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The Effects of Oil Price Changes on the Industry-Level Production and Prices in the U.S. and Japan

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Abstract

In this paper, we decompose oil price changes into their component parts following Kilian (2009) and estimate the dynamic effects of each component on industry-level production and prices in the U.S. and Japan using identified VAR models. The way oil price changes affect each industry depends on what kind of underlying shock drives oil price changes as well as on industry characteristics. Unexpected disruptions of oil supply act mainly as negative supply shocks for oil-intensive industries and act mainly as negative demand shocks for less oil-intensive industries. For most industries in the U.S., shocks to the global demand for all industrial commodities act mainly as positive demand shocks, and demand shocks that are specific to the global oil market act mainly as negative supply shocks. In Japan, the oil-specific demand shocks as well as the global demand shocks act mainly as positive demand shocks for many industries.

Keywords: Oil price; Identified VAR; Industry-level data; Japan
JEL classification: E30

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1 Introduction

There is a large body of empirical literature on the effects of oil price changes on the U.S. economy; their magnitudes, transmission mechanisms, and historical changes have been investigated. However, the underlying causes of oil price changes have not been seriously considered until recently. The way oil price changes affect the economy may be very different depending on where the changes fundamentally come from. In particular, global factors such as rapid growth in emerging economies and the integration of global supply chains seem to have become increasingly important for oil price changes themselves and their transmission mechanisms.

Moreover, much remains unknown about the effects of oil price changes in countries other than the U.S. Some recent empirical international comparative studies show that the magnitudes of the effects of oil price changes differ greatly even among oil-importing countries. In particular, Japan is different in the sense that oil price increases have little, or even a positive, effect on real economic activity.[1]

In this paper, we investigate the underlying causes of oil price changes and their transmission mechanisms in the U.S. and Japan. We decompose oil price changes into their component parts and estimate the dynamic effects of each component on industry-level production and prices in both countries using identified VAR models. Our models incorporate two major extensions to the standard models used in previous studies. First, instead of treating oil price changes as exogenous shocks, we identify the underlying demand and supply shocks to the global oil market. Second, we use industry-level data as well as aggregate data to investigate the transmission mechanisms of oil price changes in more detail.[2] Our models have three-block structures comprising the global oil market block, the domestic macroeconomy block,

[1]Recent studies, including those of Blanchard and Galí (2007) and Jiménez-Rodríguez and Sánchez (2004), show that the effects of oil price changes in Japan are exceptionally different from other oil-importing countries.

[2]We focus on manufacturing industries for which lengthy periods of monthly time series data are available. The quarterly GDP data that include nonmanufacturing industries are not compatible with the short-run restrictions on our structural VAR models.

and the domestic industry block. To our knowledge, this is the first attempt to investigate the effects of structural shocks to the global oil market on industry-level production and prices.[3]

In identifying structural shocks to the global oil market, we closely follow Kilian (2009) who proposes a structural decomposition of the real price of oil into the following three components: oil supply shocks; shocks to the global demand for all industrial commodities (global demand shocks);[4] and demand shocks that are specific to the global oil market (oil-specific demand shocks). These three structural shocks that all tend to raise the oil price have very different effects on domestic economic activity. While an unexpected disruption of oil supply and an unexpected increase in oil-specific demand tend to reduce domestic industrial production, an unexpected increase in global demand raises domestic production. One of the main reasons why the surge in oil prices from 2002 seems to have had a smaller effect on real economic activity than did the oil price increases of the 1970s is that the recent oil price surge and economic expansion were simultaneously driven by the global demand shocks.[5]

Examining the industry-level effects of oil price changes facilitates understanding of their transmission mechanisms. Lee and Ni (2002) estimate the effects of exogenous oil price shocks using U.S. industry-level data and find that oil price shocks act mainly as supply shocks for oil-intensive industries, such as petroleum refineries, and act mainly as demand shocks for many other

[3] Kilian and Park (2009) briefly analyze the effects of structural shocks to the global oil market on industry-level stock returns using a two-block VAR model.

[4] Kilian (2009) refers to this component as an "aggregate demand shock". We do not use this term because it can be confused with domestic aggregate shocks in our model.

[5] Blanchard and Galí (2007) offer other explanations for the smaller effects: the smaller share of oil in production; greater labor market flexibility; and improvements in monetary policy. Rather than consider these structural changes, we focus on changes in the nature of the shocks to the global oil market. As mentioned in the appendix, estimating our models for shorter sample periods does not greatly change most of the impulse responses to the identified shocks, except those to the oil supply shocks. Hirakata and Sudo (2009) point out that reduced oil supply variation and the associated correlation with total factor productivity may be more important than structural changes for explaining the smaller effects of oil price changes on real economic activity.

industries.[6] They distinguish between demand and supply shocks depending on whether production and prices move in the same or opposite directions in response to the shocks. Our estimation results for the domestic industry block reveal that whether oil price changes act as supply shocks or demand shocks for each industry depends on what kind of underlying shock drives the oil price changes, as well as on industry characteristics such as oil intensity. For most industries in the U.S., the global demand shocks act mainly as positive demand shocks, and the oil-specific demand shocks act mainly as negative supply shocks.[7] The oil supply shocks act mainly as negative supply shocks for oil-intensive industries and act mainly as negative demand shocks for less oil-intensive industries, as Lee and Ni (2002) found for exogenous oil price shocks.

Comparing the U.S. and Japan also enhances our understanding of the transmission mechanisms of oil price changes. In Japan, relative to the U.S., the oil supply shock has weaker negative or statistically insignificant effects, the global demand shock has stronger positive effects, and most importantly, the oil-specific demand shock has positive rather than negative effects on the production of many industries. These findings seem to confirm the results of recent studies showing that the effects of oil price increases on Japan's economy are small or even positive and very different from those of other oil-importing countries. The positive response of production to the oil-specific demand shock might be the result of global demand shifts, especially in automobiles, towards more oil-efficient products made in Japan. In this sense, unlike in the U.S., the oil-specific demand shocks act mainly as demand shocks rather than supply shocks for many industries in Japan.

[6]Lee and Ni (2002) use Hamilton's (1996) "net oil price increase" as an oil price variable. Hooker (1996), in his reply to Hamilton (1996), casts doubt on the theoretical and empirical validity of using this variable to represent oil price shocks to the macroeconomy and argues that the use of cross-sectional data on industries, regions, or countries is required for a better understanding of the effects of oil price changes.

[7]The global demand shocks and the oil-specific demand shocks are demand shocks to the global oil market and do not necessarily act as demand shocks to domestic aggregate or industrial markets. For instance, the global demand shocks may include non-oil sector productivity shocks that act as supply shocks to oil-importing countries' domestic markets.

The remainder of the paper is organized as follows. Section 2 describes our empirical framework and the identified structural shocks to the global oil market. In Section 3, we briefly discuss the estimation results for the domestic macroeconomy blocks for the U.S. and Japan. Section 4 reports the estimation results for the domestic industry blocks of both countries for each industry. In Section 5, we briefly survey the transmission mechanisms of oil price changes and interpret our estimation results in more detail. We also consider the background of the differences between the results for the U.S. and Japan. Section 6 concludes. Appendix summarizes the estimation results under several alternative assumptions and specifications of the model to check the robustness of our main results.

2 Empirical Framework

2.1 The Structural VAR Model

Our VAR models comprise the global oil market block, the domestic macroeconomy block, and the domestic industry block. Following Lee and Ni (2002), we impose block recursive restrictions so that the identified shocks to the global oil market are the same for each country and the identified macroeconomic shocks are the same for each industry. In other words, domestic variables do not affect global oil market variables, and industry-level variables do not affect aggregate variables.[8] An identified VAR model has the following form:

$$A_0 \, X_t = A_0 \, c + A_0 \, B(L) \, X_t + u_t$$

[8]This assumption may be too strong if movements in domestic economy in an individual country and linkages among countries have large impacts on the global oil market or if movements in an individual industry and linkages among industries have large impacts on the domestic aggregate economy. However, we impose these restrictions to enable comparison of impulse responses in different countries and different industries to the same structural shock to the global oil market. As mentioned in the appendix, allowing domestic aggregate variables to affect global oil market variables makes little difference to our estimation results.

or

$$A_0 \begin{pmatrix} X_{1t} \\ X_{2t} \\ X_{3t} \end{pmatrix} = A_0 \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} + A_0 \begin{pmatrix} B_{11}(L) & 0 & 0 \\ B_{21}(L) & B_{22}(L) & 0 \\ B_{31}(L) & B_{32}(L) & B_{33}(L) \end{pmatrix} \begin{pmatrix} X_{1t} \\ X_{2t} \\ X_{3t} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}.$$

X_{1t} is an N_1 dimensional column vector of global oil market variables; X_{2t} is an N_2 dimensional column vector of domestic aggregate variables; X_{3t} is an N_3 dimensional column vector of domestic industry-level variables. c_1, c_2, and c_3 are vectors of constants. $B(L)$ is a block recursive matrix of polynomials of the lag operator L. Moreover, we assume that A_0 is a lower triangular matrix such that the reduced-form residuals can be decomposed into the structural shocks, u_t. The covariance matrix of the structural shocks, $E(u_t\, u_t')$, is given by an identity matrix of dimension $N(= N_1 + N_2 + N_3)$.

We use monthly data from 1973:1 to 2008:12.[9] The lag length of the VAR is 12. Following Kilian (2009), we consider oil supply shocks, shocks to the global demand for all industrial commodities, and demand shocks that are specific to the global oil market as structural shocks to the global oil market. Correspondingly, we use the following three variables in the global oil market block ($N_1 = 3$): world crude oil production; the industrial production of the OECD countries plus major six non-member economies (hereafter, world industrial production);[10] and West Texas Intermediate spot crude oil prices.[11] The last two variables differ from those used by Kilian (2009).[12] We use the nominal price of oil rather than the real price because the deflator is endogenous with respect to the domestic macroeconomy, which would violate our assumption of a block recursive structure.[13] For the domestic macroecon-

[9] Kilian (2009) also uses monthly data from 1973:1. Consistent data on the global oil market before 1973 are difficult to obtain.

[10] This index can be downloaded from OECD websites. The six non-member economies are Brazil, China, India, Indonesia, the Russian Federation, and South Africa. Fueki and Kawamoto (2009) use this index to decompose oil price changes.

[11] Data for before 1982 are posted prices.

[12] Kilian (2009) uses an original measure of global real economic activity based on dry cargo freight rates and the U.S. refiner acquisition cost of imported crude oil deflated by the U.S. CPI (both in natural logs). The data on world crude oil production used by Kilian (2009) are the same as those we use.

[13] Hamilton (2008) and Rotemberg and Woodford (1996) point out this problem. We do

omy block, we only use aggregate industrial production ($N_2 = 1$). For the domestic industry block, we use industrial production and producer prices ($N_3 = 2$).[14] We take first differences in the logs of all variables. The data on industrial production in each block and producer prices are seasonally adjusted. The ordering of the variables in the VAR is as described above.[15] The reduced form VAR is estimated consistently by the method of ordinary least squares.

2.2 Structural Shocks to the Global Oil Market

We follow Kilian (2009) to identify the structural shocks to the global oil market. The oil supply shocks are innovations to global oil production that are assumed not to respond to innovations to the demand for oil within the same month. The global demand shocks are innovations to world industrial production that cannot be explained by the oil supply shocks. The oil-specific demand shocks are innovations to the oil price that cannot be explained by either the oil supply shocks or the global demand shocks. The oil-specific demand shocks are supposed to reflect changes in precautionary demand arising from uncertainty about future oil supply, and may also reflect changes in speculative demand. Although we use slightly different data from those used by Kilian (2009), our estimation results for the global oil market block are similar to his. Figure 1 plots the historical evolution (annual averages) of the structural shocks implied by our model. As shown by Kilian (2009), there was no unanticipated disruption of oil supply in 1978 or 1979 but there were disruptions in 1980 and 1981 associated with the Iran–Iraq War. Positive shocks to the global demand have been repeated since 2003 and a large negative shock occurred in 2008. The occurrence of the oil-specific demand

not use the refiner acquisition cost of imported crude oil for the same reason.

[14] We use the Index of Industrial Production published by the Federal Reserve Board and that published by the Japanese Ministry of Economy, Trade, and Industry. For prices data, we use the Producer Price Index from the U.S. Bureau of Labor Statistics and the Corporate Goods Price Index from the Bank of Japan.

[15] As mentioned in the appendix, changing the ordering in the domestic industry block so that prices rather than production come first makes little difference to the estimation results.

shocks has been constant throughout the sample period.

The cumulative responses of the three variables in the global oil market block to one-standard-deviation structural shocks identified above are shown in Figure 2. The oil supply shock has been normalized to represent a negative shock to oil production, whereas the other shocks have been normalized to represent positive shocks such that all shocks tend to raise the oil price. One-standard-error bands computed from a bootstrap method are indicated by dashed lines. Of the three shocks, the oil-specific demand shock has the largest and most persistent effect on the oil price. It sharply raises the oil price on impact, which remains high for a long time. The global demand shock also has a large and persistent effect, causing a gradual increase in the oil price that lasts for about a year (12 months). The oil supply shock has only a small and transitory effect, causing a gradual increase in the oil price that lasts for about 4 months. Whereas an unexpected global demand increase is associated with increases in oil production and world industrial production, an unexpected oil-specific demand increase is associated with decreases, following a 10-month lag, in oil production and world industrial production. An unexpected disruption of oil supply is also associated with a decrease in oil production and its effect on world industrial production is statistically insignificant. These results imply that the effects of the three shocks on the oil price differ in magnitude and persistence. Moreover, the effects of oil price changes on oil production and world industrial production are very different depending on what kind of underlying shock drives the oil price changes.

Figure 3 plots a historical decomposition of the oil price into the contribution of the structural shocks. The annual rate of change (difference in logs) in the oil price is indicated by the dashed line in each panel. The oil supply shocks made a small contribution to nominal oil price movements, which is consistent with the finding of Kilian (2009) for the real price of oil. Most changes in the nominal oil price before 2000 were driven by the oil-specific demand shocks. Rapid temporary changes, such as the sharp fall following the collapse of the OPEC cartel in late 1985 and the spike after Iraq's invasion of Kuwait in 1990 (which are not obvious from the annual figures), were also attributable mainly to the oil-specific demand shocks. Meanwhile, the persistent surge in the oil price from 2002 and the sharp fall in 2008 were driven by the global demand shocks as well as by the oil-specific demand shocks.

3 Macroeconomic Effects of Oil Price Changes

In this section, we briefly discuss the estimation results for the domestic macroeconomy block in our models for the U.S. and Japan and compare them. The domestic macroeconomy block includes only one variable, aggregate industrial production. The shock to this block captures all domestic aggregate disturbances not driven by the structural shocks identified in the global oil market block. Because our main concern in this paper is the industry-level effects of oil price changes and how these effects compare in the U.S. and Japan, we model the domestic macroeconomy block as simply as possible.[16]

3.1 Effects on Aggregate Production in the U.S.

Figure 4 shows the cumulative responses of aggregate industrial production in the U.S. to one standard deviation of the three structural shocks identified in the global oil market block and the domestic aggregate shock. The three structural shocks to the global oil market, which all tend to raise the oil price, have very different effects on domestic macroeconomic activity. Whereas the oil supply shock and the oil-specific demand shock reduce industrial production, the global demand shock raises production for about 10 months. Whereas the decrease in production caused by the oil supply shock lasts for about 10 months, the decrease caused by the oil-specific demand shock ac-

[16] As mentioned in the appendix, we tried an alternative specification of the domestic macroeconomy block that includes the short-term nominal interest rate and the real effective exchange rate in addition to aggregate industrial production. This extension of the domestic macroeconomy block, however, made little difference to our estimation results.

celerates around 10 months after the shock. The domestic aggregate shock raises production gradually and persistently.

Figure 5 plots a historical decomposition of U.S. aggregate industrial production into the contribution of the three global shocks and the domestic aggregate shock. The annual rate of change in U.S. industrial production is indicated by the dashed line in each panel. Changes in U.S. industrial production were driven mainly by the global demand shocks and the domestic aggregate shocks. Because U.S. production accounts for a large share of world production, it seems natural that the global demand shocks make a substantial contribution to U.S. production. It is nonetheless remarkable that movements in U.S. production in the 2000s have been driven mainly by the global demand shocks despite the fact that the U.S. share of world production declined over this period. By contrast, the contribution of the domestic aggregate shocks has declined in the 2000s, although they made a substantial contribution to U.S. expansion in the 1990s. Because the oil price and industrial production move in the same direction in response to the global demand shocks, the relationship between them seems to have changed in the 2000s when movements in these two variables have been driven by the global demand shocks.

3.2 Effects on Aggregate Production in Japan

The cumulative responses of Japan's aggregate industrial production are shown in Figure 6. They are rather different from those of the U.S. The effect of the oil supply shock on Japan's industrial production is statistically insignificant. The positive effect of the global demand shock is larger and more persistent than in the U.S. Most importantly, the oil-specific demand shock has a positive, rather than negative, effect on Japan's production, at least in the short run. Production starts decreasing around half a year (6 months) after a positive oil-specific demand shock. These findings suggest that, unlike in other oil-importing countries including the U.S., the effects of oil price increases in Japan are either negligibly negative or even positive.

The effect of the domestic aggregate shock in Japan is larger than in the U.S.

A historical decomposition of Japan's aggregate industrial production is shown in Figure 7. The annual rate of change in Japan's industrial production is indicated by the dashed line in each panel. As in the U.S., changes in Japan's industrial production have been driven mainly by the global demand shocks and the domestic aggregate shocks. Whereas the contraction of the 1990s was driven mainly by the domestic aggregate shocks, the expansion of the 2000s was driven mainly by the global demand shocks. Relative to the U.S. case, the domestic aggregate shocks have made a large contribution to Japan's industrial production.

4 Industry-Level Effects of Oil Price Changes

In this section, we report the estimation results for the domestic industry block. As mentioned in the introduction, our motivation for using industry-level data is to investigate the transmission mechanisms of oil price changes in the U.S. and Japan's economies. In particular, an important question is whether oil price changes act as supply shocks or demand shocks for each industry. Before reporting the estimation results, we briefly summarize basic statistics on the industrial structures of the U.S. and Japan, which may characterize the supply and demand sides of the transmission mechanisms. We discuss the implications of the estimation results in detail in Section 5.

4.1 Basic Statistics on Industrial Structures

Table 1 shows the value-added shares of industrial production for the 12 industries in the U.S. and Japan selected for the present study. Although the total share of our selected industries accounts for only around 40 percent of U.S. aggregate manufacturing production, they include key industries for the transmission of oil price changes such as petroleum refineries and automotive products, as discussed in Section 5. Because we must match industry-level data on production and prices, we cannot select broadly defined (three-digit

NAICS) industries. For Japan, where the total value-added share of our selected industries is around 80 percent, data on both production and prices for broadly defined industries are available, although lengthy time-series data at the highly disaggregated industry level are not available. For instance, petroleum refineries are included in "petroleum and coal products" and automotive products are included in "transportation equipment". Table 1 also shows that some industries' shares changed considerably during our sample period. For instance, in the U.S., from 1973 to 2006, chemical materials and petroleum refineries increased their shares, whereas fabricated metal products and machinery decreased their shares. In Japan, from 1975 to 2005, shares for the electrical machinery and transportation equipment increased, whereas the share for the ceramic, stone, and clay products decreased.

We consider two industry characteristics: oil intensity and export dependence. The former relates to the cost share of oil in production and is a key characteristic for the supply channel in the transmission of oil price changes, as discussed in Section 5. The latter relates to the export share of shipments and is a key characteristic for the effects of the global demand shocks. We measure these characteristics for both countries based on the 2000 Japan-U.S. input-output table from Japan's Ministry of Economy, Trade, and Industry.

Table 2 shows the cost share of oil in each industry in both countries.[17] The oil intensity of the petroleum and coal products (which includes petroleum refineries) is particularly high in both countries. Oil intensity is also relatively high in ceramics, stone, and clay products, chemical products, steel and steel products, and non-steel metals and products. We term these industries "oil-intensive industries" and refer to the others as "less oil-intensive industries". Based on the 12-industry average, Japan is less oil-intensive than the U.S.

Table 3 shows the export share of shipments in each industry in both countries. The export dependences of precision instruments, electric machinery, general machinery, and transportation equipment (which includes automotive products) are particularly high in both countries. These industries are termed "export-dependent industries". Based on the 12-industry

[17] The figures show the input cost shares of "mining" and "petroleum and coal products".

average, Japan is more export-dependent than the U.S.

4.2 Effects on Industry-Level Production and Prices in the U.S.

Figures 8 through 13 illustrate the estimated cumulative responses of production and prices of the 12 selected industries in the U.S. to one standard deviation of the three structural shocks identified in the global oil market block. Each response is accompanied by one-standard-error bands computed from a bootstrap method. The graphs for the selected industries are presented in order of oil intensity. Note that the scales of the responses are different for different industries. For cross-industry comparisons, we show the magnitudes of the 12-month cumulative responses for all 12 industries in Figure 14. In addition, in Table 4, we summarize the signs of the peak responses within 20 months to each shock, following Lee and Ni (2002).[18] This table enables us to identify the main effects of each structural shock for each industry. If production and price move in the same (opposite) direction after a shock, the dominant effect of that shock is on the demand (supply) side.

First we examine the responses of production and prices to the oil supply shock, as shown in Figures 8 and 9. In most industries, an unexpected disruption of oil supply causes a gradual decline in production that lasts for about a year. The production of petroleum refineries declines on impact and then continues to decline gradually and persistently. The responses of prices vary across industries. An unexpected oil supply disruption significantly raises the price of petroleum refineries and reduces the prices of wood product and electrical equipment. It tends to raise the prices of oil-intensive industries and tends to reduce the prices of less oil-intensive industries, although these effects for many industries are only partially (in limited periods) statistically

[18]Rather than plot the cumulative responses of first-difference series to *permanent* level shocks as we do, Lee and Ni (2002) plot the responses of level variables to *temporary* level shocks. Therefore, our responses have different interpretations, particularly in the long run, from theirs.

significant. This implies that the oil supply shocks act mainly as supply shocks for oil-intensive industries and act mainly as demand shocks for less oil-intensive industries. This finding is similar to that obtained by Lee and Ni (2002) for exogenous oil price shocks.

Figures 10 and 11 illustrate the responses to the global demand shock. An unexpected expansion in the global demand for all industrial commodities gradually increases the production of most industries. Whereas increases in the production of some export-dependent industries such as machinery and electrical equipment last for about a year, the increases in many industries last for only a few months or half a year. In particular, automotive products, furniture and related product, wood product, and some oil-intensive industries including petroleum refineries, experience only transitory increases in production. At the same time, a positive global demand shock gradually and persistently increases the prices of most industries. The price increase in petroleum refineries is the largest among the industries. Prices in many less oil-intensive industries also increase, but by less than do those in oil-intensive industries. These results imply that the global demand shocks act mainly as demand shocks, at least in the short run, for most industries. Note that these global demand shocks act as positive demand shocks for many industries, in contrast to the oil supply shocks which act as negative demand shocks for less oil-intensive industries.

Figures 12 and 13 illustrate the responses to the oil-specific demand shock. An unexpected increase in demand that is specific to the global oil market gradually and persistently reduces the production of most industries, with a half-year lag. The decrease in automotive production is the largest, and generally, production declines are relatively large in less oil-intensive industries. At the same time, a positive oil-specific demand shock persistently increases the prices of most industries. In petroleum refineries, prices increase on impact and then continue to rise until around a year after the shock, which is the largest increase among the industries. Prices in many less oil-intensive industries, including automotive products, also increase, but generally by less than those in oil-intensive industries. These results imply that the oil-specific demand shocks act mainly as supply shocks for most industries.

4.3 Effects on Industry-Level Production and Prices in Japan

Figures 15 through 20 illustrate the estimated cumulative responses of production and prices of the 12 selected industries in Japan to the same structural shocks. The magnitudes of the 12-month cumulative responses for all 12 industries are shown in Figure 21. The signs of the peak responses are summarized in Table 5.

Figures 15 and 16 illustrate the responses to the oil supply shock. An unexpected disruption of oil supply gradually decreases petroleum and coal production, which includes production of petroleum refineries, and this lasts for about a year. There are declines in production of many other industries, but only partially statistically significant. Disruption to oil supply gradually increases prices of petroleum refineries, and this also lasts for about a year. There are price falls in other oil-intensive industries such as ceramic, stone, and clay products and iron and steel products, but only partially statistically significant. The effects on prices of less oil-intensive industries are mostly statistically insignificant. Overall, the oil supply shocks act mainly as supply shocks for petroleum refineries but have insignificant effects on many other industries in Japan.

The responses to the global demand shock are shown in Figures 17 and 18. As in the U.S., an unexpected expansion in the global demand for all industrial commodities gradually increases production of most industries in Japan. Whereas the increases in production of some oil-intensive industries such as petroleum and coal products last for only about half a year, production increases in many less oil-intensive and export-dependent industries last for about a year, and the effects are larger than those in oil-intensive industries. Compared with the U.S., the global demand shocks have persistent effects on production in a wider range of industries, which include transportation equipment. At the same time, a positive oil-specific demand shock gradually and persistently raises the prices of many industries, particularly oil-intensive industries. By contrast, prices of some less oil-intensive industries such as precision instruments and transportation equipment fall, at least in the short run. As in the U.S., the global demand shocks act mainly as demand shocks for most industries in Japan. However, the magnitude and persistence of the effects in some industries differ greatly from the corresponding effects in the U.S.

The responses to the oil-specific demand shock are shown in Figures 19 and 20. Of the three structural shocks, the responses to this shock differ most between the U.S. and Japan. Unlike in the U.S., an unexpected increase in demand that is specific to the global oil market raises rather than reduces production of most industries in Japan, at least in the short run. Whereas production increases in oil-intensive industries are small and transitory, those in some less oil-intensive and export-dependent industries, such as general machinery, precision instruments, and transportation equipment, last for about a year. Therefore, the oil-specific demand shocks have similar effects on production to the global demand shocks, although the latter have much larger effects. At the same time, a positive oil-specific demand shock gradually and persistently raises the prices of most industries. Unlike in the U.S., the oil-specific demand shocks act mainly as demand shocks rather than supply shocks for many industries in Japan.

This comparison with the U.S. reveals that the oil supply shock has weaker negative or statistically insignificant effects, the global demand shock has stronger positive effects, and the oil-specific demand shock has positive rather than negative effects on production of many industries in Japan. Moreover, the effects on industry-level prices in Japan of the three structural shocks that all tend to raise the oil price are weaker than in the U.S. We will discuss the background of these differences in the next section.

5 Discussion

The estimation results for the domestic industry block in Section 4 reveal that whether the oil price changes act as supply shocks or demand shocks for each industry depends on what kind of underlying shock drives the oil price changes. It also depends on each industry's characteristics: that is, oil price changes tend to act more as supply shocks for oil-intensive industries and tend to act more as demand shocks for less oil-intensive industries, as shown by Lee and Ni (2002). However, our results imply that the global demand shocks act mainly as demand shocks and that the oil-specific demand shocks act mainly as supply shocks in the U.S., for most industries. Considering this key finding, we briefly survey the transmission mechanisms of oil price changes and interpret our estimation results in more detail. The three structural shocks to the global oil market identified in our model are transmitted to each industry through various channels, some of which are familiar and others are less familiar in the literature.[19]

Another key finding is that the transmission mechanisms differ considerably between the U.S. and Japan. In particular, the oil-specific demand shocks in Japan act mainly as demand shocks rather than supply shocks for many industries. Following discussion of the transmission mechanisms, we consider the background of the differences between the U.S. and Japan.

5.1 Transmission Mechanisms of Oil Price Changes

Oil price changes have been viewed traditionally as cost shocks or productivity shocks to oil-importing countries, and many studies focus on the supply side of their transmission mechanisms.[20] When an oil price hike pushes up production costs, producers reduce their use of oil, which may lower the

[19] The survey is limited to mechanisms relating to our estimation results. Because our models do not explicitly consider either monetary policy shocks or endogenous responses of monetary policy to oil price changes, we ignore the relationship between oil prices and monetary policy.

[20] For instance, Bruno and Sachs (1985) extensively study the supply side of the transmission mechanisms of oil price changes.

productivity of capital and labor. This cost channel or supply channel of transmission operates mainly in oil-intensive industries. According to our estimation results, the magnitudes of the price responses to any kind of structural shock to the global oil market are relatively large in oil-intensive industries, particularly petroleum refineries. However, production responses in oil-intensive industries are not particularly large. The effect of an oil-specific demand shock in the U.S. on production of oil-intensive industries is smaller than that of less oil-intensive industries such as automotive products. The production of oil-intensive industries increases rather than decreases in response to a positive global demand shock, which moves in the same direction as prices. Because the economy-wide cost share of oil is low, it is reasonable to suppose that the direct effect of the cost channel by itself cannot explain the whole impact of oil price changes on economic activity.[21]

Another important channel of the transmission is on the demand side of the economy. Kilian (2008) categorizes the effects of oil price changes on consumption expenditure into a discretionary income effect, a precautionary savings effect, an uncertainty effect, and an operating cost effect.[22] The first two effects, which operate through consumers' present and expected future incomes, relate to a wide range of goods and services, whereas the other two effects relate only to consumer durables. The uncertainty effect of oil price changes causes consumers to postpone irreversible purchases of consumer durables, and the operating cost effect causes consumers to refrain from purchasing oil-using durables, particularly automobiles. According to our estimation results, the U.S. automotive industry exhibits the largest production decrease following a positive oil-specific demand shock. This implies that the oil-specific demand shocks act as demand shocks as well as supply shocks for the U.S. automotive industry, though the negative effect on prices through the demand channel is not as strong as the positive effect on prices

[21] Hamilton (2008) discusses the empirical relevance of the cost channel in his survey of the mechanisms through which the effects of oil price changes are transmitted to the macroeconomy.

[22] Oil price changes also affect firms' investment expenditures, but these effects are considered small by Kilian (2008).

through the supply channel. Note that all the above effects of oil price increases reduce consumption expenditure; that is, they act as negative demand shocks. By contrast, the global demand shocks identified in our model act mainly as positive demand shocks. This is because, by construction, these shocks incorporate positive shocks to the income of U.S. or other countries' residents who purchase U.S. products. More precisely, however, the global demand shocks act as both positive and negative demand shocks that offset each other: the positive effects operate through positive income shocks and the negative effects operate through the oil price increases induced by the same shocks. According to our estimation results, a positive global demand shock raises U.S. automotive production only slightly and temporarily, relative to other less oil-intensive industries such as machinery and electrical equipment. This is because the negative effect that operates through the oil price increase in the automotive industry is stronger than in other less oil-intensive industries.

If oil price changes intensively affect a certain sector of the economy, whether through the supply or demand channel, sectoral shifts of resources between the affected sector and less affected sectors are likely to occur. In the process of such sectoral shifts, some resources might be unemployed by any sector because of frictions in capital and labor markets, which may further depress aggregate economic activity and amplify the negative effects of oil price changes. This reallocation effect has been discussed by many researchers including Hamilton (1988) and Davis and Haltiwanger (2001). Our estimation results, however, do not provide clear evidence of significant resource reallocation across industries either for the U.S. or Japan. Although the magnitudes of the production responses to each type of shocks differ considerably across industries, the directions of the responses are the same for most industries.

Meanwhile, some of our results imply demand shifts across countries. The production increases in export-dependent industries, such as machinery and electric equipment, following a positive global demand shock tend to be larger and more persistent than those of less export-dependent industries, both in the U.S. and Japan. This is because, as mentioned above, the global demand shocks partly reflect changes in the incomes of foreign residents who purchase domestic products. Moreover, demand shifts from U.S. products to Japanese products might constitute an explanation for the significant difference in the effects of the oil-specific demand shocks between the two countries, as discussed in the next subsection. These global transmission channels of oil price changes have received relatively less attention in the literature.[23]

5.2 Differences between the U.S. and Japan

Based on the above discussion, we consider the background of the differences between our estimation results for the U.S. and Japan. For Japan, in many industries, the production responses to the oil supply shock are weaker or statistically insignificant and those to the global demand shock are stronger than those of the U.S. These differences are explained by the facts that Japan's economy is less oil-intensive and more export-dependent than the U.S., as shown in Section 4.1.

The biggest difference is in the effects of the oil-specific demand shocks. For many industries in Japan, production as well as prices increase rather than decrease in response to a positive oil-specific demand shock. Therefore, the oil-specific demand shocks act mainly as positive demand shocks, similarly to the global demand shocks. This implies the existence of some oil-specific factors, which cannot be explained by the global demand shocks, causing global demand shifts towards Japanese products. We consider the oil efficiency of Japanese products as one of such factors. In particular, Japanese automotive manufacturers have produced smaller and more oil-efficient cars than have U.S. manufacturers since the 1970s. By causing a massive demand shift towards small cars, the oil crisis of the 1970s damaged U.S. carmakers, which produced only large cars, as documented by Bresnahan and Ramey (1993) among others. At the same time, Japanese carmakers sharply raised

[23] An exception is Abeysinghe (2001), who estimates the "indirect effect" of oil price changes on the GDP growth of 12 economies, mainly Asian emerging economies, which is transmitted through a trade matrix.

their market shares in the U.S.[24] In 2004–06, Japanese cars were still more fuel efficient than U.S. cars, as shown in Figure 22, and the market share of Japanese cars in the U.S. has been still increasing. These demand shifts might constitute an explanation for why U.S. and Japanese automotive production differ in their responses to the oil-specific demand shocks; among our selected industries, automotive production differs the most between the U.S. and Japan. Moreover, the demand for automotive products induces production of many other industries such as steel and precision instruments. Although the value-added share of passenger cars (excluding buses and trucks) in Japanese industrial production is only about 8.5 percent, the economy-wide impacts of demand shifts towards Japanese cars may be substantial.

6 Concluding Remarks

In this paper, we decomposed oil price changes into their component parts following Kilian (2009) and estimated the dynamic effects of each component on industry-level production and prices in the U.S. and Japan using identified VAR models. Our results reveal that the way oil price changes affect each industry depends on what kind of underlying shock drives the oil price changes as well as on industry characteristics. We also found that the transmission mechanisms differ considerably between the U.S. and Japan.

Our results imply that global demand shifts across countries are important factors for oil price changes themselves and their transmission mechanisms. We considered the global demand shocks as underlying causes of oil price changes and discussed the effects of global demand shifts towards more oil-efficient products. For a better understanding of the transmission mechanisms, it would be worth investigating differences in the effects of oil price changes among countries other than the U.S. and Japan. Moreover, developing open-economy dynamic stochastic general equilibrium models that

[24] There are many empirical studies on the U.S. automobile market. For instance, Goldberg (1998) examines the effects of the Corporate Average Fuel Economy Standards enacted in 1975 on automobile sales, prices, and fuel consumption, considering demand shifts towards more fuel-efficient vehicles.

incorporate the global oil market is also a promising way of deepening our understanding and would enhance the interpretation of empirical results on the effects of oil price changes.

Appendix: Robustness Checks

In this appendix, we summarize the estimation results under several alternative assumptions and specifications of the model to check the robustness of our main results.[25]

First, we changed the sample period of estimation, while keeping the model unchanged. Although we focus on changes in the nature of the shocks rather than structural changes as an explanation for the weakening effects of oil price changes on real economic activity (as stated in footnote 5), it is possible to estimate our models for shorter sample periods and check whether structural changes occurred during the full sample period. We divided the sample period into the two sub-periods, 1973:1 to 1983:12 and 1984:1 to 2008:12, following Blanchard and Galí (2007) in choosing the break point. In the later sub-period, the negative effects of the oil supply shocks on production were weakened in both the U.S. and Japan, the positive effects of the global demand shocks on production were strengthened in Japan, and the effects of the oil-specific demand shocks were little changed in both countries. Therefore, structural changes occurred only in the effects of oil price changes caused by the oil supply shocks (and the global demand shocks in Japan) which made historically a small contribution to oil price movements (as shown in Figure 3). Overall, the directions of the responses to the three structural shocks were little changed in each industry.

Second, we partially relaxed the block recursive restrictions and assumed that domestic aggregate variables could affect global oil market variables. Third, we included in the domestic macroeconomy block the short-term nominal interest rate and the real effective exchange rate in addition to aggregate

[25]The detailed results of the robustness checks will be available upon request.

industrial production.[26] Lastly, we changed the ordering of the variables in the domestic industry block (industrial production and producer prices) so that prices rather than production come first. We found that all these changes made little differences to our main results.

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[26] The short-term nominal interest rate we use is the federal funds rate for the U.S. and overnight call rate for Japan. We use the real effective exchange rates published by the Federal Reserve Board and that published by Bank of Japan.

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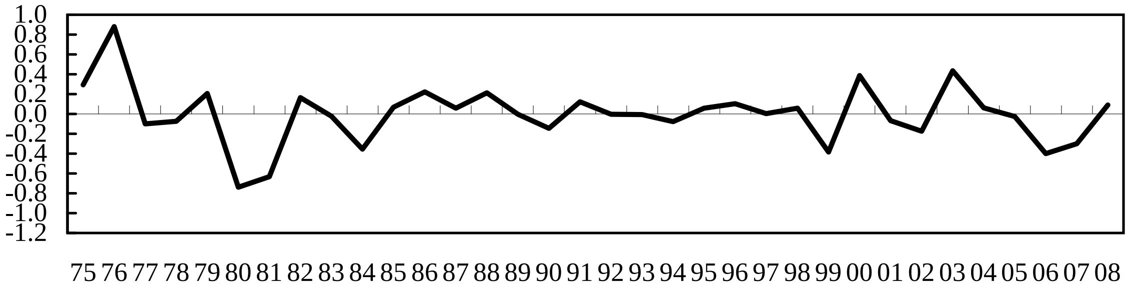
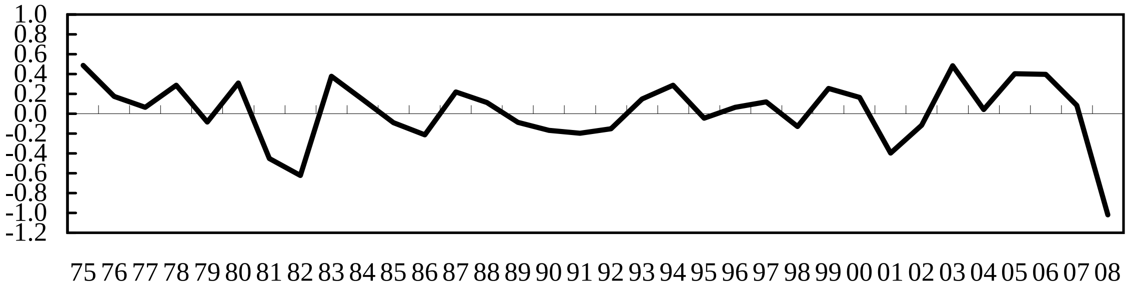
Figure 1: Historical evolution of the structural shocks

Oil Supply Shocks



Global Demand Shocks



Oil-Specific Demand Shocks

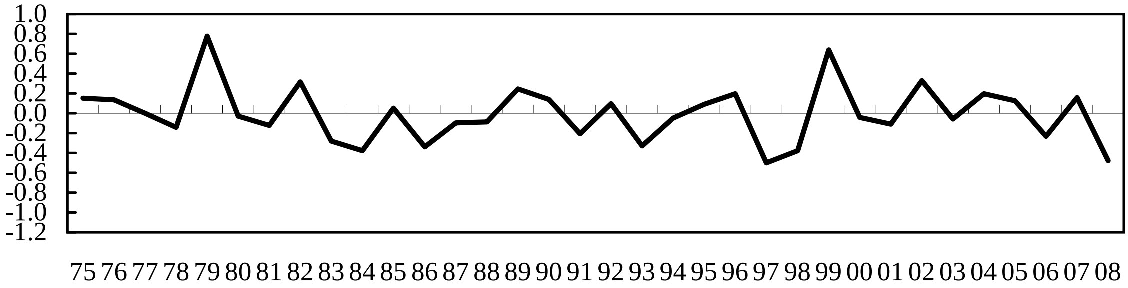


Figure 2: Cumulative responses in the global oil market block

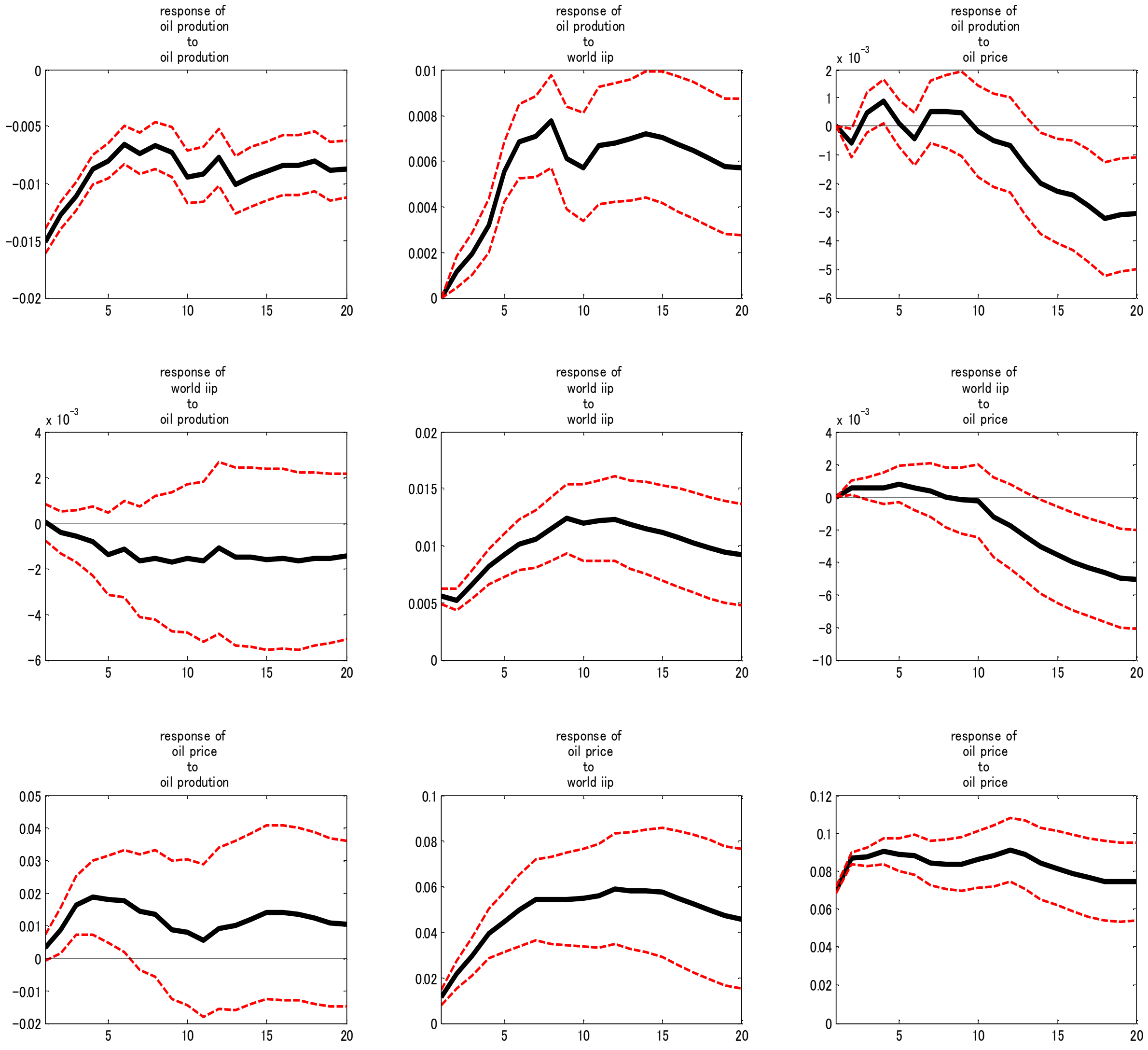
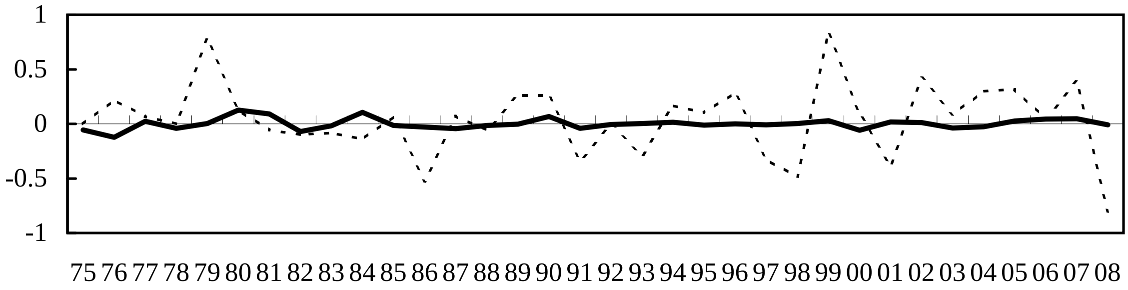
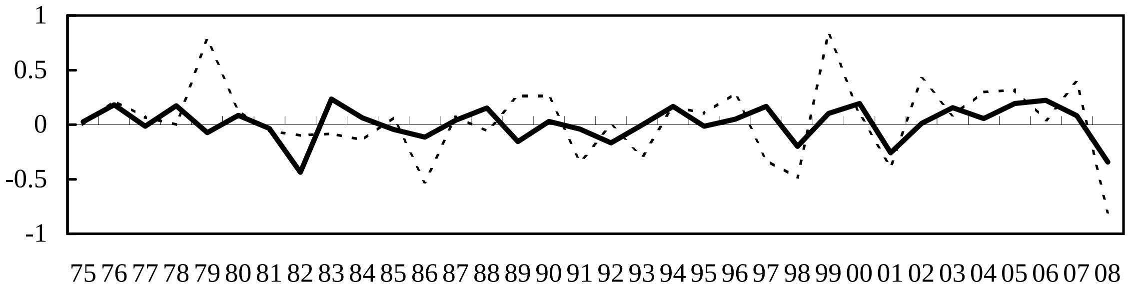


Figure 3: Historical decomposition of nominal oil price

Oil Supply Shocks



Global Demand Shocks



Oil-Specific Demand Shocks

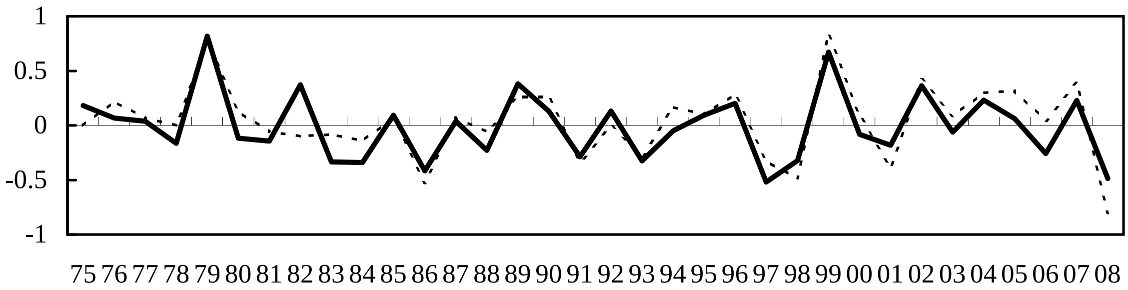


Figure 4: Cumulative responses of aggregate production (U.S.)

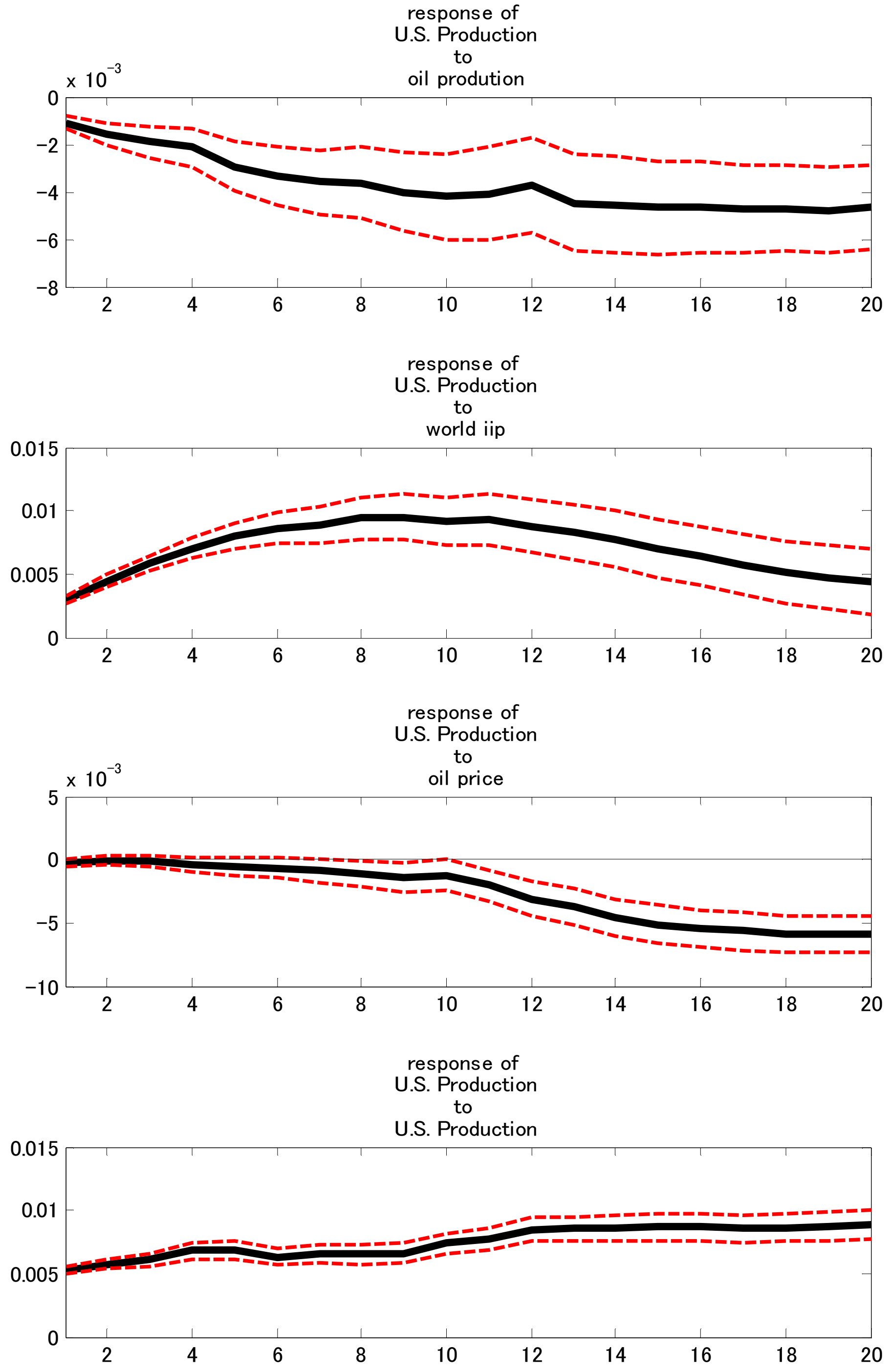
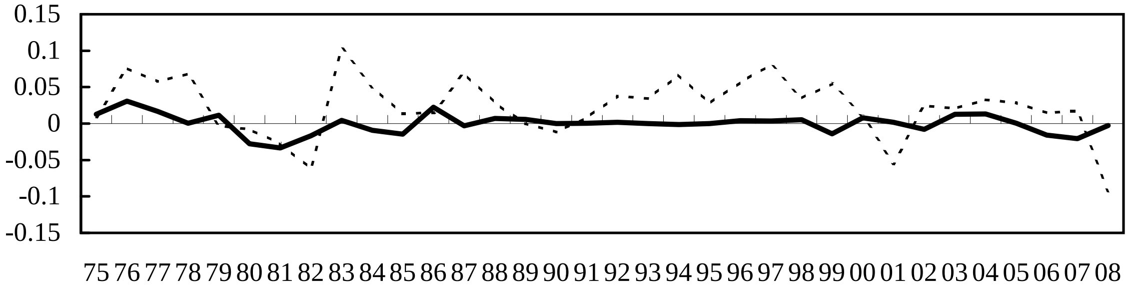
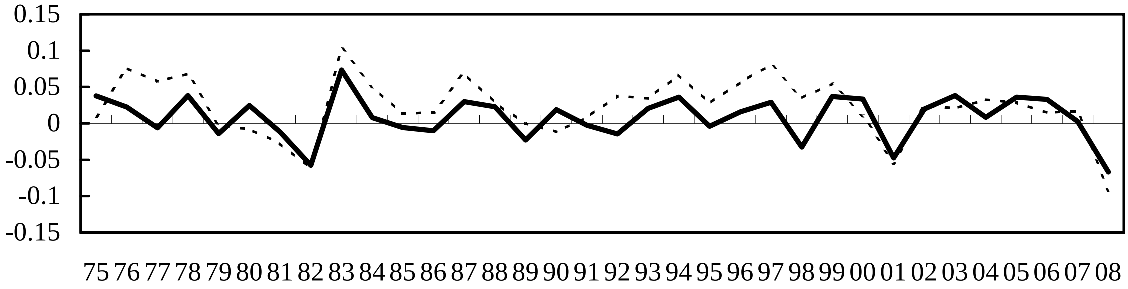


Figure 5: Historical decomposition of aggregate production (U.S.)

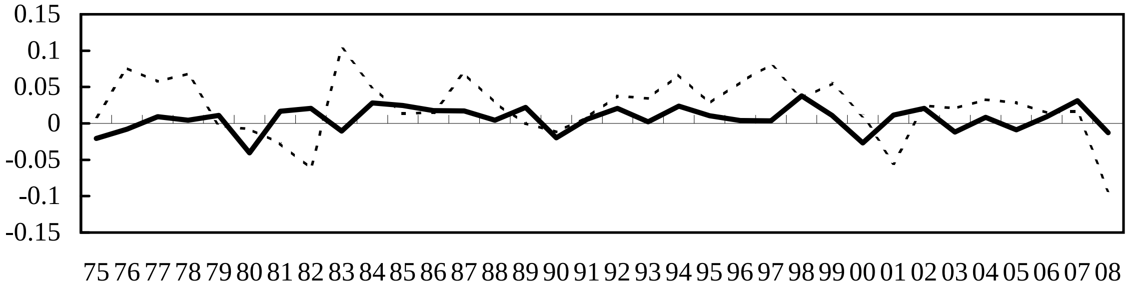
Oil Supply Shocks



Global Demand Shocks



Oil-Specific Demand Shocks



Domestic Aggregate Shocks

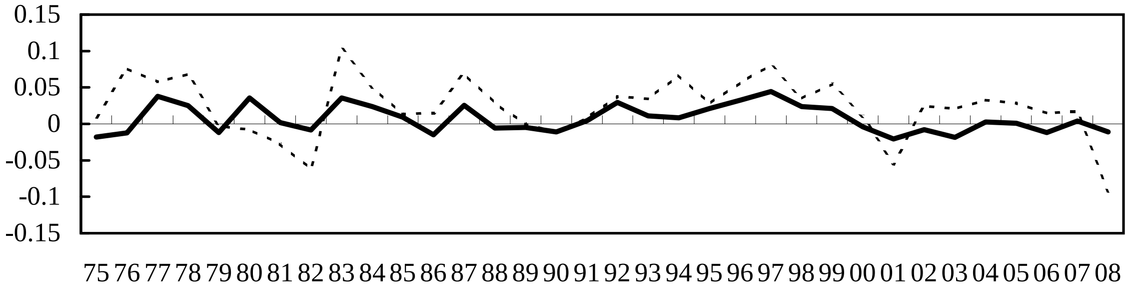


Figure 6: Cumulative responses of aggregate production (Japan)

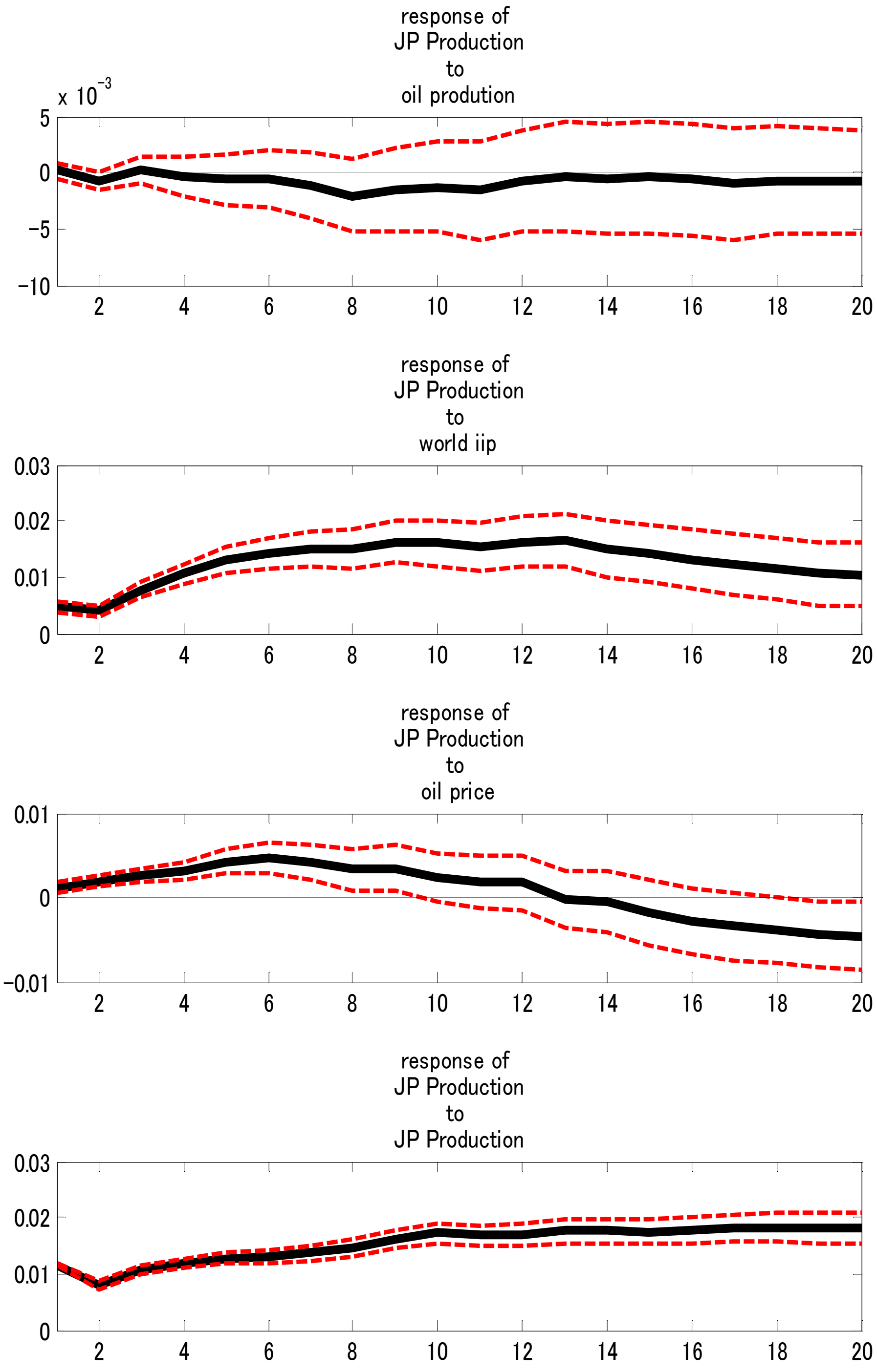
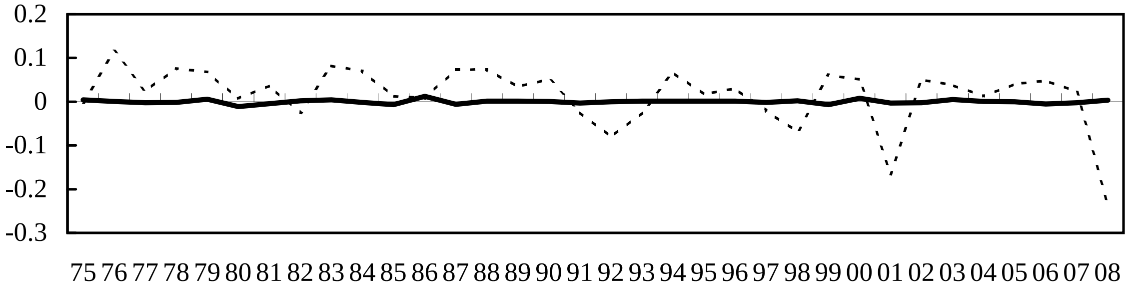
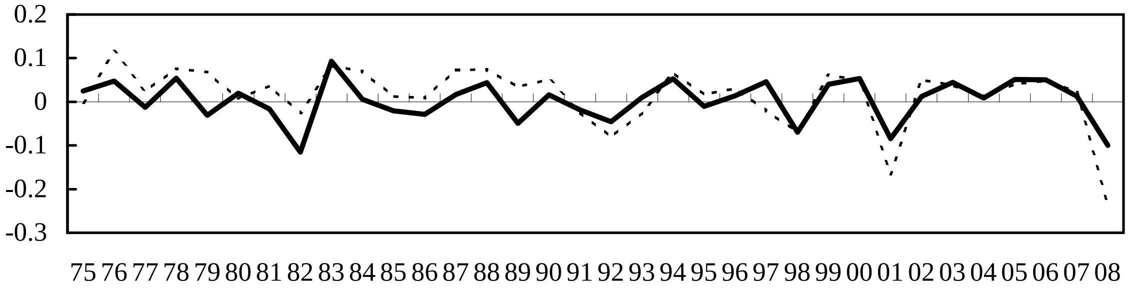


Figure 7: Historical decomposition of aggregate production (Japan)

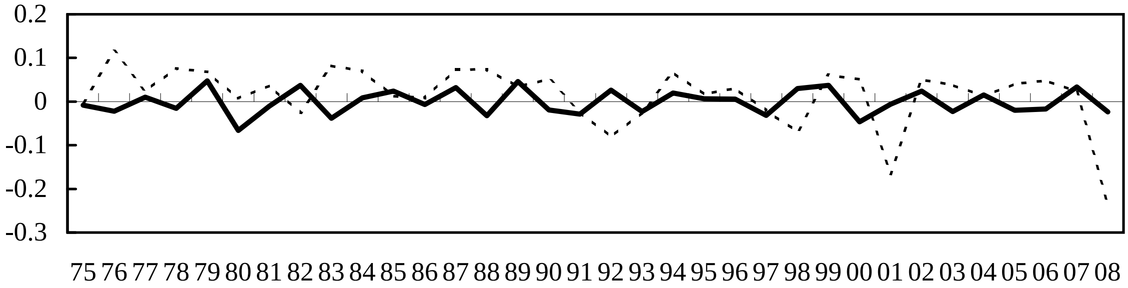
Oil Supply Shocks



Global Demand Shocks



Oil-Specific Demand Shocks



Domestic Aggregate Shocks

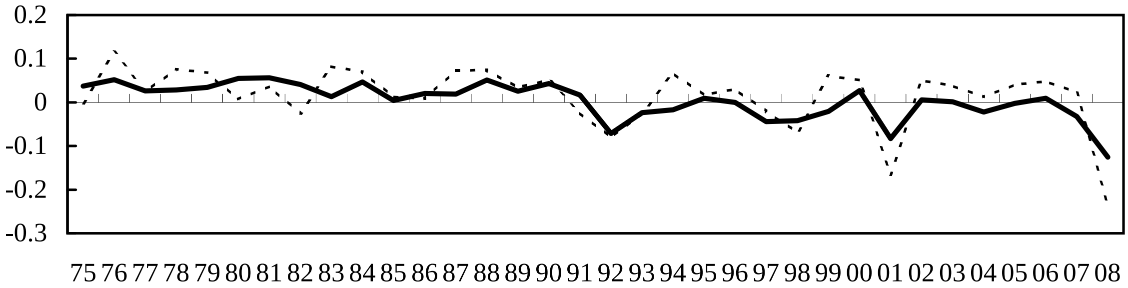


Figure 8: Cumulative responses of production to oil supply shock (U.S.)

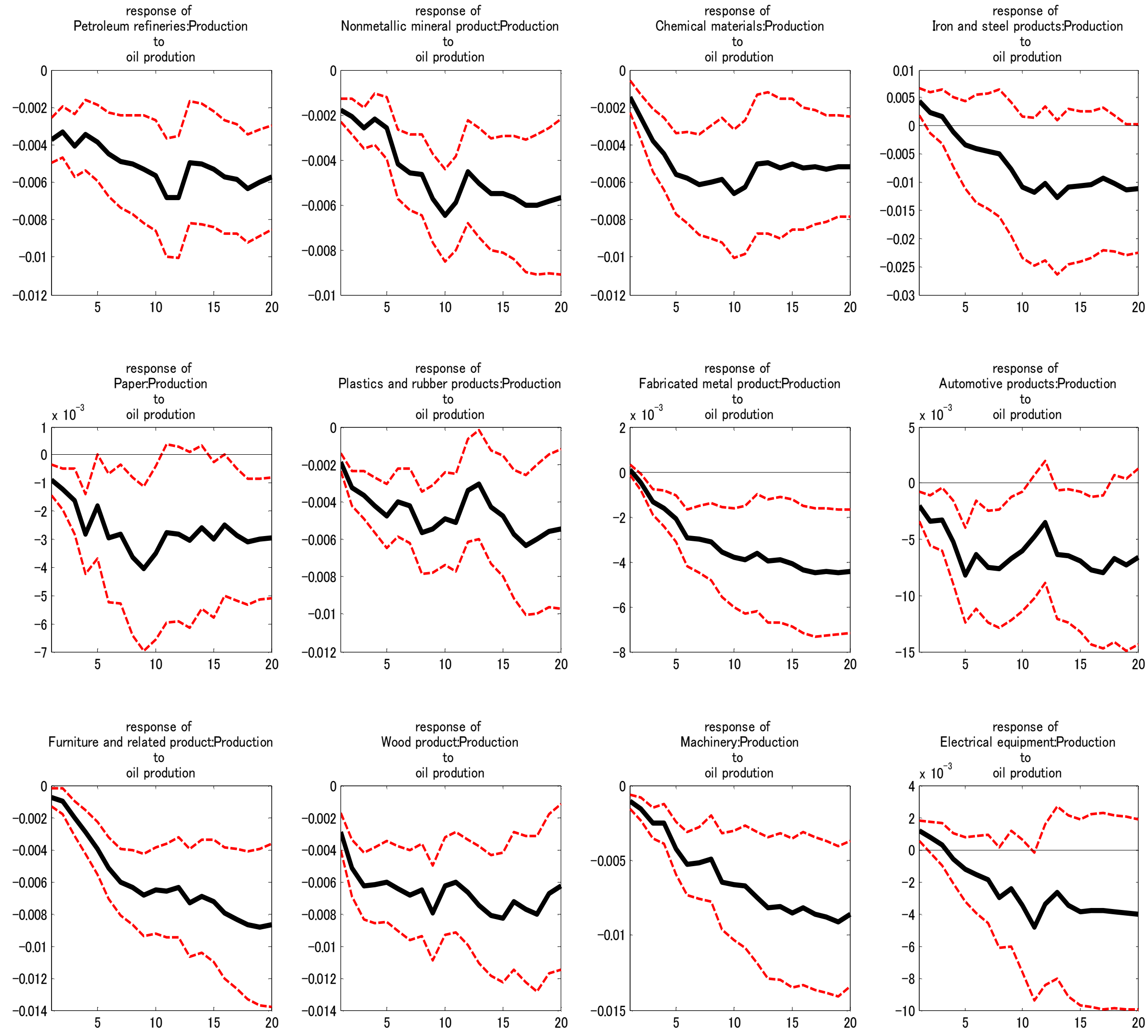


Figure 9: Cumulative responses of prices to oil supply shock (U.S.)

Figure 10: Cumulative responses of production to global demand shock (U.S.)

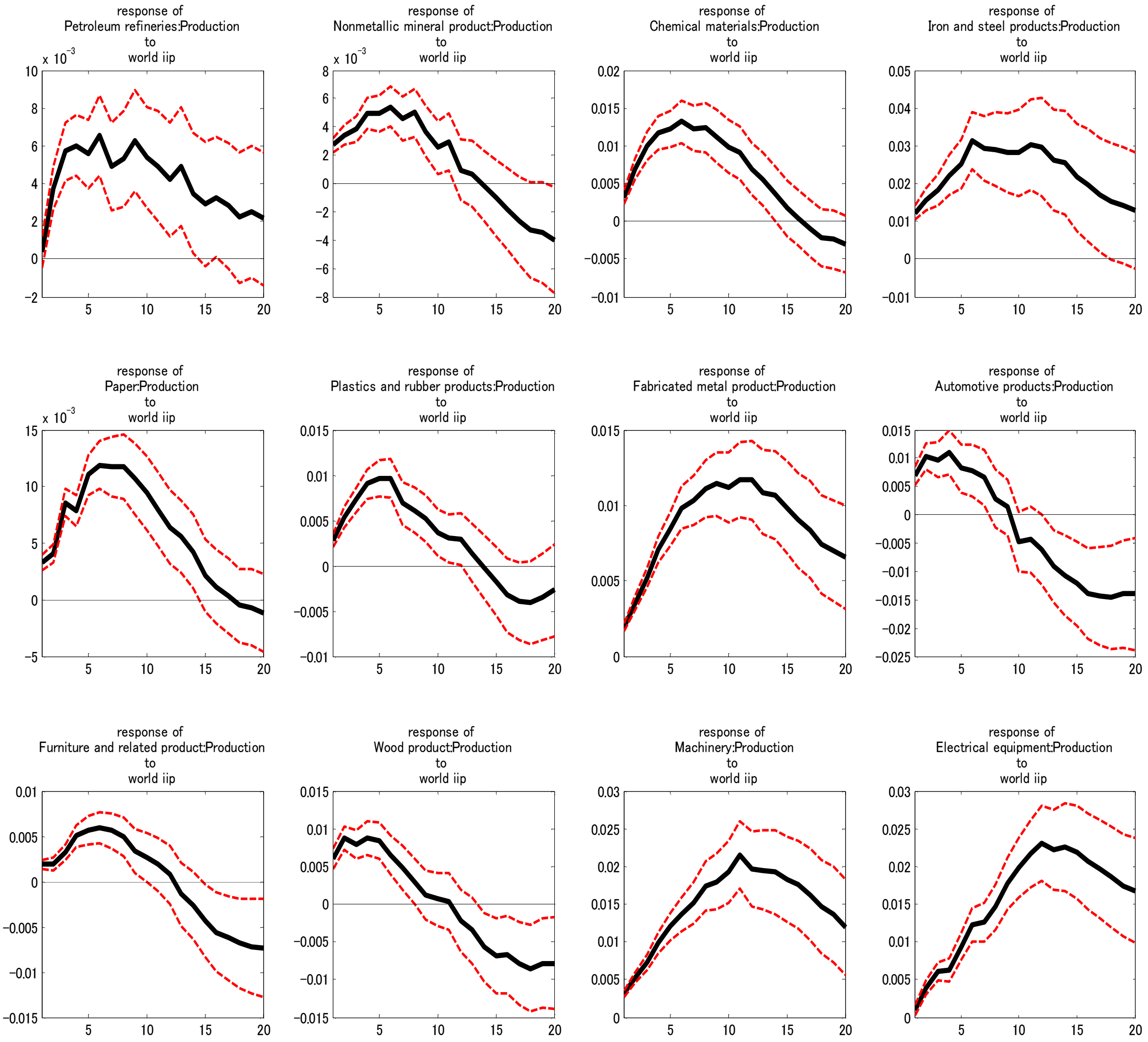


Figure 11: Cumulative responses of prices to global demand shock (U.S.)

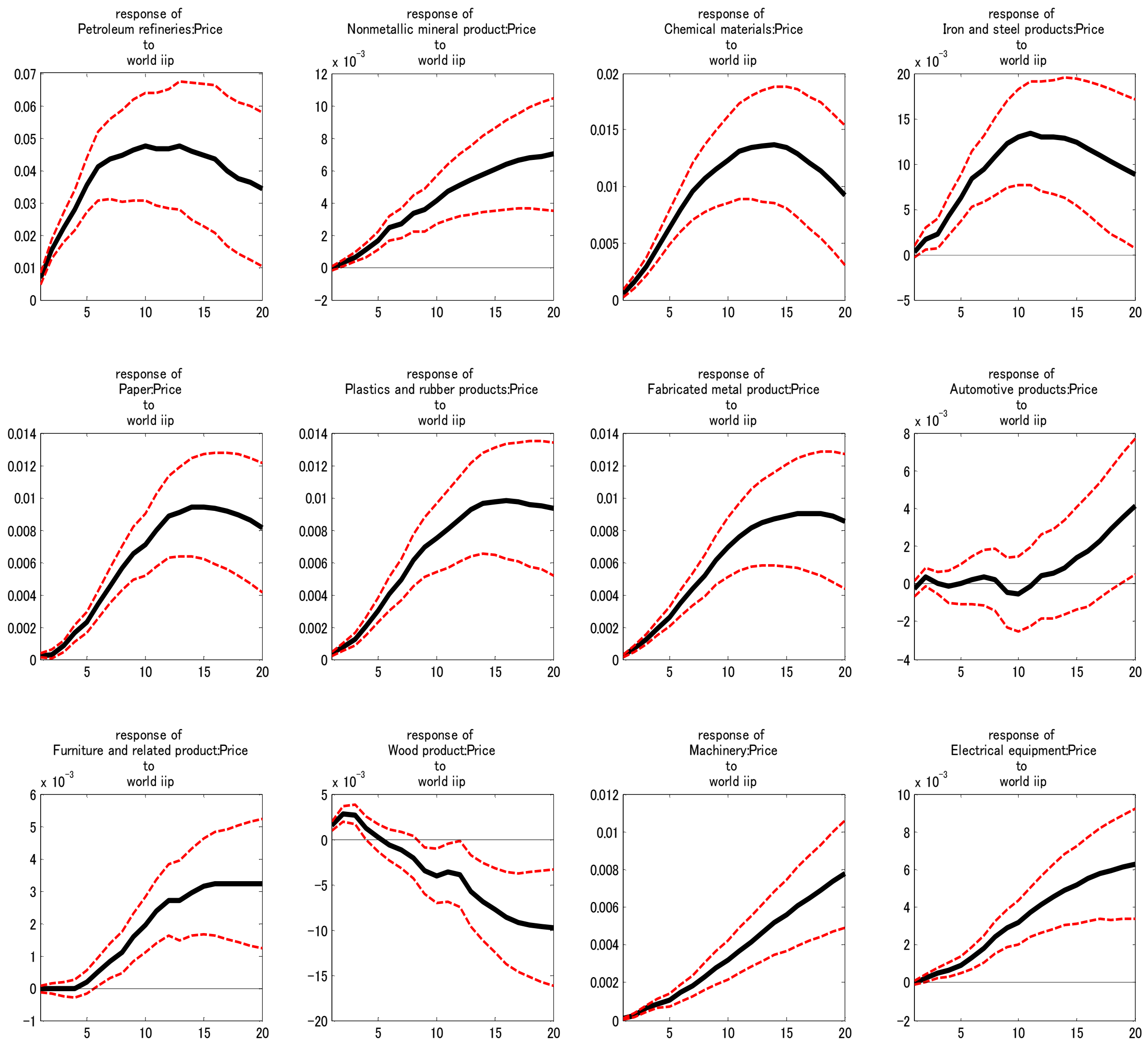


Figure 12: Cumulative responses of production to oil-specific demand shock (U.S.)

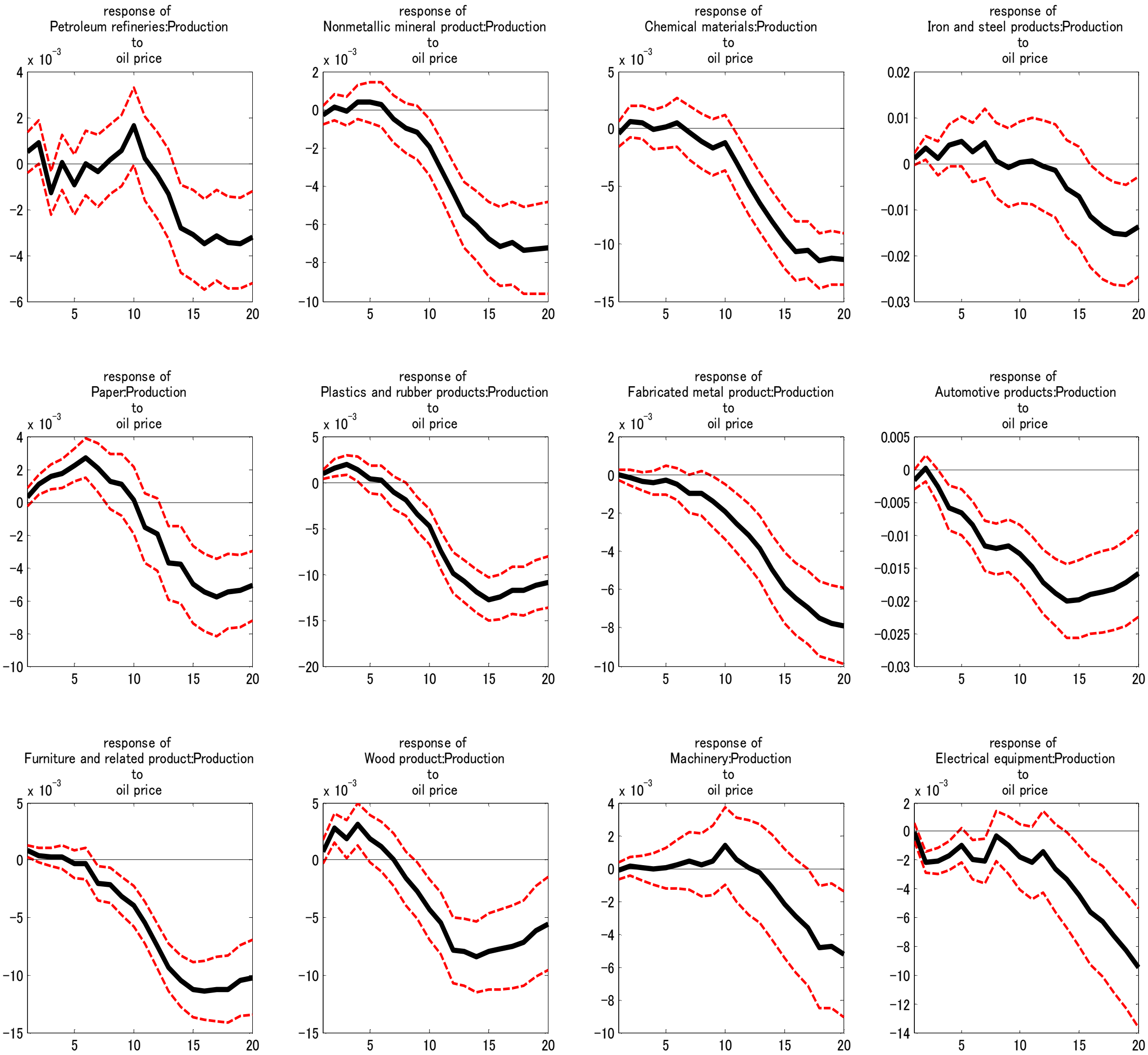


Figure 13: Cumulative responses of prices to oil-specific demand shock (U.S.)

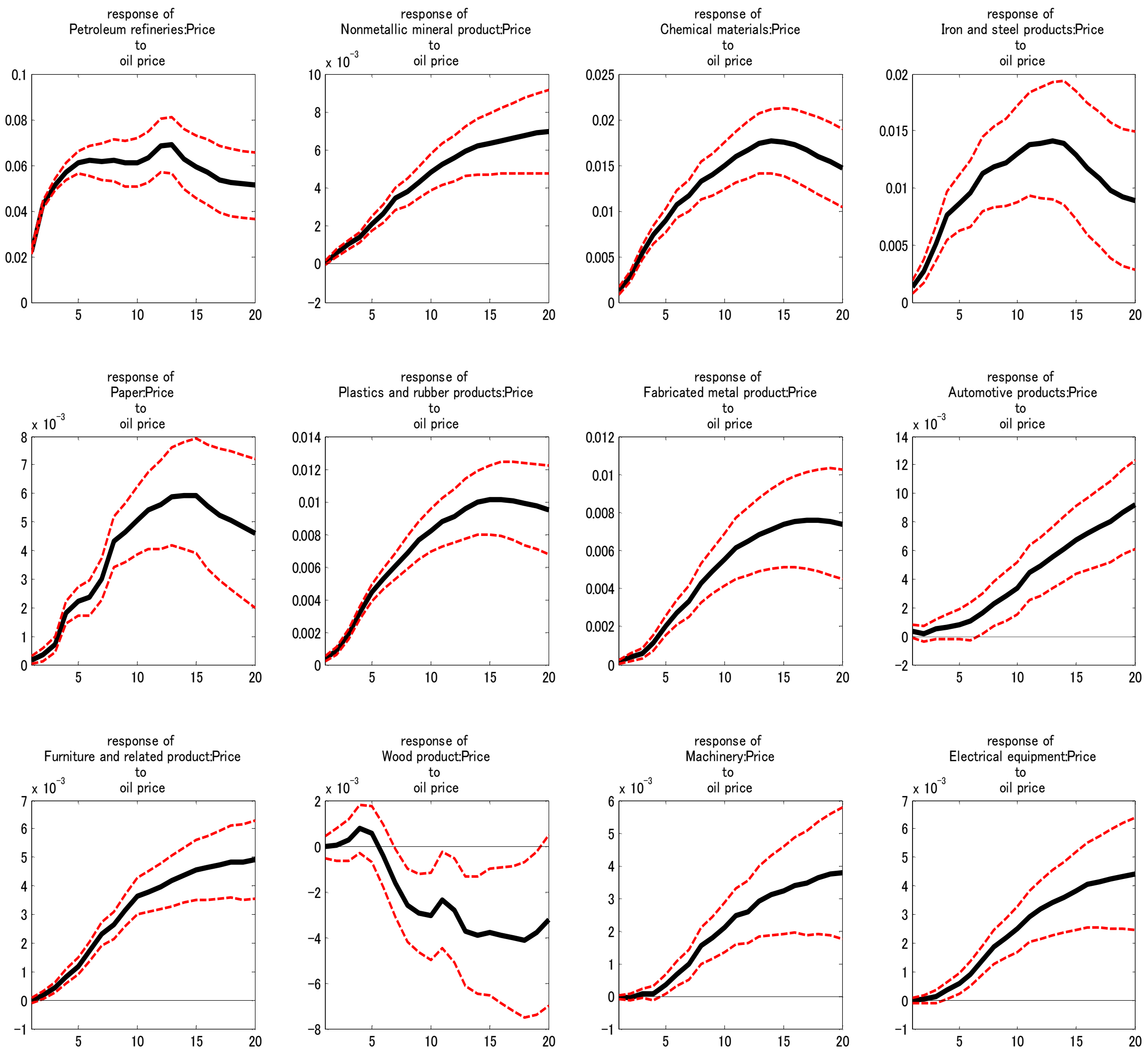


Figure 14: Magnitudes of 12-month cumulative responses (U.S.)

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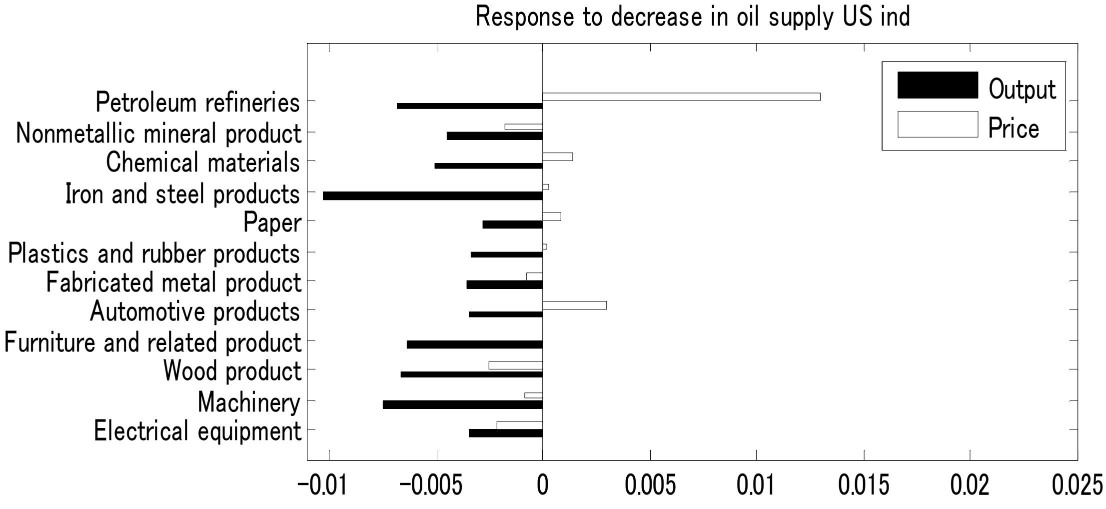

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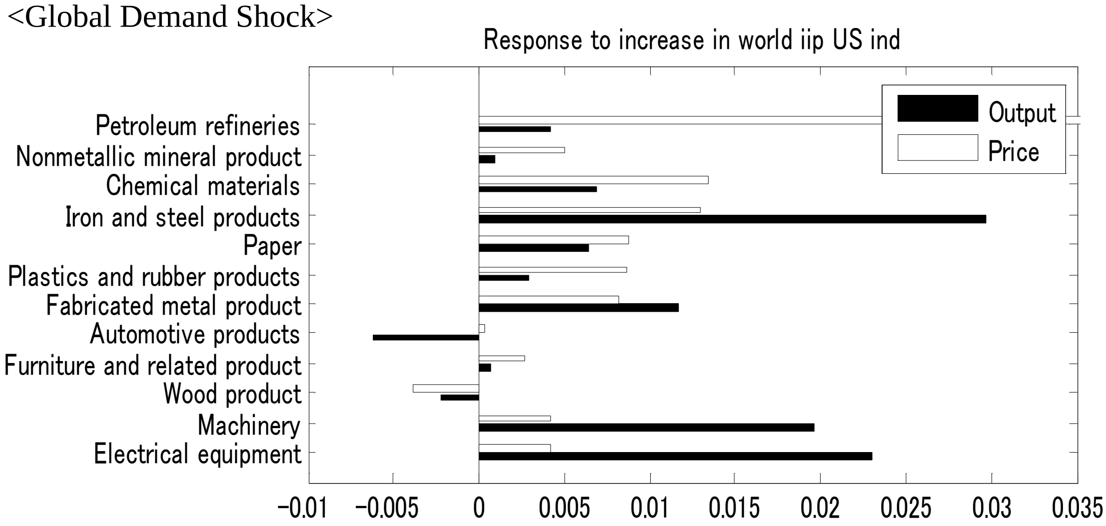

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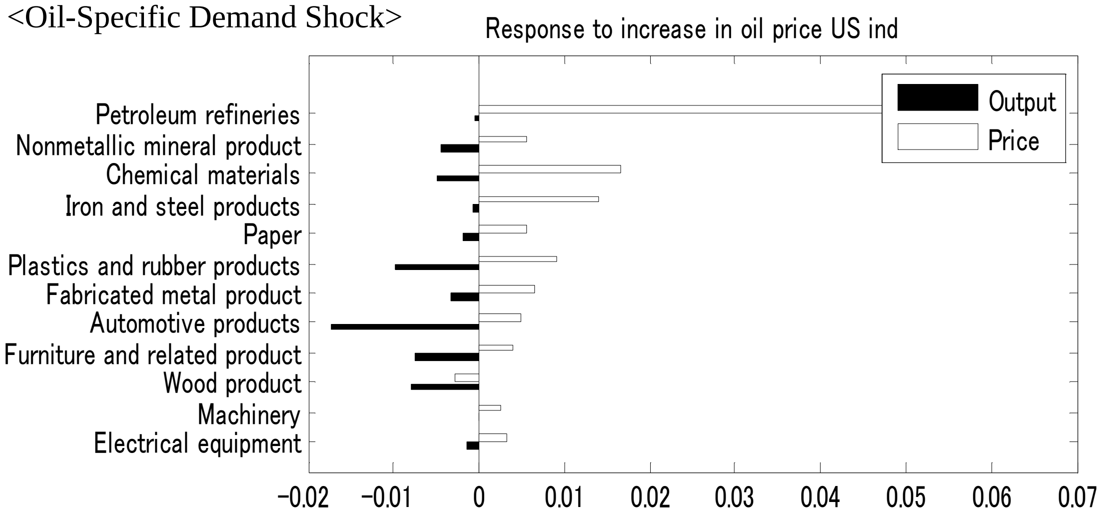


Figure 15: Cumulative responses of production to oil supply shock (Japan)

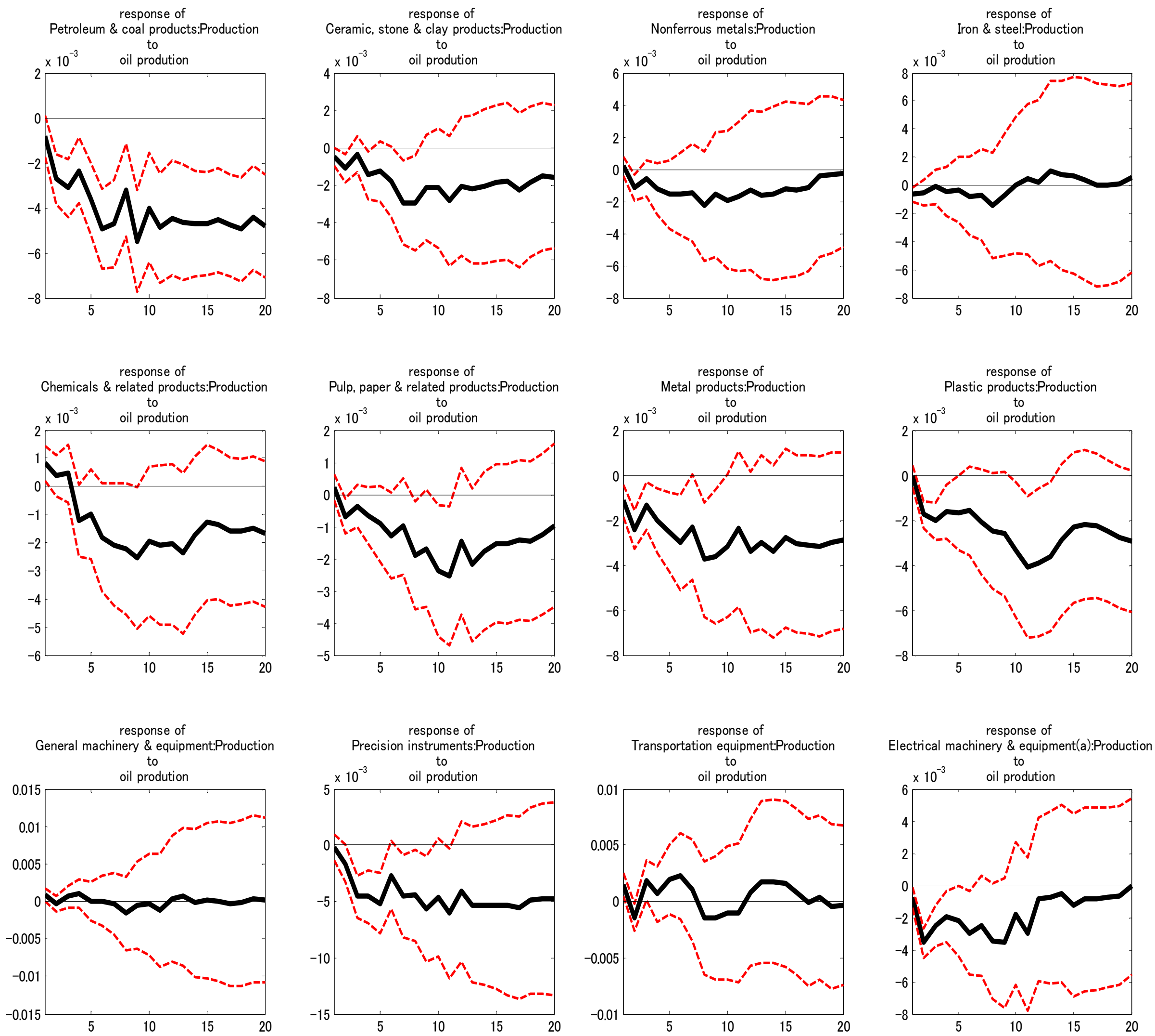


Figure 16: Cumulative responses of prices to oil supply shock (Japan)

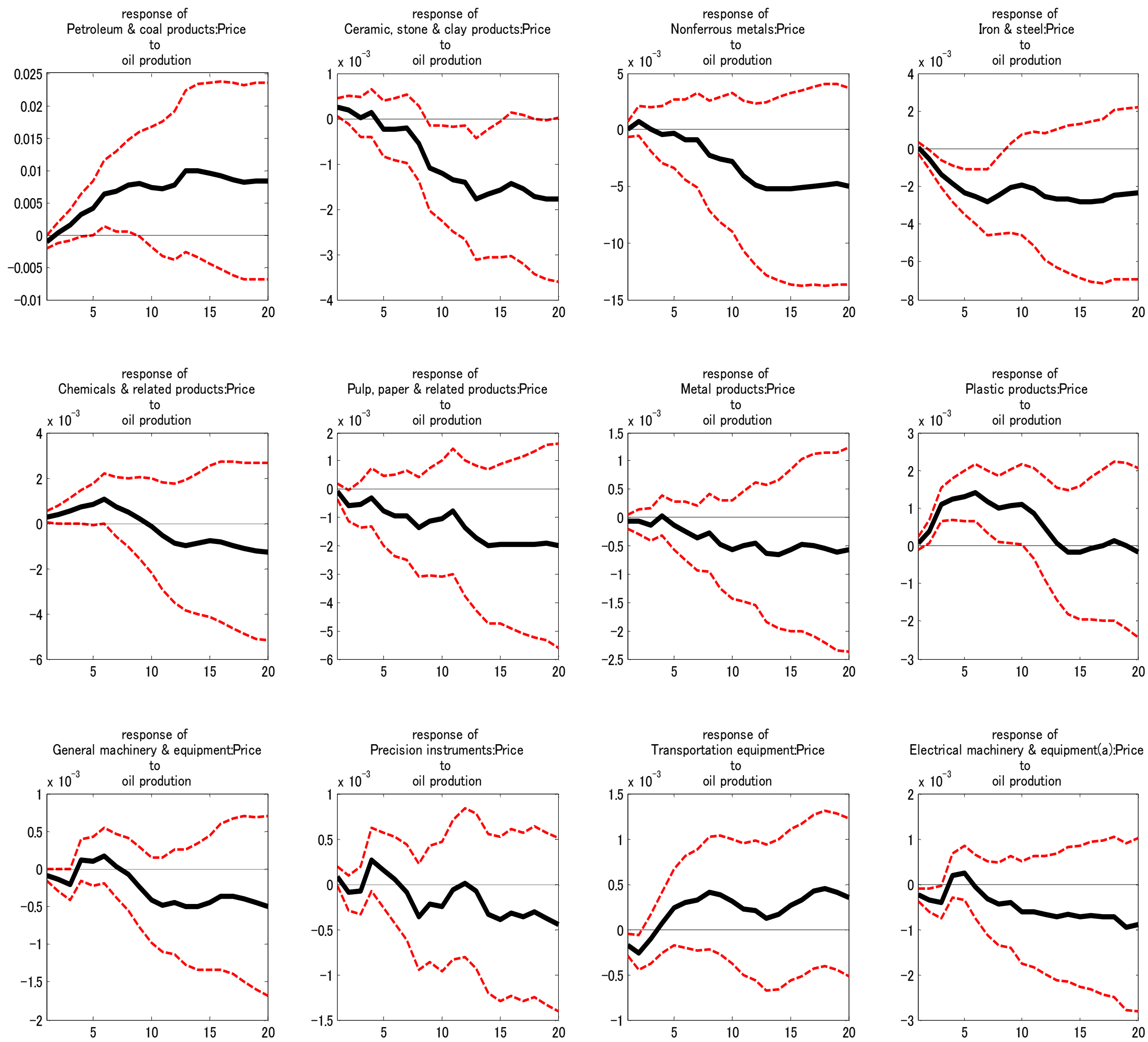


Figure 17: Cumulative responses of production to global demand shock (Japan)

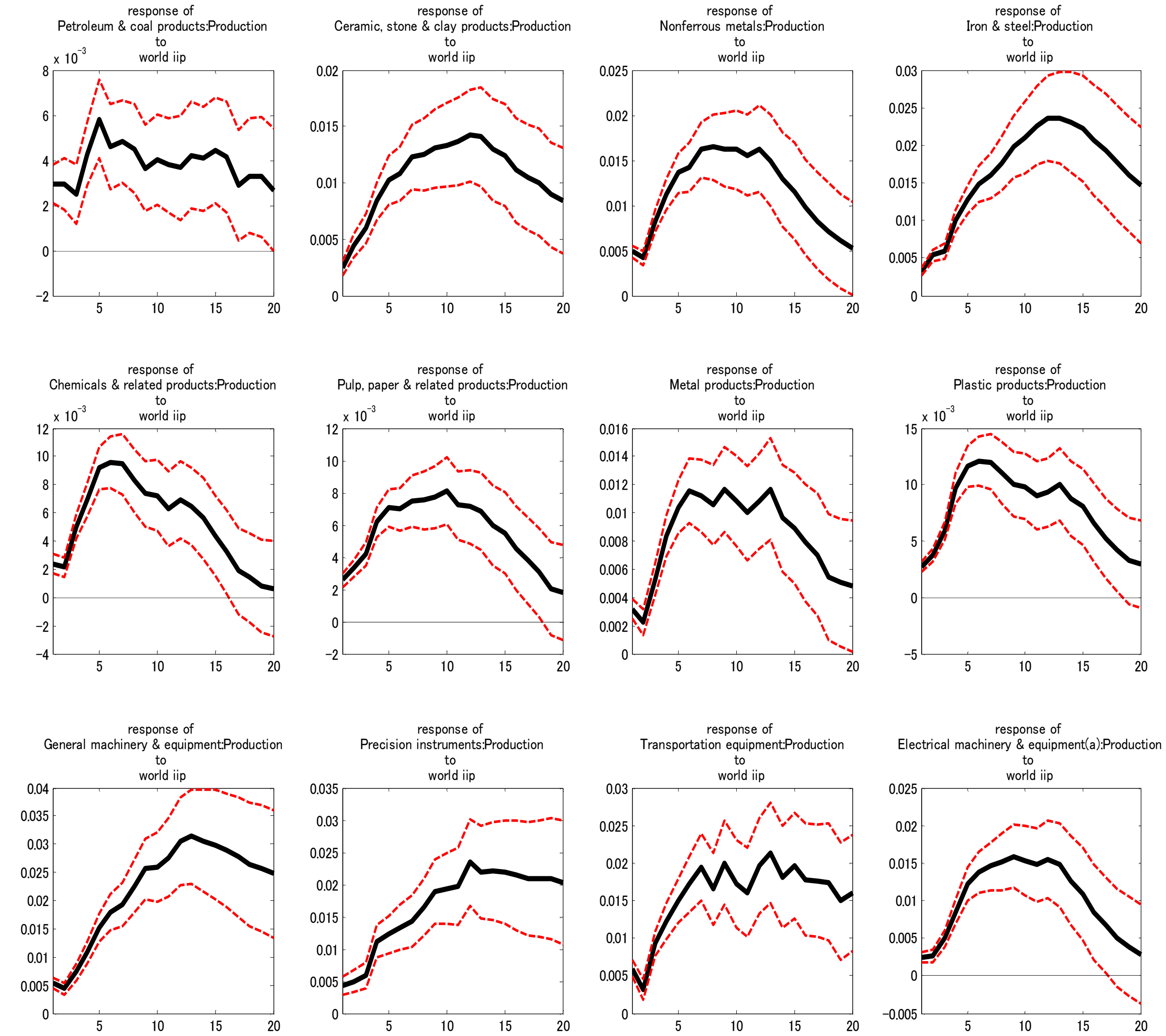


Figure 18: Cumulative responses of prices to global demand shock (Japan)

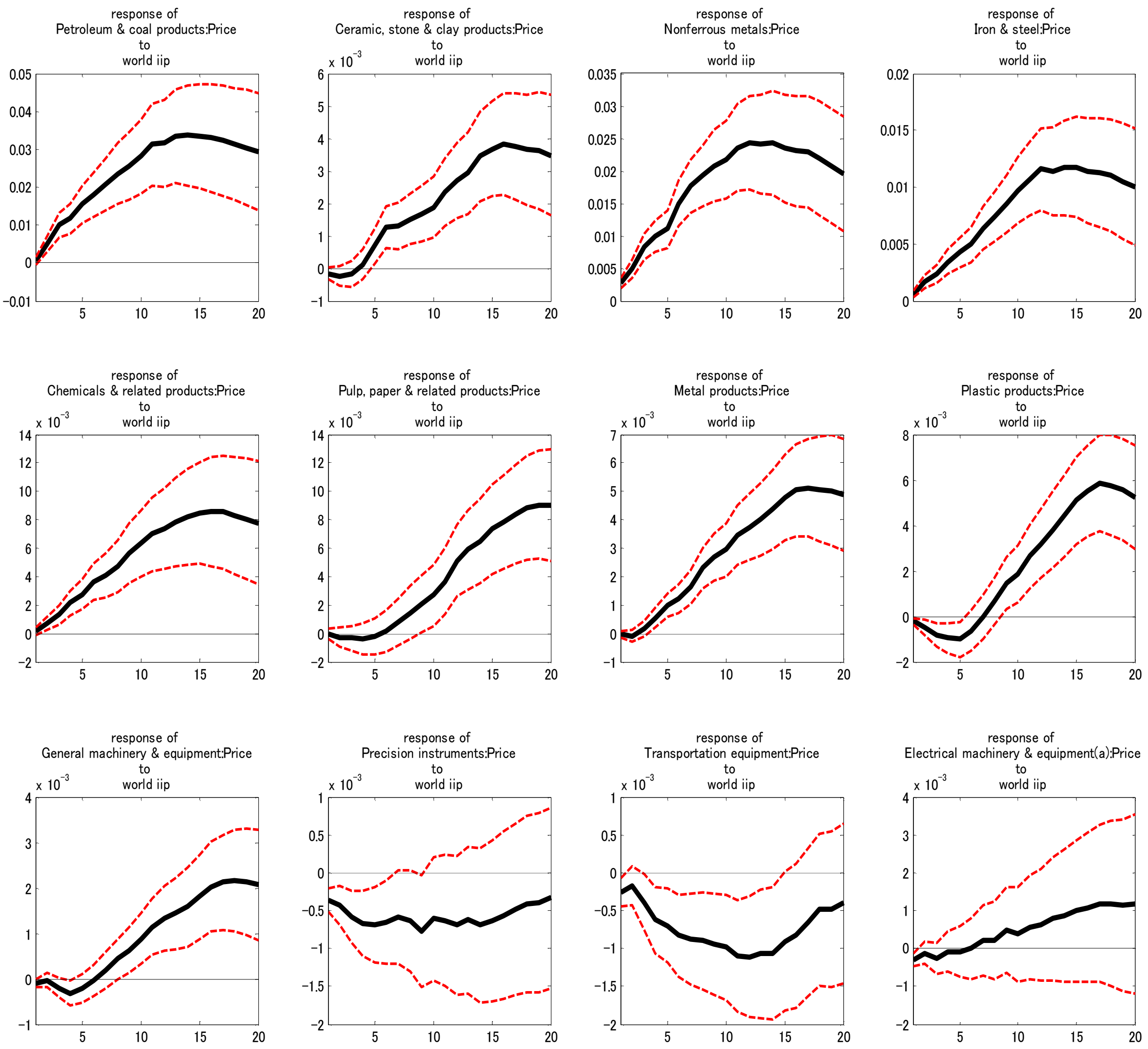


Figure 19: Cumulative responses of production to oil-specific demand shock (Japan)

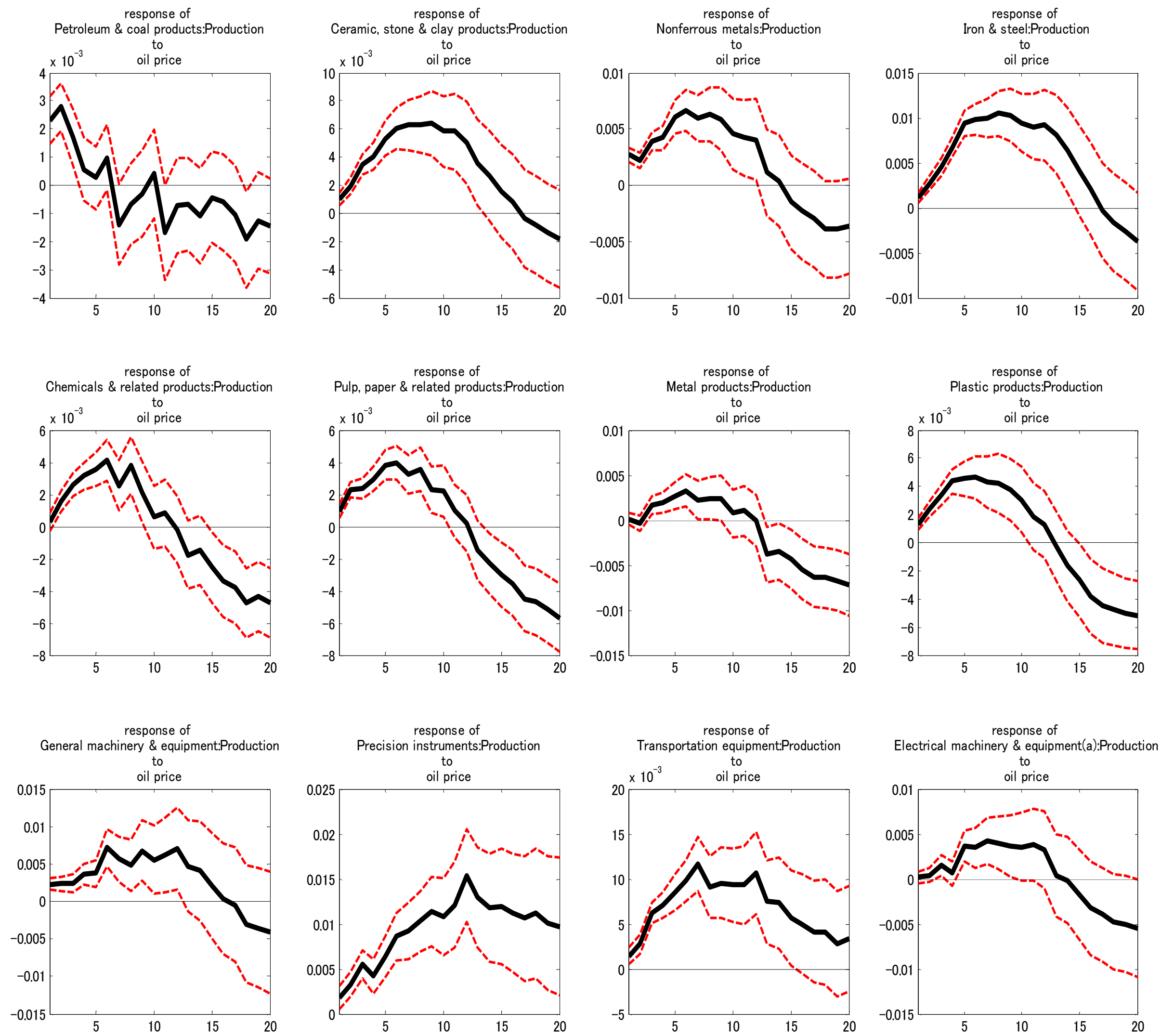


Figure 20: Cumulative responses of prices to oil-specific demand shock (Japan)

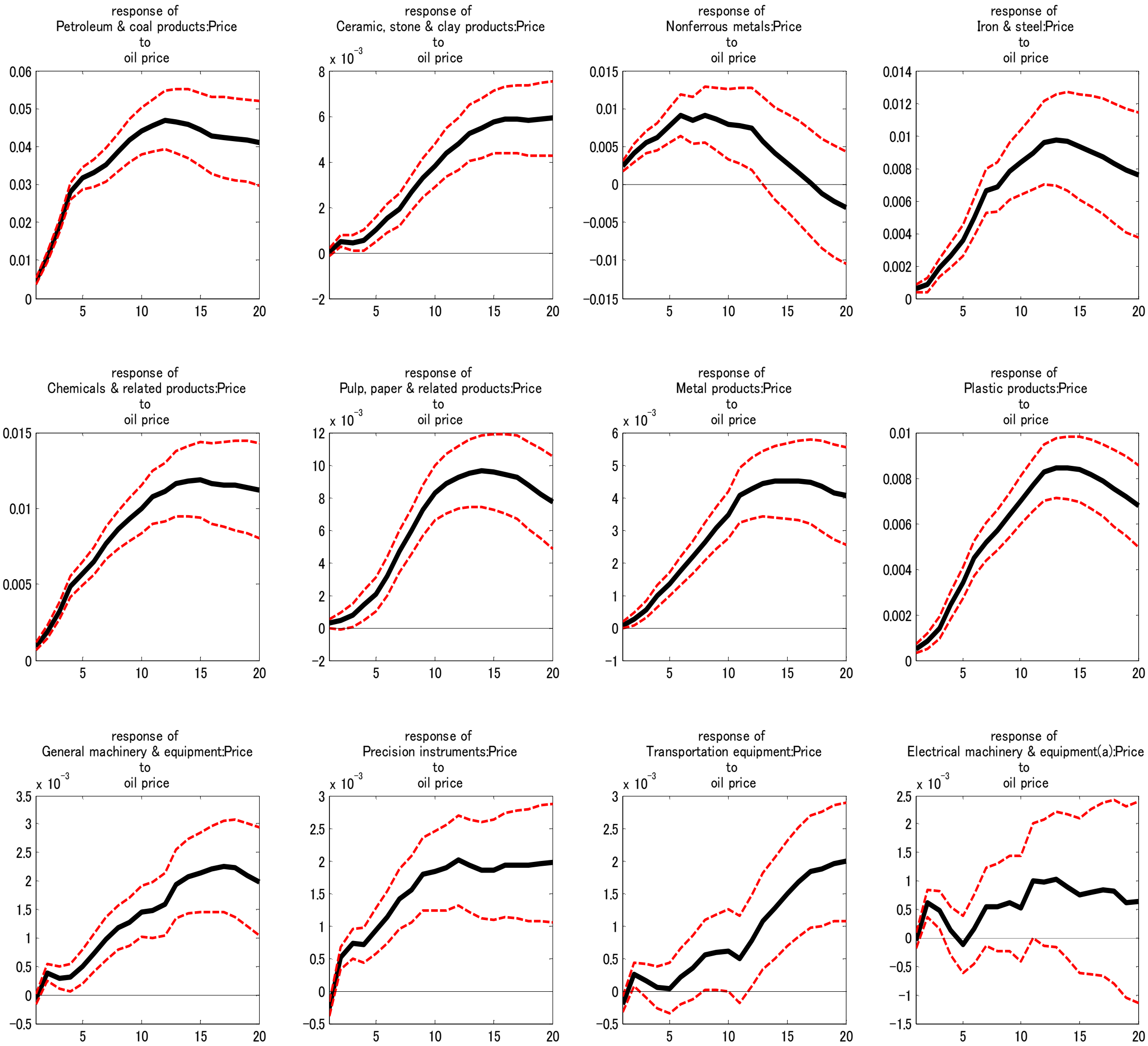
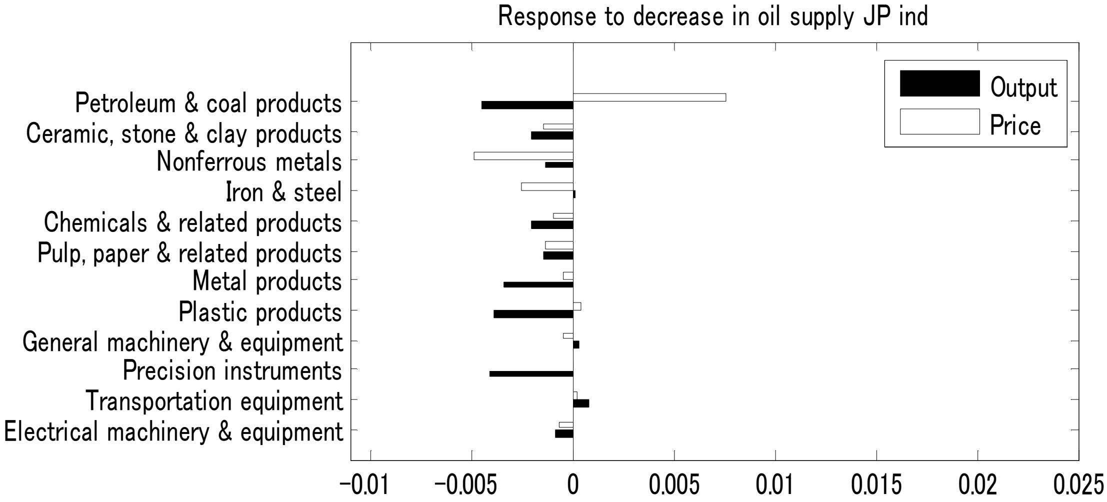


Figure 21: Magnitudes of 12-month cumulative responses (Japan)

<Oil Supply Shock>



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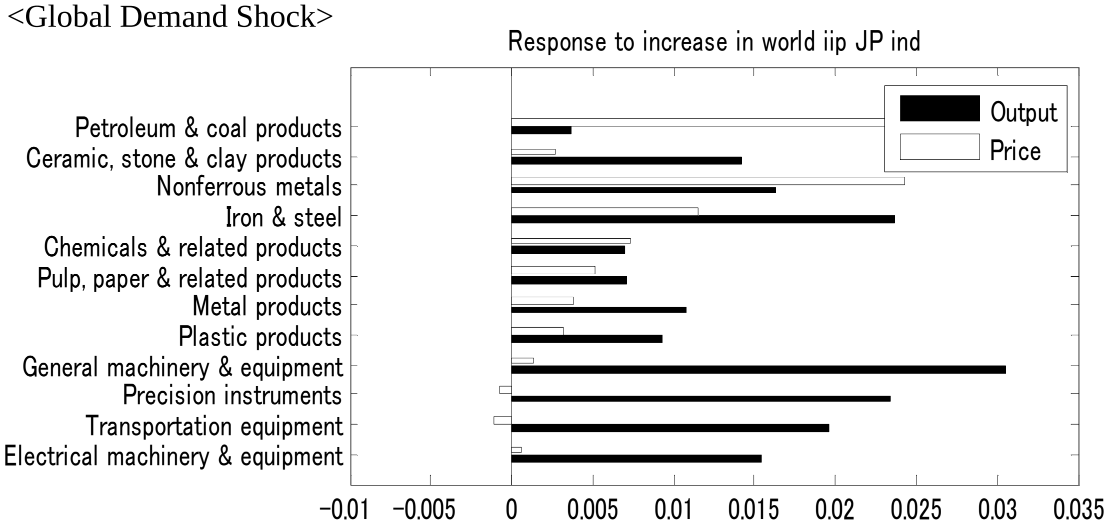

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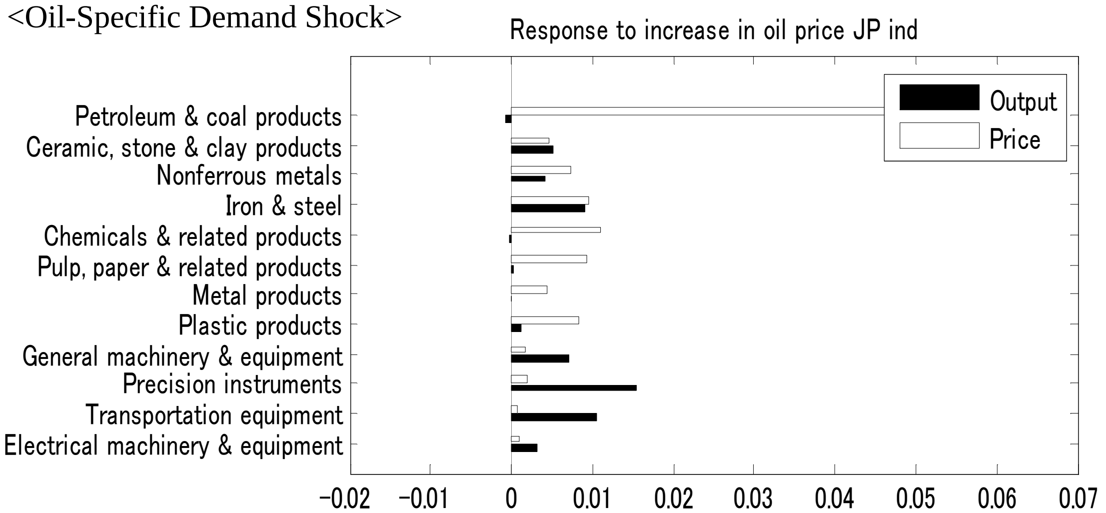
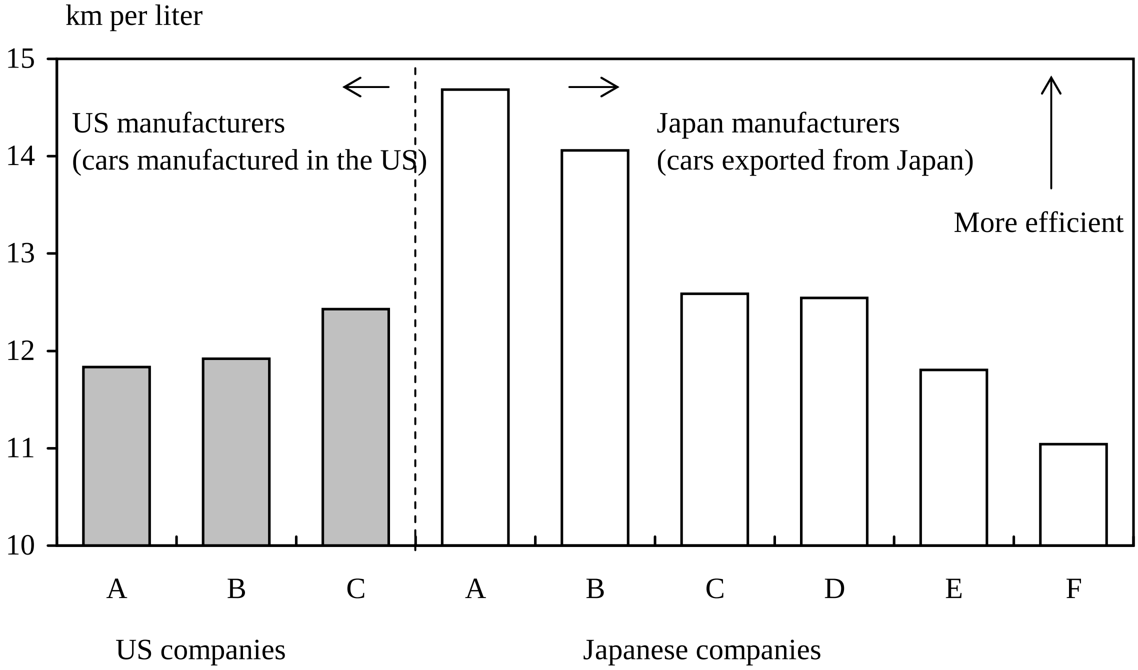


Figure 22: Average fuel consumption of cars sold in U.S.



Note: Fuel consumption is calculated for each company as 2004-2006 averages.
Fuel consumption of different vehicle types are averaged using their sales volume as weights.

Source: Research and Statistics Department, Bank of Japan (2007)

Table 1: Value-added share of production

<U.S.>

Industry	Share in 2006 (%)	Share in 1973 (%)
Fabricated metal product	5.5	6.7
Chemical materials	5.4	4.4
Machinery	5.0	8.6
Petroleum refineries	3.9	1.3
Automotive products	3.3	3.5
Plastics and rubber products	3.2	2.9
Paper	2.6	3.1
Nonmetallic mineral product	2.3	2.7
Furniture and related product	1.5	1.6
Wood product	1.4	2.1
Iron and steel products	1.4	3.1
Electrical equipment	0.6	1.1
12-industry total	36.3	41.3

<Japan>

Industry	Share in 2005 (%)	Share in 1975 (%)
Electric machinery and equipment	18.4	11.0
Transportation equipment	16.9	11.8
General machinery and equipment	13.2	12.8
Chemicals and related products	11.8	9.5
Iron and steel products	6.0	6.6
Metal products	5.7	5.0
Plastic products	3.8	2.8
Ceramic, stone and clay products	2.9	5.7
Pulp, paper and related products	2.4	3.5
Nonferrous metals and products	2.1	1.9
Precision instruments	1.0	1.6
Petroleum and coal products	1.0	2.9
12-industry total	85.2	75.3

Source: Industrial Production, Federal Reserve Board.
Indices of Industrial Production, Japanese Ministry of Economy, Trade, and Industry.

Table 2: Oil intensity (Cost share of mining and petroleum and coal products)

<U.S.>

Industry	Share in 2000 (%)
Petroleum and coal products	68.5
Ceramic, stone and clay products	6.2
Chemical products	6.2
Steel and steel products	5.5
Non-steel metals and products	2.8
Pulp, paper and wooden products	0.7
Plastic, rubber and leather products	0.5
Other metal products	0.3
Transportation equipment	0.3
General machinery	0.2
Electric machinery	0.1
Precision instruments	0.1
12-industry average	6.4

<Japan>

Industry	Share in 2000 (%)
Petroleum and coal products	40.6
Ceramic, stone and clay products	9.7
Non-steel metals and products	7.3
Steel and steel products	6.4
Chemical products	4.8
Pulp, paper and wooden products	1.2
Other metal products	0.5
Plastic, rubber and leather products	0.4
General machinery	0.3
Precision instruments	0.3
Transportation equipment	0.3
Electric machinery	0.2
12-industry average	4.0

Source: The 2000 Japan-U.S. input-output table,
Japanese Ministry of Economy, Trade, and Industry.

Table 3: Export dependence (Export share of shipments)

<U.S.>

Industry	Share in 2000 (%)
Electric machinery	30.2
Precision instruments	29.6
General machinery	26.3
Transportation equipment	20.4
Non-steel metals and products	17.3
Chemical products	17.2
Plastic, rubber and leather products	9.6
Pulp, paper and wooden products	6.6
Steel and steel products	6.4
Ceramic, stone and clay products	6.4
Other metal products	6.3
Petroleum and coal products	5.7
12-industry average	14.9

<Japan>

Industry	Share in 2000 (%)
Precision instruments	33.9
Transportation equipment	33.4
Electric machinery	33.1
General machinery	27.9
Steel and steel products	17.0
Chemical products	15.6
Non-steel metals and products	15.3
Plastic, rubber and leather products	8.6
Ceramic, stone and clay products	6.9
Other metal products	3.8
Pulp, paper and wooden products	2.1
Petroleum and coal products	1.6
12-industry average	17.1

Source: The 2000 Japan-U.S. input-output table,
Japanese Ministry of Economy, Trade, and Industry.

Table 4: Signs of peak responses (U.S.)

<Oil Supply Shock>

Industry	Peak effect on output	Peak effect on prices	Oil supply shock effects
Petroleum refineries	−*	+*	Decrease in supply
Nonmetallic mineral product	−*	−	Decrease in demand
Chemical materials	−*	+*	Decrease in supply
Iron and steel products	−	+*	Decrease in supply
Paper	−*	0	
Plastics and rubber products	−*	0	
Fabricated metal product	−*	0	
Automotive products	−*	+*	Decrease in supply
Furniture and related product	−*	0	
Wood product	−*	−*	Decrease in demand
Machinery	−*	0	
Electrical equipment	−	−*	Decrease in demand

<Global Demand Shock>

Industry	Peak effect on output	Peak effect on prices	Global demand shock effects
Petroleum refineries	+*	+*	Increase in demand
Nonmetallic mineral product	+*	+*	Increase in demand
Chemical materials	+*	+*	Increase in demand
Iron and steel products	+*	+*	Increase in demand
Paper	+*	+*	Increase in demand
Plastics and rubber products	+*	+*	Increase in demand
Fabricated metal product	+*	+*	Increase in demand
Automotive products	Mixed	+*	
Furniture and related product	Mixed	+*	
Wood product	Mixed	−*	
Machinery	+*	+*	Increase in demand
Electrical equipment	+*	+*	Increase in demand

<Oil-Specific Demand Shock>

Industry	Peak effect on output	Peak effect on prices	Oil-Specific demand shock effects
Petroleum refineries	−*	+*	Decrease in supply
Nonmetallic mineral product	−*	+*	Decrease in supply
Chemical materials	−*	+*	Decrease in supply
Iron and steel products	−*	+*	Decrease in supply
Paper	−*	+*	Decrease in supply
Plastics and rubber products	−*	+*	Decrease in supply
Fabricated metal product	−*	+*	Decrease in supply
Automotive products	−*	+*	Decrease in supply
Furniture and related product	−*	+*	Decrease in supply
Wood product	−*	−*	Decrease in demand
Machinery	−*	+*	Decrease in supply
Electrical equipment	−*	+*	Decrease in supply

Note: "+" and "−" represent peak positive and negative responses. "*" means that the peak responses are significant. "0" means the peak responses are negligible. "Mixed" means that the positive and negative responses are of similar magnitudes.

Table 5: Signs of peak responses (Japan)

<Oil Supply Shock>

Industry	Peak effect on output	Peak effect on prices	Oil supply shock effects
Petroleum and coal products	–*	+*	Decrease in supply
Ceramic, stone and clay products	–*	–*	Decrease in demand
Nonferrous metals and products	–	–	Decrease in demand
Iron and steel products	0	–*	
Chemicals and related products	–	0	
Pulp, paper and related products	–*	–	Decrease in demand
Metal products	–*	–	Decrease in demand
Plastic products	–*	+*	Decrease in supply
General machinery and equipment	0	0	
Precision instruments	–*	0	
Transportation equipment	0	0	
Electric machinery and equipment	–*	0	

<Global Demand Shock>

Industry	Peak effect on output	Peak effect on prices	Global demand shock effects
Petroleum and coal products	+*	+*	Increase in demand
Ceramic, stone and clay products	+*	+*	Increase in demand
Nonferrous metals and products	+*	+*	Increase in demand
Iron and steel products	+*	+*	Increase in demand
Chemicals and related products	+*	+*	Increase in demand
Pulp, paper and related products	+*	+*	Increase in demand
Metal products	+*	+*	Increase in demand
Plastic products	+*	+*	Increase in demand
General machinery and equipment	+*	+*	Increase in demand
Precision instruments	+*	–*	Increase in supply
Transportation equipment	+*	–*	Increase in supply
Electric machinery and equipment	+*	+	Increase in demand

<Oil-Specific Demand Shock>

Industry	Peak effect on output	Peak effect on prices	Oil-Specific demand shock effects
Petroleum and coal products	Mixed	+*	
Ceramic, stone and clay products	+*	+*	Increase in demand
Nonferrous metals and products	Mixed	+*	
Iron and steel products	+*	+*	Increase in demand
Chemicals and related products	Mixed	+*	
Pulp, paper and related products	Mixed	+*	
Metal products	Mixed	+*	
Plastic products	Mixed	+*	
General machinery and equipment	+*	+*	Increase in demand
Precision instruments	+*	+*	Increase in demand
Transportation equipment	+*	+*	Increase in demand
Electric machinery and equipment	Mixed	+	

Note: "+" and "−" represent peak positive and negative responses. "*" means that the peak responses are significant. "0" means the peak responses are negligible. "Mixed" means that the positive and negative responses are of similar magnitudes.