly structural innovation for each quarter:

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7 The first difference of world production of oil, the level of index of economic activity and the level of real price of oil are used in Kilian (2009)'s original model. Stability test for the estimated VAR is also conducted.

8 The use of IIP for Japan is a possible clue to deal with the frequency problem because IIP is monthly data which is compatible with the short-run restrictions on my structural VAR models. However, I would rather see an effect of changes in oil price on whole economy which includes nonmanufacturing industries instead than manufacturing industries only. Thus quarterly real GDP data is used instead.

$$\hat{\zeta}_{jt} = \frac{1}{3}\sum_{i=1}^{3}\hat{u}_{j,t,i}, \; j = 1,2,3, \qquad (4)$$

where $\hat{u}_{j,t,i}$ refers to the estimated residual for the *j*th structural shock in the *i*th month of the *t*th quarter of the sample. Then by regressing the first difference of real GDP and the CPI on the averaged structural innovations with lags of innovations and constant respectively, I make it possible to investigate the impact of the shocks on each economy[9]:

$$\Delta y_t = \alpha_j + \sum_{i=0}^{12}\phi_{ji}\hat{\zeta}_{jt-i} + r_{jt}, \; j = 1,2,3, \qquad (5)$$

$$\pi_t = \beta_j + \sum_{i=0}^{12}\psi_{ji}\hat{\zeta}_{jt-i} + v_{jt}, \; j = 1,2,3, \qquad (6)$$

where Δy_t and π_t refers to the first difference of real GDP and that of the CPI respectively and r_{jt} and v_{jt} are errors[10]. In this regression model, because ϕ and ϕ are interpreted as an impulse response coefficients at horizon *h*, the number of lags is determined by the maximum horizon of the impulse response function, which is set to 12 quarters.

4. Empirical Results

Although I used different data for all three variables in the SVAR from those used by Kilian (2009), the results[11] of the estimation are similar to his. Figure 1 plots the historical evolution (expressed as annual averages for readability) of the structural shocks obtained from the model. As shown by Kilian (2009), there was no evidence of unanticipated global oil supply disruptions in 1978 or 1979 but there were large negative shocks to crude oil supply in 1980 and 1981, associated with the outbreak of the Iran–Iraq War. As for oil-specific demand shocks, there was also a large positive shock in 1979. This is consistent with the fact that there was growing uncertainty about future oil supply at that time because of successive political events such as the Iranian Revolution, the Iranian hostage crisis and the Soviet invasion of Afghanistan.

Looking at the movements in the period from 2007 to the present, which is out of Kilian's sample period, there is a huge negative shock to aggregate demand in 2008. It clearly reflects the worldwide economic depression that started with the failure of Lehman Brothers Holdings Inc. on 15 September 2008. Another interesting point is that there is also a large negative disturbance to oil-specific demand. This is consistent with the view of market

[9] Note that regressions (5) and (6) rely on the assumption that within a given quarter there is no feedback from Δy_t and π_t to $\hat{\zeta}$ i.e., these shocks can be treated as predetermined with respect to the growth of real GDP and the CPI.

[10] Those errors are potentially serially correlated. For right inference on the response estimates obtained by model (5) and (6), serial correlation problem is dealt with by using block bootstrap methods. Following Kilian(2008), block size 4 and 20,000 bootstrap replications are used.

[11] The Matlab code used in this paper is developed by Kilian. It can be downloaded here: http://econpapers.repec.org/article/aeaaecrev/v_3a99_3ay_3a2009_3ai_3a3_3ap_3a1053-69.htm

watchers that there was large outflow of speculative funds from the oil market which had increased the oil price more than fundamentally determined. The disturbance to the oil-specific demand can also be interpreted, if it is understood that with the sharp drop in demand for oil, the expectations of investors for future oil demand also decreased.

4.1. Historical Decomposition of the Price of Oil

Figure 2 plots a historical decomposition of the real price of oil into the contribution of the structural shocks. The cumulative effects of each structural shock on the real price of crude oil are indicated by the solid line in each panel. This historical decomposition obtained from my model is consistent with the findings of Kilian (2009) in that oil supply shocks made a small contribution to oil price movements, and that shocks due to aggregate demand and oil-specific shocks made far bigger contributions to the real price of oil.

By taking a closer look at the recent developments to the cumulative effect of demand shock, we can see that the recent increase was driven largely by aggregate demand shocks. A large part of the surge in the real price of oil from the end of 2006 to the middle of 2008 in particular can be explained by this. It is also obvious that the level of the cumulative effect of aggregate demand shock on real price of oil in 2010 has recovered close to pre-Lefman shock level and it has helped maintain oil price at a historically high level. Meanwhile, oil-specific demand shocks played an important role in the recent surge as well. It is obvious that oil-specific demand shocks also contributed largely to the surge in oil price in early 2008 and the subsequent sharp fall at the end of 2008. This is corresponding to the views that crude oil prices became high in the early part of 2008 partly due to the speculative inflow of funds, and partly due to the tightening of supply and demand conditions (see Bank of Japan 2008a) and that the price of oil fell rapidly at the end of 2008 due to increased risk aversion among investors reflecting disruptions in global financial markets (see Bank of Japan 2008b).

4.2. The effect of Oil Price Shocks on the Economic Activity and Price Development

Figure 3-5 summarize the responses of the level of real GDP and CPI to each of the three structural shocks. Both real GDP and CPI respond very differently to each of the three structural shocks in all three countries. This clearly shows that Kilian’s findings, the way oil price changes affect the US economy is very different depending on where the changes fundamentally come from, is also true for Japan and the UK.

Oil supply disruptions cause a small decline in the US and Japan’s real GDP with some delays, whereas it leads to a small increase in the UK real GDP, but the one-standard error bands imply statistical insignificance. The corresponding effect on the level of the CPI is similar between the three economies. It is mostly flat and statistically insignificant for the first 6 quarters and then becomes negative afterwards. Regarding an aggregate demand expansion, there is a similar pattern in the response of the US, the UK and Japan’s real GDP within first two years. After the second year, real GDP in the US and the UK become flat afterwards whereas Japan’s real GDP keeps its level above initial state. At the end of the third year, the response of the US and the UK turns to be negative, which is statistically significant. Meanwhile, this shock causes a statistically significant increase in the price level of the US and the UK. In contrast, interestingly, it causes neither a statistically significant increase nor a decrease in the price level of Japan. A positive oil-market specific demand shock leads to a slight decline in the US and the UK real GDP. On the other hand, in Japan, this shock leads to a sustained increase in real GDP that reaches its maximum at the 10th quarter. This increase is statistically significant in the first three and a half years but becomes statistically insignificant after that. The corresponding effect on the level of the CPI is similar between the three economies. It results in a sustained and highly statistically significant increase.

The result suggests a fair degree of similarity in the real GDP and CPI responses between the US and the UK. The biggest difference between those two economies and the Japanese economy is that oil-specific demand shocks have a positive impact on Japanese GDP, while it results in reduction in the US and the UK real GDP. This result seems to confirm the findings of recent studies, stating that the impact of oil price increases on Japan’s economy are relatively small or even positive and very different from other oil-importing countries. For example, Fukunaga, Hirakata and Sudo (2009) compared industry-level effects of oil price change in the US and Japan and found that the increase in the price of oil caused a global demand shift, especially in automobiles, towards more oil-efficent products made in Japan and thus it increases production in Japan. In this sense, the positive response of real GDP in Japan to the oil-specific demand shock can be explained in part by the result of a global demand shift towards oil efficient products made in Japan.

5. Conclusion

The main results can be summarized as below: First, by extending the sample period from Kilian (2009), I have found that oil-specific demand shocks as well as aggregate demand shocks played an important role in the wild fluctuations in oil prices since the mid-2000s. Second, I investigated the impact of changes in the price of oil on three industrialized economies. I have shown that the statement that the way oil price changes affect economy is very different depending on where the changes fundamentally come from is also true for Japan and the UK. The most interesting finding is that oil-specific demand shocks increase real GDP in Japan, which is very different from the US and the UK where oil-specific demand shocks lead to reduction in real GDP. This difference possibly comes from the oil efficiency of Japanese products. In this sense, a rise in the price of oil does not necessarily have a negative impact on Japan’s economy, which is in contrast to the public belief that an increase in oil price has negative consequences for the lives of Japanese people.

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Figure 1: Historical evolution of the structural shocks (1973-2010)

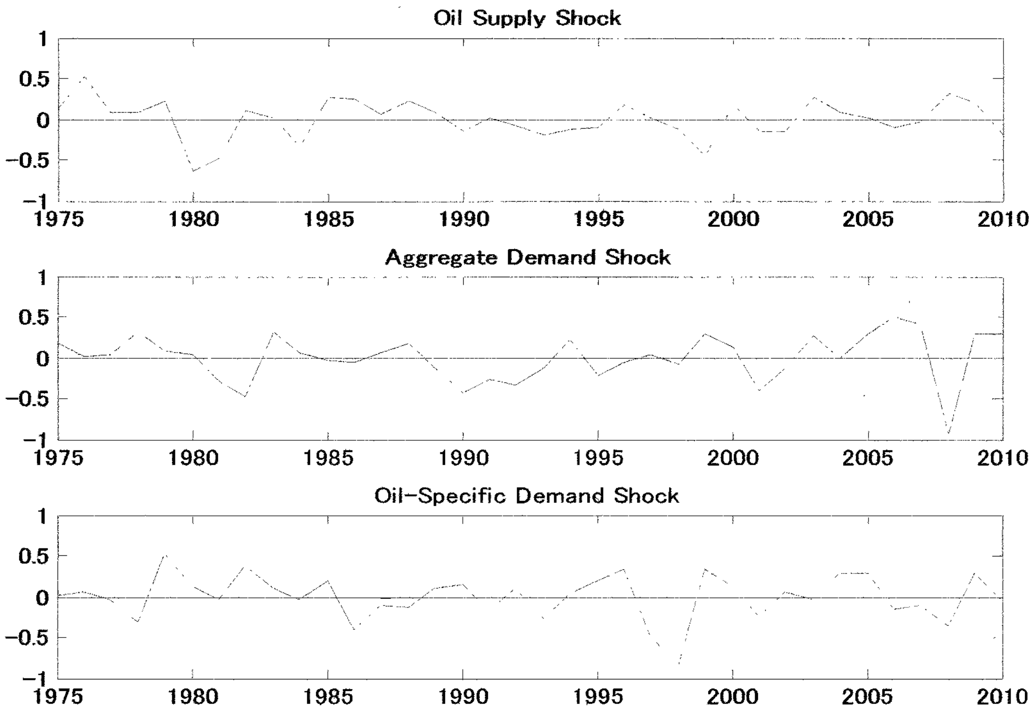
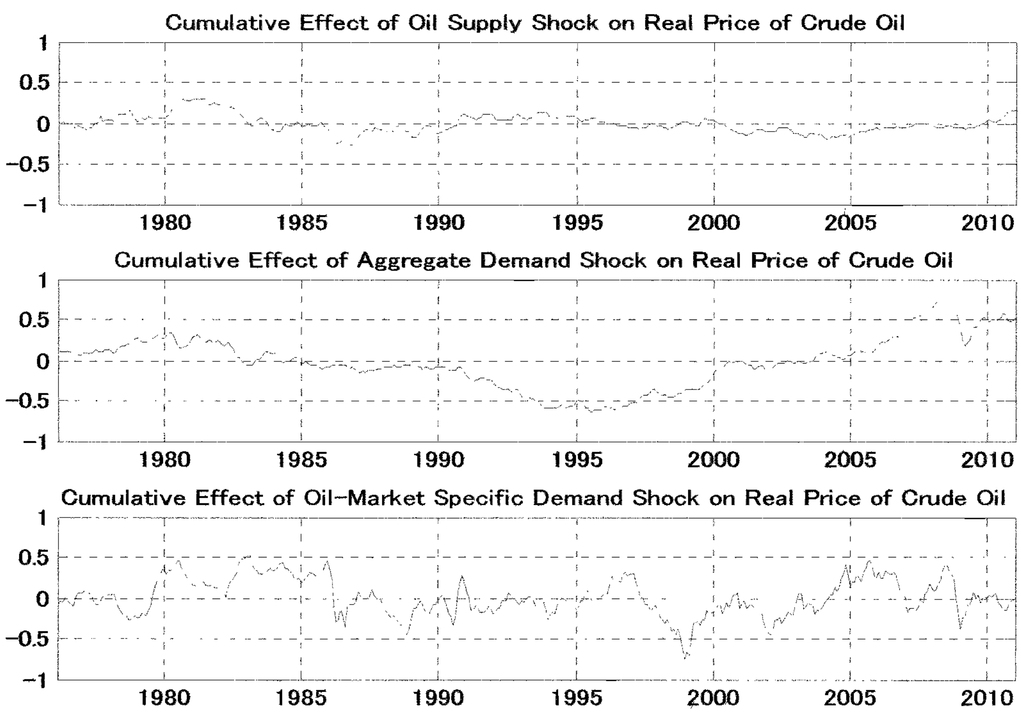


Figure 2: Historical decomposition of real oil price s (1973-2010)



Notes: Estimation based on model (2).

Figure 3: Cumulative responses of Japan's real GDP and CPI to each structural shock

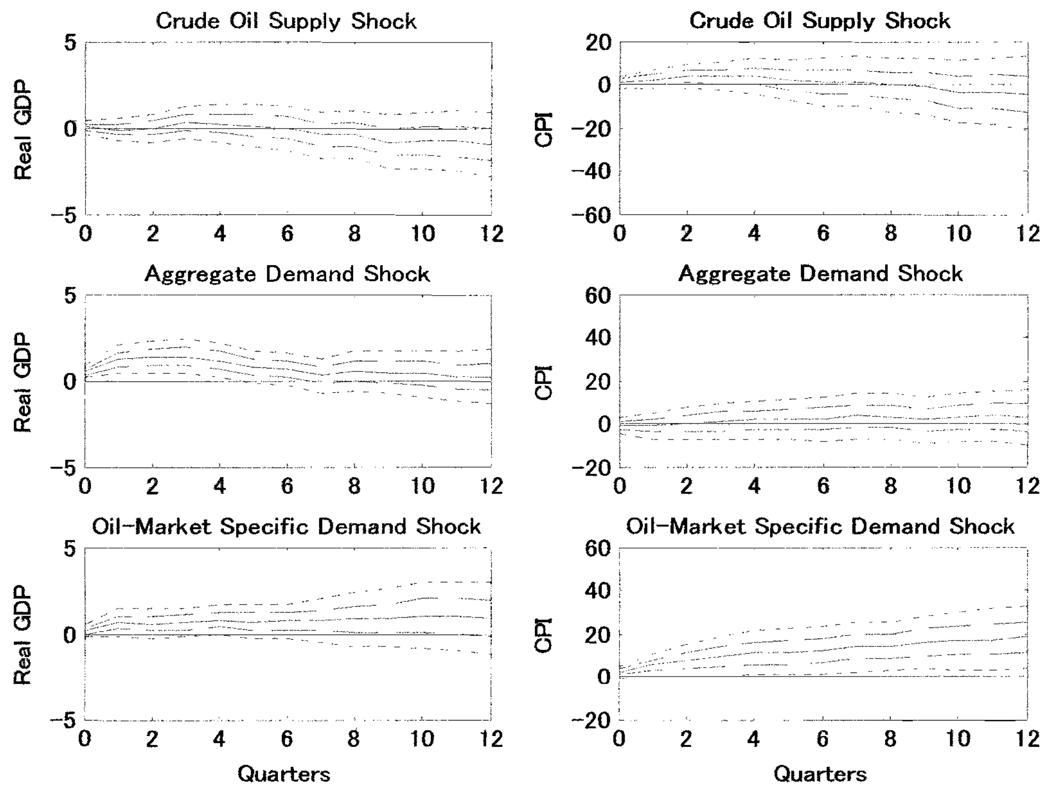


Figure 4: Cumulative responses of the US real GDP and CPI to each structural shock

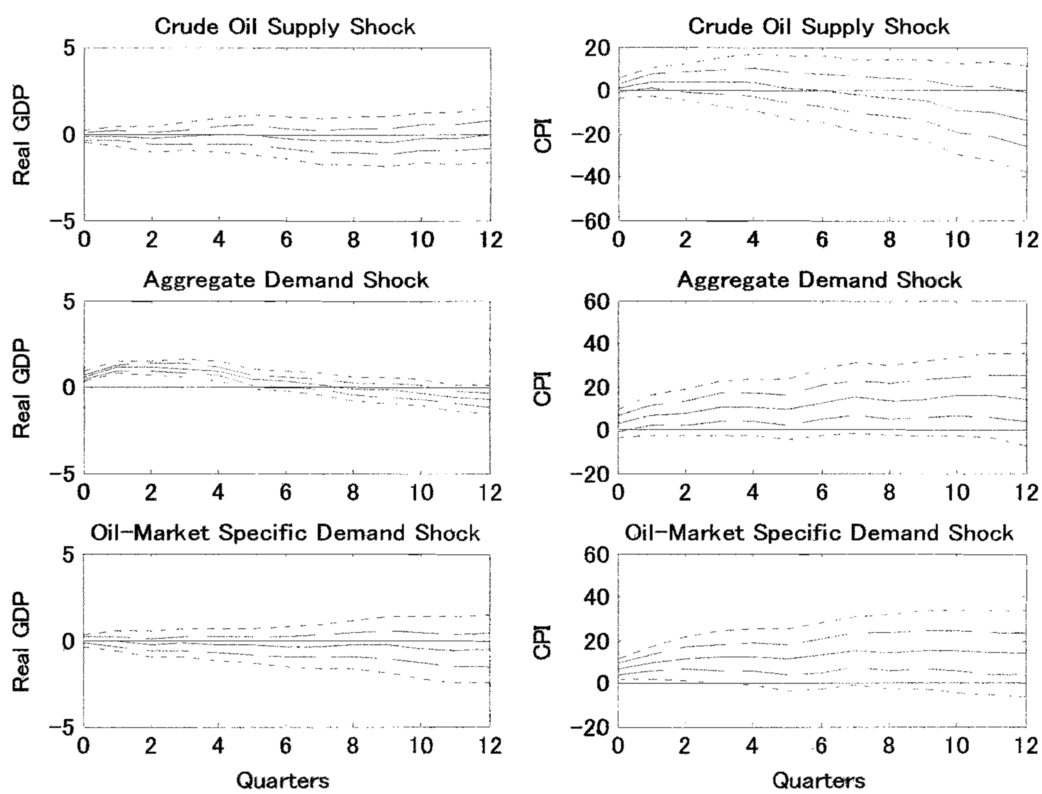
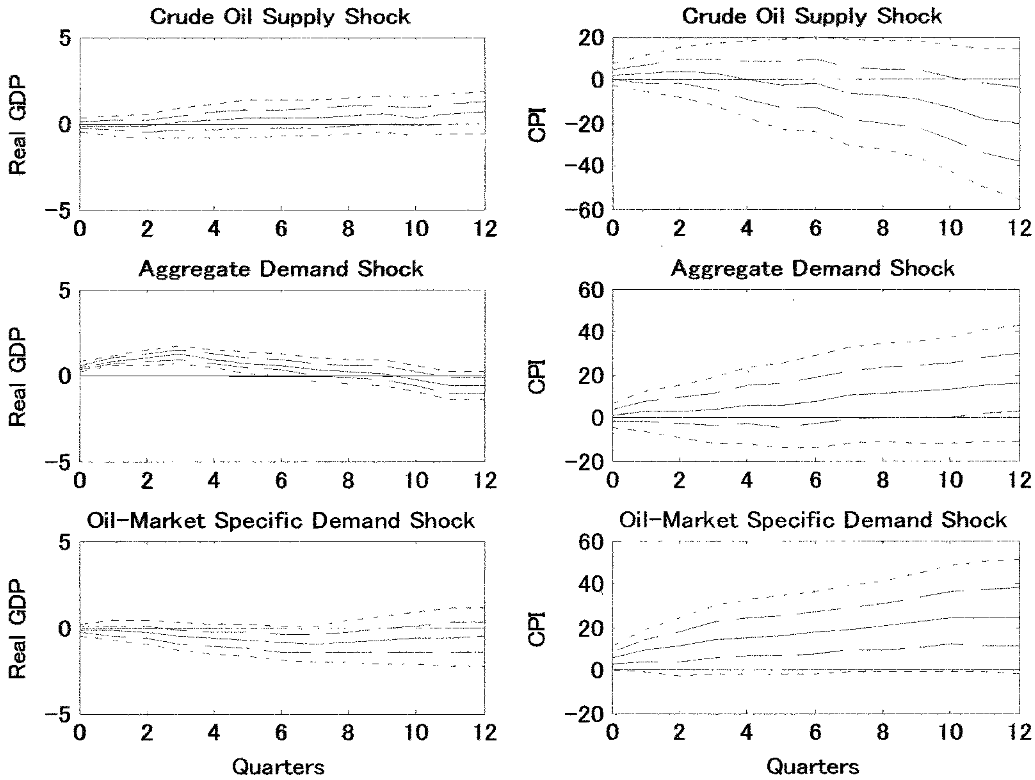


Figure 5: Cumulative responses of the UK real GDP and CPI to each structural shock



Notes: Estimation based on model (5) and (6). One and two-standard error bands are shown by dashed line and dotted line respectively.