# Oil and the regional economies in Japan: Analysis using a VAR with block exogeneity

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**Abstract:** In this paper, we use a VAR with block exogeneity to study the effects of oil price shocks on four regions in Japan. In addition to that, we analyze how these effects are influenced by the regional heterogeneity, and compare these empirical results with that of ASEAN countries. Our findings are as follows. i )The qualitative effects of oil shocks on the regional economies in Japan are quite similar. ii )The quantitative effects oil shocks, however, differ considerably across regions. iii )Regions with lower temperature during winter, or smaller share of the service sector tend to have CPI to be more susceptive to oil price fluctuations due to oil-market specific demand shocks. On the other hand, regions with higher share of the transportation equipment industry tend to be more affected by global demand shocks. iv )The results on CPI for regions in Japan are comparable with those for ASEAN countries, but that is not true for the case of IIP.

**Keywords: Japanese regional economies, oil price fluctuations, VAR, block exogeneity.**
**JEL codes: F41, Q43, F33.**

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## 1. Introduction

Since 2000s, the sharp rise of oil price has become important agenda for the world economy. Recently, a large number of empirical studies were conducted in this area (Hamilton(1983), Kilian(2009), Fukunaga, Hirakata, and Sudo(2009), Park, Chung and Lee(2011) ).

Oil price has been especially important agenda for Japan, because Japan heavily depends on energy imports. On the other hand, many economists point out that in Japan, regional differences in economic growth are large in recent years. But, much less works has been done on relationship between regional economic performance and external shocks such as energy price.

In this paper, we try to assess the impact of oil price on regional economy of Japan. We focus on four regions of Japan: Tohoku, Kanto, Kinki, and Kyushu[3]. These areas are selected mainly for data availability.

In the case of Japan, the cross-regional differences in such aspects as industrial structure, climate condition, and geographical condition are large. We pick up some factors of the regional differences and analyze relationship between regional heterogeneity and impacts of shocks. This analysis provides useful information for the conduct of economic policy.

From the point of view of small open economy, the economic scales of regions in Japan are comparable to that of ASEAN economies. So, Comparisons between both groups is interesting in order to recognize the characteristics of both areas. We conduct this based on empirical results of our previous paper (Vu and Nakata (2014)).

In our analysis, we use the structural VAR with block exogeneity. Our VAR model includes two blocks; world oil market block, and regional economy block. As we discuss later, this method is especially suitable for small open economy. And, we decompose oil price fluctuations to factors such as supply shock, demand shock, and oil-market specific shock because different types of shocks are thought to have different effect on economic variables. In doing so, we follow the method of Kilian(2009).

The remainder of the paper is organized as follows. Section 2 presents our empirical methodology. Section 3 gives an explanation of data used in our empirical study. In Section 4, we present our empirical results of the structural VAR. Section 5 provides conclusions.

## 2. Methodology

In this paper, we use structural VAR with block exogeneity. Our VAR model comprises 2 blocks; world oil market and regional economy. The structural form of our model is as follows.

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[3] In definition of regions, we follow the definition of METI (Ministry of Economic, Trade and Industry). Each regions include following prefectures: Tohoku (Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima), Kanto (Ibaragi, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Nagano, Yamanashi), Kinki (Fukui, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama), Kyushu (Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima).

$$\begin{bmatrix} C_{11} & 0 \\ C_{21} & C_{22} \end{bmatrix} \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{bmatrix} B_{11}(L) & 0 \\ B_{21}(L) & B_{22}(L) \end{bmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \quad (1)$$

Here, $y_{1t}$ is a vector of variables in world oil market, and $y_{2t}$ is a vector of variables in regional economy.

$$y_{1t} \equiv [\Delta log(oilprod), \quad globrea, \quad log(noilp)]$$

$$y_{2t} \equiv [\Delta log(cpi), \quad \Delta log(iip)]$$

$C_{ij}$ are coefficient matrices, and $B_{ij}(L)$ are polynomials made up from coefficient matrices in the lag operator.

The structural form of (1) can be rewritten as follows.

$$C_{11} y_{1t} = B_{11}(L) y_{1t-1} + \varepsilon_{1t} \quad (2a)$$

$$C_{21} y_{1t} + C_{22} y_{2t} = B_{21}(L) y_{1t-1} + B_{22}(L) y_{2t-1} + \varepsilon_{2t} \quad (2b)$$

The equation (2), and (3) mean that variables and structural shocks in regional economy block can't affect variables in world oil market block, but latter can affect former. When we suppose the Cholesky order as the structure of shocks, some empirical results are inconsistent with our intuition. For example, effects of industrial production of Japanese region on world oil price are statistically significant. From perspective of relative size of regional economy, these results are implausible. In case of our approach, we can exclude the effects of regional economy on world oil market.

Equation (2a) can be transformed to the reduced form.

$$y_{1t} = C_{11}^{-1} B_{11}(L) y_{1t-1} + C_{11}^{-1} \varepsilon_{1t} \quad (3)$$

By impose the Cholesky restriction on $C_{11}$, we can identify structural shock in world oil market block. We adopt the Cholesky restriction following Kilian(2009). This scheme has the following implications for the relationship between the variables in this block. (i)Current oil production level is not affected by global economic activity and oil price in the same month. (ii) Current global economic activity is affected by oil production in the same month, but not by oil market specific shock in the same month. (iii) Current oil price in affected by oil production and global economic activity in the same month. With this scheme, we can decompose oil price fluctuations into three types of structural shocks: (i) oil supply shock (ii) oil demand shock (iii) oil market specific demand shock(which is also called speculative shock in the literature).

Next, Equation (2b) can be transformed to the reduced form.

$$y_{2t} = D_{21}(L) y_{1t-1} + D_{22}(L) y_{2t-1} - {C_{22}}^{-1} C_{21} {C_{11}}^{-1} \varepsilon_{1t} + {C_{22}}^{-1} \varepsilon_{2t} \quad (4)$$

Here, $D_{21}$ , and $D_{22}$ are the polynomial of coefficient matrices $D_{21} \equiv C_{22}^{-1} B_{21}(L) - C_{22}^{-1} C_{21} C_{11}^{-1} B_{11}(L)$, and $D_{21} \equiv C_{22}^{-1} B_{22}(L)$.

Because we focus on the response of variables in regional economy to structural shocks in world oil market block, the coefficient matrix $A_{21} \equiv {C_{22}}^{-1} C_{21} C_{11}^{-1}$ must be identified. On the other hand, we have no need to identify the coefficient matrix $C_{22}^{-1}$ in this approach.

By regressing the residual vector $u_{2t} \equiv -{C_{22}}^{-1} C_{21} {C_{11}}^{-1} \varepsilon_{1t} + {C_{22}}^{-1} \varepsilon_{2t}$ on $\varepsilon_{1t}$ which is already obtained, we can identify the matrix $A_{21}$.

Our approach doesn't need to specify the structure of regional economy. In so doing, we can avoid the ad hoc or unrealistic assumptions. In this respect, our approach is more robust than others.

In addition to that, our approach enables us to reduce the number of parameters needed to estimation. That leads to improve the quality of estimation given the limited sample size.

## 3. Data

In this study, we use monthly data for the following variables. Our sample is from January 1999 to March 2015.

For the world oil market block, we take oil production data from U.S. Energy Information Administration. As for a measure of global real economic activity, we use the index constructed by Lutz Kilian which we downloaded from his website. Oil price data is taken from IMF's Primary Commodity Prices Statistics, and is the average of three spot prices (Dated Brent, West Texas Intermediate, and the Dubai Fateh). Oil production data is transformed to growth rate, and oil price data is transformed to logarithms.

For the regional economy block, we take index of industrial production (IIP) of Japan and the four regions (Tohoku, Kanto, Kinki, Kyushu) from the website of the Ministry of Economic, Trade and Industry (METI). National and regional data of Japanese headline CPI is taken from the website of the Statistics Bureau of Japan. Data of IIP and CPI are seasonally adjusted. Both data are transformed to first difference of their logarithms and multiplied by 1200.

## 4. Results and Analysis

Figure 1 shows the IRFs of variables in the VAR model to world oil market shocks. In each box the median IRF is shown together with the 95 percent error bands. The numbers in the horizontal and vertical axes denote, respectively, months after the shock and the percentage change of the corresponding variable.

Regarding world oil market block, we observe that a positive global demand shock, which reflects an exogenous increase in global real economic activity, raises the world market oil price in the first year. World oil production increases with a time lag of three months. An oil-market specific demand shock does not change global real economic activity at the impact, which is so by definition, but it raises global real economic activity from the second to the fifth month. As pointed out in the literature (see e.g. Kilian 2009), this result suggests the possibility that this shock is a news shock which reflects changes in expectations of investors about future global demand for oil and thus and thus their speculative behavior in the international oil markets. This story is consistent with the result that oil price rises at the impact in response to the shock. As for the oil supply shock, for which we consider a negative one here, although by definition it reduces world oil production, its effects on global real economic activity and oil price are not significant.

Turning to the effects of world oil market shocks on Japan, we observe that a positive global demand shock raises the IIP and CPI of Japan in the horizon from the fourth to the eighth month, and in the horizon from the ninth to the twelfth month, respectively. The effect on IIP is probably through the trade channel, while that on CPI is the aggregate demand channel and input cost channel (as the price of imported oil goes up).

On the other hand, a positive oil-market specific demand shock does not affect IIP of Japan for the first few months but then increases it in the horizon from the fourth to the ninth month. This might provide further evidence about the news shock property of this shock as mentioned above: The increase of IIP of Japan is due to the increase in exports to the world which in turn is due to the rise in global real economic activity which is predicted beforehand by the investors in the international oil markets. Note further that there is another effect on IIP of Japan of this shock that works in the opposite direction: that due to the increase of the oil price and thus the input cost for Japan. A positive oil-market specific demand shock also raises CPI of Japan from the fourth month and the effect remains very persistent. Similarly to the case of global demand shock noted above, the effects of the oil-market specific demand shock here are probably through at least two channels: the aggregate demand one and the input cost one.

The qualitative effects of world oil market shocks on the regional IIP and CPI are basically similar to those on IIP and CPI of Japan as a whole. However, we do observe some differences across regions quantitatively. Figure 2 helps us to see this point more clearly. For the case of the IRF of CPI to the global demand shock, IIP of Tohoku reacts stronger than other regions: at the peak the rise in CPI of Tohoku is 0.23% while the numbers for other regions are around 0.15%. For the case of the IRF of CPI to the oil-market specific demand shock, the same result about CPI of Tohoku is also observed, while we also note that the response of CPI of Kinki is much weaker than any other regions.

The regional differences in the effects of oil shocks are shown further in Figure 3. This figure is drawn based on the variance decomposition results obtained using our estimated VAR model. Regarding the results on the contribution of oil-market specific demand shock to variation in CPI, we could see considerable differences across regions. For example, the oil-market specific demand shock accounts more 21.7% of variation in CPI for the case of Tohoku, while the number for Kanto is 13.4%, and for Kinki is 10.7%. The differences across regions are also remarkable when we look at the contribution of global demand shock to variation in IIP. The contribution of the shock is largest for the case of Kyushu (18.2%), and lowest for the case of Kinki (10.8%).

Since the focus of our paper is on the differences in the effects of oil shocks on the regional economies of Japan, we investigate a bit more what might have been the factors underlying the regional differences found above. Some of factors we think of, for which data at the regional level is available, are temperature and economic structure.

Figure 4 shows the relationships between the various types of the regional differences and the differences in the effects of oil shocks across regions. For the case of the effects of oil shocks on CPI, while there seem to be no clear relationship between the share of the industry sector(in terms of employment), there appears a negative correlation between the share of the service sector and the contribution of oil-market specific demand shock to variation of CPI. This result may be explained based on the fact that is often found in the literature that the passthrough of an oil shock to the prices of other goods and services tend s to be slow in the service sector (think of the response of taxi fare to fluctuations in gasoline price, for example). As for temperature, we observe a negative correlation between regional temperature during winter and the contribution of oil-market specific demand shock to variation of CPI. An explanation for this is that, in a region with colder winter (such as Tohoku) more oil is consumed for heating and the weight of oil in the CPI basket is greater, which means a larger influence of oil price fluctuations on the variation of CPI. This is also consistent with the positive correlation between regional consumption of oil per household and the contribution of oil-market specific demand shock to variation of CPI as shown in Figure 4.

Regarding the effects of oil shocks on IIP, we do not see a clear tendency between these effects and the regional share of the service sector or that of the industry sector. However, there is a strong correlation between the share of transportation equipment in all industries and the contribution of global demand to variation of IIP at the 12 month horizon. This fact is also consistent with the finding of Sato and Shrestha(2012). The reason for this is that, as the transportation equipment industry is one of the major exporting industries of Japan, it has a strong linkage with the condition of the global market, therefore in a region with a larger share of this industry, IIP would be more susceptible to changes in global demand.

Before ending this section, we provide a comparison, in terms of the effects of oil shocks on macroeconomic variables, between regions in Japan and ASEAN countries which we have analyzed in a previous study. The results are displayed in Figure 5. We can see that regions in Japan are comparable in terms of the contribution of oil-market specific demand shock to variations in CPI at the 12-month horizon. For the case of IIP, the contribution of global demand shock to variation of this variable is considerable larger in the Japanese regions than in ASEAN countries. This result appears a bit puzzling to us since the openness (measured as the ratio of exports and imports to GDP) is much higher in ASEAN countries than it is in Japan. It seems that more investigation is needed for this issue.

## 5. Concluding remarks

In this paper, we have asked and analyzed the question: How shocks occurring in the world oil market would affect the economies of different regions in a country like Japan, given the heterogeneity between these regions in terms of natural condition, economic structure etc. We believe that this question is of considerable interest and our view point is relatively unique, that is, a large part of the huge literature on the effects of oil price fluctuations study national economies, while our focus is on regional economies in the same country.

We used the method of a VAR with block exogeneity in which there are two blocks, namely, the world oil market and a region of Japan. A region of Japan (the second block) is treated as a small open economy which is affected by changes in the world oil market (the first block), but it is assumed that there is no feedback from the second block to the first. This structure is realistic given the relatively small size of a region in Japan compared to the world oil market, and it also enables us to identify structural shocks to the world oil market in a parsimonious and reasonable way.

Our main findings are as follows. The qualitative effects of oil shocks on the regional economies in Japan are quite similar. This is understandable since the variables we studied here, namely CPI and IIP, are very highly correlated across regions. Some of the results that are similar across regions are (i) the headline CPI rises in response to a positive oil-market specific demand shock with a lag of about three or four months, and to a positive global demand shock with a lag of about nine months, and (ii) the IIP increases in response to a positive oil-market specific demand shock with a lag of about five months, and to a positive global demand shock with a lag of about three or four months. The quantitative effects oil shocks, however, differ considerably across regions. CPI and IIP of Tohoku react stronger, and IIP of Kinki weaker to global demand shocks and oil-market specific demand shocks than other regions. Investigating the factors that might have been related to the regional differences in the effects of oil shocks, we find that regions with lower temperature during winter, or smaller share of the service sector tend to have CPI to be more susceptive to oil price fluctuations due to oil-market specific demand shocks. On the other hand, regions with higher share of the transportation equipment industry tend to be more affected by global demand shocks. Finally, the results on CPI for regions in Japan are comparable with those for ASEAN countries, but that is not true for the case of IIP.

**References**

Fukunaga, Ichiro, Naohisa Hirakata and Nao Sudo, 2009. "The Effects of Oil Price Changes on the Industry-Level Production and Prices in the U.S. and Japan," IMES Discussion Paper Series 09-E-24, Institute for Monetary and Economic Studies, Bank of Japan.

Kilian, Lutz, 2009. "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," American Economic Review 99:3, 1053-1069.

Hamilton James D., 1983. "Oil and the Macroeconomy since World War II," Journal of Political Economy 91:2, 228-248.

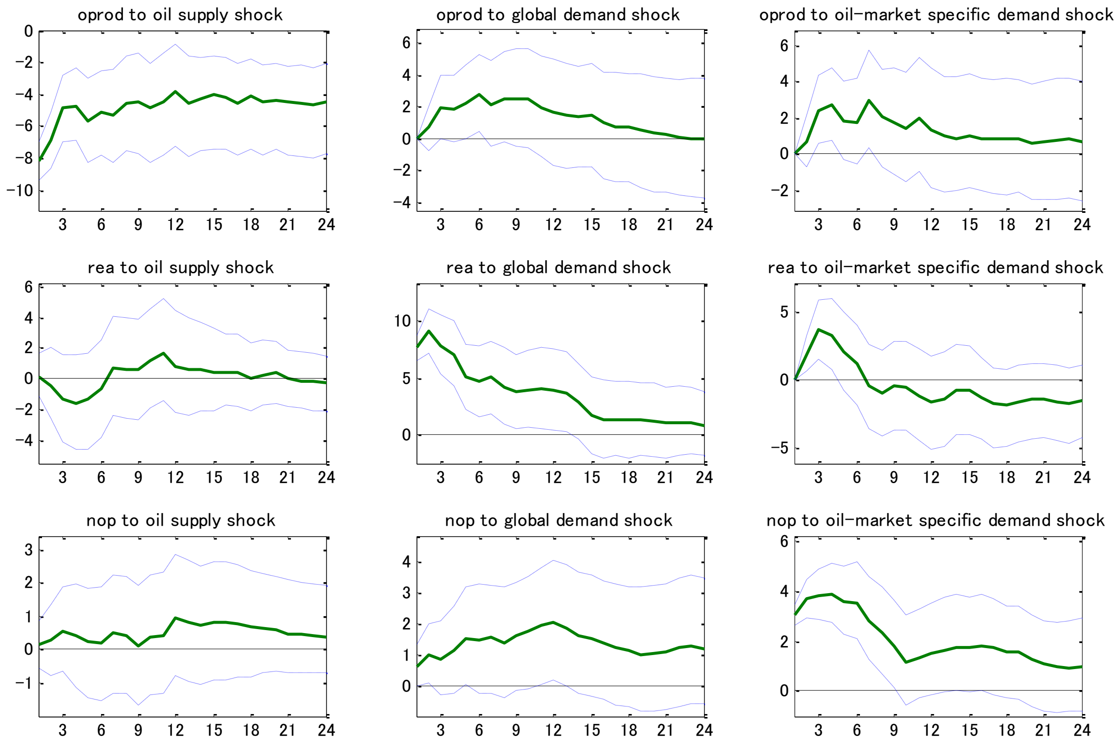
Park, Chuhwan, Mo Chung and Sukgyu Lee (2011), "The effects of oil price on regional economies with different production structures; A case study from Korea using a structural VAR model," Energy Policy 39, 8185–8195.

Sato, Kiyotaka and Nagenda Shrestha (2012), "International Shock Transmission in East Asia and the United States," Yokohama National University, Manuscript

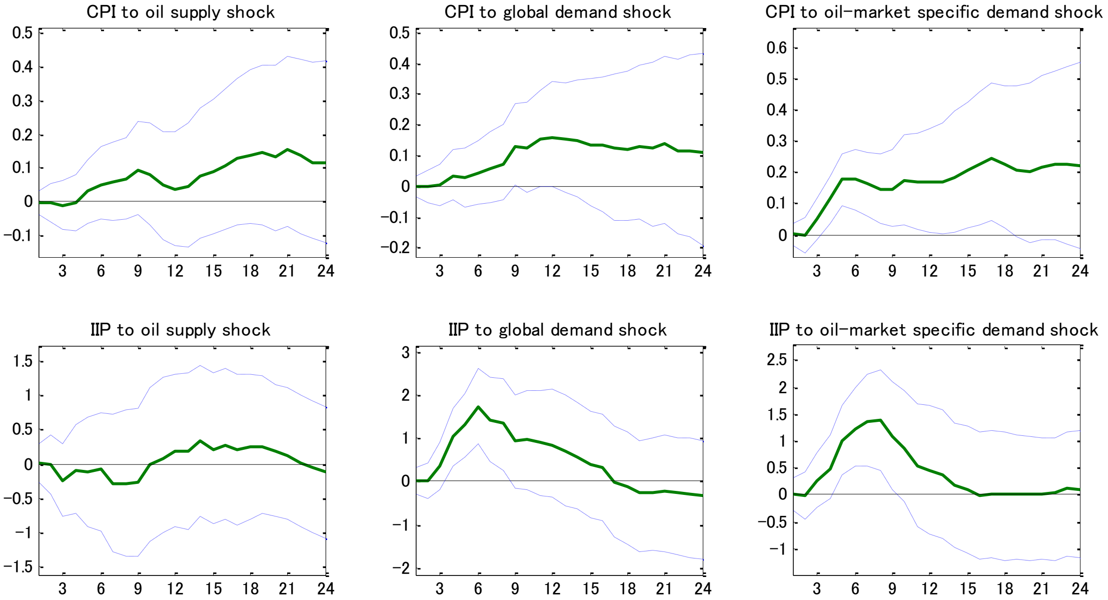
Vu, Tuan Khai and Hayato Nakata, 2014. "The Macroeconomic Effects of Oil Price Fluctuations in ASEAN Countries: Analysis Using a VAR with Block Exogeneity," IER Discussion Paper Series (A) No.619, Institute of Economic Research, Hitotsubashi University.

**Figure 1: IRFs to world oil market shocks**

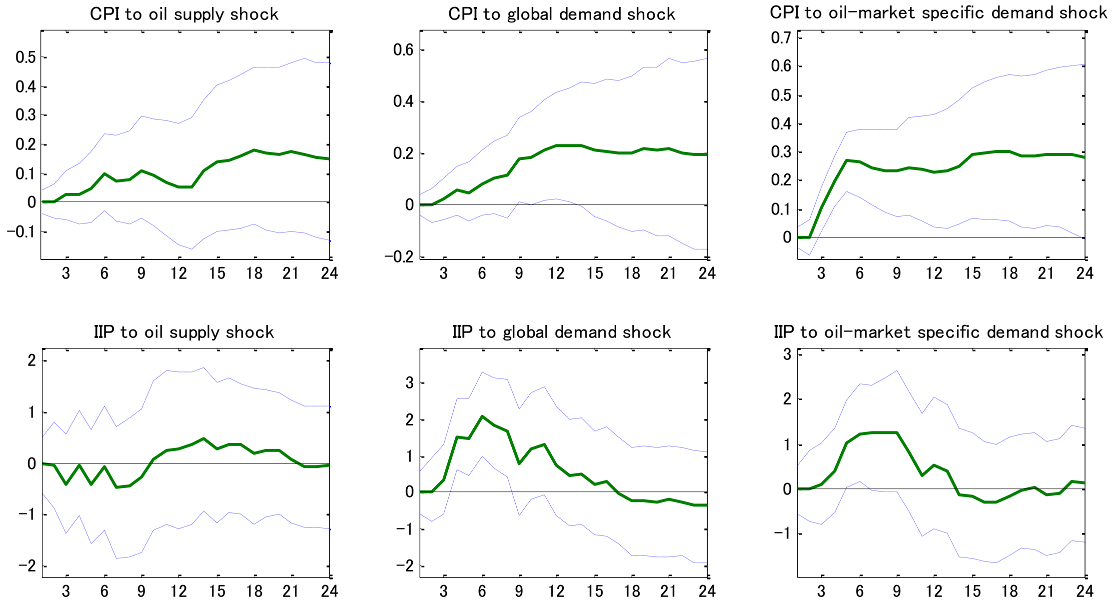
*World oil market variables*



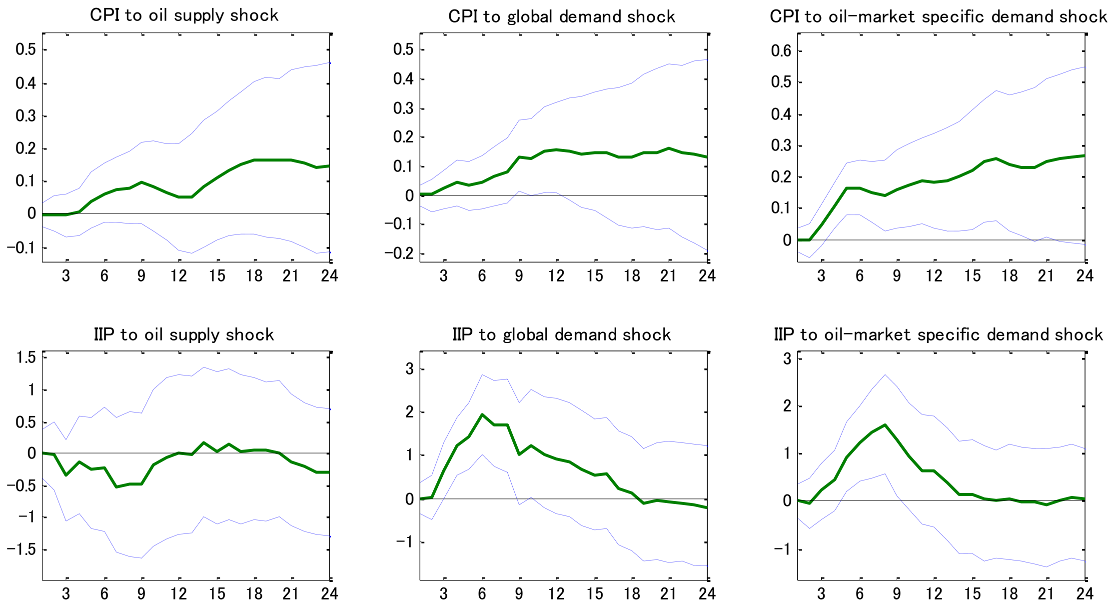

*CPI and IIP of Japan*



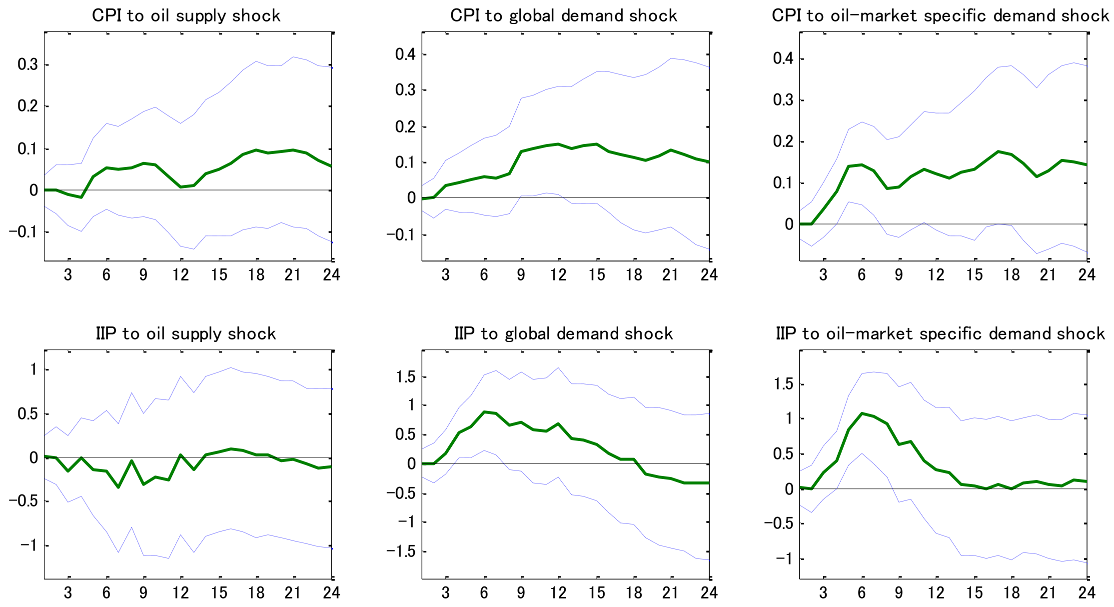
*CPI and IIP of Tohoku*



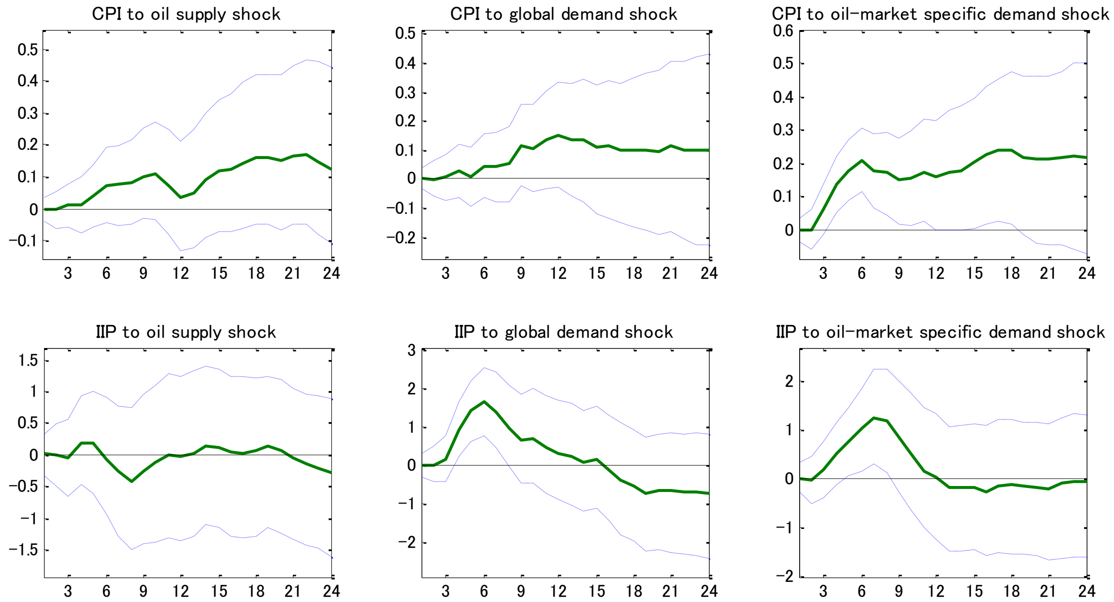

*CPI and IIP of Kanto*



*CPI and IIP of Kinki*



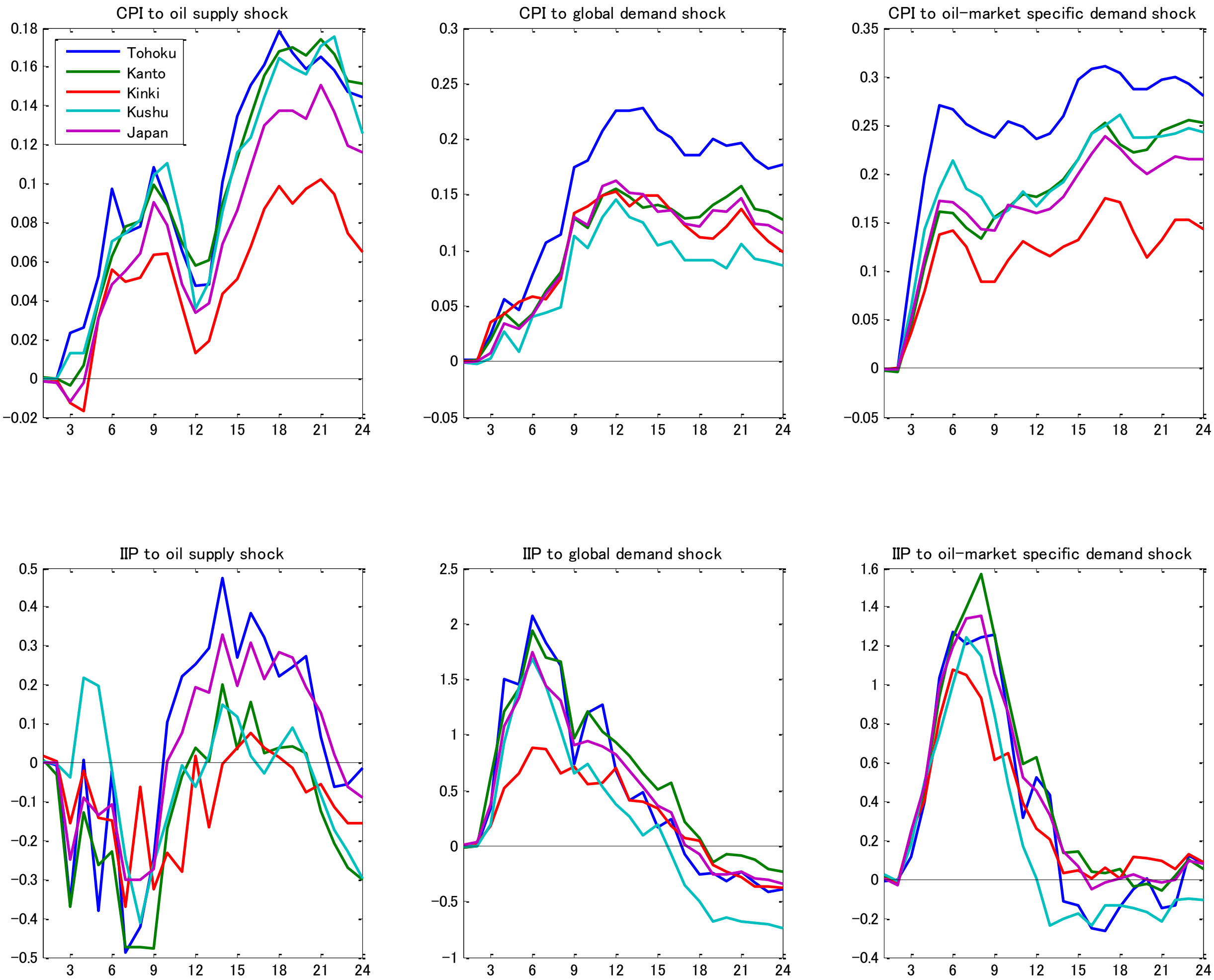

*CPI and IIP of Kyushu*




Note: In each box, numbers in the vertical axis show the annualized rates of change in percent. Numbers in the horizontal denote months after the shock. Dashed lines are error bands with ±2 se, and solid lines are the median of the IRF.

**Figure 2: A comparison between IRFs of CPI and IIP of Japanese regions to world oil market shocks**

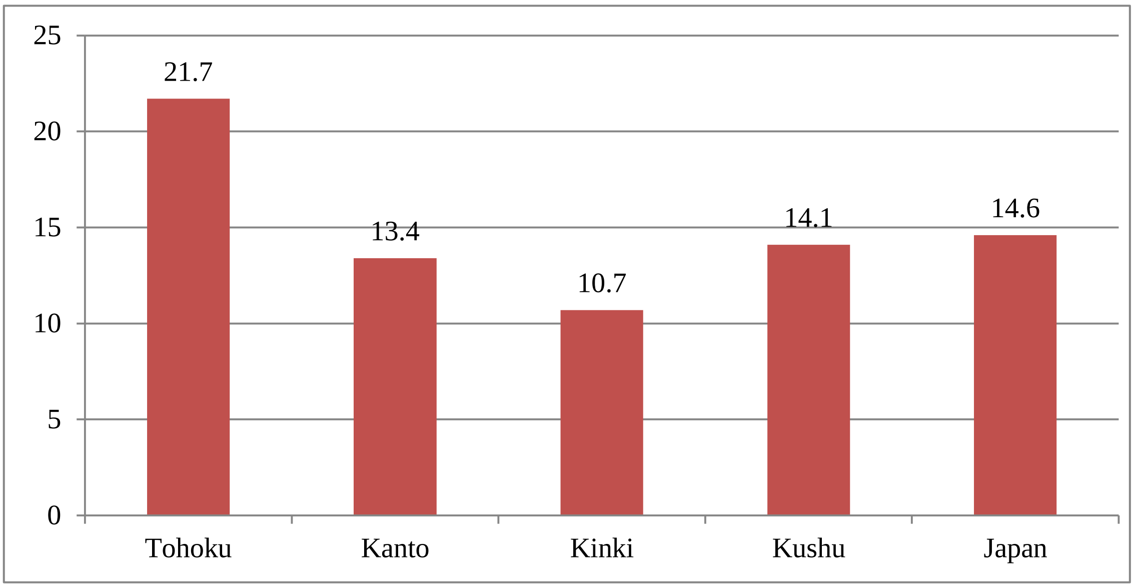
**Sample period: 1999-2015**




Note: The lines here are the median of the IRFs shown in Figure 1.

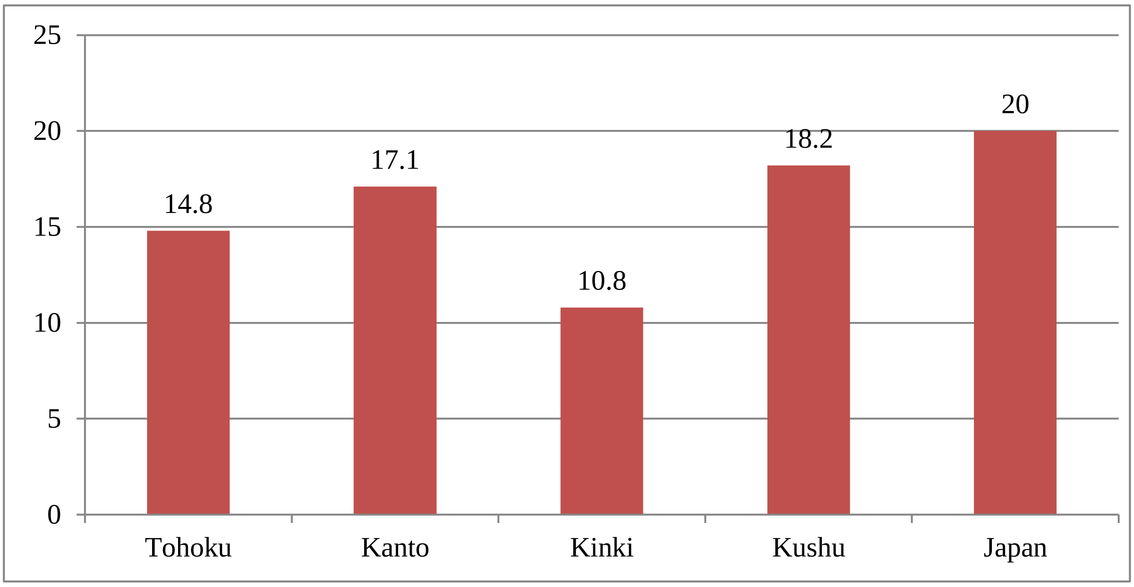
**Figure 3: Variance decomposition results: A comparison between regions in Japan**

Contribution of oil-market specific demand shock to variations in CPI at the 12-month horizon




Note: The numbers here are the median.

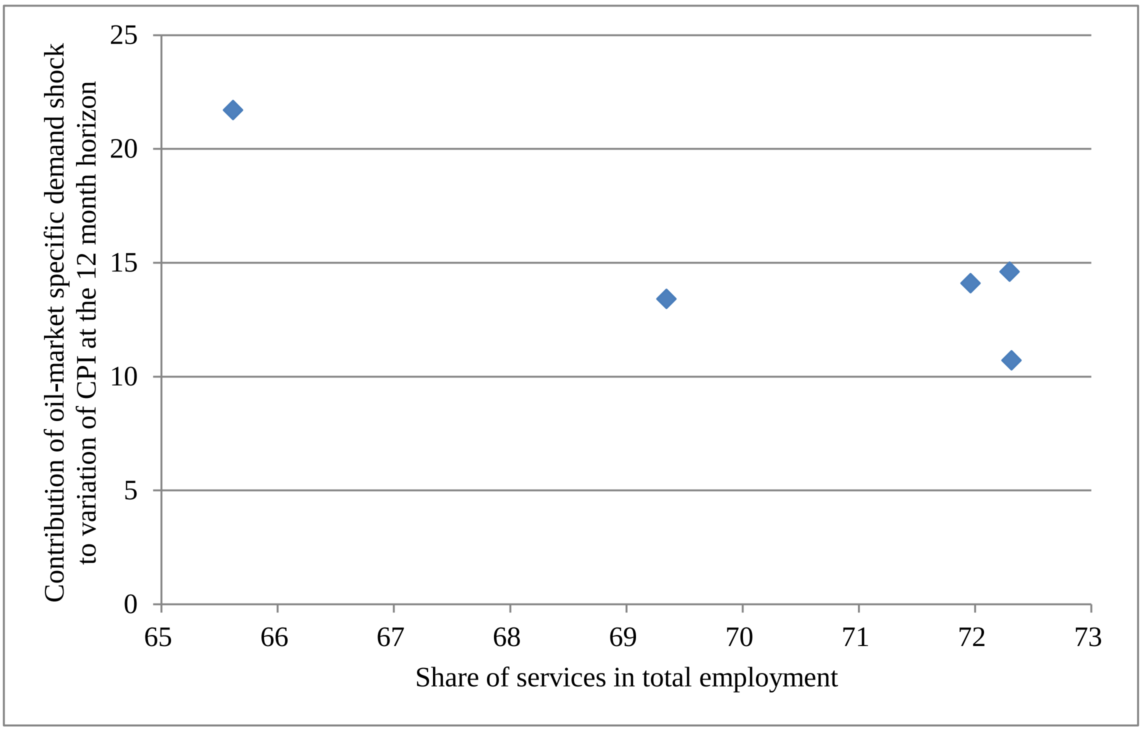
Contribution of global demand shock to variations in IIP at the 12-month horizon

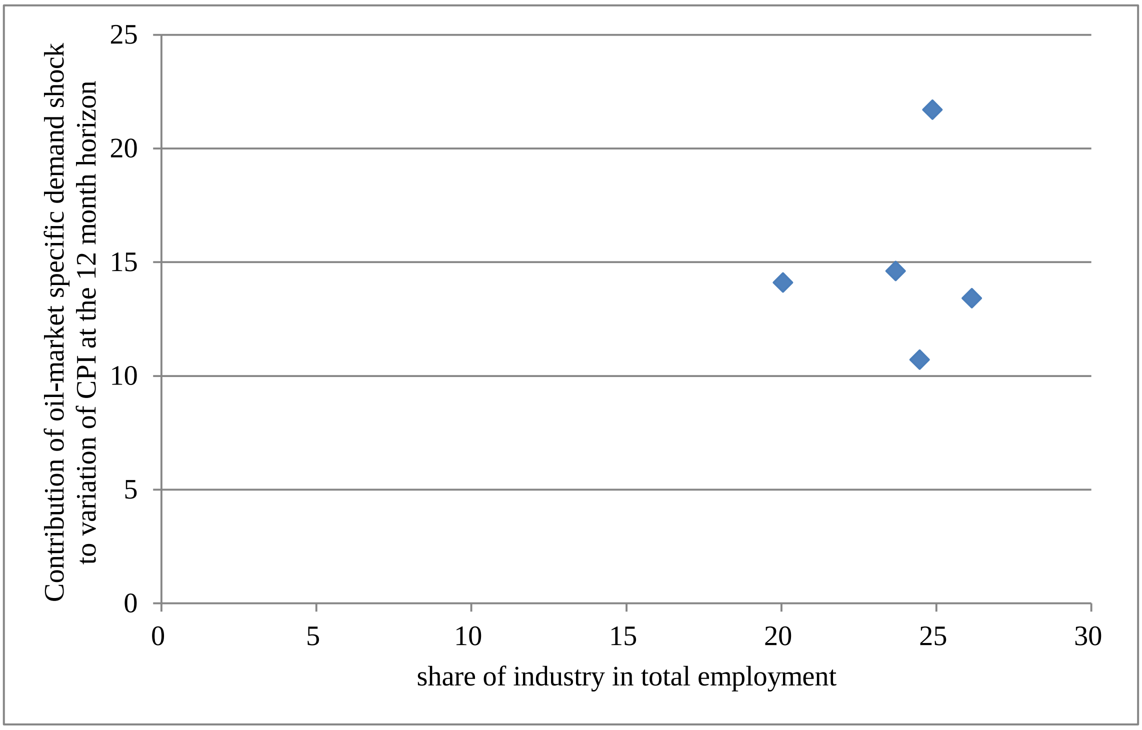



Note: The numbers here are the median.

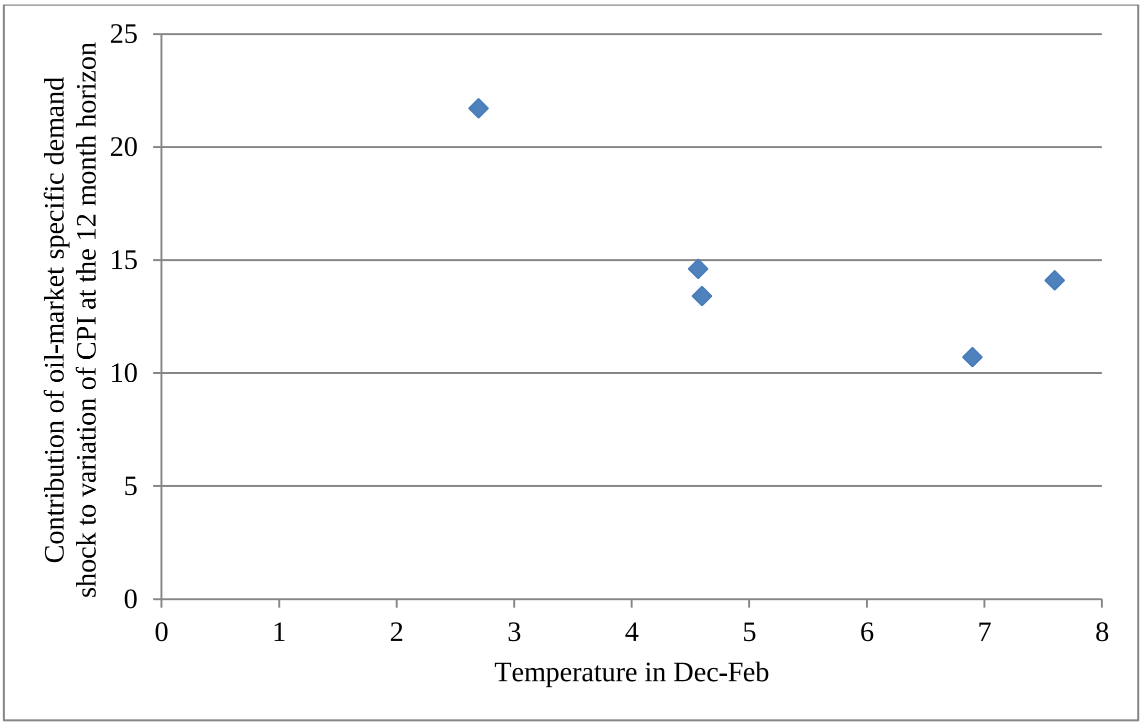
**Figure 4: Various types of the regional differences and the differences in the effects of oil shocks across regions**

<ins>1, Regional differences in economic structure and the effects of oil shocks on CPI</ins>

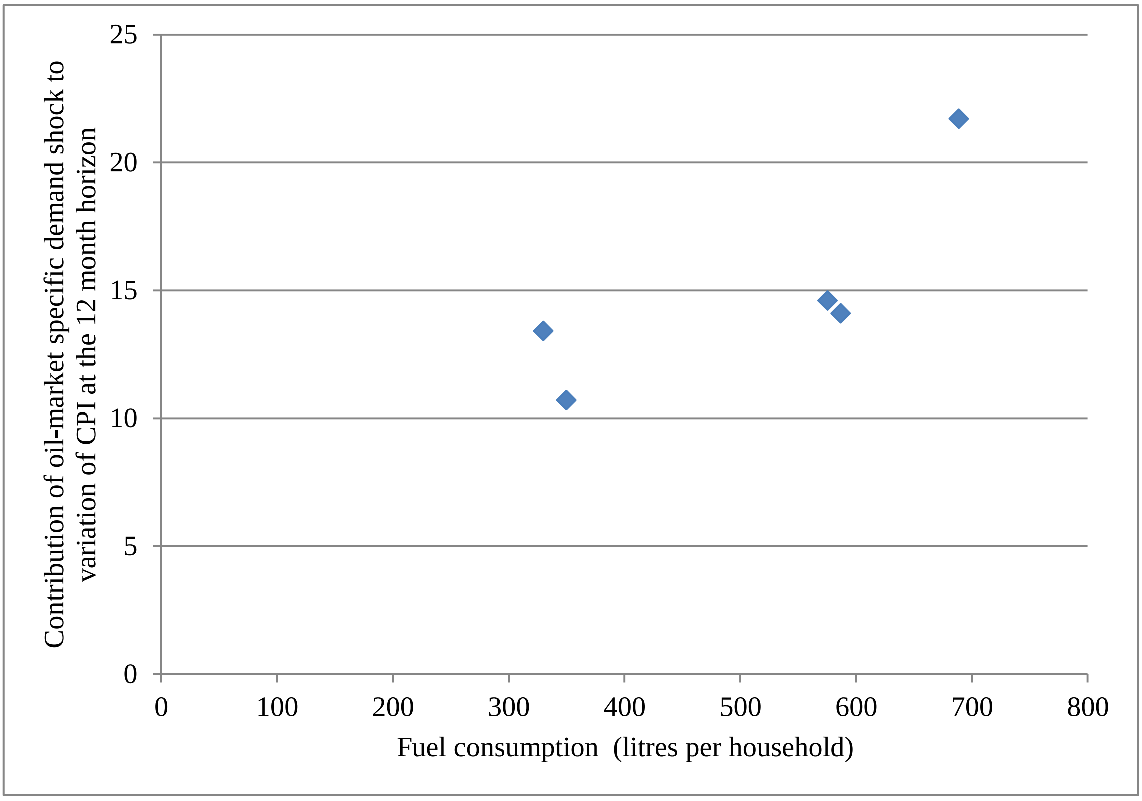


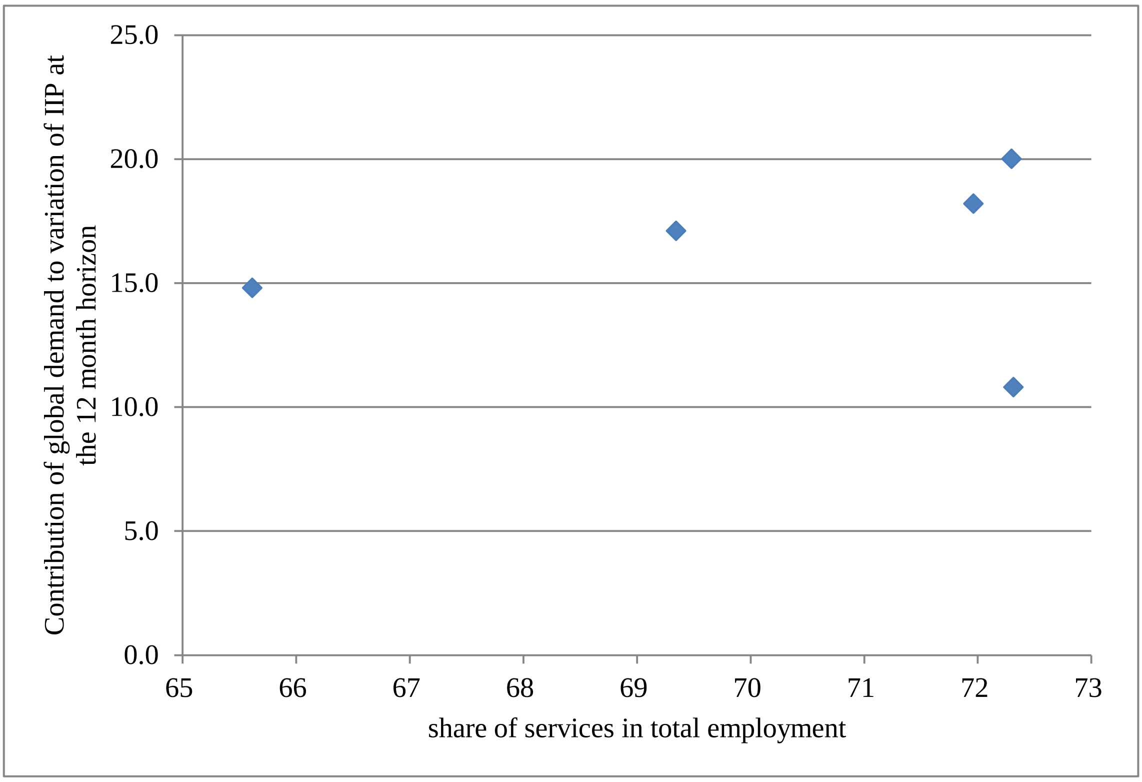
2, Regional differences in temperature and the effects of oil shocks on CPI

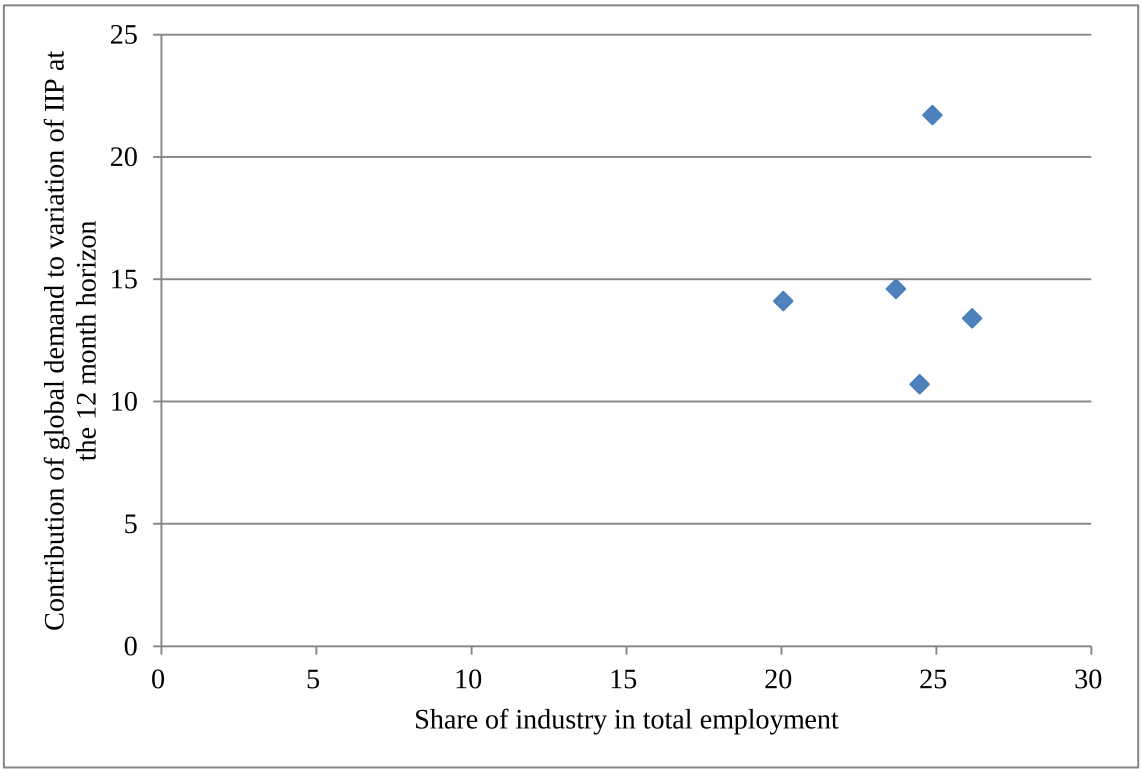


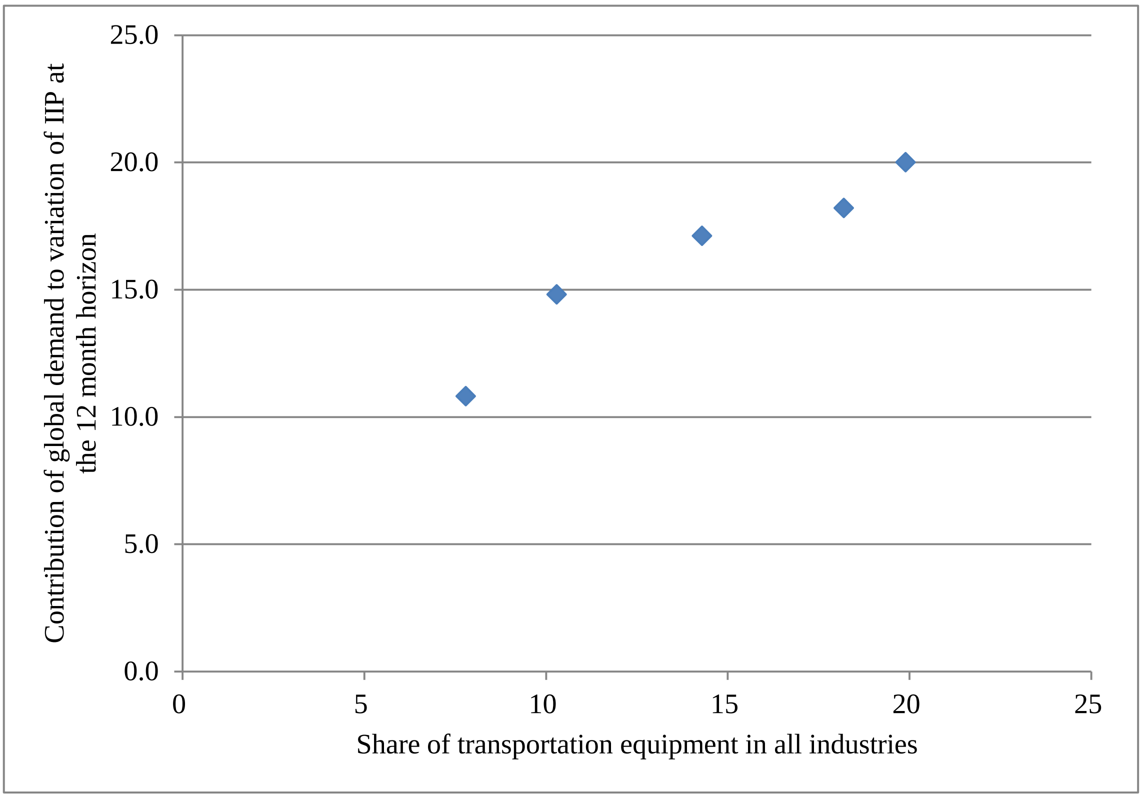

3, Regional differences in consumption of oil and the effects of oil shocks on CPI



4, Regional differences in economic structure and the effects of oil shocks on IIP






Source:

Share of sectors in total employment: 2010 Population Census of Japan

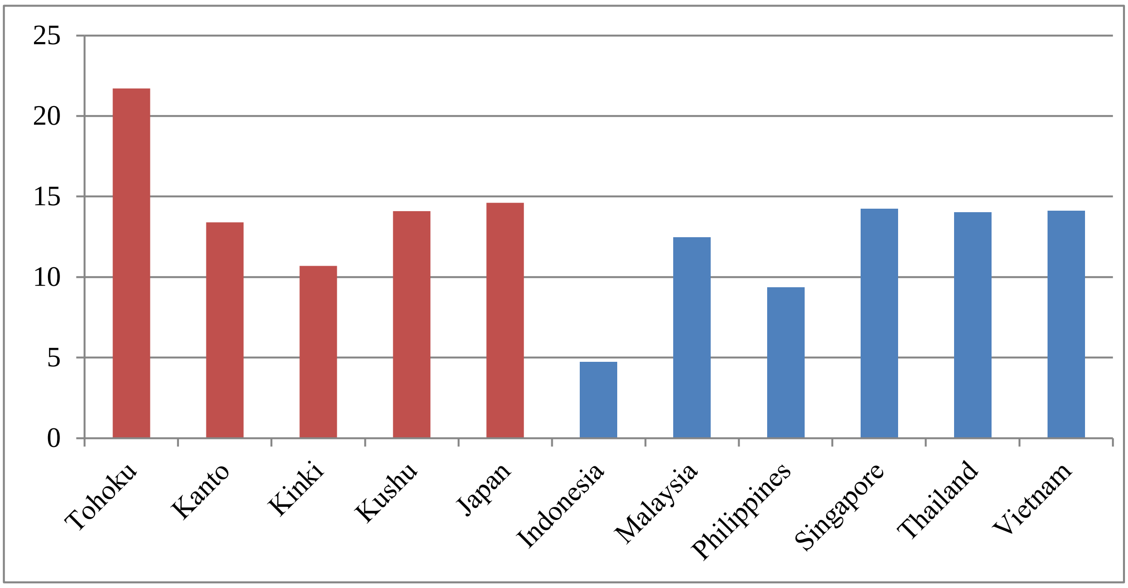
Temperature (Average temperature in principal cities of regions) : Website of Japan Meteorological Agency

Fuel consumption: Energy consumption survey 2011

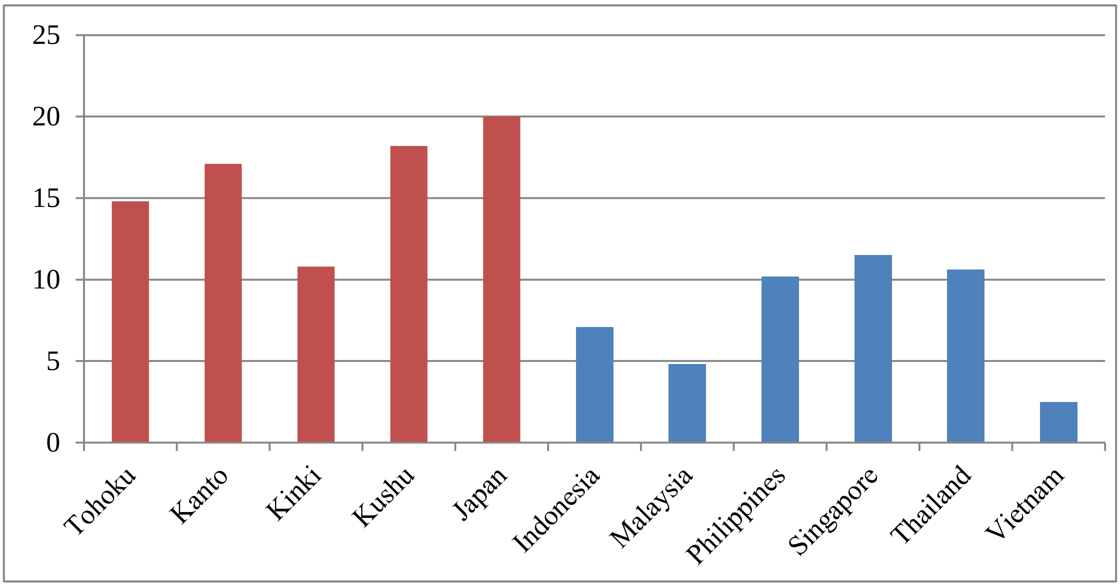
Share of transportation equipment in all industries: Website of the Ministry of Economic, Trade and Industry (METI).

**Figure 5: Variance decomposition results: A comparison between regions in Japan and ASEAN countries**

Contribution of oil-market specific demand shock to variations in CPI at the 12-month horizon




Contribution of global demand shock to variations in IIP at the 12-month horizon




Note: Results for ASEAN are obtained by estimating the same VAR model with the lag length 12 using the data on ASEAN countries in the period 1999-2013; more details of this ASEAN dataset are explained in Vu and Nakata (2014).