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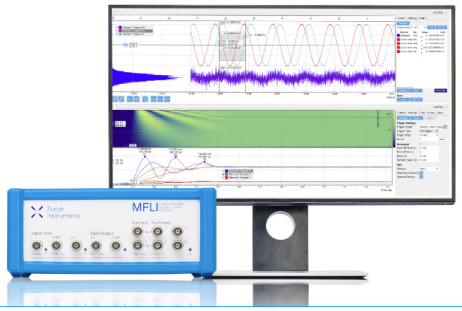

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An Investigation on the Impacts of Oil Price Shocks on Domestic Inflation: A SVAR Approach

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Abstract. Oil price can have influential effects on inflation as oil is used as the main source in many productions. In this paper, we perform comparative analyses on studying the impacts of oil price shocks on determining the domestic inflation in two groups of countries, i.e. oil importing versus oil exporting countries. In particular, we look into the effects of oil supply and oil demand shocks on determining the domestic inflation. A structural vector autoregressive model is used in analyzing the effects of orthogonalized shocks on inflation. A Blanchard-Quah identification is applied on the long-run impact matrix. We focus the analyses on ten oil importing and ten oil exporting countries respectively. The data ranging from 1973M1 onwards till 2015M1. Our results detect interaction effects among variables. We also observe that oil supply shock is more influential in explaining CPI inflation compared to oil demand shocks. Oil supply shock can be a determinant to inflation in oil importing countries but oil demand has very limited explanatory power on explaining inflation in most countries. Inflation in the main oil exporting countries does not respond to neither oil supply shock nor oil demand shock. The results reveal that oil dependency may determine the magnitude impact of oil supply and oil demand shocks on inflation.

INTRODUCTION

Oil price can have significance effect on determining the economic performance as oil is the main source used in productions of many goods. In particular, oil price changes may pass-through into production cost. Higher production cost may lead to higher consumer price. Therefore, excesses fluctuation in oil price may lead to volatility in domestic inflation which may later influence the economic stability and performance globally.

History reported that the world had experienced several large oil price shocks in the past 30 years, i.e. 1973-74, 1979-80, 1990 and 1999, [1]. Oil price spikes had generated cost-push inflation. Although the impacts of oil price on inflation are evident, there are debates on the magnitude impact of oil price shocks on economic (particularly inflation). This is because the impacts of oil price shocks on macroeconomic performance observed to be different across countries, [2] and over periods. Hooker [3] who focused the study on U.S. found that the relationship between oil prices and macroeconomic performance were strong in the post 1973 but the relationships were weakened thereafter and that oil price shocks failed to explain the dynamics of business cycles in the post 1979-80 period.

Based on the previous debates on the impacts of oil price shocks on macroeconomics (inflation) and the changes relationship between oil price and inflation across countries and periods, we further explore the oil price- inflation relationship between oil importing versus oil exporting groups. We follow the approach in Kilian [4] to distinguish the effects of oil demand and oil supply shocks in studying the underlying evolution of real price of oil on domestic inflation. Our main objective is to determine the interactions effects between oil demand, oil supply and inflation for the two groups of countries based on their oil dependency. Our results show that oil dependency factor is crucial on determining the magnitude impacts of oil on inflation. Oil supply shock is more influential on determining inflation but oil demand shock has very limited effect on determining inflation in majority countries. Inflation in the main oil producing countries is not responsive to both oil supply and oil demand shocks as their oil dependency is very low. The remaining paper is organized as follows: section 2 provides a review on literature; section 3 explains the data; section 4 explains the methodology; section 5 discusses the results and section 6 concludes the findings.

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LITERATURE REVIEW

The effects of oil price on inflation can be explained through aggregate demand and supply and also the policy responses. From the supply side, lower oil price implies lower production cost, [5]. Lower production cost may pass-through on consumer price so that inflation is reduced. From the demand side, lower oil price means lower energy bills and higher consumers' real income. This will lead to higher consumption ([6] and [7]).Changes in oil price may lead to higher inflation or recession. The central bank may react to oil price changes by implementing a contractionary monetary policy to stabilize inflation and an expansionary policy to boost economy during recession, [8].

In general, majority studies reported significance impacts of oil price changes on inflation. However, oil price shocks substantially differ across industries and countries. The impacts also vary over time and depend on the nature of oil price shocks and oil specifications. A number of studies showed that the impacts of oil price on economy activity had declined over time (see [9], [10] and [11]. Previous studies had provided several explanations on the decline relationship between oil price and inflation. These explanations include the decline in real wage rigidities, higher credibility of monetary policy and the decrease in the share of oil in consumption and in production [12]; higher energy efficiency of production processes, the price setting due to globalization and also the better conduct of monetary policy that help to reduce the impact of oil price shocks [13].

A number of studies also reported different effects of oil price shocks across countries. For instance, Alvarez *et al.* [13] focused their study on Spanish and Euro area using a general equilibrium model. Their results showed that oil price changes have limited impacts on domestic inflation although oil price fluctuation is the main determinant of inflation variability. The impacts of oil price shocks on inflation are higher in Spanish. The results also detected increasing direct effects of oil price changes on inflation but declining trend in the indirect effect. On the other hand, Basnet and Upadhyaya [14] applied a structural VAR model to study the effects of oil price shocks on determining the economies in ASEAN5 countries. They reported that oil price shocks were not the driver of macroeconomics changes in ASEAN5 countries with the exception of Thailand as oil price shocks lead to higher inflation in Thailand.

At disaggregate levels, previous studies showed that the impacts of oil price shocks on consumer prices can be different across industries. Previous studies reported different pass-through rates of oil price shocks into disaggregated prices across industries. These studies include Baffes [15] and Harri *et al.* [16]. Previous studies also reported significance impacts of oil price shocks on food prices [17] and agricultural prices ([18] and [19]). Changes in oil prices can affect the commodity prices of food and agricultural as energy intensive inputs (example fertilizers and transportation costs) may transmit into higher cost of production of food and agricultural so that prices of final foods also increase [17]. The pass-through rates of oil prices into disaggregate prices vary depending on the energy intensity of the sectors.

Lamazoshvili [19] pointed out that the effects of oil price shocks could be examined through source of shocks, the transmission mechanism of shocks and the structure of energy flows. In order to have deeper analyses on the impacts of oil price shocks on macroeconomics, some studies distinguished the effects of oil shocks based on the nature of shocks, i.e. either the shocks are demand driven or supply driven. Kilian [4] took the first initiative to examine the source of oil shocks i.e. either oil price is driven by supply side or demand side. The study applied structural VAR models on U.S. data. The results revealed that oil price is dominated by demand shocks. Badel and McGillicuddy [20] extended the data in Kilian [4] to January 2015 and repeated the analyses. They concluded that the role of oil supply on oil prices has been small.

Taking consideration on the sources of oil price shocks, some studies include oil demand and oil supply shocks in analysing their impacts on macroeconomics. For instance, Cashin *et al*. [21] applied a Global VAR model to study the effects of oil demand and oil supply shocks on 38 economies. The results showed that both oil supply and oil demand shocks have different effects on oil importing and oil exporting countries. Oil supply shocks have positive impacts on the economics of oil exporting countries as these countries have large oil or gas reserves. However, oil demand shocks generate long run inflationary pressure and increase in real output in majority countries. Similar study was conducted by Peersman and Robays [22] in Belgium using the VAR method. They found that higher oil prices leads to the decline in economic activity in oil importing countries but the impacts are positive in oil exporting countries. Oil demand disturbances induce long-run inflationary pressures in almost all countries. These results imply that the sources of oil shocks may determine the impacts of oil price on macroeconomics across different groups of economies.

DATA

The main focus of the study is on top oil importing and oil exporting countries. We have selected the two groups of countries by referring to the Organization of Petroleum Exporting Countries (OPEC) and U.S. Energy Information Administration (EIA) websites. The countries include:

a) Oil importing: U.S., China, Japan
b) Oil exporting: Saudi Arabia, Russia

There are four variables used in the analysis, i.e. CPI (index), nominal exchange rate of domestic currency per US$, oil supply which is proxied by the crude oil production (thousand barrels per day, US$), oil demand which is proxied by the index of global real economic activity in industrial commodity markets (monthly percent deviations from trend) calculated by Kilian [4], see http://www-personal.umich.edu/~lkilian/paperlinks.html. The CPI and exchange rate data are collected from the World Bank while the oil supply data is collected through U.S. Energy Information Administration. The data take the range starting 1973M1 until 2015M2. However some countries may have a later starting date depending on the data availability. China has the starting date of 1987M1; Nigeria and Saudi Arab 1980M1; Singapore 1974M1; Korea 1982M1and Russia 1994M1.

METHODOLOGY

In order to study the interaction effects between oil price shocks (oil demand and oil supply) and domestic inflation shock, a structural vector autoregressive (SVAR) model is applied. This model provides dynamic analysis on the transmission of shocks through impulse responses and variance decompositions. For simplicity, we assume that the domestic economy can be represented by a structural model:

$$\begin{aligned} &\mathbf{A_0} Xt = A_1 X_{t-1} + \ldots + A_q X_{t-q} + \mathbf{B}\varepsilon_t \\ &X_t = \left[\Delta OS_t \quad \Delta OD_t \quad \Delta EX_t \quad \Delta P_t\right]' \end{aligned} \tag{1}$$

where $\mathbf{A_0}$ and $\mathbf{B}$ are the ($K \times K$) matrices contain instantaneous relationship between X_t (endogenous variables) and ε_t (structural shocks) and $A_1,\ldots,A_q$ are ($K \times K$) coefficient matrices. The structural equation can be transformed into reduced form by pre-multiplying both sides of equation (1) with $\mathbf{A_0^{-1}}$ (see [23]):

$$X_t = A_1^* X_{t-1} + \ldots + A_q^* X_{t-q} + e_t \tag{2}$$

where $A_j^* = \mathbf{A_0^{-1}} A_j$ given j=1,..., q); $e_t = \mathbf{A_0^{-1}}\mathbf{B}\varepsilon_t$ and $E\left[\varepsilon\varepsilon'\right] = I$. Equation (1) can be written in a generic form (see [24]) as below:

$$\left[I_K - A(L)\right] X_t = \mathbf{B} e_t \tag{3}$$

such that $A(L) = \sum_{i=1}^{q} A_i L^i$ to be invertible, we assume $\mathbf{A_0} = I_K$. Inverting this term $\left[I_K - A(L)\right]$ give to the product of Wold moving average representation of structural VAR process:

$$X_t = C(L)\varepsilon_t = \Psi_{0\varepsilon_t} + \Psi_1 \varepsilon_{t-1} + \ldots + \Psi_s \varepsilon_{t-s} \tag{4}$$

where $C(L) = \left[I_K - A(L)\right]^{-1}\mathbf{B}$ and $\Psi_0 = \mathbf{B}$. Since $\mathbf{A_0} = I_K$ which is the identity matrix, we obtain this relationship: $\varepsilon_t = \mathbf{B}^{-1} e_t$. Using this relationship into equation (4), we finally reach the Wold representation of the reduced form of VAR process:

$$X_t = C(L)\varepsilon_t = C(L)\mathbf{B}^{-1} e_t = \Phi_0 e_t + \Phi_1 e_{t-1} + \ldots + \Phi_s e_{t-s} \tag{5}$$

where $\Phi_i = \Psi_i \mathbf{B}^{-1}$ and $\Phi_0 = I_K$ given i=0, 1, ...

Blanchard Quah Identification

We apply the Blanchard Quah identification [25] by imposing long-run restrictions on the cumulative impulse response function. There are totally $K(K\text{-}1)/2 = 6$ restrictions in this study where K=4 (number of variables). Applying the Blanchard Quah identification, our long run impact matrix can be written as:

$$e_t = C(1)\varepsilon_t$$

$$\begin{pmatrix} e_t^{os} \\ e_t^{od} \\ e_t^{ex} \\ e_t^{p} \end{pmatrix} = \begin{pmatrix} C(1)_{11} & 0 & 0 & 0 \\ C(1)_{21} & C(1)_{22} & 0 & 0 \\ C(1)_{31} & C(1)_{32} & C(1)_{33} & 0 \\ C(1)_{41} & C(1)_{42} & C(1)_{43} & C(1)_{44} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{os} \\ \varepsilon_t^{od} \\ \varepsilon_t^{ex} \\ \varepsilon_t^{p} \end{pmatrix}$$

$C(1)$ is the long run matrix of $C(L)$. The long run impact matrix is in lower triangular choleski decomposition so that the ordering of the variables may give different effects on the dynamic structure of the shocks. The first variable is ordered on the top so that it has impacts on all variables below it but it will not be affected by other variables. The second variable has impacts on influencing all variables below it except the first variable. It receives impacts from the first variables. This rule holds for all subsequent variables. In this study, the oil supply is the first variable, followed by oil demand, exchange rate and CPI. Both oil variables are expected to influence the macroeconomic variables so it is reasonable to put them on the top. CPI is the domestic variable and it is expected to receive influences from all the three external shocks above it.

RESULTS AND DISCUSSIONS

Before conducting the SVAR model analysis, we perform the unit-root tests (Augmented Dicky-Fuller (ADF) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test and unit-root with structural break test). The tests are performed on all variables (in level and first differenced), with constant compared with constant and trend specifications respectively. The numbers of lags are as suggested by Schwarz Info Criterion (SIC) and Akaike Info Criterion (AIC). In general, all variables are stationary after first differencing transformation. Therefore, we proceed with the estimation using the first differenced variables. Again, in the SVAR model specifications, we refer to the AIC and SIC on the selection of lag lengths.

Table 1 (3rd column) summarizes the results on the contemporaneous impact matrix. The results show that CPI inflation receives influences from the oil variables and exchange rate but the impacts are very small in the short run. We also observe interaction effects among the four variables in the short run with relatively small effects to each other except the change in oil demand. Oil demand changes are more sensitive to the impacts of shocks (oil supply changes, exchange rate changes and CPI inflation) as the coefficient estimates of these shocks are much larger on oil demand changes. The results hold for all countries. This condition may due to the important role played by oil as main source in manufacturing or production of many goods.

Table 1 (2nd column) shows the long-run impacts matrix. The long run impact matrix is restricted using Blanchard Quah identification that takes the lower triangular choleski decomposition. The coefficient estimates on the diagonal are significant, showing the respective shocks to its own movement. The off diagonal coefficient estimates show the interaction effects of shocks to each variable. The results show that oil supply shock has significant impact on determining the CPI inflation in the long-run in oil importing group. However, no significant impact from oil demand shock is observed on inflation in the same group of countries. Producers of oil importing group are concerned about the supply or production of oil as this can affect the oil price changes. They are not concerned on the demand or the oil consumed by others. Exchange rate shock also has very limited or low impact on inflation in the long run in these countries. Oil supply shock can have significant effect on the oil demand changes. The relationship is negative and this result holds in both groups of countries. Comparing the results with oil exporting group, we observe that the inflation of the main oil exporters (Russia and Saudi Arabia) are not affected by both oil supply and oil demand shocks and exchange rate shocks.

The results of FEVD are summarized in Table 2. FEVD shows the relative impacts of oil supply and oil demand shocks on predicting the movement of four variables in the system equation at different time horizons (1st, 6th, 12th, 18th and 24th months). As observed, CPI inflation in oil importing countries are mostly determined by its own shock. Oil demand shock has a limited explanatory power on inflation in these countries except Japan. Oil supply shocks are quite influential on determining the inflation in oil importing countries. This result

is consistent with the results shown in the long-run impact matrix. Comparing the results with oil exporting countries, the results show that inflation is not responsive to oil supply and oil demand shocks.

The results of long-run impact matrix and FEVD are consistent. The results show that oil supply shock is more influential on determining inflation compared to oil demand shock. Oil supply shock can explain the movement of inflation in majority countries except the main oil exporting countries (Russia and Saudi Arabia). Oil demand shock has very low explanatory power on inflation in majority countries. There are interaction effects among the four variables in the system equations.

TABLE 1. Long-run and contemporaneous impact matrix

Country	Long-run impact matrix	Contemporaneous impact matrix
U.S.	$\begin{bmatrix} 0.0163^{***} & 0 & 0 & 0 \\ -1.5992^{*} & 5.3978^{***} & 0 & 0 \\ 0.0104^{***} & -0.0049^{***} & 0.0152^{***} & 0 \\ 0.0065^{***} & 0.0010 & 0.0008 & 0.0065^{***} \end{bmatrix}$	$\begin{bmatrix} 0.0110^{***} & 0.0038^{***} & -0.0032^{***} & -0.0087^{***} \\ 0.0994 & 4.9295^{***} & 2.8171 & 0.8084^{**} \\ 0.0008 & -0.0053^{***} & 0.0107^{***} & -0.0047^{***} \\ 0.0016^{***} & -0.0004^{*} & 0.0005^{*} & 0.0017^{***} \end{bmatrix}$
China	$\begin{bmatrix} 0.0107^{***} & 0 & 0 & 0 \\ -1.8679^{*} & 6.0909^{***} & 0 & 0 \\ -0.0020 & -0.0014 & 0.0248^{***} & 0 \\ 0.0410^{*} & -0.0091 & 0.0521 & 0.2849^{***} \end{bmatrix}$	$\begin{bmatrix} 0.0190^{***} & 0.0045^{**} & 0.0014^{*} & 0.0006^{*} \\ -1.9176^{**} & 5.4874^{***} & 0.1047 & -0.5725^{***} \\ -0.0015 & -0.0028^{*} & 0.0234^{***} & -0.0007 \\ -0.0135 & 0.0289 & 0.0735 & 0.8007^{***} \end{bmatrix}$
Japan	$\begin{bmatrix} 0.0139^{***} & 0 & 0 & 0 \\ -1.5341^{*} & 6.1488^{***} & 0 & 0 \\ -0.0024 & 0.0039 & 0.0332^{***} & 0 \\ 0.0056^{***} & -0.0027 & -0.0035^{*} & 0.0112^{***} \end{bmatrix}$	$\begin{bmatrix} 0.0171^{***} & 0.0035^{***} & 0.0008 & -0.0051^{***} \\ -0.7398 & 4.9635^{***} & -1.0621^{*} & 2.5870^{***} \\ 0.0008 & 0.0016 & 0.0224^{***} & 0.0005 \\ -0.0135^{***} & 0.0289^{***} & 0.0735 & 0.8007^{***} \end{bmatrix}$
Russia	$\begin{bmatrix} 0.0105^{***} & 0 & 0 & 0 \\ -2.7839^{***} & 5.3967^{***} & 0 & 0 \\ -0.0026^{**} & -0.0081 & 0.0431^{***} & 0 \\ 0 & 0.0019 & 0.0037 & 0.0139^{***} \end{bmatrix}$	$\begin{bmatrix} 0.0135^{***} & 0.0069^{***} & 0.0034^{*} & -0.0012^{***} \\ -3.7971^{***} & 4.3342^{***} & 3.2343^{***} & 0.6164^{*} \\ 0.0026 & -0.0070^{**} & 0.0156^{***} & -0.0042^{***} \\ 0.0013^{**} & -0.0011^{*} & 0.0007 & 0.0053^{***} \end{bmatrix}$
Saudi Arabia	$\begin{bmatrix} 0.0132^{***} & 0 & 0 & 0 \\ -0.3651^{*} & 6.5914^{***} & 0 & 0 \\ 0.0057^{**} & -0.0047^{*} & 0.0195^{***} & 0 \\ 0.0006 & -0.0012 & -0.0008 & 0.0068^{***} \end{bmatrix}$	$\begin{bmatrix} 0.0181^{***} & 0.0024^{**} & -0.0054^{***} & -0.0026^{*} \\ -0.7083 & 5.3765^{***} & 1.7359^{***} & 0.4719^{*} \\ 0.0047^{***} & -0.0042^{***} & 0.0122^{***} & -0.0006 \\ 0.0006^{*} & -0.0005 & 0.0001 & 0.0034^{***} \end{bmatrix}$

TABLE 2. Forecast error variance decomposition

Country	Horizon	Oil supply shocks				Oil demand shocks			
		OS	OD	EX	P	OS	OD	EX	P
U.S.	1	0.55	0.07	0.05	0.34	0.00	0.74	0.24	0.02
	6	0.53	0.07	0.05	0.36	0.02	0.70	0.24	0.04
	12	0.51	0.09	0.05	0.34	0.03	0.68	0.23	0.06
	18	0.51	0.10	0.05	0.34	0.03	0.68	0.23	0.06
	24	0.11	0.10	0.05	0.34	0.03	0.68	0.23	0.06
China	1	0.94	0.05	0.01	0.00	0.11	0.88	0.00	0.01
	6	0.92	0.07	0.01	0.00	0.13	0.84	0.00	0.02
	12	0.90	0.08	0.01	0.00	0.14	0.83	0.00	0.03
	18	0.89	0.08	0.01	0.01	0.14	0.83	0.00	0.03
	24	0.89	0.09	0.01	0.01	0.14	0.83	0.00	0.03
Japan	1	0.88	0.04	0.00	0.08	0.02	0.75	0.03	0.20
	6	0.86	0.05	0.01	0.08	0.05	0.71	0.04	0.20
	12	0.85	0.06	0.01	0.08	0.05	0.69	0.04	0.21
	18	0.85	0.06	0.01	0.08	0.05	0.69	0.04	0.21
	24	0.85	0.06	0.01	0.08	0.05	0.69	0.04	0.21
Russia	1	0.75	0.20	0.05	0.01	0.33	0.43	0.24	0.01
	6	0.71	0.22	0.06	0.01	0.35	0.44	0.21	0.01
	12	0.68	0.23	0.08	0.01	0.33	0.45	0.21	0.01
	18	0.67	0.24	0.08	0.01	0.33	0.44	0.22	0.01
	24	0.67	0.24	0.08	0.01	0.33	0.44	0.22	0.01
Saudi Arabia	1	0.89	0.02	0.08	0.02	0.02	0.89	0.09	0.01
	6	0.85	0.03	0.09	0.02	0.03	0.85	0.11	0.01
	12	0.85	0.03	0.10	0.02	0.04	0.84	0.11	0.01
	18	0.85	0.03	0.10	0.02	0.04	0.84	0.11	0.01
	24	0.85	0.03	0.10	0.02	0.04	0.84	0.11	0.01

The first three countries are oil importing countries and the next two countries are oil exporting countries.

CONCLUSION

In this study, we apply a structural vector autoregressive model to study the interaction effects of variables (oil supply changes, oil demand changes, exchange rate changes and CPI inflation) across oil importing and oil exporting countries. In particular, we seek to investigate the different impacts between oil supply and oil demand shocks on determining inflation in these two groups of countries. Our results detect interaction effects among variables. Oil supply shock is more influential on determining inflation in oil importing countries. In contrast, oil demand shock has very low explanatory power on inflation in most cases. The inflation in the main oil exporting countries like Russia and Saudi Arabia are not responsive to both oil supply and oil demand shocks. The result is as expected as these countries have low dependence on oil and they have very high oil reserves. These countries are the main oil producers and they are able to influence on the supply and prices of oil. In conclusion, oil dependency factor may determine the magnitude impacts of oil supply and oil demand shocks on inflation.

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