Oil Price Fluctuations and Macroeconomic Variables

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ABSTRACT

This study identifies exogenous fluctuations (i.e., shocks) in oil prices and examines their causal effects on macroeconomic variables in Japan. Following a recent line of research that identifies exogenous changes in oil prices (Kilian, 2009), we decompose fluctuations in real prices into crude oil supply shocks, shocks to the global demand for commodities, and demand shocks to the crude oil market. This study provides three main findings. First, an exogenous change in oil prices on the supply side decreases GDP, consumption, investment, and wages. Second, an exogenous change in oil prices on the demand side increases GDP, consumption, investment, and wages. Third, shocks that cause an increase in oil prices increase aggregate price levels, regardless of whether they originate on the supply or demand side. We provide evidence counter to the conventional wisdom that an increase in oil prices always hampers the Japanese economy.

Key words: Energy price, Oil price shocks, Structural VAR, Local projection

JEL Classification: F31, F41, Q43

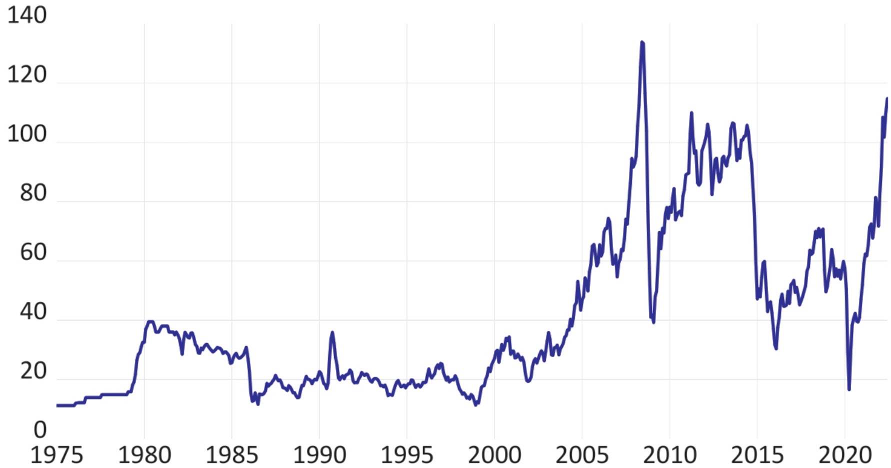


Fig. 1 Fluctuation in crude oil price (West Texas Intermediate, USD per barrel)

1. Introduction

As a macroeconomic shock, changes in oil prices are among the factors that have a major impact on the Japanese economy. Figure 1 shows that volatility in crude oil prices has a significant impact on the Japanese economy. Furthermore, political concerns have led to a global rise in the demand for clean energy in response to climate change and other factors, coupled with Russia's invasion of Ukraine. As a result, crude oil prices soared. The increase in oil prices caused a rapid increase in trading losses for Japan, which has a low energy self-sufficiency ratio (Cabinet Office, 1982; Cabinet Office, 2011). Thus, the rise in oil prices has acted as a downward pressure on the high-energy-dependent economy.

In fact, the literature has paid particular attention to how oil price fluctuations have influenced macroeconomic variables since the oil crisis that happened in the 1970s. This is because oil price shocks may have a causal relationship with macroeconomic performance. Since the publication of Hamilton (1983), a large body of literature has emerged that shows a negative association between oil price increases and macroeconomic performance (Burbidge and Harrison, 1984; Gisser and Thomas, 1986; Hamilton, 1996). An unexpected rise in oil prices generates an increase in production costs and inflation, thereby reducing aggregate demand and trade volume.

However, the literature documents weaker impacts of oil prices on the domestic economy since the mid-1990s (Blanchard and Gali, 2007; Gregorio et al., 2007). For example, Hooker (1996) shows evidence that oil prices no longer exhibit Granger causality in many U.S. macroeconomic variables since the mid-1970s. Hooker (2002) finds that the pass-through of oil prices to U.S. domestic prices has been weakened significantly since around 1980. Regarding the Japanese economy, Shioji and Uchino (2009) confirm a decline in the oil price pass-through. Barsky and Kilian (2002) and Barsky and Killian (2004) conclude that disturbances in the oil market are likely to matter less for U.S. macroeconomic performance than has commonly been thought.

Why have the effects of oil prices become weaker than before? Blinder and Rudd (2009) and Shioji and Uchino (2009) summarize three possible explanations. The first reason is the increased credibility of monetary policy. The second reason is greater wage flexibility. The third reason is changing industrial structure after the two oil crises. As for the third reason, Shioji and Uchino (2011) point out that firms have shifted from energy-using technology to energy-saving technology[1].

Focusing on the Japanese experience, what are the reasons behind the stylized fact that the impact of the second oil shock was less severe than that of the first? Itoh et al. (2015) point out two reasons. The first reason is slack supply and demand. When the first oil crisis occurred, the economy was at a peak and there was excess supply and weak demand. However, when the second oil crisis occurred, the economy was on a recovery path and capacity utilization was low, which implied additional room for supply. Thus, inflation rates were unlikely to increase. The second reason is active macroeconomic policies. Flexible implementation of monetary policy partly served to keep inflation expectations stable, leading to policy coordination among firms, labor unions, and households. In fact, BOJ (2000) and Cabinet Office (2010) point out that inflation expectations did not rise during the second oil crisis because of proactive monetary policies and the learning effect of the public. Consequently, inflation rates rose only moderately.

However, there is a new strand of literature on oil price shocks. One seminal study is Kilian (2009). Kilian (2009) suggests that crude oil price fluctuations can be decomposed into two exogenous fluctuations originating on the supply side and the demand side. The two series of shocks identified allow us to provide deeper insights into the impacts of oil price fluctuations on macroeconomic variables. In fact, Kilian (2009) find that the two series of shocks have different impacts. An oil price shock originating on the supply side reduces production and investment. In contrast, a shock originating on the demand side leads to increased production and investment. To the best of our knowledge, however, this novel identification strategy has never been applied to the Japanese case.

This study identifies the impact of crude oil price fluctuations on macroeconomic variables in Japan. Following a recent line of research that identifies exogenous changes in oil prices (Kilian, 2009), we decompose fluctuations in real prices into crude oil supply shocks, shocks to the global demand for commodities, and demand shocks to the crude oil market. Using the identified shocks, we examine their impacts on the Japanese economy.

The arguments of this study are as follows. First, exogenous changes in oil prices originating on the supply side decrease GDP, consumption, investment, and wages. Second, an exogenous change in oil prices originating on the demand side increases GDP, consumption, investment, and wages. Third, shocks that cause an increase in oil prices increase aggregate price levels, regardless of whether they originate on the supply or demand side. Our results suggest that it is important to consider where shocks occur when analyzing the causal effects of oil price shocks. We provide evidence counter to the conventional wisdom that an increase in oil prices always hampers the Japanese economy.

The remainder of this paper is organized as follows. Section 2 presents a theoretical prediction of the effect of oil price shocks on macroeconomic performance. Section 3 identifies the oil price shocks. Section 4 presents the impulse response functions of macroeconomic variables to oil price shocks originating on the supply and demand sides. Section 5 presents the conclusions of the study.

2. Theoretical prediction

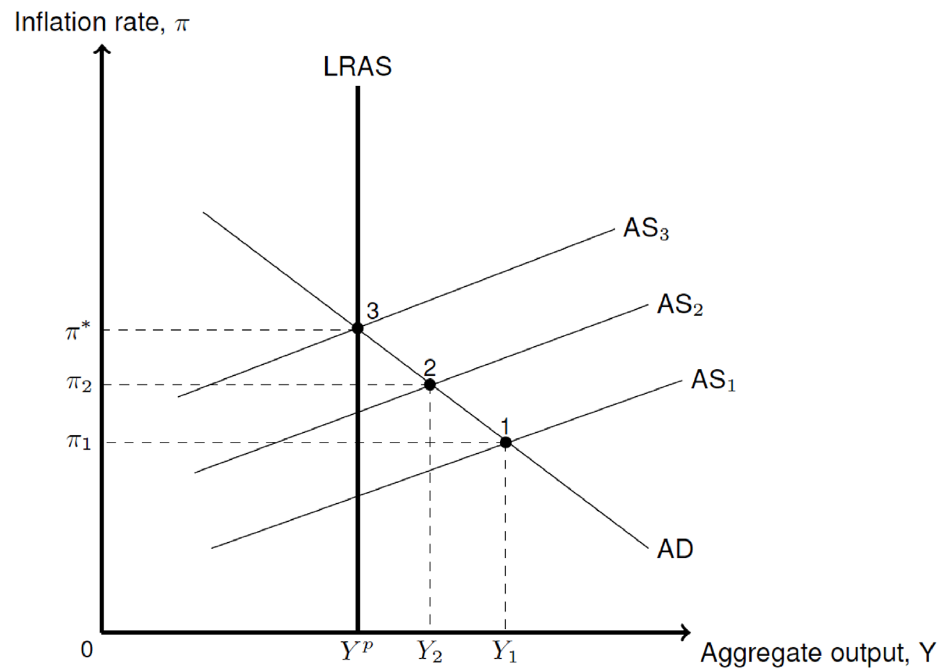
2.1. Supply side shock

The top of Figure 2 shows that the initial equilibrium occurs at point 1, the intersection of the aggregate demand curve AD and the initial short-run aggregate supply curve AS_1. The equilibrium output levels are greater than the potential output Y^p. In addition, there is excessive tightness in the labor market. Hanse the positive output gap at Y_1 drives wages up and causes firms to raise their prices at a more rapid rate. Then, inflation rises above the initial inflation rate π_1. At this higher level of inflation, firms and households adjust their expectations in the next period and expected inflation becomes higher. Wages and prices then rise more rapidly, and the aggregate supply curve shifts upward and to the left from AS_1 to AS_2.

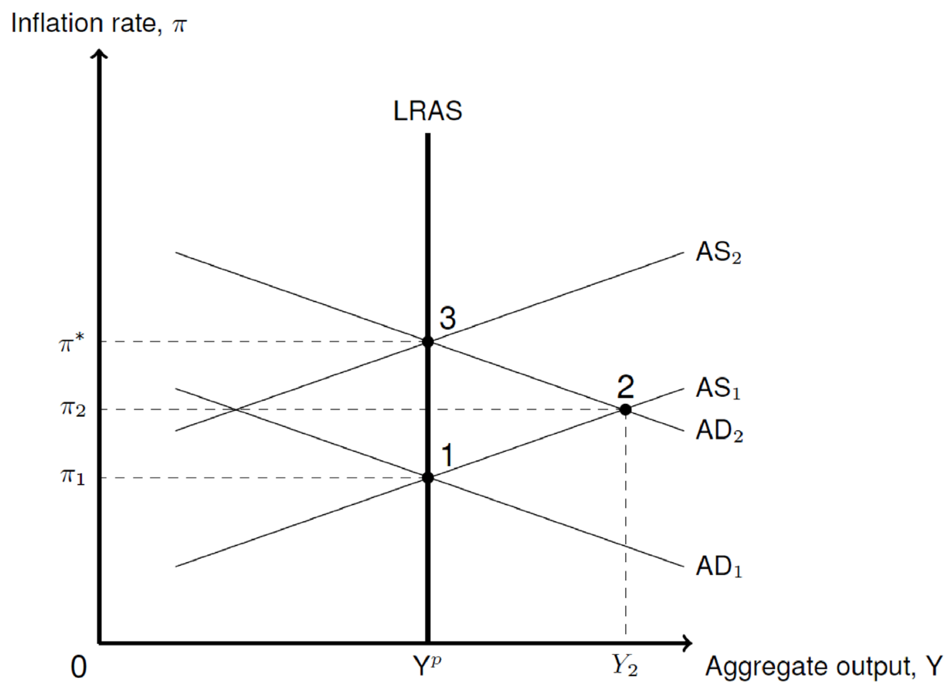
The new equilibrium at point 2 is an upward movement along the aggregate demand curve and output falls to Y_2. However, because aggregate output Y_2 is still above potential output Y^p, inflation again rises above its value in the last period. Expected inflation rises further, eventually shifting the aggregate supply curve up and to the left to AS_3. The economy reaches equilibrium at point 3 on the vertical long run aggregate supply curve (LRAS). Because output is at potential, there is no further pressure on inflation to rise, and thus no further tendency for the aggregate supply curve to shift.

2.2. Demand side shock

The bottom of Figure 2 shows the economy initially in long-run equilibrium at point 1, where the initial aggregate demand curve AD_1 intersects the short-run aggregate supply AS_1 curve at Y^p and the inflation rate is π_1. Suppose that consumers and businesses become more optimistic and that the resulting increases in autonomous consumption and investment create positive demand shocks that shift the aggregate demand curve to the right to AD_2. The economy moves up the



(a) Supply side shocks



(b) Demand side shocks

Fig. 2 Macroeconomic model incorporating supply-side and demand-side shocks

short-run aggregate supply curve AS1 to point 2, and output and inflation rise to Y_2 and π_2, respectively. However, the economy will not remain at point 2 in the long run because the output at Y_2 is above the potential output. Expected inflation will rise, and the short-run aggregate supply curve will eventually shift upward to AS_2. Thus, the economy (equilibrium) moves up the

AD_2 curve from point 2 to point 3, which is the point of long-run equilibrium at which inflation equals $\pi*$ and output returns to Y^p. Although the initial short-run effect of the rightward shift in the aggregate demand curve is an increase in both inflation and output, the ultimate long-run effect is only an increase in the price level.

3. Identification of crude oil price shocks

In this section, we follow Kilian (2009) in identifying oil price shocks as two types of shocks: one originating on the supply side and the other on the demand side. Kilian (2009) proposed a further decomposition of oil price shocks by focusing on changes in crude oil supply and demand. Specifically, he proposed decomposing crude oil price shocks into shocks that originate from the global crude oil supply capacity, shocks that originate from increases or decreases in demand for crude oil, and shocks that cannot be explained by these two shocks. Kilian (2009) used the following structural VAR as a specific identification method

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

$$e_t \equiv \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{oil supply shock}} \\ \varepsilon_t^{\text{aggregate demand shock}} \\ \varepsilon_t^{\text{rest of the shock}} \end{pmatrix}, \tag{2}$$

where the vector Z_t is $(\Delta prod_t, rea_t, rpo_t)$ ' and $\Delta prod_t$, rea_t, and rpo_t are the monthly rate of change in global crude oil production capacity, the logarithm of the global real economic activity index, and the logarithm of the real oil price, respectively[2]. The ε_t in Equation (1) is a structural shock, consisting of an oil supply shock ($\varepsilon_t^{\text{oil supply shock}}$), a demand shock ($\varepsilon_t^{\text{aggregate demand shock}}$), and an oil price shock that is not explained by these shocks ($\varepsilon_t^{\text{rest of the shock}}$).

To identify ε_t in Equation (1), we assume a recursive structure in the contemporaneous interdependence of the variables. Specifically, in Equation (2), all components of the upper triangular matrix A_0^{-1} are set to zero. That is, we assume that $a_{12} = a_{13} = a_{23} = 0$. This implies, first, that the only structural shock (ε_t) that affects the global oil supply capacity at the same time is the shock originating on the oil supply side ($\varepsilon_t^{\text{oil supply shock}}$)[3]. Second, the only structural shock (ε_t) that affects global economic activity at the same time is the shock originating from oil supply and demand. Under this so-called “recursive constraint”, all structural shocks are identified[4].

For the identification strategy, we follow Kilian (2009). We identify demand-side oil price

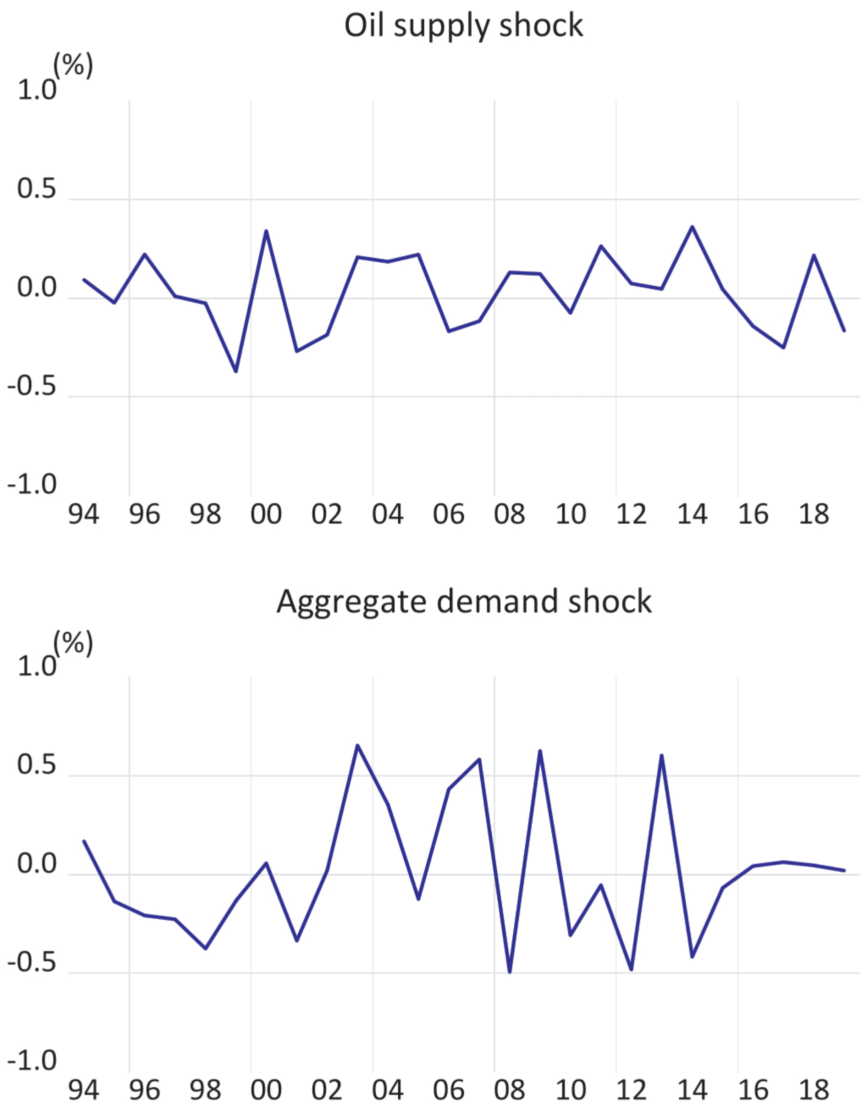


Fig. 3 Fluctuation of identified oil price shocks

shocks ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$) that correspond to aggregate demand shocks. Kilian (2009) points out that innovations to global real economic activity that cannot be explained based on crude oil supply shocks will be referred to as shocks to the global demand for industrial commodities (or aggregate demand shocks for short). Thus, we consider $\hat{\varepsilon}_t^{\text{aggregate demand shock}}$ as aggregate demand shocks and estimate the impulse response functions of macroeconomic variables in the next section.

4. Response of macroeconomic variables to oil price shocks

In this section, following Jorda (2005), we estimate the response of macroeconomic variables to exchange rate shocks (impulse response functions) using the local projection technique.

$$\log y_{t+h} - \log y_{t-1} = \beta_h^S \hat{\varepsilon}_t^{\text{oil supply shock}} + \sum_1^k \gamma_k X_{t-k} + e_{t+h} \tag{3}$$

$$\log y_{t+h} - \log y_{t-1} = \beta_h^D \hat{\varepsilon}_t^{\text{aggregate demand shock}} + \sum_1^k \gamma_k X_{t-k} + e_{t+h} \tag{4}$$

$\log y_{t+h}$ denotes the logarithm of macroeconomic variables from period t to quarter h[5]. The vector X contains the lag (log) of the macroeconomic variable y_t, the oil price shock ($\hat{\varepsilon}_t^{\text{oil price shock}}$) originating on the supply side in Equation (3), and the lag of the crude oil price shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$) originating on the demand side in Equation (4)[6]. The coefficients of interest are β_h^S and β_h^D. The coefficients $\beta_h^S(\beta_h^D)$ when h varies from 0 to 15 represent the impact of a supply-side (demand-side) originating oil price shock on macroeconomic variables h periods ahead. In the following section, we first confirm the impact of the oil price shock on the demand side (GDP, capital investment, and consumption) and then examine the impact of the oil price shock on prices and income to provide more background on the factors behind the changes in demand items.

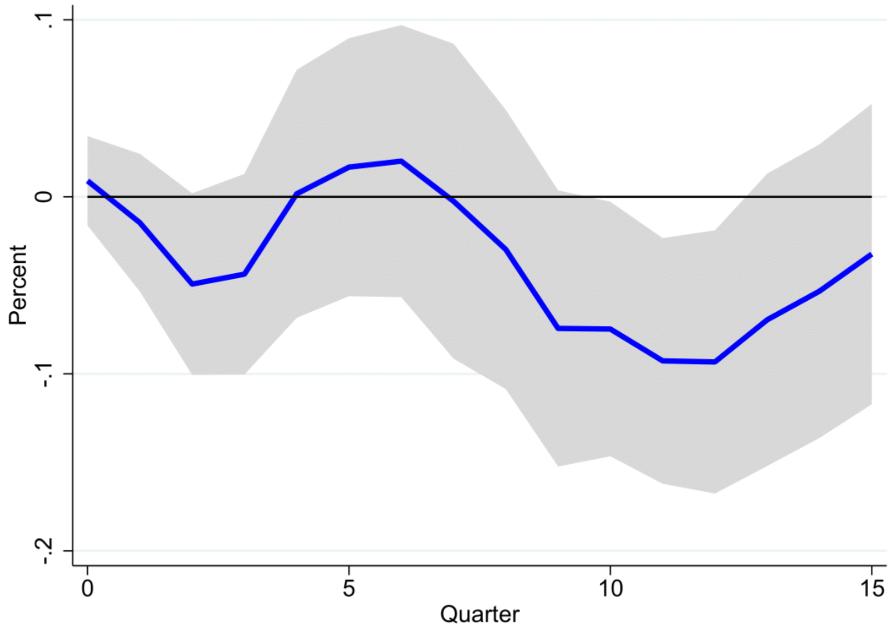
Equations 3 and 4 do not include $\hat{\varepsilon}_t^{\text{rest of the shock}}$ as a control variable. We check robustness when we estimate the impulse response functions by including $\hat{\varepsilon}_t^{\text{rest of the shock}}$. A robustness check confirms that the benchmark results presented in the subsequent subsections do not change.

4.1. Response to GDP

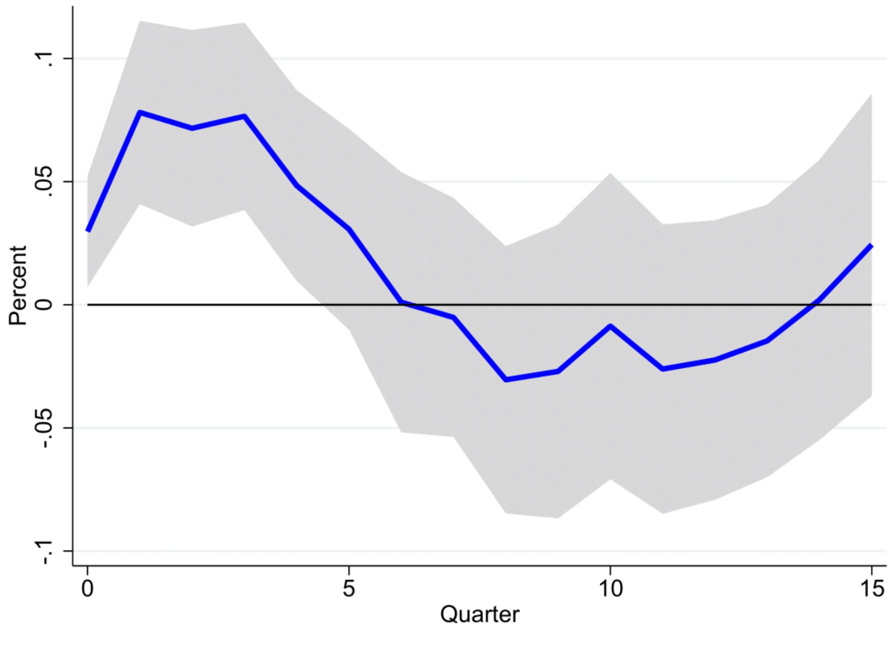
Figure 4 shows the response of GDP to a 1% oil price shock[7]. The top and bottom panels of Figure 4 show the response of GDP to a supply-side shock ($\hat{\varepsilon}_t^{\text{oil supply shock}}$) and a demand-side shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$), respectively. The upper panel of Figure 4 shows that a supply-side shock reduces GDP. GDP declines 10 quarters after the shock, with a decline of −1.0% for a 10% shock. The finding that supply-side shocks reduce GDP is consistent with that of the Cabinet Office (2004), which estimated the impact of higher oil prices on GDP[8]. In contrast, the lower panel of Figure 4 shows that demand-side shocks increase GDP. GDP immediately increases significantly after a shock, by 0.7% in response to a 10% shock. The finding that demand-side shocks to oil prices have a positive impact on output is consistent with the results of Fueki and Kawamoto (2009) and Iwaisako and Nakata (2015).

4.2. Response to capital investment

Figure 5 shows the response of capital investment to a 1% oil price shock. The upper and lower panels of Figure 5 show the response of capital investment to a supply-side shock ($\hat{\varepsilon}_t^{\text{oil supply shock}}$) and a demand-side shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$), respectively. The upper panel of Figure 5 shows that a supply-side shock reduces capital investment. Capital investment declines



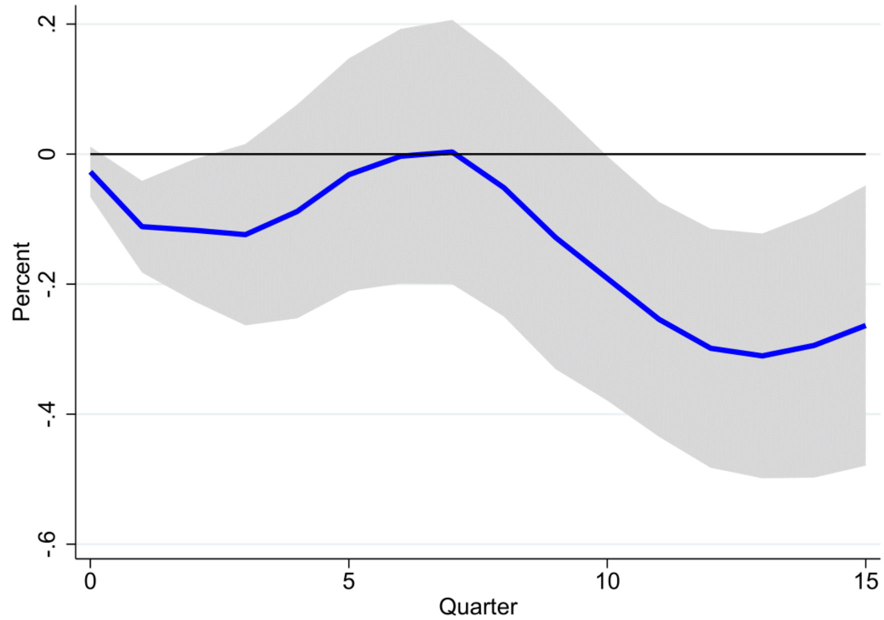
(a) Supply-side shocks



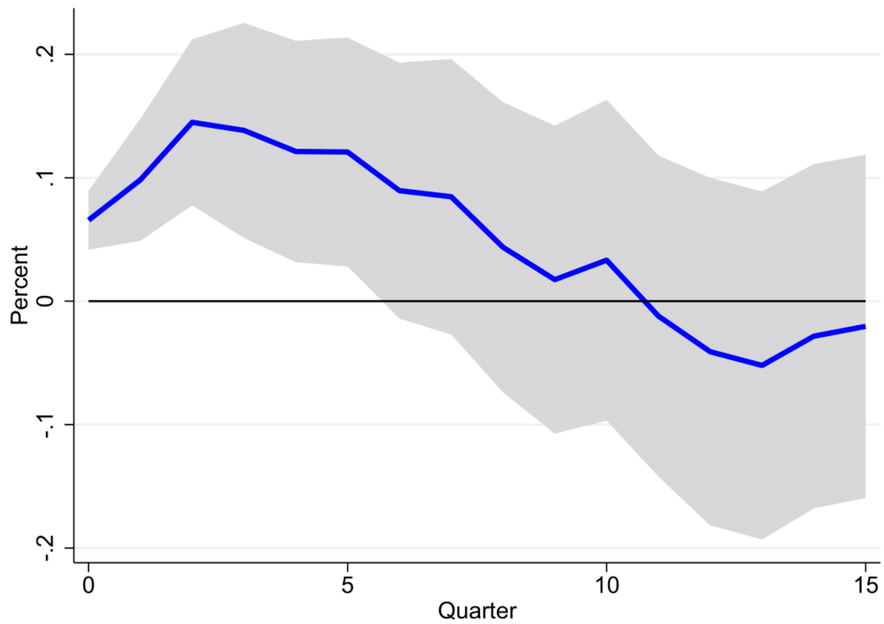
(b) Demand-side shocks

Fig. 4 GDP response to a 1% oil price shock. Colored area indicates confidence interval (±1 standard deviation).

significantly one quarter after the shock. Although it slowly returns to the previous level, it declines again 10 quarters after the shock, with a maximum decline of −3.0% in response to a 10% shock. By contrast, the lower panel of Figure 5 shows that demand-side shocks increase capital investment. As in the case of GDP, the response of capital investment to an oil price shock differed depending on whether the shock originated on the supply or demand side. This



(a) Supply-side shocks



(b) Demand-side shocks

Fig. 5 Capital investment response to a 1% price shock. Colored area indicates confidence interval (±1 standard deviation).

result suggests that it is important to identify the causes of changes in oil prices rather than focusing on changes in oil prices themselves.

4.3. Response to household final expenditure

Figure 6 shows the response of household final consumption expenditures to a 1% oil price shock. The upper and lower panels of Figure 6 show the response of consumption to a supply-side shock ($\hat{\varepsilon}_t^{\text{oil supply shock}}$) and a demand-side shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$), respectively. The upper panel of Figure 6 shows that a supply-side shock reduces consumption. Consumption significantly declines three quarters after the shock. The maximum decline is −0.4% for a 10% shock. By contrast, the lower panel of Figure 6 shows that a demand-side shock increases consumption. As in the cases of GDP and capital investment, the response of consumption to an oil price shock was the opposite, depending on whether the shock originated on the supply or demand side.

4.4. Response to the price level

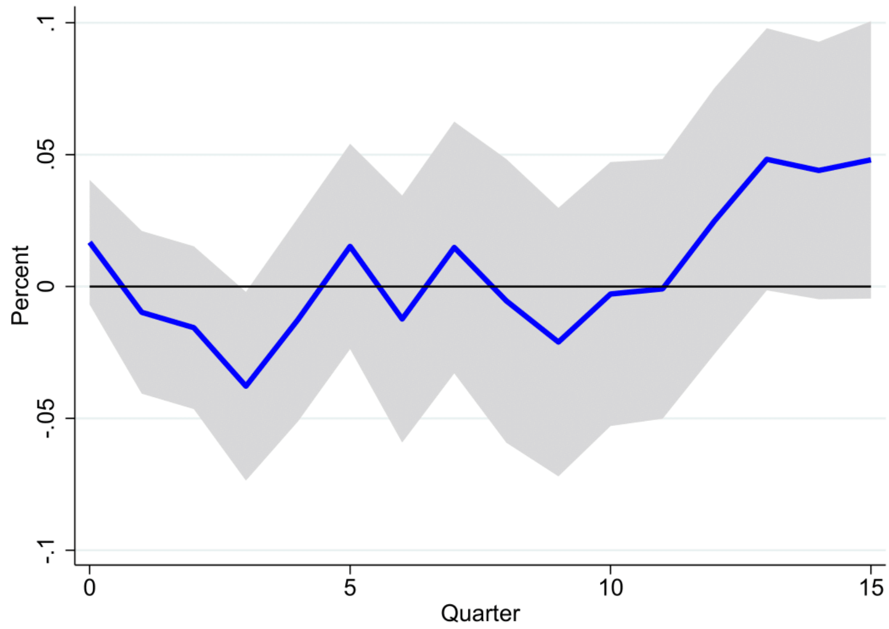
Figure 7 shows the response of the price level (i.e., the consumer price index (composite), seasonally adjusted) to a 1% oil price shock. The upper and lower panels of Figure 7 show the response of the price level to a supply-side shock ($\hat{\varepsilon}_t^{\text{oil supply shock}}$) and a demand-side shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$), respectively. The upper panel of Figure 7 shows that a supply-side shock raises prices. Prices moderately rise immediately after the shock, with the maximum impact occurring six quarters later. The maximum increase is 0.5% in response to a 10% shock. Likewise, the lower panel of Figure 7 shows that demand-side shocks also cause prices to rise. Prices moderately rise immediately after the shock, with the largest impact occurring four quarters later. The maximum increase is 0.3% for a 10% shock. Prices rose regardless of whether the oil price shock originated on the supply or demand side. The impact of an oil price shock on prices is similar to that in Cabinet Office (2004)[9].

4.5. Response to real wages

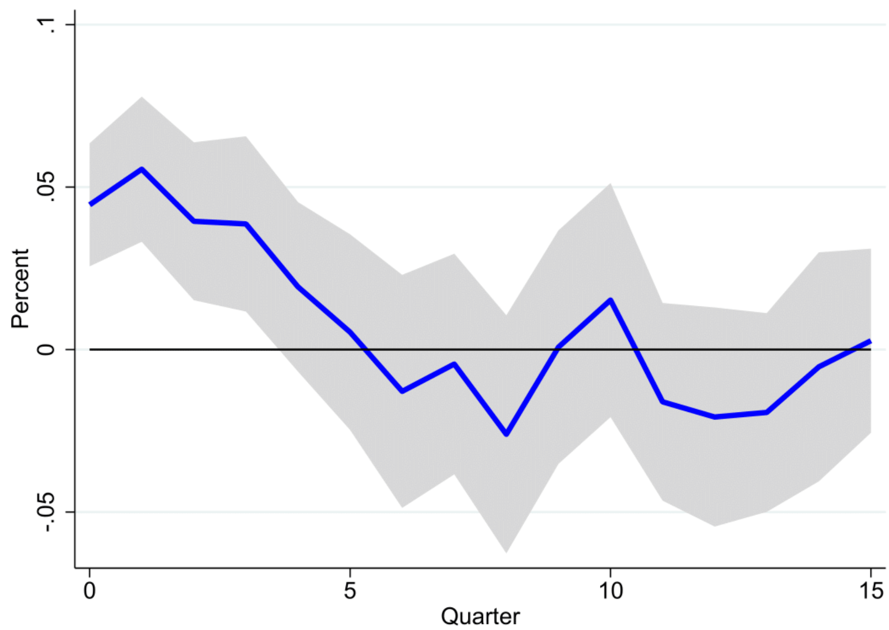
Figure 8 shows the response of wages (i.e., total cash payrolls (real), seasonally adjusted) to a 1% oil price shock. The upper and lower panels of Figure 8 show the wage response to a supply-side shock ($\hat{\varepsilon}_t^{\text{oil supply shock}}$) and a demand-side shock ($\hat{\varepsilon}_t^{\text{aggregate demand shock}}$), respectively. The upper panel of Figure 8 shows that supply-side shocks cause wages to decline. Wages significantly fall immediately after the shock. Wages subsequently decline with some fluctuations, with a maximum decline of −0.6% in response to a 10% shock five quarters later. By contrast, the lower panel of Figure 8 shows that a demand-side shock raises wages. As with GDP, capital investment, and consumption, wages responded to shocks in opposite ways, depending on whether the oil price shock originated on the supply or demand side.

5. Conclusion

When oil prices change, a complex set of supply- and demand-side factors are at work. Therefore, the impact of each shock on the Japanese economy can differ when crude oil price fluctuations are decomposed into two types: one originating on the supply side and the other on the demand side. This study identified the impact of crude oil price fluctuations on



(a) Supply-side shocks

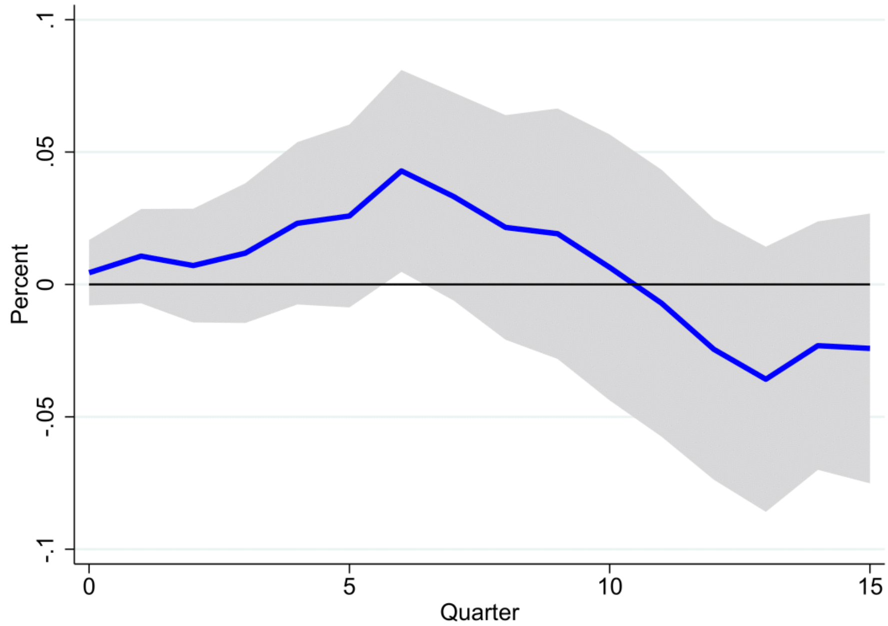


(b) Demand-side shocks

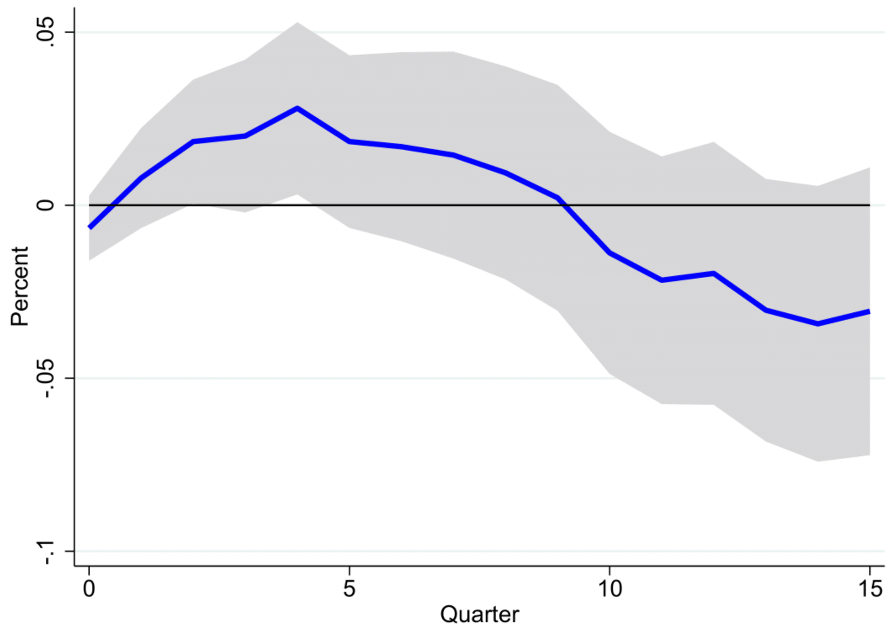
Fig. 6 Household final expenditure response to a 1% price shock. Colored area indicates confidence interval (±1 standard deviation).

macroeconomic variables in Japan. Following a recent line of research that identifies exogenous changes in oil prices (Kilian, 2009), we decomposed our analysis into shocks from supply-side changes and those from demand-side changes.

This study provides three main findings. First, an exogenous change in oil prices on the supply side decreases GDP, consumption, investment, and wages. Second, an exogenous change in oil



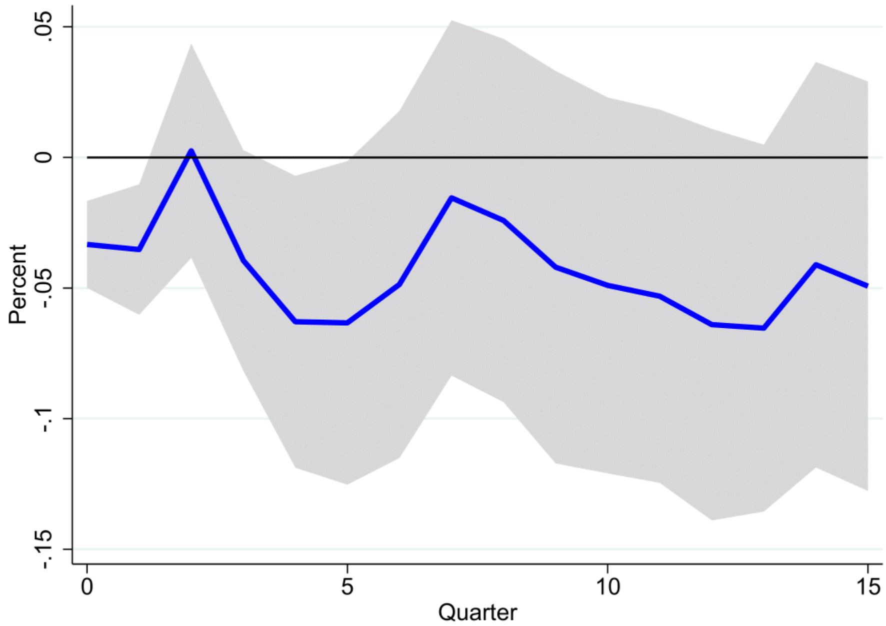
(a) Supply-side shocks



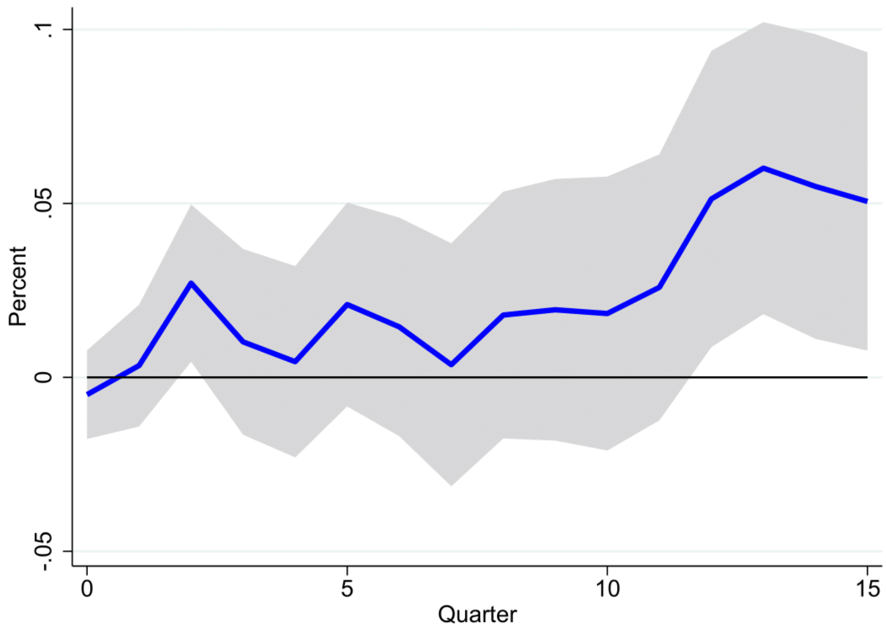
(b) Demand-side shocks

Fig. 7 Price level response to a 1% price shock. Colored area indicates confidence interval (±1 standard deviation).

prices on the demand side increases GDP, consumption, investment, and wages. Third, shocks that cause an increase in oil prices increase aggregate price levels, regardless of whether they originate on the supply or demand side. This study shows that decomposing oil price fluctuations provides evidence countering the conventional wisdom that a rise in oil prices always hampers the Japanese economy.



(a) Supply-side shocks



(b) Demand-side shocks

Fig. 8 Response of wages (total employee income (real), seasonally adjusted) to a 1% crude oil price shock. Colored area indicates confidence interval (±1 standard deviation).

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NOTES

1. Another strand of literature suggests that uncertainty about the price of oil is an important channel by which oil price shocks cause business cycle variations. Nakov and Pescatori (2010) and Blanchard and Gali (2007) find that less volatile oil price fluctuations can explain a decline in the volatility of inflation and GDP growth after 1984. However, Bjørnland (2018) argue that large fluctuations in oil prices are a recurrent feature of the economic environment. The literature has attempted to identify oil price shocks by examining the effects of oil price fluctuations.
2. The monthly rate of change in global crude oil production ($\Delta prod_t$) and real crude oil price (rpo_t) were obtained from the U.S. Energy Information Administration website, and the U.S. Consumer Price Index was used to convert crude oil prices into real terms. For the global real economic activity index (rea_t), we used the index published by Kilian on his website (https://sites.google.com/site/lkilian2019/). The selection and processing of these variables are the same as those in Kilian (2009).
3. This means that the global crude oil supply capacity in period t is not affected by $\varepsilon_t^{\text{aggregate demand shock}}$ and $\varepsilon_t^{\text{rest of the shock}}$.
4. Figure 3 shows the fluctuation of the two identified oil price shocks $\hat{\varepsilon}_t^{\text{oil supply shock}}$ and $\hat{\varepsilon}_t^{\text{aggregate demand shock}}$). By averaging the monthly shocks for each year, we can see the underlying trend of each shock. Figure 3 shows that the demand-side shocks to crude oil prices since 1994 have been relatively large. Crude oil prices soared from 2003 to 2004, reaching a record high in the fall of 2004. Factors originating on the supply side, such as a decline in excess production capacity, have also been identified (Cabinet Office, 2004). However, considering the identified shocks, the impact of the global increase in demand was significant. The unexpected fluctuations in crude oil prices before and after the Lehman Brothers insolvency shock also suggest that demand-side factors played a major role. Supply side shocks have shown large swings since 2013, and these movements are likely to have been influenced by an imbalance between supply and demand caused by the so-called "shale revolution," in which shale oil production in the U.S. went into full swing (Cabinet Office, 2015).
5. The sample used in the estimation is quarterly data (i.e., real GDP, capital investment, household final consumption expenditure, consumer price index, and total employment income (all real and seasonally adjusted)) from 1994 to 2019. Crude oil price shocks (i.e., two series), which originated from supply and demand, were converted to quarterly series by adding up the monthly identified series for each quarter.

6. The lag length was set to 1 (i.e., k = 1) according to the BIC standard. Even when the lag length is changed to 3, the results of the impulse response function estimates shown below do not change significantly.
7. Real GDP was used for GDP. Unless otherwise noted, all economic variables are real values.
8. It should be noted, however, that the estimates by Cabinet Office (2004) are based on the impact of the rise in crude oil prices on GDP, not on the impact of shocks.
9. Using the Input-Output Table, Cabinet Office (2004) estimates that a 10% increase in crude oil prices, if 100% of the increase is passed on to all goods and services, would push up consumer prices by a maximum of 0.16%.

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