Economic Impacts of Oil Price Fluctuations in Developed and Emerging Economies

Naoyuki Yoshino, Farhad Taghizadeh-Hesary*

Abstract:

This paper assesses the impact of crude oil price movements on two macro-variables, GDP growth rate and the CPI inflation rate, in three countries: the US and Japan (developed economies) and China (emerging economy). These countries were chosen for this research because they are the world's three largest oil consumers. The main objective of this research is to see whether these economies are still reactive to oil price movements. The results obtained suggest that the impact of oil price fluctuations on developed oil importers' GDP growth is much milder than on the GDP growth of an emerging economy. On the other hand, however, the impact of oil price fluctuations on China's inflation rate was found to be milder than in the two developed countries that were examined.

Keywords: oil, GDP growth rate, CPI inflation, developed economies, emerging economies

JEL Classification: Q43, E31, O57

1. Introduction

More than 40 years have passed since the first oil price shock of 1973. During this period, global demand for oil has risen drastically, while at the same time new energy-related technologies and new energy resources have made global consumers more resistant to oil shocks. Since the oil shocks of the 1970s, emerging economies have come to play a much larger role in global energy consumption. China's share, for example, is 5 times larger than it was in the 1970s. On the other hand, the shares of the two largest developed oil consumers, the US and Japan, decreased from about 32 percent and 10 percent to 21 percent and 5 percent, respectively.

Following the 1970s oil crises and the economic recessions that followed, several studies found that oil price shocks played a significant role in economic downturns. In recent years, both the sharp increase in oil prices that began in 2001 and the sharp decline that followed in 2008 following the subprime mortgage crisis have renewed interest in the effects of oil prices on the macroeconomy. Following the financial crisis of 2007-2008, the WTI[1] crude oil price dropped from US$ 145.18 on July 14, 2008, to below US$ 33.87 on December 19, 2008, due to decreased global demand. Shortly after this drop, however, the prices started to rise sharply again.

* Naoyuki Yoshino, Dean, Asian Development Bank Institute
Farhad Taghizadeh Hesary (Correspondence), Ph.D. Candidate of Economics, Keio University, Visiting Scholar, The Institute of Energy Economics, Japan

[1] West Texas Intermediate

In this research, we will assess and compare the impact of oil price fluctuations on the following macroeconomic factors: the GDP growth rate and consumer price index (CPI) inflation. We look at these factors in the three largest crude oil consumers: The US and Japan (developed economies) and China (emerging economy). We will answer the question of whether these economies are still elastic to oil price movements, or if new energy-related technologies and resources like renewables and shale gas have completely sheltered them from shocks. If they are still elastic, are the emerging and developed economies influenced to the same degree?

This paper is structured as follows: In the next section, we present an overview of oil and energy in China, Japan and the US. In the third section, we provide a theoretical framework including: the relationship of energy prices and economic growth, the relationship of energy prices and general price level and the impact of higher energy prices on the supply and demand sides of the economy. The fourth section explains our model, and in the fifth section we describe our empirical analysis. The sixth section contains this paper's concluding remarks.

2. Overview of China, Japan and US's oil and energy

2.1. China

China has quickly risen to the top ranks in global energy demand over the past few years. It is the world's second largest oil consumer behind the United States and became the largest global energy consumer in 2010. The country was a net oil exporter until the early 1990s, and became the world's second largest net importer of crude oil and petroleum products in 2009. China's oil consumption growth accounted for one-third of the world's oil consumption growth in 2013, and EIA projects the same share in 2014. Natural gas use in China has also increased rapidly in recent years, and China has sought to raise natural gas imports via pipeline and liquefied natural gas (LNG). China is the world's top coal producer, consumer and importer, and accounts for approximately half of global coal consumption.

According to a project[2] implemented by the Institute of Energy Economics of Japan, (IEEJ), China's oil consumption will almost double over the coming 30 years, reaching 866 million tons of oil equivalent[3] (Mtoe) by 2040. During this period, China will replace the US as the world's largest oil consumer. Driving the increase will be the transportation sector, including road transportation. With China's great potential to expand its vehicle market from its current 7% vehicle ownership rate, the number of vehicles in China is expected to increase to 360 million in 2040, meaning that the transportation sector will double its oil consumption. China's share of global gasoline consumption will expand from the current 8% to 18%, exceeding its share of global population. This projection continues by stating that by 2040 China will have the world's largest nuclear power generation capacity, and will account for half of the increase in global nuclear generation capacity between 2011 and 2040. Renewable energy will account for 9.7% of China's primary energy consumption in 2040.

[2] Asia/World Energy Outlook 2013
[3] Equal to about 6,186 million barrels of oil equivalent (Mboe)

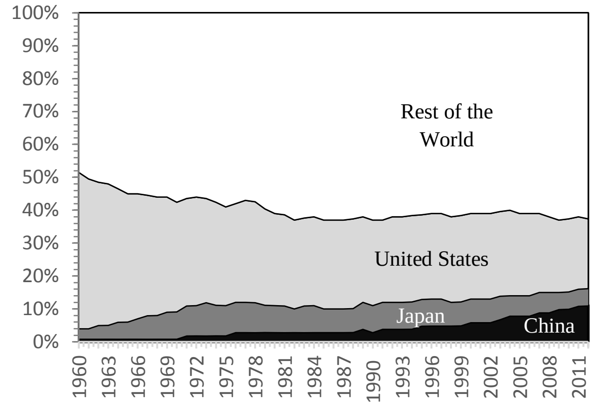

Figure 1. Share of three major oil consumers in global oil consumption, 1960-2012

Source: Annual statistical bulletin of the Organization of the Petroleum Exporting Countries (OPEC), 2013

Figure 1 shows the share of the world's three major oil consumers: the US, Japan and China. As the figure clearly shows, the US and Japan shares are decreasing and the shares of China and the rest of the world are on the rise.

2.2. Japan

Japan is the world's largest liquefied natural gas (LNG) importer, the second largest coal importer, and third largest net oil importer behind the United States and China. Japan has limited domestic energy resources, meeting less than 15% of its own total primary energy use from domestic sources.

Oil demand in Japan has declined overall since 2000 by nearly 15%. This decline stems from structural factors, such as fuel substitution, a declining population, and government-mandated energy efficiency targets. In addition to the shift to natural gas in the industrial sector, fuel substitution is occurring in the residential sector as high prices have decreased demand for kerosene in home heating. Japan consumes most of its oil in the transportation and industrial sectors, and it is also highly dependent on naphtha and low-sulfur fuel oil imports. Demand for naphtha has fallen as ethylene production is gradually being displaced by petrochemical production in other Asian countries.

In March 2011, a 9.0 magnitude earthquake struck off the coast of Sendai, Japan, triggering a large tsunami. The damage to Japan resulted in the immediate shutdown of about 10 GW of nuclear electric generating capacity. Between the 2011 Fukushima disaster and May 2012, Japan lost all of its nuclear capacity as a result of scheduled maintenance and lack of government approval to restart operation. Japan replaced the significant loss of nuclear power with generation from imported natural gas, low-sulfur crude oil, fuel oil and coal. This caused the price of electricity to rise for the government, utilities and consumers. Increases in the cost of fuel imports have resulted in Japan's top 10 utilities losing over $30 billion in the past two years. Japan spent $250 billion on total fuel imports in 2012, a third of the country's total import charge. Despite strength in export markets, the yen's depreciation and soaring natural gas and oil import costs from a greater reliance on fossil fuels continued to deepen Japan's recent trade deficit throughout 2013. In the wake of the Fukushima nuclear incident, oil remains the largest source of primary energy in Japan, although its share of total energy consumption has declined from about 80% in the 1970s to 43% in 2011. Japan consumed over 4.7 million barrels per day (bbl/d) of oil in 2012.

2.3. United States

In 2012, the US consumed over 94 quadrillion British Thermal Units (BTU) of primary energy, making the country the world's second largest energy consumer after China. As for oil consumption, the US still ranks high among global oil consumers, with consumption of about 18.49 million bbl/d[4].

Today, oil meets 36 percent of US energy demand, with 70 percent directed to fuels used in transportation – gasoline, diesel and jet fuel. Another 24 percent is used in industry and manufacturing, 5 percent is used in the commercial and residential sectors, and less than 1 percent is used to generate electricity. Oil is the main mover of the US's national commerce and its use for transportation has made America more easily connected. Almost all US transportation is dependent upon fuel in concentrated liquid form. The major sources of US imported oil are Canada, Mexico and OPEC, particularly Saudi Arabia, including 20 percent coming from the Persian Gulf.[5] The EIA estimates US proven oil reserves at about 23 billion barrels.

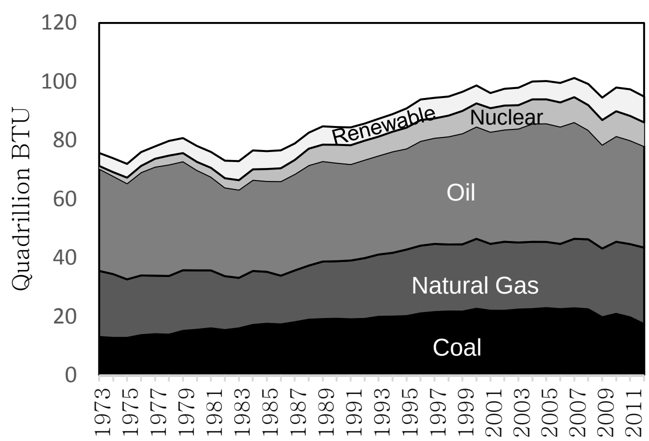

Figure 2. US primary energy consumption by source, 1973-2013

Note: Natural gas consumption is excluding supplemental gaseous fuels.

Source: US Energy Information Administration (EIA), February 2014 Monthly Energy Review

Figure 2 shows US primary energy consumption by source. The share of crude oil decreased from 46 percent in 1973 to 36 percent in 2012, while the shares of natural gas (driven especially by the shale gas revolution), nuclear electric power and renewable energy are rising drastically.

3. Theoretical Framework

3.1. Relationship of Energy Prices and Economic Growth

[4] US Energy Information Administration (EIA), Monthly Energy Review (January 2014)

[5] Energy Overview, Institute for Energy Research (IER)

On the supply side of the economy, in addition to elements of labor and capital, energy is also considered a substantial element of production. Therefore, production would be a function of labor, capital and energy. Hence:

$$Q_t = (L_t(\tfrac{W_t}{P_{Qt}}, Q_t), K_t(i_t, Q_t), E_t(\tfrac{P_{Et}}{P_{Qt}}, Q_t)) \tag{1}$$

where Q_t stands for gross output, L_t is labor input, K_t is capital input, E_t is energy (oil, gas and coal) input, W_t denotes nominal wage rate, i_t is nominal interest rate and P_{Et} and P_{Qt} are energy price[6], and consumer price index (CPI), respectively. Eq. (1) shows that the three elements of Labor, Capital and Energy lead to the alteration of levels of production. Furthermore, there are direct relationships between the use of such elements and the level of production. In other words, a rise of each of the foregoing elements leads to an increase in production:

$$\frac{\partial Q_t}{\partial L_t} > 0, \frac{\partial Q_t}{\partial K_t} > 0, \frac{\partial Q_t}{\partial E_t} > 0 \tag{2}$$

In addition, the consumption of each energy resource including oil, gas, and coal is a reverse function of their price levels:

$$\frac{\partial E_t}{\partial P_{Et}} < 0 \quad \text{and} \quad \frac{\partial E_{Ot}}{\partial P_{Ot}} < 0, \frac{\partial E_{Gt}}{\partial P_{Gt}} < 0, \frac{\partial E_{Ct}}{\partial P_{Ct}} < 0 \tag{3}$$

where, E_{Ot}, E_{Gt}, E_{Ct} stands for oil, gas and coal consumption, respectively. P_{Ot} denotes oil price, P_{Gt} gas price, and P_{Ct} coal price. Therefore, if the general index of energy prices is increased, its consumption decreases. However, if only the price of one source (given oil) increases among other sources of energy, or if its price increase is higher than other sources, then the increase in price of that source will partly be offset by a substitution of other sources. The rates of such substitution will depend on the technical ability of other sources to replace it and on the period of time available for such an adjustment. Therefore, an increase in oil price will lead to the substitution of oil by other sources of energy. Furthermore, as it is a production factor, it will have short-term effects on the increase of production costs and will lead to the reduction of real production of oil importer countries. In the long run, too, it leads to a rise in costs; the rate of which will depend on the ability of other sources to replace oil. If ability to substitute exists, such price increases will have no important effect on costs. Usually, most researchers consider the relationship between "energy" and "labor and capital" to be a substitution under normal conditions. However, they consider the cross elasticity between them to be negative in the short run. In other words, "energy" and "labor and capital" will be supplements of each other in the short run because the structure of industries is so that they may not react against a rise in costs (Bohi, 1991). Hence, we may conclude that the short-term effect of an energy price shock will be bigger than its long-term one. This is reasonable because when there is a rise in energy prices in the long run, industries change the structure of their production as much as possible to use fewer costlier resources. In industries where energy is used as an intermediary resource of production, a rise in energy prices drastically affects the potential production output, thereby affecting GDP. If we consider that "energy" and "labor and capital" are substitutable, the rise of energy prices leads to an increase in the use of the two parameters of capital and labor, which makes the allocation costs of parameters and relative shares for the two parameters of labor and capital rise (Taghizadeh et al., 2013).

[6] Weighted average of crude oil, natural gas and coal prices.

This section showed that higher energy prices as one of the production inputs reduce the output level. On the other hand, following higher energy prices, household consumption and the demand side of the economy also suffer, resulting in a lower GDP level. (See Section 3.3 of this paper).

3.2. Relationship of Energy Prices and General Price Level

In order to show the relationship between the energy prices and general price level, we adopt a three-input Cobb-Douglas production function:

$$Q_t = \mathrm{T} L_t^{\alpha}{}_{(\frac{W_t}{P_{Qt}}, Q_t)} K_t^{\beta}{}_{(i_t(M_t), Q_t)} E_t^{\gamma}{}_{(\frac{P_{Et}}{P_{Qt}}, Q_t)} \tag{4}$$

and assuming:

$$L_t = L_1 \frac{P_{Qt} Q_t}{W_t} \tag{5}$$

$$K_t = K_1 \frac{Q_t}{i_t(M_t)} \tag{6}$$

$$E_t = E_1 \frac{P_{Qt} Q_t}{P_{Et}} \tag{7}$$

where; α, β, γ are the output elasticities of labor, capital and energy, respectively, and assuming that their summation is equal to one, it means a constant return to scale. These values are constants determined by available technology and T is the total factor productivity which is assumed to be constant. M_t is money supply, which determines the interest rate level. By substituting Eqs. (5) – (7) in Eq. (4) and log linearizing the result, then taking the first derivative with respect to time and writing the result for CPI, we obtain the below equation of growth rates:

$$\frac{\partial LnP_{Qt}}{\partial t} = \delta \frac{LnW_t}{\partial t} + \chi \frac{Lni_t(M_t)}{\partial t} + \eta \frac{LnP_{Et}}{\partial t}; \delta = \frac{\alpha}{\alpha+\gamma}, \chi = \frac{\beta}{\alpha+\gamma}, \eta = \frac{\gamma}{\alpha+\gamma} \tag{8}$$

or:

$$\dot{P}_{Qt} = \delta \dot{W}_t + \chi \dot{i}_t(M_t) + \eta \dot{P}_{Et} \tag{9}$$

Equation 9 depicts the relationship between energy price growth rate and the CPI inflation rate on the supply side of the economy, where it is shown that higher energy prices push up the general price level.

Following higher energy prices, not only the supply side of the economy but also household consumption and the demand side of the economy suffer as well. More complete explanations which describe the reactions of both the supply and demand sides of the economy to higher energy prices are graphically demonstrated in the following Section.

3.3. Impact of Higher Energy Prices on Supply and Demand Sides of the Economy

A simple aggregate supply and demand model will clarify the analysis of this section:

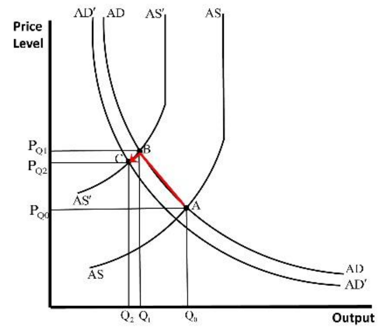

Figure 3. Impact of higher energy prices on output and price level

Note: We are assuming that there is a technological progress that is why the output level in full employment also increased.

In Figure 3, the economy initially is in equilibrium with price level P_{Q0} and real output level Q_0 at point A. AD is the aggregate demand curve and AS stands for the aggregate supply curve. The aggregate supply curve is constructed with an increasing slope to show that at some real output level, it becomes difficult to increase real output despite increases in the general level of prices. At this output level, the economy achieves full employment. Let us suppose that the initial equilibrium, point A, is below the full employment level.

When the relative price of energy resources (crude oil, natural gas, coal, etc.) increases, the aggregate supply curve shifts to AS'. The employment of existing labor and capital with a given nominal wage rate requires a higher general price for output, if sufficient amounts of the higher-cost energy resources are to be used.

The *productivity* of existing capital and labor resources is reduced so that potential real output declines to Q_1. In addition, the same rate of labor employment occurs only if real wages decline sufficiently to match the decline in productivity. This, in turn, happens only if the general level of prices rises sufficiently (P_{Q1}), given the nominal wage rate. This moves the economy to the level of output (Q_1) and price level (P_{Q1}). This point is indicated in Figure 3 at point B, which is a disequilibrium point. Given the same supply of labor services and existing plant and equipment, the output associated with full employment declines as producers reduce their use of relatively more expensive energy resources and as plant and equipment become economically obsolete.

On the other hand, in the demand side of the economy, when price of energy resources rise, their consumption declines. Because of this drop in consumption, the aggregate demand curve shifts to AD', which in turn reduces the prices from the previous disequilibrium level at P_{Q1} and sets them to P_{Q2} as the final equilibrium price. This lowers the output levels due to less consumption in the economy, from the previous point of Q_1 to Q_2. This point is indicated in Figure 3 at point C, which is the final equilibrium point.

The economy may not adjust instantaneously to point C, even if point C is the new equilibrium. For example, price rigidities due to slow-moving information or other transactions costs can keep nominal prices from adjusting quickly (Tatom, 1981). Consequently, output and prices move along an adjustment path such as that indicated by the arrow in Figure 3.

In this case, aggregate supply is the main chain of transmission of energy price shocks compared to aggregate demand. This means that the supply side of the economy is more affected by oil price shocks than the demand side of the economy, resulting in higher prices and lower output levels at the final equilibrium point (C) when compared to the initial equilibrium point (A). However, if the demand side of the economy is the main transmission channel, the result will be a decrease in output and a lower price level compared to the initial equilibrium point.

4. Model

The main objective of this research is to assess the impact of price movements of crude oil, which is the main energy resource, on two macroeconomic variables, GDP growth rates and CPI inflation rates, of emerging and developed economies and compare these impacts. In developing this model, we used Taghizadeh and Yoshino (2013a) as a reference. In their model, they assumed oil price movement transfer to macro-variables through either supply (aggregate supply curve) or demand channels (aggregate demand curve). In order to examine the effects of this transfer, they used an IS curve to look at the demand side and a Phillips curve to analyze inflationary effects from the supply side.

Using this aforementioned research as an inspiration, we chose to use the following variables in our survey: crude oil prices, natural gas prices, GDP, consumer price index (CPI), money supply and the exchange rate. We included the natural gas price because it is the main substitute energy source for crude oil. GDP and CPI are included in our variables mainly because their movements have an impact on the crude oil market (Taghizadeh and Yoshino 2013b; 2014; Yoshino and Taghizadeh 2014), and also because our objective is to assess the impact of oil price fluctuations on these two macro-variables. The money supply and the exchange rate are monetary policy variables that have an impact on the crude oil market (Taghizadeh and Yoshino 2014; Yoshino and Taghizadeh 2014).

Taghizadeh and Yoshino (2014) explain that oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time, interest rates (the federal funds rate) subsided from 16.7 percent per annum to about 0.1 percent. By running a simultaneous equation model, they found that during the period of 1980-2011, global oil demand was significantly influenced by monetary policy and supply actually remained constant. Aggressive monetary policy stimulates oil demand, while supply is inelastic. The result is skyrocketing crude oil prices, which inhibit economic growth.[7]

The figures below depict two monetary policy factors, base money and real effective exchange rate movements, along with crude oil price movement:

[7] Taghizadeh and Yoshino (2014), in order to define determinants of crude oil prices, used two substitution sources for crude oil prices (natural gas price and coal price), two monetary policy factors (exchange rate and interest rate) and GDP growth rate, which shows economic activity growth. In this present paper, since we use an SVAR model, in order to avoid identification problems, we must use a minimum possible number of variables. As such, for substitution sources of crude oil we limited our selection to natural gas which is the main substitute fuel and eliminated coal throughout our study. As for monetary policy factors, since in the second sub-period we focus on (2000m08 – 2013m12), the Federal Reserve and some other monetary authorities' behavior kept interest rates near zero, we used a Money Supply variable instead of interest rate in our analysis. Moreover, we added CPI, since it is one of the variables that we suppose to measure oil price movement impacts on.

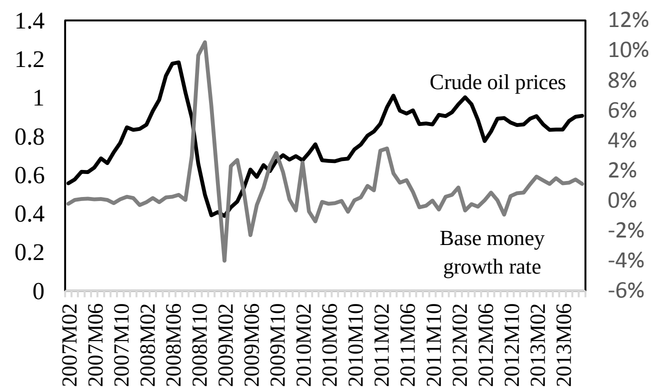

Figure 4. Base money and crude oil price Feb 2007 – Sep 2013 Note: crude oil prices are in constant dollars obtained using a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, deflated by the US consumer price index (CPI). The base money growth rate is for the US, seasonally adjusted. The left-hand scale is for the crude oil real prices and the right-hand scale is for the base money growth rate. **Source:** Yoshino and Taghizadeh (2014)

Fig. 4 illustrates the base money growth rate trend and the crude oil price movements during the period of February 2007 to September 2013. As it is clear, in most cases they tend to follow the same path.

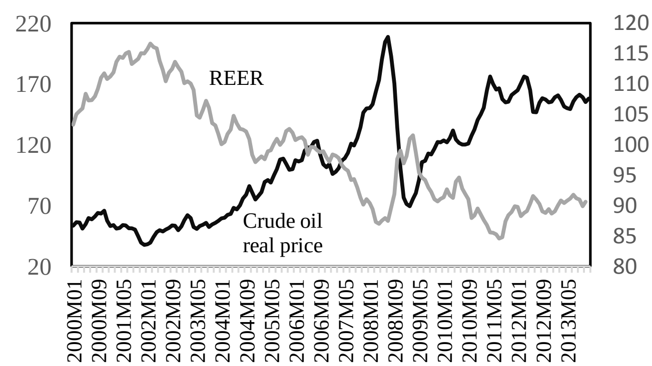

Figure 5. Exchange rate and crude oil Prices Jan 2000 - Dec 2013 Note: crude oil prices are in constant dollars obtained using a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, deflated by the US consumer price index (CPI). The Real Effective Exchange Rate (REER) is for US dollars. The right-hand scale is for REER and the left-hand scale is for real crude oil prices. Source: International Energy Agency (IEA) 2013, International Financial Statistics (IFS) 2013 and The Energy Data and Modelling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ).

Fig. 5 shows the Real Effective Exchange Rate (REER) and real crude oil price movements during the period of January 2000 to December 2013. The inverse relationship between these two variables is apparent in this figure. In most cases, crude oil prices began to rise following the depreciation of US dollars, and dropped following an appreciation.

To assess the relationship between crude oil prices, natural gas prices, GDP, consumer price index (CPI), money supply, and the exchange rate variables, we adopt the N variable Structural Vector Autoregression (SVAR) model and start with following VAR model:

$$Y_t = A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t \tag{10}$$

where Y_t is a $(N \times 1)$ vector of variables. $A_{i\,(i=1,\dots,p)}$ are $(N \times N)$ fixed coefficient matrices, p is the order of the VAR model and u_t is a $(N \times 1)$ vector of VAR observed residuals with zero mean and covariance matrix $E(u_t u_t') = \sum_u$. The innovations of the reduced form model, u_t, can be expressed as a linear combination of the structural shock, ε_t, as in Breitung et al. (2004):

$$u_t = A^{-1} B \varepsilon_t \tag{11}$$

where, B is a structural form parameter matrix. Substituting Eq. (10) into Eq. (11) and following minor operations, we get the following equation, which is the structural representation of our model:

$$AY_t = A_1^* Y_{t-1} + \ldots + A_p^* Y_{t-p} + B\varepsilon_t \tag{12}$$

where $A^*_{j\,(j=1,\dots,p)}$ is a $(N \times N)$ matrix of coefficients, and $A_j = A^{-1} A^*_{j\,(j=1,\dots,p)}$ and ε_t are a $(N \times 1)$ vector of unobserved structural shocks, with $\varepsilon_t \sim (0, I_k)$. The structural innovation is orthonormal, and the structural covariance matrix, $\sum_\varepsilon = E(\varepsilon_t \varepsilon'_t)$, I_N is the identifying matrix. This model is known as the AB model, and is estimated in the form below:

$$Au_t = B\varepsilon_t \tag{13}$$

The orthonormal innovations ε_t ensure the identifying restriction on A and B:

$$A \sum A' = BB' \tag{14}$$

Both sides of the expression are symmetric, which means that $N(N+1)/2$ restrictions need to be imposed on $2N^2$ unknown elements in A and B. At least $2N^2 - N(N+1)/2$ additional identifying restrictions are needed to identify A and B. Considering the 6 endogenous variables that we have in our model: $M_t, X_t, P_{Gt}, P_{Ot}, P_{Qt}, Q_t$, which are money supply, exchange rate, natural gas price, crude oil price, CPI and GDP, the errors of the reduced form VAR are : $u_t = u_t^M + u_t^X + u_t^{P_G} + u_t^{P_O} + u_t^{P_Q} + u_t^Q$. The structural disturbances, $\varepsilon_t^M, \varepsilon_t^X, \varepsilon_t^{P_G}, \varepsilon_t^{P_O}, \varepsilon_t^{P_Q}, \varepsilon_t^Q$, are money supply, exchange rate, natural gas price, crude oil price, CPI and GDP shocks, respectively. This model has a total of 72 unknown elements, and a maximum number of 21 parameters can be identified in this system. Therefore, at least 51 additional identifiable restrictions are required to identify matrices A and B. The elements of the matrices that are estimated are assigned a_{rc}. All of the other values in the A and B matrices are held fixed at specific values. Since this model is over-identified, a formal likelihood ratio (LR) test is carried out in this case to test whether the identification is valid. The LR test is formulated with the null hypothesis that the identification is valid. Our system will be in the following form:

$$\begin{array}{c} \\ M_t \\ X_t \\ P_{Gt} \\ P_{Ot} \\ P_{Qt} \\ Q_t \end{array}
\overset{\text{Matrix A}}{\begin{array}{cccccc} M_t & X_t & P_{Gt} & P_{Ot} & P_{Qt} & Q_t \\ \hline 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ 0 & a_{32} & 1 & 0 & 0 & 0 \\ 0 & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & 0 & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{array}}
\begin{bmatrix} u_t^M \\ u_t^X \\ u_t^{P_G} \\ u_t^{P_O} \\ u_t^{P_Q} \\ u_t^Q \end{bmatrix} =
\overset{\text{Matrix B}}{\begin{array}{cccccc} M_t & X_t & P_{Gt} & P_{Ot} & P_{Qt} & \\ \hline b_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} \end{array}}
\begin{bmatrix} \varepsilon_t^M \\ \varepsilon_t^X \\ \varepsilon_t^{P_G} \\ \varepsilon_t^{P_O} \\ \varepsilon_t^{P_Q} \\ \varepsilon_t^Q \end{bmatrix} \quad (15)$$

The first equation in this system represents the money supply as an exogenous shock in the system[8]. The second row in the system specifies exchange rate responses to money supply shocks[9]. The third row represents natural gas real price responses to exchange rate shocks. The forth equation allows crude oil prices to respond contemporaneously to exchange rate and natural gas price shocks. The fifth equation exhibits CPI responses to money supply, exchange rate and crude oil price shocks. The last equation depicts GDP as the most endogenous variable in this system. Money supply, exchange rate, natural gas price, crude oil price and CPI are variables that have an impact on the GDP; (see, *inter alia*, Taghizadeh and Yoshino 2013a, Taghizadeh et al. 2013). The main purpose of this paper is to measure and compare a_{54} & a_{64} which are the impacts of crude oil prices on CPI and GDP for three countries: China, Japan and the US. In order to accomplish this, we need to run this system for each of these three countries separately.

5. Empirical Results

As mentioned earlier, the increase in oil prices that began in 2001, the sharp decline that followed the 2008 Lehman shock, and the immediate recovery that they experienced shortly after have renewed interest in the effects of oil prices on the Macroeconomy. Following the financial crisis of 2007-2008, the WTI crude oil price dropped from US$ 145.18 on July 14, 2008, to below US$ 33.87 on December 19, 2008, due to decreased global demand. Shortly after this drop, however, they started to rise sharply again. In the current paper, for this reason, we selected a period which covers the significant fluctuations mentioned above. We ran regressions for our SVAR for each of these three countries during the two sub periods 2000m1-2008m07 and 2008m8-2013m12, before and after Lehman shock, the event that caused the most recent fluctuations in crude oil prices, and compared the findings.

In order to reach a more realistic analysis, we use all variables in real terms. Crude oil prices are obtained using a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market all in constant dollars. Natural gas prices are in constant dollars obtained using a simple average of three major natural gas prices: US Henry Hub, UK National Balancing Point (NBP) and Japanese imported LNG average prices. The GDP of all

---

[8] For more information about exogeneity tests in structural systems with monetary application, please see: Revankar and Yoshino (1990)

[9] For the impact of money supply on the exchange rates, please see: Yoshino, Kaji, and Asonuma (2012)

three countries is in constant US dollars, fixed PPPs, seasonally adjusted. All of the three data series above were deflated by the US consumer price index (CPI), as most crude oil and natural gas markets are denominated in US dollars and the amount of GDP for each country was also in US dollars. For the exchange rate in Chinese SVAR, we used the Chinese Yuan Real Effective Exchange Rate (REER), for Japan we used the Japanese Yen REER and for the US, we used the US dollar's REER (2005=100). As for the money supply, we used M2 of China, Japan and the US for each country's SVAR. From now on, whenever we refer to the price of crude oil, natural gas and GDP, unless otherwise stated, we refer to their real values. Sources of data are: International Energy Agency (IEA) 2013, International Financial Statistics (IFS) 2013, The Energy Data and Modelling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ), Monthly Energy Review of the US Department of Energy (DOE), and the Bank of Japan (BOJ) database.

In order to evaluate the stationarity of all series, we used an Augmented Dickey–Fuller (ADF) test. The results that we found imply that, with the exception of US M2 and Chinese GDP, which were stationary at log-level, all other variables are non-stationary at log-level. However, when we applied the unit root test to the first difference of log-level variables, we were able to reject the null hypothesis of unit roots for each of the variables. These results suggest that the M2 of China and Japan, the exchange rates of all three countries, Japanese and US GDP, crude oil prices, and natural gas price variables each contain a unit root. Once the unit root test was performed and it was discovered that the variables are non-stationary in level and stationary in first differences level, they were integrated of order one. In the next step, in order to identify the cointegrating vectors among all variables, we conducted a cointegration analysis using Johansen's technique. The Johansen test does not reject the null hypothesis of non-cointegrating variables. This means that variables are not co-integrated, hence, because variables are only integrated of order one I(1) and not co-integrated, they will appear in the SVAR model in first difference form. This means that instead of CPI, we will have the CPI growth rate or the inflation rate, and instead of GDP we will have the GDP growth rate. For other variables, we will have their growth rates in our regressions.

In order to test whether the identification is valid, the LR test was run for each country's SVAR. The LR test does not reject the under-identifying restrictions at the 5 percent level, implying that the identification is valid.

Table 1. Empirical results

Country	**2000m01 – 2008m07**		**2008m08-2013m12**	
China	$-a_{64}^{CN}$ = - 0.26	S.E.= 0.07**	$-a_{64}^{CN}$ = -0.27	S.E.= 0.39
	$-a_{54}^{CN}$ = 0.02	S.E.= 0.02	$-a_{54}^{CN}$ = 0.02	S.E.= 0.02
Japan	$-a_{64}^{JP}$ = 0.03	S.E.= 0.005**	$-a_{64}^{JP}$ = -0.1	S.E.= 0.02**
	$-a_{54}^{JP}$ = 0.03	S.E.= 0.007**	$-a_{54}^{JP}$ = -0.01	S.E.= 0.007
US	$-a_{64}^{US}$ = -0.06	S.E.= 0.002**	$-a_{64}^{US}$ = -0.01	S.E.= 0.01

$-a_{54}^{US} = 0.07$	S.E.= 0.002**	$-a_{64}^{US} = 0.03$	S.E.= 0.01*

Note: $-a_{64}^{i}(i = CN, JP, US)$ shows the impact of oil price fluctuations on GDP growth, $-a_{54}^{i}(i = CN, JP, US)$ shows the impact oil price fluctuations on CPI inflation, z-Statistic obtained by: $-a_{64}^{i}(i = CN, JP, US) / S.E.$ and $-a_{54}^{i}(i = CN, JP, US) / S.E$. To get an interpretation of the contemporaneous coefficients, the sign of A matrix is reversed; this follows from Eq. 12. * indicates significance at 5%, ** indicates significance at 1%, S.E. stands for Standard Error.

The signs, sizes and significances of contemporaneous impacts of crude oil price movements on GDP growth rates and on CPI inflation rates deserve discussion because they have important policy and theoretical implications.

According to Table 1, China's elasticity of GDP growth rate and inflation rate to oil price movements did not change after the 2008 financial crisis. Before the crisis, the elasticity of the country's GDP growth rate and inflation rate to crude oil price changes was -0.26 (significant) and 0.02 (non-significant), respectively, and after the crisis they were -0.27(non-significant) and 0.02 (non-significant). There are two reasons for this issue. First, because of higher economic growth in this country compared to advanced economies, the recovery time in higher economic growth countries is usually faster. Second, because of the Chinese government's significant role during this crisis that preserved the country from huge suffering following the bankruptcy of Lehman Brothers, the Chinese government changed its policy emphasis from curbing inflation to ensuring stable economic growth. The Chinese government followed a combination of active fiscal policy and easy monetary policy. As for fiscal policy, an RMB 4 trillion (US$588 billion) investment plan was released in November 2008, one of the largest fiscal rescue packages world-wide. To stimulate short-term economic growth, China decided to make increasing household consumption the most important issue. In order to reach that goal, the government has implemented a series of fiscal policies including increasing tax rebate policies to stimulate the economy, lowering corporate taxes, keeping the tax rates on stock trading constant and not increasing them, lowering the stamp duty for stock trades and maintaining a freeze on taxes on interest income from savings and stock accounts. Moreover, in order to reduce the uncertainty of households about the future, the Chinese government raised the fiscal expenditures in social welfare, especially for healthcare, education and social safety. During the crisis, the People's Bank of China (PBoC) continued to keep sufficient liquidity in the banking system. As a part of the easy monetary policy PBoC followed, The RMB's deposit and loan interest rates have been reduced from 4.14 percent and 7.47 percent to 2.25 percent and 5.31 percent, respectively. The required reserve ratio has declined from 17.5 percent to 13.5 percent. The credit quota applied by PBoC on commercial banks was cancelled in the fourth quarter of 2008. Bank loans increased by RMB 1.62 trillion in January 2009, one-third of the increment recorded in 2008. More support has been given to the agricultural sector, Small and Medium Sized Enterprises (SMEs) and other weak sections.

Following the aforementioned macroeconomics policies of the Chinese government, and because of advanced economies' quantitative easing (QE) policies, the RMB appreciated in front of other major currencies, making the situation more advantageous for the Chinese economy. QE policies of the advanced economies following the 2007-2008 crisis, and the situation of China being heaven for investors compared to advanced economies, made this area a pleasant destination for foreign capital, hence, a tremendous amount of foreign capita entered China which appreciated the RMB.

In the oil market, after the oil price reached the bottom in December 2008, oil prices started to increase sharply. This occurred because of a mild recovery in the global economy and huge QE policies of the US and other advanced countries' monetary authorities (Yoshino and Taghizadeh 2014). Because of the appreciated Yuan, the price of crude oil in the Chinese domestic market did not fluctuate so much. The result is that both before and after the crisis, the impact of crude oil prices on the Chinese economy (GDP and inflation) was almost constant.

Japan's elasticity of the GDP growth rate to oil price fluctuations became negative after the 2008 financial crisis, and shows -0.1 (significant). The reason for this is that in the wake of the Fukushima nuclear incident in March 2011, oil remains the largest source of primary energy in Japan[10]. The disaster made this country fully depend on imports of fossil products, especially on crude oil and LNG. Japan spent $250 billion on total fuel imports in 2012, a third of the country's total import charge. Our results show that during the second subperiod, 2008m08-2013m12, an increase in the real growth rate of crude oil prices by 100 basis points would reduce Japanese real GDP growth rate by 10 percent. Before the crisis, in first sub-period, the elasticity of the Japanese GDP growth rate to crude oil price movements was positive, at 0.03 (significant). This is in line with Taghizadeh et al. (2013), which found positive elasticity for Japanese GDP to crude oil prices during 1990Q1–2011Q4. These findings are in accordance with those of Jiménez-Rodríguez and Sánchez (2004), Blanchard and Galí (2007) and Kilian (2008) who all conclude that Japan has fared relatively well in the face of exogenous oil price shocks. However, the findings by Korhonen and Ledyaeva (2010) for Japan are the reverse, as they observed negative impacts of oil shocks on its GDP. The positive elasticity that we found exists due to several reasons, such as increased energy efficiency, accumulating huge strategic reserves of crude oil, declining crude oil demand stemming from structural factors like fuel substitution (use of nuclear electric power and natural gas), and population decline. Another reason is that in first sub-period, although crude oil prices saw huge increases, because of appreciation of the Japanese yen resulting from accumulated foreign reserves in this country, energy prices in the domestic market did not rise so much.

As for the elasticity of CPI inflation to crude oil price growth rates, in the first subperiod, the value is 0.03 (significant) and after the crisis it became negative (-0.01 non-significant). The reason for this negative impact on general prices is that in Japan, aggregate supply (AS) is almost constant. Higher energy prices mainly affect the demand side of the economy. This is clearly evident in the second subperiod, shortly following the uncertain situation that occurred in the country after the Fukushima nuclear disaster. This uncertainty caused domestic consumption to shrink, resulting in price deflation.

The absolute value of the US elasticity of the GDP growth rate to the oil price growth rate was reduced following the 2008 financial crisis because of lower aggregate demand in the country, which was caused by the recession that the economy entered. Moreover, the impact of higher oil prices on inflation decreased in the second period because of lower aggregate demand. Another reason for this decrease in the elasticity of the US economy to oil prices in the second subperiod compared to the first one is that, in the second subperiod, US energy production raised greatly. Larger oil production and the shale revolution will make this country independent in the energy sector in the near future. According to the US Energy Information Administration (EIA), total US energy production reached 81.7 quadrillion British thermal units (quads) in 2013, enough to satisfy 84% of total US energy demand, which totaled 97.5 quads. Natural gas was the largest domestically produced energy resource for the third year in a row, and,

[10] Following the Fukushima nuclear incident, fuel oil and gas imports raised dramatically, and because gas prices (LNG prices) are linked to oil prices, we mainly focused on oil price in this survey.

together with the other fossil fuels (coal, crude oil and hydrocarbon gas liquids), accounted for more than three-quarters of US energy production. In total, the United States consumed 97.5 quads of energy, 82% of which was fossil fuels. Renewable and nuclear energy made up 10% and 8%, respectively, of US energy consumption. The portion of US energy consumption supplied by domestic production has been increasing since 2005, when it was at its historical low point (69%). Since 2005, production of domestic resources, particularly natural gas and crude oil, has been increasing as a result of the application of technologies that can develop harder-to-produce resources. At the same time, reduced road travel, improved vehicle efficiency, and competition among fuels for electric power generation have limited consumption of petroleum and coal. All these reasons tend to lower the sensitivity of the US economy to oil price fluctuations in second subperiod of our survey.

As Table 1 shows, the impact of oil price fluctuations on US and Japanese GDP is much milder than on China. The reason is that, in developed countries due to having slower economic growth and more mature transportation sectors, the elasticity of GDP to higher oil prices is lower comparing to emerging economies which have higher economic growth rates and are developing in various energy consuming sectors, hence, having a higher growth rate in energy demand and higher elasticity to energy prices.

On the other hand, Chinese CPI as an emerging economy sees smoother rates of inflation caused by oil shocks compared to the US and Japan, because of the higher growth rate in the Chinese economy, which shifts the AS curve forward and avoids higher prices in oil shocks. However, in Japan’s case, the AS curve has been almost constant recently, and in the US it is seeing only a small forward shift, hence, the inflation rate of general price levels caused by oil price shocks in developed countries is generally expected to be higher compared to emerging economies.

6. Conclusions

In this paper, we analyzed the impact of oil price fluctuations on two macro-variables of two developed countries and one emerging country. The purpose is to compare these two groups’ impacts and to see whether economies are still reactive to oil price fluctuations. For our analysis, we selected a period that includes the most recent financial crisis: the subprime mortgage crisis of 2007-2008. This means that we simultaneously compare these impacts in the period 2000m1-2008m7 with the period following the crisis: 2008m08-2013m12.

Our results show that the impact of oil price fluctuations on GDP growth rates in developed oil importers (US and Japan) is much milder than on an emerging economy’s (China). An increase in the crude oil price growth rate by 100 basis points changes the Chinese GDP growth rate by -26 to -27 percent, the Japanese GDP growth rate by -10 to +3 percent, and the US GDP growth rate by -6 to -1 percent. The reasons for the difference between the impacts on these two groups are: high fuel substitution (higher use of nuclear electric power, gas and renewables), a declining population (for the case of Japan), the shale gas revolution (for the US), greater strategic crude oil stocks and government-mandated energy efficiency targets in developed economies compared to emerging economies, which make them more resistant to oil shocks. On the other hand, the impact of higher crude oil prices on Chinese CPI inflation is milder than in the two advanced economies. The reason for this is that a higher economic growth rate in China results in a larger forward shift of aggregate supply, which avoids large increases in price levels after oil price shocks.

By comparing the results of these two subperiods, we conclude that in the second subperiod the impact of oil price fluctuations on the US GDP growth rate and inflation rate is milder than in the first subperiod, because of less crude oil and aggregate demand, resulting from a recession in the economy. For Japan, the second subperiod coincides with the Fukushima nuclear disaster that followed a massive earthquake and tsunami in March 2011, which raised the dependency on oil imports. Hence, the elasticity of GDP growth to oil price fluctuations rose dramatically. CPI elasticity was reduced, however, due to diminished consumption, which resulted from uncertainty in the nation's future after this devastating disaster. China's GDP growth and inflation rate elasticities to oil price fluctuations were almost constant in both subperiods. The main reason for this is appreciation of the Chinese Yuan. Slightly after the subprime mortgage crisis, oil prices started to increase sharply due to a mild recovery in the global economy and huge quantitative easing (QE) policies of the US and monetary authorities in other countries. Simultaneously, the Chinese Yuan appreciated compared to other currencies, which means the price of crude oil in the Chinese domestic market did not fluctuate as much. The result is that before and after the crisis, the impact of crude oil prices on the Chinese economy (GDP and Inflation) was almost constant.

Acknowledgments

We would like to thank Mr. Akira Yanagisawa and Mr. Hiroshi Hashimoto for their collaborations in providing necessary data for this paper, Mr. Masakazu Toyoda, the chairman and CEO of IEEJ, Dr. Ken Koyama, Mr. Yuji Morita, Mr. Yoshikazu Kobayashi, and the directors and researchers at IEEJ who kindly provided us with valuable suggestions and comments to improve this paper.

References:

Asia/World Energy Outlook-Analyzing Changes Induced by the Shale Revolution. The Institute of Energy Economics, Japan (IEEJ), Oct 2013.

Blanchard O.J,, Galí J. (2007). The macroeconomic effects of oil price shocks: Why are the 2000s so different from the 1970s? NBER Working paper, No. 13368

Bohi D.R. (1991). On the macroeconomic effects of energy price shocks. *Resources and Energy*, 13(2): 45–162

Breitung, J., Bruggemann, R., Lutkepohl, H., (2004). Structural vector autoregressive modeling and impulse responses. In: Lutkepohl, H., Kratzig, M. (Eds.), *Applied Time Series Econometrics*. Cambridge University Press, Cambridge, pp. 159–196

Jiménez-Rodríguez R., Sánchez, M., (2004). Oil price shocks and real GDP growth: Empirical evidence for some OECD countries. European Central Bank Working Paper Series, No. 362

Kilian, L., (2008). A comparison of the effects of exogenous oil supply shocks on output and inflation in the G7 countries. Journal of the European Economic Association, 6(1): 78–121

Korhonen I., Ledyaeva S. (2010). Trade linkages and macroeconomic effects of the price of oil. Energy Economics. 32(4): 848–856

Revankar, S., and N. Yoshino. (1990). "An 'Expanded Equation' Approach to Weak-Exogeneity Tests in Structural Systems and a Monetary Application." *The Review of Economics and Statistics* 72 (1): 173–177.

Taghizadeh Hesary, F., and N. Yoshino. 2013a. "Which Side of the Economy Is Affected More by Oil Prices: Supply or Demand?". *United States Association for Energy Economics (USAEE) Research Paper* No. 13-139. doi: 10.2139/ssrn.2333991.

Taghizadeh Hesary, F., and N. Yoshino. 2013b. "Empirical Analysis of Oil Price Determination Based on Market Quality Theory." *Keio/Kyoto Global COE Discussion Paper Series* No. DP2012-044.

Taghizadeh Hesary, F., and N. Yoshino. 2014. "Monetary Policies and Oil Price Determination: An Empirical Analysis." *OPEC Energy Review* 38 (1): 1-20. doi:10.1111/opec.12021.

Taghizadeh Hesary, F., N. Yoshino, G. Abdoli, and A. Farzinvash. 2013. "An Estimation of the Impact of Oil Shocks on Crude Oil Exporting Economies and Their Trade Partners." *Frontiers of Economics in China* 8 (4): 571–591. doi: 10.3868/s060-002-013-0029-3.

Tatom, J.A. 1981, 'Energy Prices and Short-Run Economic Performance,' Federal Reserve Bank of St. Louis Review, Jan: 3-17.

US Energy Information Administration (EIA), Monthly Energy Review (January 2014)

US Energy Information Administration (EIA), Monthly Energy Review (February 2014)

Yoshino, N., and F. Taghizadeh Hesary. 2014. "Monetary Policies and Oil Price Fluctuations Following the Subprime Mortgage Crisis: An Empirical Analysis." *IEEJ Energy Journal* 9 (2): 38-54.

Yoshino, N., S. Kaji, and T. Asonuma. 2012. "Choices of Optimal Monetary Policy Instruments under the Floating and the Basket-Peg Regimes." *The Singapore Economic Review* 57 (4): 1250024-1 -1250024-31. doi: 10.1142/S0217590812500245.

Contact: report@tky.ieej.or.jp