# MONETARY POLICY AND OIL PRICE DETERMINATION

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*This thesis is dedicated to Prof. Naoyuki Yoshino and to my beloved family*

# Contents

*In the Name of "God"*

*the Compassionate and the Merciful*

# I. Abstract


This thesis provides a series of studies about the impact of monetary policy on the crude oil prices. Also it provides several surveys regarding the modeling of oil prices in both theoretical and practical aspects.

While the oil price shocks of 1970s can be explained by pure supply factors, starting in the 1980s oil prices increasingly began to come under a different type of pressure. Oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time interest rates subsided from 16.7 percent per annum to about 0.1. This thesis explains how this long-term price increase was, in most cases, caused by expansionary monetary policies that heightened oil prices through interest rate channels. Aggressive monetary policies stimulated oil demand and blew up oil prices, a trend that led to slower economic growth.

Moreover in this thesis we showed that after the subprime mortgage crisis the weaker exchange rate of the United States (US) dollar caused by the country's quantitative easing pushed oil prices in US dollars upward over the period of 2009–2012, by causing investors to invest in the oil market and other commodity markets while the world economy was in recession in this period. This trend had the effect of imposing a longer recovery time on the global economy, as oil has been shown to be one of the most important production inputs.

Other finding of this thesis is that, by developing a general equilibrium model we concludes that movements in the oil prices mainly affect the economy through the demand side (shifting the Aggregate demand curve) by affecting household expenditures and energy consumption.

Moreover results of this thesis suggests 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 oil importer. On the other hand, however, the impact of oil price fluctuations on the emerging

economies' inflation rate was found to be milder than in the developed countries that were examined.

And the last findings of this thesis is for the Japanese economy. Recently Bank of Japan (BOJ) in order to overcome the deflation and achieve sustainable economic growth, set the inflation target at 2 percent and implement aggressive monetary policy to achieve this target as soon as possible. Although prices started to rise after the BOJ implemented monetary easing, but main reason for this price elevation may not come directly from easy monetary policy, but other sources such as higher oil prices. Expensive oil prices in Japanese yen which is result of depreciated Japanese yen is one of the main causes of the inflation.

# II. Preface

Energy, especially oil is considered one of the key factors of production in an economy. It is widely used in different sectors including transportation, production, energy supply, and as a raw material in the production of petrochemical products; this is why it has great value and affects other energy sources. Since the first oil price shock of 1973, examining the macroeconomic effects of oil prices has become one of the most fundamental issues of energy economics.

While the oil price shocks of 1970s can be explained by pure supply factors, starting in the 1980s oil prices increasingly began to come under a different type of pressure.

A descriptive analysis of crude oil markets enables us to observe oil price movements during two subperiods: 1960–1980 and 1980–2011. The initial period of 1960–1980 witnessed a series of oil price shocks in which price hikes culminated in 1980 at a price of $36.83/barrel in nominal terms from $1.9/barrel in 1960, mainly because of supply side shocks.

During the second period of 1980–2011, in the early 1980s, a recession reduced crude oil demand and exerted significant downward pressure on oil prices. By the end of the decade, prices had declined substantially to below $25 USD per barrel. The 1990s brought the Persian Gulf War (1990–1991), which had an impact on supply and prices as well. During the second period (1980–2011), average oil prices saw an extreme rise, from about $36/barrel in 1981 to beyond $111/barrel in 2011. At the same time, average interest rates (Federal funds rate) devalued from 16.7 per cent annually in 1981 to about 0.1 per cent annually in 2011.

The first chapter of this dissertation explains how this long-term price increase was, in most cases, caused by expansionary monetary policies that heightened oil prices through interest rate channels. Aggressive monetary policies stimulated oil demand and blew up oil prices, a trend that led to slower economic growth. As for elasticities, the results described in this chapter show that oil demand price elasticity is low value and unlike some earlier literature states, supply price elasticity is statistically significant but economically low. In last section, the results show that oil prices adjust instantly, declaring the existence of equilibrium in the oil market during the period from 1960 to 2011.

The second chapter develops a general equilibrium model incorporating monetary policy variables to evaluate how oil prices affect the consumer economy's GDP and inflation over the period 1960-2011. This New-Keynesian model assumes that changes in the oil price transfer to macro variables through either supply (aggregate supply curve) or demand channels (aggregate demand curve). The empirical analysis concludes that movements in the oil price mainly affect the economy through the demand side (shifting the Aggregate demand curve) by affecting household expenditures and energy consumption. This analysis provides several additional findings, among which is the finding that easy monetary policies amplify energy demand more than supply, resulting in skyrocketing crude oil prices, which inhibit economic growth.

The third chapter examines how monetary policy affected crude oil prices after the subprime mortgage crisis. First chapter found that easy monetary policy had a significant impact on energy prices during the period of 1980–2011. This chapter finds that after the subprime mortgage crisis the weaker exchange rate of the United States (US) dollar caused by the country's quantitative easing pushed oil prices in US dollars upward over the period of 2009–2012, by causing investors to invest in the oil market and other commodity markets while the world economy was in recession in this period. This trend had the effect of imposing a longer recovery time on the global economy, as oil has been shown to be one of the most important production inputs.

The forth chapter assess the impact of crude oil price movements on two macro-variables, GDP growth rate and the CPI inflation rate, in three countries: U.S. 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 chapter is to see whether these economies are still reactive to oil price movements. Moreover in order to see which group of countries whether developed or emerging economies get milder impact on their GDP growth rate and inflation rates following by the oil shocks. 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.

The fifth and last chapter is titled 'impact of energy prices and the effectiveness of the easing monetary policy in Japanese economy'. Recently Bank of Japan (BOJ) in order to overcome the deflation and achieve sustainable economic growth, set the inflation target at 2 percent and implement aggressive monetary policy to achieve this target as soon as possible. Although prices started to rise after the BOJ implemented monetary easing, but main reason for this price elevation may not come directly from easy monetary policy, but other sources such as higher oil prices. Expensive oil prices in Japanese yen which is result of depreciated Japanese yen is one of the main causes of the inflation. Moreover, result of this chapter shows that quantitative easing may not stimulate the Japanese economy. Aggregate demand which includes private investment did not increase significantly in Japan when the interest rate is lowered. Private investment displays this unconventional behavior because of uncertainty about the future and ageing population. We believe that remedy of Japanese economy is not monetary policy. The government needs to look for serious structural changes and growth strategies.

It is our sincere hope that this thesis will be useful for both academics and policymakers in order to raise the global awareness for the impact of easy monetary policy in creating inflations in asset markets including crude oil market. Moreover we wish that the resources that this thesis creates will be useful for scholars for the modeling of oil prices in both theoretical and practical aspects.

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# Chapter 1: Monetary Policies and Oil Price Determination: An Empirical Analysis[1]

## Abstract

While the oil price shocks of 1970s can be explained by pure supply factors, starting in the 1980s oil prices increasingly began to come under a different type of pressure. Oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time interest rates2 subsided from 16.7 percent per annum to about 0.1. This chapter explains how this long-term price increase was, in most cases, caused by expansionary monetary policies that heightened oil prices through interest rate channels. Aggressive monetary policies stimulated oil demand and blew up oil prices, a trend that led to slower economic growth. As for elasticities the results described in this chapter show that demand is price elastic and, unlike some earlier literature states, it is significantly elastic to income too. In last section, the results show that oil prices adjust instantly, declaring the existence of equilibrium in the oil market during the period from 1960 to 2011.

Keywords: Oil market, monetary policy, interest rate, equilibrium vs. disequilibrium

JEL Classification: Q31, Q41, E52

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[1] Another version of this chapter published as:

Taghizadeh H.F. and Yoshino, N. (2014) 'Monetary Policies and Oil Price Determination: An Empirical Analysis', *OPEC Energy Review*, 38(1): pp. 1–20.

[2] Federal funds rate

# 1. Introduction

A descriptive analysis of crude oil markets enables us to observe oil price movements during two sub-periods: 1960-1980 and 1980-2011. The initial period of 1960–1980 witnessed a series of oil price shocks in which price hikes culminated in 1980 at a price of $36.83/barrel in nominal terms from $1.9/barrel in 1960. Fig. 1 illustrates crude oil price movements in nominal and real terms during 1960-2011.

Fig. 2 shows crude oil price growth rates in both real and nominal terms during the period of 1960-2011, and exhibits that both prices followed the same path.

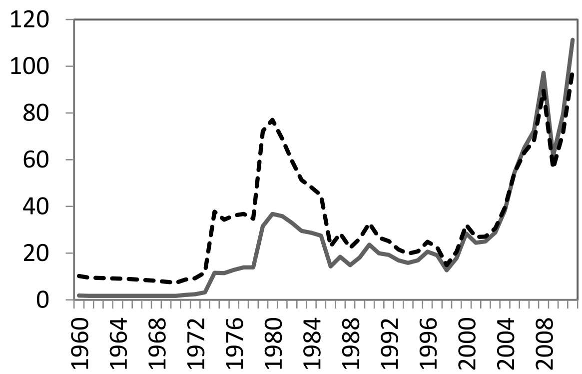


**Fig. 1. Crude oil prices 1960 – 2011:** Prices are in U.S. dollars per barrel. 1960-1983: Arabian Light posted at Ras Tanura.1984-2011: Brent dated, The dashed line is real price, and the solid line is the nominal price.

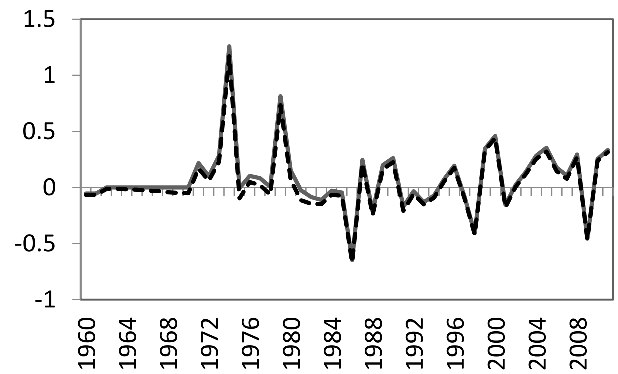


**Fig. 2. Changes in log crude oil prices 1960 – 2011:** The dashed line is the real price, and the solid line is the nominal price.

The production of crude oil increased during the first period (1960–1980) at an average rate of 4.95%, moving to a production rate of 59.4 million barrels/day (mbd) in 1980 from 21 mbd in 1960 (Fig. 3). In contrast to the stable crude oil output growth before 1973, the first oil price shock in 1973 initiated recurrent changes in oil production and a dissociation between OPEC and non-OPEC output. Fig. 3 shows the remarkable contrast in the behavior of OPEC and non-OPEC production in the period after the first oil price shock until 1985. From 1985 to 2011, however, both OPEC and non-OPEC output moved almost steadily parallel to each other. Fig. 4 shows the growth rate of OPEC and global crude oil output.

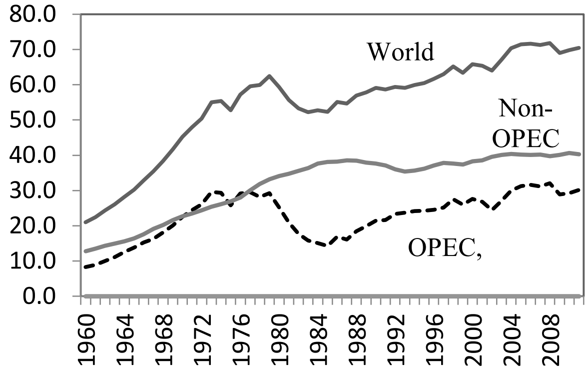


**Fig. 3. Crude oil output 1960 – 2011, million barrel/day**

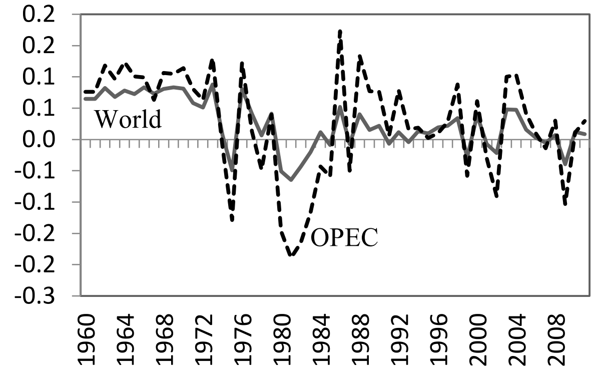


**Fig. 4. Changes (log difference) in OPEC and the global oil output 1960-2011.**

During the second period of 1980-2011, in the early 1980s a recession reduced crude oil demand and exerted significant downward pressure on oil prices. By the end of the decade, prices had declined substantially to below $25 USD per barrel. The 1990s brought the Persian Gulf War, (1990-1991) which had an impact on supply and prices, as well.

Despite the low prices for crude oil for most of the 1990s, there was little interest within OPEC to try to raise prices. This lack of action by OPEC kept oil prices low for an extended period. However, when crude oil prices descended to $10 USD per barrel following the Asian financial crisis in 1998, OPEC instituted a series of production cuts starting in late 1999, making it possible for them to raise oil prices. During the second period, (1980-2011) average oil prices saw an extreme rise, from about $36/barrel in 1981 to beyond $111/barrel in 2011. At the same time, average interest rates devalued from 16.7 percent annually in 1981 to about 0.1 percent annually in 2011. We explain this long-term price increase, especially after the year 2000, to be caused by expansionary monetary policies that led to lower interest rates, amplified both credit and aggregate demand, and expanded demand for oil, leading to elevated oil prices. Bernanke et al. (1997) stated that the Federal Reserve tends to raise interest rates too high in response to high oil prices, which can lead to depressed economic activity that exceeds the negative effects of oil price shocks. In short, they showed that expansionary monetary policies could have largely eliminated the negative output consequences of the oil-price shocks on the U.S. economy. This view has, in turn, been challenged by Hamilton and Herrera (2004), who argue that Bernanke, Gertler, and Watson's

(BGW) empirical results are driven by model misspecification. Hamilton and Herrera reproduce the BGW experiment using a different model specification, and found that increases in the price of oil lead directly to contractions in real output. Tightening monetary policy plays only a secondary role in generating the downturn.

There are several other recent research studies that critically reevaluate Bernanke et al.'s (1997) results. For example, Leduc and Sill's (2004) findings approximated the Federal Reserve's behavior since 1979, showing that the monetary policy contributes to an approximate 40 percent drop in output following a rise in oil prices. Or, in a more recent research study, Anna Kormilitsina (2011) used an estimated dynamic stochastic general equilibrium model with the demand for oil to contrast the Ramsey optimal with estimated monetary policy. The study found that monetary policy amplified the negative effect of the oil price shock. Our results in this chapter are in agreement with these later critical papers, as we found that monetary policy indeed has negative effects on the demand side of the crude oil market and, subsequently, on oil prices. We argue that global oil demand was significantly influenced by interest rates. Our research indicates that aggressive monetary policy stimulates oil demand. This demand however, is met with rigid oil supply, creating inflationary trends and disrupting economic growth.

In the last section of this research, we attempted to shed light on the hypothesis of equilibrium vs. disequilibrium in oil market; our results showed that oil prices adjust instantly, indicating the existence of equilibrium in the oil market during the period of 1960-2011.

# 2. The theoretical framework

## *2.1. Oil consumption*

Our assumed oil importer country has a multi-input production function, with five production inputs:

$$y_t = f(K_t, N_t, q_{1t}^d, q_{2t}^d, q_{3t}^d) \tag{1}$$

where $y_t$ is total production (the monetary value of all goods produced in a year), $K_t$ is capital input (the monetary worth of all machinery equipment and buildings), $N_t$ is labor input (the total number of man-hours worked in a year), $q_{1t}^d$ is crude oil input (in barrels), $q_{2t}^d$ is natural gas input (in cubic feet), and $q_{3t}^d$ is coal input (in short tons). An oil importer's profit equation is:

$$Max\pi_t^d = P_{yt}.y_t - i_t K_t - w_t N_t - e_t p_{1t} q_{1t}^d - e_t p_{2t} q_{2t}^d - e_t p_{3t} q_{3t}^d \tag{2}$$

where $P_{yt}$ is the output price level, $w_t$ is the labor wage, $i_t$ is borrowed capital real rent, $p_{1t}$ is the crude oil price in USD, $p_{2t}$ is the natural gas price in USD, $p_{3t}$ is the coal price in USD, and $e_t$ is the exchange rate[3]. The Lagrange function is defined as:

$$L_t = \left(P_{yt} y_t - i_t K_t - w_t N_t - e_t p_{1t} q_{1t}^d - e_t p_{2t} q_{2t}^d - e_t p_{3t} q_{3t}^d\right) - \lambda\left[y_t - f(K_t, N_t, q_{1t}^d, q_{2t}^d, q_{3t}^d)\right] \tag{3}$$

This produces the FOC for crude oil:

$$\partial L_t / \partial q_{1t}^d = -\left[e_t p_{1t} + \left(\partial p_{1t} / \partial q_{1t}^d\right) e_t q_{1t}^d\right] + P_{yt}\left(\partial f / \partial q_{1t}^d\right) = 0 \tag{4}$$

More specific results can be obtained by adopting the Cobb-Douglas production function (Romer, 2001):

$$y_t = f(K_t, N_t, q_{1t}^d, q_{2t}^d, q_{3t}^d) = b_t K_t^{\alpha} N_t^{\beta} \left(q_{1t}^d\right)^{\gamma_1} \left(q_{2t}^d\right)^{\gamma_2} \left(q_{3t}^d\right)^{\gamma_3} \tag{5}$$

where; $\alpha, \beta, \gamma_1, \gamma_2, \gamma_3$ are the output elasticities of capital, labor, crude oil, natural gas and coal, respectively. These values are constants determined by available technology and b is total factor productivity. We assumed that capital comes from the competitive market and the crude oil market is oligopolistic. For oligopolistic market we inspired by Revankar & Yoshino (2008). By rewriting Eq. 4 while accounting for our Cobb-Douglas production function, we get:

[3] The exchange rate we used is the effective exchange rate of USD, since all inputs, including crude oil, natural gas and coal are denominated in USD.

$$-\left[e_t p_{1t} + \left(\partial p_{1t} / \partial q_{1t}^d\right) e_t q_{1t}^d\right] + P_{yt}\gamma_1\left(y_t / q_{1t}^d\right) = 0 \tag{6}$$

In order to show that capital and labor inputs are function of what variables, we rewrite Eq.5 as bellow[4]

$$y_t = b_t K_t^{\alpha}{}_{(i_t, y_t)} N_t^{\beta}{}_{(\frac{w_t}{P_{yt}}, y_t)} \left(q_{1t}^d\right)^{\gamma_1} \left(q_{2t}^d\right)^{\gamma_2} \left(q_{3t}^d\right)^{\gamma_3} \tag{7}$$

and as we know:

$$q_{it}^d = f(p_{it}/P_{yt}); (i = 1,2,3) \tag{8}$$

and for the estimation purposes we can express oil demand function in simplified log-linear form as bellow[5]:

$$\tilde{q}_{1t}^d = d_0 + d_1\tilde{p}_{1t} + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} + d_4\tilde{y}_t + d_5\tilde{i}_t + d_6\tilde{e}_t + u_{dt} \tag{9}$$

where $\tilde{q}_{1t}^d$ is logarithm of $q_{1t}^d$, $\tilde{p}_{it}$ is logarithm of $p_{it}/P_{yt}; (i = 1,2,3)$, the coefficient $d_1$ is the price elasticity of global demand for crude oil, $d_2$ and $d_3$ are substitution elasticities of natural gas and coal respectively, which are two main substitutions for crude oil. These two values are anticipated to be positive. To demonstrate the effect of changes in the world's income on the demand for oil, we use the real GDP of the world in a logarithmic format ($\tilde{y}_t = \log(y_t/P_{yt})$). We also included two monetary policy factors: real interest rate $\tilde{i}_t$ and real exchange rate $\tilde{e}_t$. We expect negative values for $d_5$ and as for the exchange rate we expect a negative value for $d_6$, implying that a depreciation of the U.S. dollar would increase oil demand. Section 2.1.1 of this chapter comprehensively describes the channels of how monetary policy is transmitted to oil consumption.

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[4] From Eq. 6 and Eq.7 we obtain an implicit function for crude oil demand that has all variables in its in real term as follows: $q_{1t}^d = h(p_{1t}/P_{yt}, p_{2t}/P_{yt}, p_{3t}/P_{yt}, y_t/P_{yt}, i_t, e_t)$

[5] Since the labor wage does not have a significant impact on crude oil demand, we omitted it from our demand equation.

### *2.1.1. Channels of transmission of monetary policies to oil consumption:*

Monetary policies affect oil prices through a number of channels, including interest rates and exchange rates. Channels of interest rate transmission could be completely described by classical monetarism, as well as in modern literature such as the Keynesian IS-LM model. Easing interest rates increase the demand for credit and increase aggregate demand, including the demand for commodities. This increased demand for commodities also contains energy demand, especially for crude oil and derivatives because they are major energy carriers.

Keynes (1936) examined the effects that lowered interest rates have on aggregate demand. Expansionary monetary policy reduces the interest rate, and when the interest rate is lower than the marginal productivity of capital, it broadens investment demand until the marginal productivity of capital is equalized to a lower interest rate. The expansion of investment creates an accelerator-multiplier effect, causing aggregate demand to expand. This expansion of aggregate demand amplifies demand for commodities and puts pressure on commodity prices. This could be generalized for energy carriers as well, especially crude oil. In the end, this process leads to increased pressure on oil prices. Ricardo (1817) studied the relationship between discount rates and commodity prices, stating that lower discount rates would lead to credit augmentation, which would increase commodity prices under the condition that money velocity is constant.

As for the exchange rate transmission channel, most of the world's crude oil demand is overshadowed by oil imports of non-producers or oil deficit producers. This means that a depreciation of the U.S. dollar would make oil imports cheaper in non-dollar-denominated currencies, raising oil imports and oil demand. Another exchange rate channel is as follows: A depreciation of the U.S. dollar would cause an appreciation of non-dollar-dominated financial assets and would, in turn, arouse world oil demand because of the wealth effect.

Depending on the paper, certain research studies claim that monetary policies have a beneficial on the oil market, while others claim that it is detrimental. Bernanke et al. (1997) states that the Federal Reserve raises interest rates too much in response to high oil prices, a practice that depresses economic activity beyond the negative effect of oil price shocks. Anna Kormilitsina (2010) found that monetary policy amplified the negative effects of the oil price shock. Askari and

Krichene (2010) measured that global oil demand was significantly influenced by interest and dollar exchange rates when oil supply was rigid. They found that oil supply and demand have very low price elasticity, and this characteristic makes oil prices highly volatile and subject to wider fluctuations than the prices of other commodities.

Fig. 5 illustrates the relationship between interest rates and crude oil prices. Here we used the federal funds rate, a key interest rate, as a dominant factor. The federal funds rate follows the same pattern as the Libor rate: both are money market rates and are used as a benchmark for pricing loans by adding spreads that depend on risk and maturity. As can be seen in this figure, the relationship between interest rates and crude oil prices is asymmetric. For the area that is our main scope, the period of 1981-2011, average oil prices accelerated from about \$35/barrel in 1981 to beyond \$111/barrel in 2011. At the same time, average interest rates subsided from 16.7 percent per annum in 1981 to about 0.1 percent per annum in 2011.

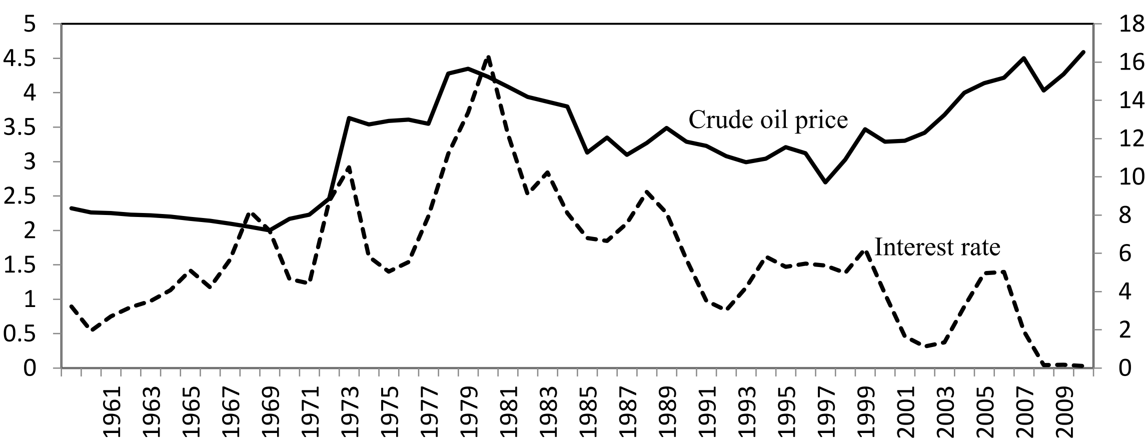


**Fig. 5: Interest rates and crude oil prices 1960 – 2011** Note: Crude oil prices are in logarithmic form. Source of crude oil prices: 1960-1983 Arabian Light posted at Ras Tanura, 1984-2011 Brent dated. Interest rates are the U.S. money market rate, percent per annum. Left hand side scale is for the logarithm of crude oil prices and the right hand side scale is for interest rates.

## *2.2. Crude oil output*

Supposing that over the period t-1 to t, crude oil output or extraction of crude oil is given by $q_t^s$ we write the following equations:

$$Q_t^s = \sum_{t=0}^{T} q_t^s \tag{10}$$

$$TR_0 \geq R_t + Q_t^s \tag{11}$$

$$R_t + Q_t^s = R_{t-1} + Q_{t-1}^s \tag{12}$$

$$R_t = R_{t-1} - q_t^s \tag{13}$$

where $Q_t^s$ is the cumulative extraction at the end of period t, $TR_0$ is the total amount of crude oil resources (proven and non-proven) at period 0 and $R_t$ is the amount of proven reserves at period t. Eq. 13 states that the amount of proven reserve is diminishing every year by $q_t^s$ . Eq. 12 and Eq. 13 are under the condition that there is no new discovery of oil. The cost function is obtained from a convex function, depending negatively on the amount of remaining proven reserves. The so-called stock effect is mainly due to the pressure dynamics affecting petroleum extraction. This type of cost specification is also considered by Livernois and Uhler(1987) , Farzin (1992) and Favero et al. (1994). The Favero cost function is given as:

$$C_t(q_t^s, R_{t-1}) = \alpha q_t^s - \frac{1}{2}\beta(R_{t-1})^2 > 0 \quad ;\alpha > 0, \beta > 0 \tag{14}$$

where the first part of this cost function $\alpha q_t^s$ represents extraction cost, and the second part of it $1/2\,\beta(R_{t-1})^2$ shows scarcity cost. Crude oil suppliers will choose an extraction profile to maximize the discounted stream of profits over the life of the field.

$$Max \sum_{t=0}^{T} \theta^t \left[\pi_t(q_t^s, R_{t-1})\right] ; 0 \leq \theta < 1 \tag{15}$$

$$\text{s.t. } (R_t - R_{t-1}) = -q_t^s \tag{16}$$

$$\theta = 1/(1 + r + \omega); r > 0 \tag{17}$$

where $\theta$ is the subjective rate of discount, $p_t^e$ is the expected real price of crude oil in USD per barrel, and $\omega$ is the risk premium. By considering Eq. 13, we write the profit equation for a crude oil producer, which is the function of expected price at time *t*, the output of crude oil, extraction cost and scarcity cost:

$$\pi_t = \theta\left[ e_t p_t^e q_t^s - \alpha q_t^s + \frac{1}{2}\beta(R_t + q_t^s)^2 \right] \tag{18}$$

We assume that the oil market is an oligopolistic market. First-order conditions for the optimization problem are given by:

$$e_t p_t^e + e_t\left(\partial p_t^e / \partial q_t^s\right) q_t^s - \alpha + \beta(R_{t-1}) \tag{19}$$

Solving Eq.19 for $q_t^s$, results in the crude oil supply equation[6]:

$$q_t^s = \left[\alpha - \beta(R_{t-1}) - e_t p_t^e\right] / \left[e_t(\partial p_t^e / \partial q_t^s)\right] \tag{20}$$

For estimation purposes a smplified log-linear form of oil supply equation and a simultaneous supply and demand equation model (SEM) have been developed for world crude oil incorporating monetary factors. We are assuming rational expectations and gave market information the role of determining supply behavior (Muth, 1961):

$$\tilde{q}_{1t}^d = d_0 + d_1\tilde{p}_{1t} + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} + d_4\tilde{y}_t + d_5\tilde{i}_t + d_6\tilde{e}_t + u_{dt} \tag{21}$$

$$\tilde{q}_t^s = s_0 + s_1\tilde{p}_t^e + s_2\tilde{i}_t + s_3\tilde{e}_t + s_4\tilde{R}_{t-1} + s_5 Z_{1t} + s_6 Z_{2t} + s_7 Z_{3t} + u_{st} \tag{22}$$

where we have the following variables, which are all in logarithmic form with the exception of exchange and interest rates. Nominal values are converted to real values using $P_{yt}$[7].

$\tilde{q}_{1t}^d$ is the logarithm of crude oil consumption, in million barrels per day. $\tilde{q}_t^s$ is the crude oil output, in millions of barrels per day. $\tilde{p}_{1t}$ is the logarithm of the real crude oil price[8], in USD per barrel.

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[6] Since oil is expected to be depleted at time $T$, it must be that $E_{T-1}(q_T^s) = E_{T-1}(R_{T-1} - R_T)$ and $E_T(q_{T+1}^s) = 0$. That is, in the period after which the last barrel of oil is extracted, extraction of oil must be equal to zero. $\beta$ is a function of the interest rate, so the resulting implicit function for crude oil supply is : $q_t^s = n(p_t^e, i_t, e_t, R_{t-1})$; where $i_t$ is the interest rate in time t.

[7] Since all input prices including crude oil, natural gas and coal prices are in USD, we divided them by a U.S. GDP deflator (2005=100) in order to get real values.

[8] 1960-1983 Arabian Light posted at Ras Tanura.
1984-2011 Brent dated.

$\widetilde{p}_t^e$ is the logarithm of the expected real price of crude oil in USD per barrel. $\widetilde{p}_{2t}$ is the logarithm of the U.S. Natural gas wellhead real price in U.S. cents per thousand cubic feet. $\widetilde{p}_{3t}$ Is the logarithm of the American coal real price (F.O.B.) rail /barge prices in USD per short ton. $\widetilde{y}_t$ is the logarithm of the real global GDP. $\widetilde{i}_t$ is the U.S money market rate in real term, a key interest rate. $\widetilde{e}_t$ is the real effective exchange rate for USD, $\widetilde{R}_{t-1}$ is the logarithm of the amount of proven crude oil reserves in previous period. $Z_{1t}, Z_{2t}, Z_{3t}$ are dummy variables for the 3 major oil shocks. $d_0$ and $s_0$ are constants. $u_{dt}$ and $u_{st}$ are random error terms.

The expected variable $\widetilde{p}_t^e$ is formed rationally: $\widetilde{p}_t^e = E(\widetilde{p}_{1t} | I_{t-1})$. $I_{t-1}$ is the information set in the period $t-1$ upon which expectations $E(\widetilde{p}_{1t} | I_{t-1})$ were based. The supply of crude oil is a function of expected price, proven crude oil reserves, monetary factors and dummy variables for large fluctuations in oil prices. Following McCallum (1976), the actual and expected prices are expressed as: $\widetilde{p}_{1t} = \widetilde{p}_t^e + \eta_{st}$, where $\eta_{st}$ is a forecast error that is uncorrelated with $I_{t-1}$. In addition, as per Hausman et al., (1987) and Revankar & Yoshino (1990), we can obtain the estimated random error term from our crude oil demand equation as an explanatory variable $\widetilde{u}_{dt}$ in supply equation. Rearranging Eq. (22) by substituting for $\widetilde{p}_t^e$ and including $\widetilde{u}_{dt}$, the two equations become as listed below. $u_{dt}$ and $u_{st}$ are random error terms, assumed to be serially uncorrelated, independently and identically distributed with mean zero and uncorrelated with the exogenous variables.

$$\widetilde{q}_{1t}^d = d_0 + d_1 \widetilde{p}_{1t} + d_2 \widetilde{p}_{2t} + d_3 \widetilde{p}_{3t} + d_4 \widetilde{y}_t + d_5 \widetilde{i}_t + d_6 \widetilde{e}_t + u_{dt} \tag{23}$$

$$\widetilde{q}_t^{\,s} = s_0 + s_1 \widetilde{p}_{1t} + s_2 \widetilde{i}_t + s_3 \widetilde{e}_t + s_4 \widetilde{R}_{t-1} + s_5 Z_{1t} + s_6 Z_{2t} + s_7 Z_{3t} + s_8 \widetilde{u}_{dt} + (u_{st} - \eta_{st}) \tag{24}$$

# 3. Empirical Analysis

## *3.1. Data*

We use annual data from 1960 to 2011. We define crude oil prices in U.S. dollars per barrel, natural gas price in U.S. cents per thousand cubic feet, coal prices in U.S. dollar per short tons, and global GDP, all in real terms as the ratio of nominal values to the U.S. GDP deflator (2005=100)[9]. From now on whenever we refer to the price of crude oil, price of natural gas, price of coal, and GDP, unless otherwise stated, we refer to their real values. As for crude oil output, crude oil consumption and GDP series, we used world data from The OPEC Annual Statistical Bulletin 2012. In earlier studies we infrequently found research studies that used global data. We believe that, by using global data, we can obtain more feasible results in order to generalize findings for most areas and countries.

As for crude oil prices for the period of 1960-1983, we used Arabian Light prices posted at Ras Tanura, and for the period 1984-2011, we used Brent dated rates released from BP [10]Statistical Review of World Energy 2012. For coal prices[11], because of lack of data, we used one of the world's dominant source rates, which are the U.S. total short ton prices. We got this series from the U.S. Energy Information Administration (EIA)[12]. Because we lacked data on natural gas for this period as well, we limited our references to one of the preeminent natural gas sources and used U.S. natural gas wellhead prices, published by the U.S. Energy Information Administration. As oil prices are denominated in U.S. dollars, for the exchange rate series we used the U.S. dollar's real

[9] Other possible deflators are the world commodities price index and the world consumer price index.
[10] British Petroleum
[11] Prices are free-on-board (F.O.B.) rail/barge prices, which are the F.O.B. prices of coal at the point of first sale, excluding freight or shipping and insurance costs. For 1960-2000, prices are for open market and captive coal sales; for 2001-2007, prices are for open market coal sales; for 2008 and onward, prices are open market and captive coal sales.

[12] Sources: • 1960-1975—Bureau of Mines (BOM), Minerals Yearbook. • 1976—U.S. Energy Information Administration (EIA), Energy Data Report, Coal Bituminous and Lignite in 1976, and BOM, Minerals Yearbook. • 1977 and 1978—EIA, Energy Data Reports, Bituminous Coal and Lignite Production and Mine Operations, and Coal—Pennsylvania Anthracite. • 1979—EIA, Coal Production, and Energy Data Report, Coal—Pennsylvania anthracite. • 1980-1992—EIA, Coal Production, annual reports. • 1993-2000—EIA, Coal Industry Annual, annual reports and unpublished revisions. • 2001-2010—EIA, Annual Coal Report, annual reports. • 2011—EIA, Form EIA-7A, "Coal Production Report," and U.S. Department of Labor, Mine Safety and Health Administration, Form 7000-2, "Quarterly Mine Employment and Coal Production Report."

effective exchange rate (REER). For interest rates, we used the federal funds rate[13] in real term as the key interest rate that influences other key interest rates.

**Table 1. Series: unit root tests, 1960-2011**

| | Notation | *1960-2011* | | *1960-1980* | | *1980-2011* | |
|---|---|---|---|---|---|---|---|
| | | *ADF* | *CV* | *ADF* | *CV* | *ADF* | *CV* |
| *Test on level* | | | | | | | |
| Crude oil consumption | $\tilde{q}_1^d$ | -3.68** | -2.92 | *-3.48** | *-3.03* | *0.71* | *-2.96* |
| Crude oil output | $\tilde{q}^s$ | -5.94** | -2.92 | *-3.12** | *-3.03* | *-0.22* | *-2.96* |
| Price of crude oil | $\tilde{p}_1$ | -0.99 | -2.92 | *0.38* | *-3.03* | *-1.13* | *-2.96* |
| Price of natural gas | $\tilde{p}_2$ | -1.87 | -2.92 | *0.44* | *-3.03* | *-2.38* | *-2.99* |
| Price of coal | $\tilde{p}_3$ | -2.81 | -2.92 | *-0.27* | *-3.03* | *-2.92* | *-2.98* |
| Interest rate | $\tilde{i}$ | -1.50 | -2.92 | *-0.29* | *-3.04* | *-2.50* | *-2.98* |
| Exchange rate | $\tilde{e}$ | -2.34 | -2.92 | *-2.09* | *-3.03* | *-2.09* | *-2.99* |
| Oil reserves | $\tilde{R}$ | -2.33 | -2.92 | *-1.86* | *-3.03* | *-1.60* | *-2.98* |
| Income | $\tilde{y}$ | -1.09 | -2.92 | *0.21* | *-3.04* | *-1.09* | *-2.92* |
| *Test on first differences*[14] | | | | | | | |
| Crude oil consumption | $\tilde{q}_1^d$ | -2.70 | -2.92 | *-1.35* | *-3.03* | *-4.23*** | *-2.96* |
| Crude oil output | $\tilde{q}^s$ | -3.97** | -2.92 | *-0.29* | *-3.08* | *-5.48*** | *-2.96* |
| Price of crude oil | $\tilde{p}_1$ | -6.95** | -2.92 | *-4.21*** | *-3.03* | *-3.96*** | *-2.97* |
| Price of natural gas | $\tilde{p}_2$ | -3.37* | -2.92 | *-1.29* | *-3.03* | *-2.54* | *-2.99* |
| Price of coal | $\tilde{p}_3$ | -4.54** | -2.92 | *-3.18** | *-3.03* | *0.009* | *-2.98* |
| Interest rate | $\tilde{i}$ | -6.53** | -2.92 | *-2.99* | *-3.08* | *-4.65*** | *-2.98* |
| Exchange rate | $\tilde{e}$ | -5.27** | -2.92 | *-3.41** | *-3.04* | *-0.98* | *-2.99* |
| Oil reserves | $\tilde{R}$ | -2.93* | -2.92 | *-2.84* | *-3.03* | *-2.80* | *-2.98* |

[13] The federal funds rate follows the same pattern as the LIBOR rate. Both are money market rates and are used as benchmarks for pricing loans by adding spreads that depend on risk and maturity.

[14] Gas price series for 1980-2011 became stationary with -3.11 value (CV=-2.99) in 2nd differences. Coal price series for 1980-2011 became stationary with -5.27 value (CV=-2.98) in 2nd differences. Exchange rate series for 1980-2011 became stationary with -5.53 value (CV=-2.99) in 2nd differences. Oil reserves series for 1960-1980 became stationary with -5.94 value (CV=-3.04) in 2nd differences. Oil reserves series for 1980-2011 became stationary with -11.91 value (CV=-2.98) in 2nd differences.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Income | $\widetilde{y}$ | -4.46** | -2.92 | *-4.60*** | *-3.04* | *-4.46*** | *-2.92* |

Notation: ADF, augmented Dickey–Fuller statistics; CV, critical value at 5% significance level; * indicates significance at 5%; ** indicates significance at 1%

For this reason, we chose it to model global demand for crude oil. REER, interest rates, world proven oil reserves, and the U.S. GDP deflator (2005=100) series are from International Financial Statistics (IFS) of the International Monetary fund (IMF), OPEC Annual Statistical Bulletin 2012 and World Bank database 2012. We tested all series for unit roots (in logarithmic form), using the Augmented Dickey–Fuller test. Results are summarized in Table1.

We have performed the ADF[15] test on level and first differences. Both crude oil consumption and crude oil output reveal an interesting feature: they were stationary on level during 1960-2011 and 1960-1980. This shows a stable structure that helped to maintain consumption and output around a stationary level. Most series, except crude oil consumption and crude oil output, were non-stationary in level, but almost all series became stationary in first differences.

### *3.2. Empirical Results*

It would be necessary to run a regression in order to assess the basic properties of oil markets, determinants of crude oil prices, and follow by evaluating the impact of monetary factors such as interest rates and exchange rates on the oil market. For this reason, we ran the regression for our SEM[16] using the weighted two-stage least squares (W2SL) method. Results are summarized in Table 2.[17]

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[15] Augmented Dickey–Fuller

[16] Simultaneous weighting matrix & coefficient iteration. Convergence achieved after: 1 weight matrix, 2 total coefficient iterations. The Akaike Information Criterion (AIC) has been used to select the lag orders for each SEM in which the maximum lag is set to two

[17] Since there is a sluggish adjustment in oil demand, it forced us to insert $\widetilde{q}^{d}_{1t-1}$ in right hand side of our demand equation, hence the SEM that we done our estimations based on it is below:

$$\begin{cases} \widetilde{q}^{d}_{1t} = d_0 + d_1\widetilde{p}_{1t} + d_2\widetilde{p}_{2t} + d_3\widetilde{p}_{3t} + d_4\widetilde{y}_t + d_5\widetilde{i}_t + d_6\widetilde{e}_t + d_7\widetilde{q}^{d}_{1t-1} + u_{dt} \\ \widetilde{q}^{s}_{t} = s_0 + s_1\widetilde{p}_{1t} + s_2\widetilde{i}_t + s_3\widetilde{e}_t + s_4\widetilde{R}_{t-1} + s_5Z_{1t} + s_6Z_{2t} + s_7Z_{3t} + s_8\widetilde{u}_{dt} + u'_{st} \end{cases}$$

The estimated coefficient for $\widetilde{q}^{d}_{1t-1}$ in 1960-2011 is C.E. =0.93 (t=14.03)** S.E: 0.07, for 1960-1980 is C.E. =0.80 (t=6.03) ** S.E: 0.13 and for the last sub period (1980-2011) is C.E. =0.66 (t=3.88) ** S.E: 0.17. We tested the null hypothesis of $d_7 = 1$, using the t-statistic (t = (C.E.-1)/ S.E). Results for all three periods let us to accept the null hypothesis. This means that $\widetilde{q}^{d}_{1t}$ is I(1), so we

As it is clear from the data, our results for oil demand price elasticity agree more with those researches that found low values for oil demand price elasticities in the short-run and long-run. For the short-run, our results suggest a demand price elasticity of -0.08 (significant), -0.10(significant) and -0.05(significant) for 1960-2011, 1960-1980 and 1980-2011 respectively. For the long-run for 1960-2011, our calculations show a -0.33 value, which is in line with Bentzen and Engsted (1993), who found short-run and long-run price elasticities of -0.13 and -0.46, respectively. Pesaran et al. (1999) found aggregate and sectorial long-run price elasticities of energy demand for Asian countries of: -0.33; industry, -0.52; transport, -0.36; residential, -0.47; and commercial, -0.08. Gately and Huntington (2002) found between -0.12 and -0.64 for both OECD and non-OECD countries, and Krichene's (2006) results were between -0.03 and -0.08 for various countries in the short-run. His long-run price elasticity was significantly low: 0.05 in 1918–1999, 0.13 in 1918–1973 and almost zero during 1973–1999. Askari and Krichene (2010) found -0.009 to -0.008 for short-run elasticities, and Mohaddes (2012) found -0.15 for the short-run price elasticity of global oil demand. Demand for crude oil administrated a large structural change after

**Table 2. Empirical results**

| | *Notation* | *1960-2011* | *1960-1980* | *1980-2011* |
|---|---|---|---|---|
| ***Demand Side*** $\tilde{q}_1^d$ | | | | |
| Price elasticity of demand | $\tilde{p}_1$ | *-0.08(-3.50)*** | *-0.10(-4.16)*** | *-0.05(-2.54)** |
| Price of natural gas | $\tilde{p}_2$ | *0.03(1.55)* | *0.07(2.80)** | *0.03(1.66)* |
| Price of coal | $\tilde{p}_3$ | *0.10(3.09)*** | *0.06(1.78)* | *0.06(1.81)* |
| Income elasticity of demand | $\tilde{y}$ | *0.13(2.00)** | *0.14(0.85)* | *0.14(3.06)*** |
| Interest rate | $\tilde{i}$ | *-0.01(-3.64)*** | *-0.02(-0.98)* | *-0.006*(-2.38)* |
| Exchange rate | $\tilde{e}$ | *-0.02(-0.46)* | *0.06(0.44)* | *0.007(0.27)* |
| | | *R-square:0.75* | *R-square:0.82* | *R-square:0.61* |
| ***Supply Side*** $\tilde{q}^s$ | | | | |
| *Price elasticity of supply* | $\tilde{p}_1$ | *0.24(2.15)** | *0.05(1.34)* | *0.12(2.00)** |
| *Interest rate* | $\tilde{i}$ | *0.01(0.80)* | *-0.01(-1.45)* | *0.01(1.21)* |

used first differences for the left hand side of our demand equation. The economic reason of this issue is that there is a sluggish adjustment in oil demand.

| | | | | |
|---|---|---|---|---|
| *Exchange rate* | $\widetilde{e}$ | *0.37(1.06)* | *0.19(0.39)* | *0.19(1.43)* |
| *Oil reserves* | $\widetilde{R}$ | *0.22(1.04)* | *1.13(15.78)*** | *0.23(0.84)* |
| | | *R-square:0.76* | *R-square:0.98* | *R-square:0.76* |

T-statistics are in parentheses, * indicates significance at 5%, ** indicates significance at 1%

the oil shocks of the 1970s: high energy-taxation in oil importing countries, establishment of the Strategic Petroleum Reserve (SPR), and a rise in the market shares of other energy carriers such as natural gas in the energy baskets of energy importing countries. This contributed to a significant reduction in the demand elasticity by consolidating through energy conservation and substitution. This is the reason that oil price elasticity decreased from -0.10 in 1960-1980 to -0.05 in 1980-2011. Oil demand is significantly elastic to natural gas prices during 1960-1980 and to coal during the main period (1960-2011). Substitution elasticities of crude oil demand to natural gas and coal during these two significant periods are 0.07 and 0.10 respectively.[18]

**Table 3.World oil demand and supply: long-run elasticities (1960-2011)**

| ***Demand Side*** $\widetilde{q}_1^d$ | *Notation* | *C.E.* | *S.E.* |
|---|---|---|---|
| Price elasticity of demand | $\widetilde{p}_1$ | -0.33 | 0.09 |
| Price of natural gas | $\widetilde{p}_2$ | 0.27 | 0.08 |
| Price of coal | $\widetilde{p}_3$ | 0.51 | 0.09 |
| Income elasticity of demand | $\widetilde{y}$ | 0.005 | 0.04 |
| Interest rate | $\widetilde{i}$ | -0.03 | 0.005 |
| Exchange rate | $\widetilde{e}$ | -0.14 | 0.18 |
| ***Supply Side*** $\widetilde{q}^s$ | | | |
| *Price elasticity of supply* | $\widetilde{p}_1$ | 0.03 | 0.005 |
| *Interest rate* | $\widetilde{i}$ | 0.002 | 0.0009 |

[18] Consider the lag model for oil supply: $\widetilde{q}_t^s = \alpha_0 + \alpha_1 \widetilde{q}_{t-1}^s + \alpha_2 g_t + \alpha_3 g_{t-1} + u'_{st}$, where g is vector of all variables that has effect on oil supply. In an error correction form it becomes
$\Delta\widetilde{q}_t^s = \alpha_0 + \alpha_2 \Delta g_t + (\alpha_1 - 1)\widetilde{q}_{t-1}^s + (\alpha_2 + \alpha_3) g_{t-1} + u'_{st} = \alpha_0 + \alpha_2 \Delta g_t + (\alpha_1 - 1)\left[\widetilde{q}_{t-1}^s + (\alpha_2 + \alpha_3)/(\alpha_1 - 1) g_{t-1}\right] + u'_{st}$.
The term $\widetilde{q}_{t-1}^s + (\alpha_2 + \alpha_3)/(\alpha_1 - 1) g_{t-1} = 0$ represent the long run relation. Since we are looking for long run relation, it would be compulsory to add lagged dependent variable to our model. Because of short period for two subperiods, we limited long run elasticity estimation to main period 1960-2011 only.

| | | | |
|---|---|---|---|
| *Exchange rate* | $\widetilde{e}$ | 0.05 | 0.026 |
| *Oil reserves* | $\widetilde{R}$ | 0.013 | 0.01 |

We used Johansen Cointegration test in order to get long-run elasticities.

Notation: C.E, coefficient; S.E, Standard error.

Oil supply price elasticity for crude oil in the short-run is small but significant in 2 out of our 3 periods. We calculated 0.24 (significant) for 1960-2011, 0.05 (insignificant) for 1960-1980, and for the last period (1980-2011) 0.12 (significant). Long-run oil supply price elasticity for 1960-2011 was computed at 0.03. This small long run oil supply price elasticity is in line with several studies. Griffin (1985) calculated -0.48 to 0.19 for OPEC member countries and -0.06 to 3.36 for 11 non-OPEC countries for the period of 1973-1997. He found a negative price elasticity of oil supply for five OPEC member countries, while negative and significant elasticity coefficients were also obtained for the other five non-OPEC countries. Jones (1990) found -0.229 to 0.048 for OPEC member countries, Krichene (2002) computed oil supply short-run price elasticity from -0.08 to 0.08 for the period of 1918–1999, and long-run price elasticities of 0.10 to 1.10. Ramcharran (2002) obtained negative and significant supply elasticity for 7 of the 11 OPEC members. Askari and Krichene's (2010) experiment results showed short-run oil supply price elasticity of -0.48 to 0.660 for the period of 1970 (Q1) to 2008 (Q4), and long-run price elasticity of -0.02 to 0.008. Some people assume that oil supply price elasticities were deliberately kept low, reasoning that oil supply was determined by oil discoveries and technological factors. We computed a small value for the long-run price elasticity of supply. Crude oil Producers may emphatically abstain from increasing production at the time of a price rise in order to preserve this gain in price, as experienced in 2002–2008. Proven oil reserves had a significant positive impact on oil supply during the period of 1960-1980 with a large coefficient of 1.13, but in the second sub period and in the main period its influence was slight and not significant.

For the income elasticity of demand, our findings suggest 0.13 (significant), 0.14 (insignificant) and 0.14 (significant) for 1960-2011, 1960-1980 and 1980-2011, respectively. The long-run elasticity for 1960-2011, however decreased to 0.005. Our findings are in line with Askari and Krichene (2010), who reported 0.02 to 0.327, and lower than the estimated value of 0.678 by

Mohaddes (2012). 1.0-1.2 was suggested by Pesaran et al (1999) for developing Asian countries, while Gately and Huntington (2002) arrived at 0.95, and Krichene's (2006) estimated 0.54 to 0.90.

For monetary policy that affects oil prices through two main channels, interest rates and exchange rates; during 1960-2011 and 1980-2011 our regressions establish a significant role for interest rate that affects oil demand. For interest rate coefficients in demand side, we calculated -0.01 (significant) for 1960-2011,

-0.02 (insignificant) for 1960-1980, and for the last period (1980-2011) -0.006 (significant). For long-run in 1960-2011 we calculated -0.03. An increase in interest rates by 100 basis points would reduce oil demand by -0.6 to -2 percent. Askari and Krichene (2010) for the interest rate coefficients of world oil demand found; -0.001, -0.002, -0.005, and -0.005 for 1970Q1–2008Q4, 1970Q1–1986Q3, 1986Q3–2001Q4, and 2001Q4–2008Q4, respectively. They measured that, an increase in interest rates by 100 basis points would reduce oil demand by -0.1 to -0.5 percent.

Our results show that global oil demand during 1960-2011 and 1980-2011 significantly influenced by interest rates, but the impact of exchange rate depreciations on oil demand was not significant, and supply actually remained constant. Aggressive monetary policy stimulates oil demand, while supply is inelastic to interest rates. The result is skyrocketing crude oil prices, which inhibit economic growth.

Stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive. Our findings for interest rates is in line with Fig.5 of this chapter that illustrates the relationship between interest rates and crude oil prices. For 1981-2011 in Fig.5 average oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time, average interest rates subsided from 16.7 percent per annum in 1981 to about 0.1 percent per annum in 2011, and our regressions show significant negative coefficient for interest rate in demand side.

Since we used demand and supply of oil in our model, we need to test the hypothesis of equilibrium vs. disequilibrium in our oil model. Section 4 tests this hypothesis.

## 4. Testing for Equilibrium vs. Disequilibrium in the Oil Market

The literature on disequilibrium in the oil market has seen a bit of a boom recently. In this section we attempt to shed light on the following question: How can one test the hypothesis of equilibrium vs. disequilibrium in oil models? The simple version of the disequilibrium oil model based on our findings is given as:

$$\begin{cases} \tilde{q}_{1t}^{d} = d_0 + d_1\tilde{p}_{1t} + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} + d_4\tilde{y}_t + d_5\tilde{i}_t + d_6\tilde{e}_t + u_{dt} \\ \tilde{q}_{t}^{s} = s_0 + s_1\tilde{p}_{1t} + s_2\tilde{i}_t + s_3\tilde{e}_t + s_4\tilde{R}_{t-1} + s_5 Z_{1t} + s_6 Z_{2t} + s_7 Z_{3t} + s_8\tilde{u}_{dt} + u'_{st} \\ \tilde{q}_{1t}^{*} = \min(\tilde{q}_{1t}^{d}, \tilde{q}_{t}^{s}) \end{cases} \tag{25}$$

$$u'_{st} = u_{st} - \eta_{st} \tag{26}$$

$$\Delta\tilde{p}_{1t} = \lambda(\tilde{q}_{1t}^{d} - \tilde{q}_{t}^{s}) \tag{27}$$

where we call $\tilde{q}_{t}^{*}$ the *equilibrium quantity,* in which we assume that the price equation is non-stochastic. This type of testing for the hypothesis of equilibrium vs. disequilibrium in the oil market by incorporating monetary factors is another unique part of this chapter that has not been found in earlier studies. Various estimation methods have been proposed for this model, and maximum likelihood methods are available. In addition, several two-stage, three–stage and instrumental-variable estimators are possible, according to Amemya (1974), Laffont and Monfort (1979), Goldfeld and Quandt (1980) and Ito and Ueda (1981). In this chapter we follow Goldfeld and Quandt (1980) and Bowden's (1978) methods.

If we solve for the reduced form of the price equation in our model, we obtain:

$$\tilde{p}_{1t} = \frac{1}{\frac{1}{\lambda} + (s_1 - d_1)} \begin{bmatrix} (d_0 - s_0) + (d_5 - s_2)\tilde{i}_t + (d_6 - s_3)\tilde{e}_t \\ + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} + d_4\tilde{y}_t - s_4\tilde{R}_{t-1} - s_5 Z_{1t} \\ - s_6 Z_{2t} - s_7 Z_{3t} - s_8\tilde{u}_{dt} + (u_{dt} - u'_{st}) \end{bmatrix} + \frac{\tilde{p}_{1t-1}}{1 - \lambda(d_1 - s_1)} \tag{28}$$

Based on this, we write the equilibrium model as is given below:

$$\begin{cases} \tilde{q}_{1t}^{d} = d_0 + d_1\tilde{p}_{1t}^{*} + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} + d_4\tilde{y}_t + d_5\tilde{i}_t + d_6\tilde{e}_t + u_{dt} \\ \tilde{q}_{t}^{s} = s_0 + s_1\tilde{p}_{1t}^{*} + s_2\tilde{i}_t + s_3\tilde{e}_t + s_4\tilde{R}_{t-1} + s_5 Z_{1t} + s_6 Z_{2t} + s_7 Z_{3t} + s_8\tilde{u}_{dt} + u'_{st} \\ \tilde{q}_{1t}^{*} = \tilde{q}_{1t}^{d} = \tilde{q}_{t}^{s} \end{cases} \tag{29}$$

where $\tilde{p}_{1t}^{*}$ denotes the market clearing price of crude oil:

$$\tilde{p}_{1t}^{*} = \frac{1}{s_1 - d_1}\begin{bmatrix} (d_0 - s_0) + (d_5 - s_2)\tilde{i}_t + (d_6 - s_3)\tilde{e}_t + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} \\ + d_4\tilde{y}_t - s_4\tilde{R}_{t-1} - s_5 Z_{1t} - s_6 Z_{2t} - s_7 Z_{3t} - s_8\tilde{u}_{dt} \end{bmatrix} + \frac{u_{dt} - u'_{st}}{s_1 - d_1} \tag{30}$$

$$\tilde{q}_{1t}^{*} = \frac{\begin{bmatrix} (s_1 d_0 - d_1 s_0) + (s_1 d_5 - d_1 s_2)\tilde{i}_t + (s_1 d_6 - d_1 s_3)\tilde{e}_t + s_1 d_2\tilde{p}_{2t} \\ + s_1 d_3\tilde{p}_{3t} + s_1 d_4\tilde{y}_t - d_1 s_4\tilde{R}_{t-1} - d_1 s_5 Z_{1t} - d_1 s_6 Z_{2t} - d_1 s_7 Z_{3t} - d_1 s_8\tilde{u}_{dt} \end{bmatrix}}{s_1 - d_1} + \frac{s_1 u_{dt} - d_1 u'_{st}}{s_1 - d_1} \tag{31}$$

The equilibrium is close to the disequilibrium model, in which prices adjust instantly. We judge the result of testing equilibrium vs. disequilibrium by looking at the size of $\lambda$ which is "Adjustment speed". If it is large, the process of adjustment is rapid. In other words: $\lim_{\lambda\to\infty}\tilde{p}_{1t} = \tilde{p}_{1t}^{*}$ and $\lim_{\lambda\to\infty}\tilde{q}_1^{d} = \lim_{\lambda\to\infty}\tilde{q}^{s} = \tilde{q}_{1t}^{*}$. But because it is inefficient to test whether $\lambda$ is large enough to accept the hypothesis of equilibrium in the market, Bowden (1978) provided a more convenient formulation of this method:

$$\tilde{p}_{1t} = \delta\tilde{p}_{1t-1} + (1-\delta)\tilde{p}_{1t}^{*} \tag{32}$$

$$\tilde{p}_{1t} = \delta\tilde{p}_{1t-1} + (1-\delta)\left[\frac{1}{s_1 - d_1}\begin{bmatrix} (d_0 - s_0) + (d_5 - s_2)\tilde{i}_t + (d_6 - s_3)\tilde{e}_t + d_2\tilde{p}_{2t} + d_3\tilde{p}_{3t} \\ + d_4\tilde{y}_t - s_4\tilde{R}_{t-1} - s_5 Z_{1t} - s_6 Z_{2t} - s_7 Z_{3t} - s_8\tilde{u}_{dt} \end{bmatrix} + \frac{u_{dt} - u'_{st}}{s_1 - d_1}\right] \tag{33}$$

In the above equation $\tilde{p}_{1t}^{*}$ is given by Eq. 30 and $\lim_{\delta\to 0}\tilde{p}_{1t} = \tilde{p}_{1t}^{*}$ , $\lim_{\delta\to 0}\tilde{q}_1^{d} = \lim_{\delta\to 0}\tilde{q}_t^{s} = \tilde{q}_{1t}^{*}$ . In this reformulation, equilibrium corresponds to $\delta = 0$. Although perhaps not immediately apparent, the Bowden formulation is equivalent to re-parameterizing Eq. 27. This can be seen most easily by substituting for $\tilde{p}_{1t}^{*}$ from Eq.30 into Eq.32. The result is Eq.33 with $\delta = 1/1 - \lambda(d_1 - s_1)$ . Thus Eq.32

is directly analogues to Eq.27 and the equilibrium condition $\lambda = \propto$ is equivalent to $\delta = 0$. From the point of view of hypothesis testing, the Bowden formulation is obviously of considerable convenience (Goldfeld and Quandt, 1980). Now by testing the null hypothesis that $\delta = 0$, we can evaluate the equilibrium vs. disequilibrium in the oil market. Table 4 shows the results of estimated coefficients for a reduced form equation. We could not reject the null hypothesis for $\tilde{p}_{1t-1}$ 's coefficient (t=1.50). This suggests rapid adjustment in the oil market and equilibrium during the period of 1960-2011, which means that we can retain our empirical results in section 3.2.

**Table 4. Reduced form equation with substituted coefficients: 1960-2011**

$$\tilde{p}_1 = 0.19\tilde{p}_1(-1) - 0.02\tilde{i} - 1.65\tilde{e} - 0.026\tilde{y} + 0.57\tilde{p}_2 + 0.46\tilde{p}_3 + 0.47\tilde{R} - 0.23Z_1 + 0.33Z_2 + 0.21Z_3 + 1.87\tilde{u}_{dt}$$

(1.50) (-1.15) (-5.25)** (-0.22) (4.29)** ( 2.89)** (1.85) (-1.07) (2.04)* (1.01) (1.05)

R-squared= 0.95

Durbin-Watson stat= 1.62

T-statistics are in parentheses, * indicates significance at 5% ** indicates significance at 1%

# 5. Conclusions

In this chapter we examined the global crude oil market over the period of 1960-2011. We analyzed the properties of oil markets and determinants of crude oil prices during this period. In order to reach worthwhile analytical results, we have done our estimations during the main period above and two sub-periods, 1960-1980 and 1980-2011. The reason for classifying in this way is that, while most price volatilities during 1970s have supply reasons, we believe in the second period, crude oil prices skyrocketed mainly due to another type of inflating pressure. We argued that this second period, with the exception of Persian Gulf War (1990-1991) oil price shock, had another reason for its price expansion, which was on the demand side instead of the supply side. In this research, we explained that in most cases, this uninterrupted price increase was caused by expansionary monetary policies that led to low interest rates, credit demand augmentation, and aggregate demand expansion, which heightened oil prices. We found that global oil demand was significantly influenced by interest rates, but the impact of exchange rate depreciations on oil demand was not significant, and supply actually remained constant. Aggressive monetary policy stimulates oil demand, while supply is inelastic to interest rates. The result is skyrocketing crude oil prices, which inhibit economic growth. We argue that stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive.

At the same time, we reviewed crude oil price determinants and price properties, as well as elasticities during the main period and two sub-periods. We found that price elasticity of crude oil demand decreased in the second sub-period, because the crude oil market administrated a large structural change after the 1970s oil shocks: high energy-taxation in oil importing countries, the establishment of the Strategic Petroleum Reserve (SPR), and a raise in share of other energy carriers such as natural gas in the energy baskets of energy importing countries. These factors all contributed significantly to the reduction in demand elasticity. For the income elasticity of demand, our findings suggests significant elasticity during 1960-2011 and 1980-2011. Unlike earlier research studies, we found that oil supply is elastic to prices in short-run, and during the second sub-period, the price elasticity increased compared to the first sub-period. Our attempts to test the hypothesis of equilibrium vs. disequilibrium in the oil market showed that crude oil prices adjust instantly and the results declare the existence of equilibrium in the oil market during the total period of 1960-2011.

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# Chapter 2: Which Side of The Economy is Affected More by Oil Prices: Supply or Demand?[19]

## Abstract

This chapter develops a New-Keynesian model to examine a theoretical global economy with two basic macroeconomic components: An energy[20] producer and an energy consumer. This simple economy uses these two components to evaluate how oil prices affect the consumer economy's GDP and inflation over the period 1960-2011. This model assumes that changes in the oil price 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, an IS curve is used to look at the demand side and a Phillips curve is used to analyze inflationary effects from the supply side. The empirical analysis concludes that movements in the oil price mainly affect the economy through the demand side (shifting the Aggregate demand curve) by affecting household expenditures and energy consumption. This analysis provides several additional findings, among

[19] Another version of this chapter is available as:

Taghizadeh H.F. and Yoshino, N. (2013) '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, Ohio, US.

[20] From now on in this chapter whenever we refer to the "energy" or "energy prices", we refer to "crude oil" and "crude oil price", which is the main source of energy.

which is the finding that easy monetary policies amplify energy demand more than supply, resulting in skyrocketing crude oil prices, which inhibit economic growth.

Keywords: Oil prices, New-Keynesian model, IS Curve, Phillips curve, monetary policies,

JEL classification: Q41, Q43, E12, E52,

# 1. Introduction

Both the sharp increase in oil prices that began in 2001 and the sharp decline that followed in 2008 have renewed interest in the effects of oil prices on the Macroeconomy. Much research has been done on this subject, and the findings consistently indicate that rising oil prices have a large adverse impact on the rate of GDP growth. Bohi (1991), for example, examined the oil shocks in the 1970's by analyzing disaggregated industry data for Japan, the U.S., the U.K., and Germany, and found that each price shock sparked a decline in GDP. Hamilton (1983) turned his attention to the U.S. economic recession that followed these oil shocks, and hypothesized that this recession was due in large part to elevated oil prices. He came to this conclusion by using the Granger-causality model along with six other variables that can reduce the real U.S. GDP. Alterman (1985) brought a higher level of specificity to his analysis, stating that higher energy prices could have accounted for a decline in the growth of the U.S. GNP by as much as 0.72% in 1974 and 0.36% in 1979-1980. To give a basis for comparison, actual GNP growth went from 4.5% in 1972-1973 to -0.8% during 1974-1975, and from 4.7% during 1976-1978 to 0.9% during 1979-1980. Javier (1993) found the absolute value of the price elasticity of GNP on the price of oil to be 0.055%. Cunado and Perez de Gracia (2003) turned their research to a sample of several European economies and found that oil prices have a significant impact growth in Europe as well, and in a more recent study, Taghizadeh et al. (2013) evaluated the impact of oil price shocks on oil producing and consuming economies, examining their trade patterns during 1991Q1 2011Q4. They found that among oil-producers in their survey, Iran and Russia benefit from oil price shocks but Canada seems to suffer, while for oil-consuming economies, the effects are more diverse, with some benefitting and others ending up worse off.

These papers have mainly empirical approaches to their research, however, a theoretical analysis in this field is relatively scarce. In addition to the lack of theoretical foundation behind the analyses contained in these papers, they often contradict each other when it comes to the issue of whether the supply of economy (aggregate supply) or demand side of the economy (aggregate demand) is affected more by increases in the oil price. Research in the early 1980s tended to indicate that the supply side of the economy was more heavily impacted by changes in the oil price, but recent research often states that the demand side of the economy takes more of the brunt. This includes Bernanke (2006), who states that the demand channel is the more affected of the two because of decreases in consumer spending. In this chapter, we use a solid theoretical base followed by empirical analysis to determine which side of the economy is more greatly affected by oil prices movements: Supply or demand.

**Table 1. Principal Causes of Crude Oil Price Increases: 1947–2011**

| Oil Price Episode | Principal Factors |
|---|---|
| 1947–48 | Previous investment in production and transportation capacity inadequate to meet postwar needs; decreased coal production resulting from shorter work week; European reconstruction |
| 1952–53 | Iranian oil nationalization; strikes by oil, coal, and steel workers; import stance of the Texas Railroad Commission |
| 1956–57 | Suez Crisis |
| 1969 | Secular decline in U.S. reserves; strikes by oil workers |
| 1970 | Rupture of trans-Arabian pipeline; Libyan production cutbacks; coal price increases (strikes by coal workers; increased coal exports; environmental legislation) |
| 1973–74 | Stagnating U.S. production; OPEC embargo |
| 1978–79 | Islamic revolution of Iran |
| 1980–81 | Iran-Iraq war; removal of U.S. price controls |
| 1990 | Iraqi invasion of Kuwait and the Persian Gulf War |
| 1998–2000 | Asian financial crisis, Asian Pacific oil consumption decline |
| 2011 | Libyan uprising |

**Source: 1947–1981 from Hamilton (1983), 1990-2011 from Taghizadeh et al. (2013)**

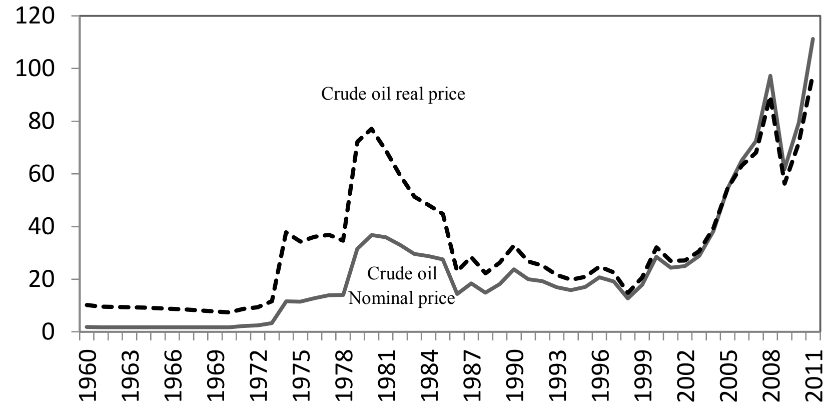


**Fig. 1. Crude oil prices 1960 – 2011**: Prices are in U.S. dollars per barrel. 1960-1983: Arabian Light posted at Ras Tanura.1984-2011: Brent dated. The dashed line is real price, and the solid line is the nominal price. Source of Figure: Taghizadeh and Yoshino (2014)

Figure 1 illustrates crude oil price movements in nominal and real terms during 1960-2011. Causes for major price movements become clear when comparing Figure 1 with Table 1. 1973-1974: stagnating U.S. production and OPEC embargo, 1978-79: Islamic revolution of Iran, 1980-81: Iran-Iraq war and removal of U.S. price controls, 1990: Iraqi invasion of Kuwait; The Persian Gulf War, 1998-2000: Asian financial crisis; Asian Pacific oil consumption decline and 2011 price increases caused by the Libyan uprising.

We ran this research in order to achieve three purposes: (i) to determine the channels of transmission of higher oil prices to the Macroeconomy. (ii) To develop a theoretical framework that could explain the role of oil prices in both the demand and supply sides of the economy while contributing toward asserting our empirical yields. (iii) To clarify the role of monetary policy impacts on the demand and supply sides of the oil market. For these purposes, we developed a New-Keynesian model for an open-economy with a Micro foundation for two economies: (i) Energy consumers and (ii) Energy producers. We used this model to evaluate how oil prices affect the macroeconomic variables of output and inflation over the period 1960-2011.

For the first purpose of writing this chapter (listed above), we assume that: In the New-Keynesian model that we developed, oil price changes can be transmitted through two channels to macro variables. Our model allows oil prices to have temporary and persistent effects on output through the supply and the demand sides of the economy. Stated more specifically, we allow oil prices to shift the IS curve to proxy for temporary demand-side effects and to affect the Phillips curve to capture inflationary effects through the supply side.

This chapter is structured as follows. In the following section we present theoretical framework, which describes theoretical considerations. After this, we present the three parts of our model: households, firms and energy producers. The last part of this section is for monetary policies and crude oil prices. The third section describes our empirical analysis, which includes data and empirical results. The forth section is for our conclusions.

# 2. Theoretical framework

## *2.1. Theoretical considerations*

As stated earlier, there are two channels for transmission of crude oil price movements to the economy. We refer to these two channels as case 1 and 2. In case 1, the aggregate supply channel is stated as the main transmission channel of oil price movements and in case 2 the aggregate demand channel is shown as the main transmission channel of oil price movements to the economy:

**Case 1) Oil shocks mainly affect the supply side of the economy (Aggregate supply is the main transmission channel of oil shocks)**

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

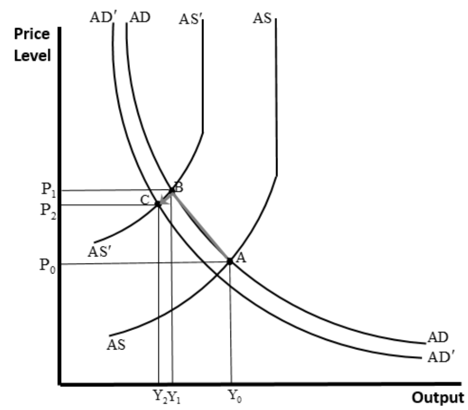


**Fig. 2. The effect of higher relative price of crude oil (energy price) on output and the price level**

*(Case 1: Supply side of the economy is more affected by oil shocks compared to demand side)*

In Figure 2, the economy initially is in equilibrium with price level, $P_0$ and real output level, $Y_0$ , 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 (Tatom, 1981). 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 $Y_1$. 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 ($P_1$), given the nominal wage rate. This moves the economy to the level of output ($Y_1$) and price level ($P_1$). This point is indicated in Figure 2 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 $P_1$ and sets them to $P_2$ as the final equilibrium price. This lowers the output levels due to less consumption in the economy, from the previous point of $Y_1$ to $Y_2$. This point is indicated in Figure 2 at point $C$, which is the final equilibrium point.

This is an issue that (Tatom, 1981) did not mention in his paper, as he only examined AS movements in his analysis and not AD movements.

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 2.

In Case 1, 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 ($A$).

**Case 2) Oil shocks mainly transmit through the demand side of the economy (Aggregate demand is the main transmission channel of oil shocks)**

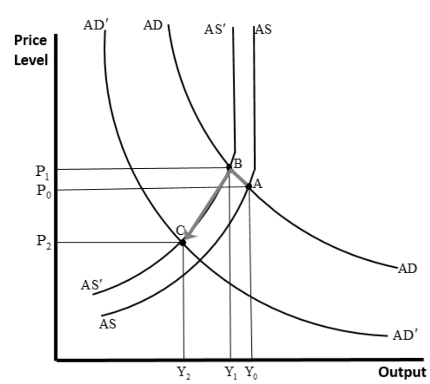


**Fig. 3. The effect of higher relative price of crude oil (energy price) on output and the price level**

*(Case 2: demand side of the economy is mainly affected by oil shocks comparing to supply side*

As per case 1, in this case also, the economy initially is in equilibrium with price level $P_0$, and real out level $Y_0$. Initial equilibrium point is indicated in Figure 3 at point $A$. When the relative price of energy resources 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 $Y_1$. 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 ($P_1$), given the nominal wage rate. This moves the economy to the level of output ($Y_1$) and price level ($P_1$), indicated in Figure 3 at point $B$, which is a disequilibrium point. On the demand side of economy, higher energy prices (crude oil, natural gas, coal and etc.) force consumption to decline, which reduces the total consumption of the economy, resulting in a shift of the aggregate demand curve to $AD'$. This shift reduces prices from the previous level of $P_1$ and sets them to $P_2$ as the final equilibrium price, while also lowering output levels because of lower consumption in the economy. Consumption moves from the previous point; $Y_1$ to the new point $Y_2$, showing that the final equilibrium point is $C$.

In Case 2, aggregate demand is the main chain of transmission of energy price shocks. As can be seen in Figure 3, the shift in the aggregate demand curve is larger than the one in the aggregate supply curve, resulting in lower prices and lower output levels in the final equilibrium point ($C$) than the initial equilibrium point ($A$).

## *2.2. Basic Model*

We provide a model in New Keynesian framework following Yoshino et al. (2012), in which we assume that there are two economies in the world; an energy consumer (in this chapter, U.S.[21]) and

[21] In 2010 the U.S. consumed over 19 million (bbl/day), which was more than 20% of global consumption. Despite the growth in crude oil consumption in China, Russia, Latin America and Middle East, the U.S. remains by far the largest user of oil. In our research since we have to use one country as the consumer of crude oil, and the U.S. is the best choice because of its huge consumption of oil.

an energy producer. In the energy consumer economy, there are two sectors: households and firms. Both sectors import energy from the energy producing country.

*2.2.1. Households*

Let $C_t$ be the following index of consumption of non-energy commodities ($C_t^{NG}$) and energy goods ($C_t^G$):[22]

$$C_t = (C_t^{NG})^A (C_t^G)^{1-A}; A < 1 \tag{1}$$

where $A$ is the elasticity of substitution between two groups of commodities. We then can write the consumption price index (CPI) as follows[23]:

$$P_t^C = \left(\frac{A}{P_t^{NG}}\right)^{-A} \left(\frac{1-A}{P_t^G}\right)^{A-1} \tag{2}$$

Where $P_t^C$ denotes consumer price index (CPI) and $P_t^{NG}$ and $P_t^G$ are the prices of non- energy commodities, and energy, respectively.

The utility of a representative household is a function of: $U_t = f(\overset{+}{C_t}, \overset{-}{L_t}, \overset{+}{M_t})$ , so the utility function of a representative household can be expressed by the following:

$$U_t = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\eta}(C_t)^{1-\eta} - \frac{1}{1+\kappa}(L_t)^{1+\kappa} + \frac{\chi}{1-\sigma}(M_t)^{1-\sigma} \right] \tag{3}$$

[22] By cost minimization of the representative household, we obtain the following demand condition. As in Dixit-Stiglitz (1977), Clarida et al. (2002) and Yoshino et al. (2012), the purchase of each good satisfies the following:

$$C_t^{NG} = AC_t \left(\frac{P_t^{NG}}{P_t^C}\right)^{-1} \tag{1}$$

$$C_t^G = (1-A)C_t \left(\frac{P_t^G}{P_t^C}\right)^{-1} \tag{2}$$

[23] Substituting (1) and (2) of footnote no. 22 into Eq. 1 of the main text, the consumption price index (CPI) yields:

$$P_t^C = \left(\frac{A}{P_t^{NG}}\right)^{-A} \left(\frac{1-A}{P_t^G}\right)^{A-1} \tag{1}$$

Inside the brackets, the first term captures the instantaneous utility from consumption (both energy and non-energy commodities), the second term expresses disutility from labor effort, and the last term defines the instantaneous utility from money holdings, where $M_t$ denotes the representative household's real money holding, $L_t$ is the labor supply by the representative household, and $\beta^t$ is the discount factor. The household's budget constraint in real terms is:

$$C_t = \frac{W_t}{P_t^C} L_t - \frac{M_t - M_{t-1}}{P_t^C} \tag{4}$$

Where $W_t$ denotes the household's nominal wage per hour working. The representative household maximizes (3) subject to (4). The Euler[24], money demand and labor supply equations are derived from first-order conditions with respect to consumption in t and t+1, money holdings, and labor.

$$\frac{(C_t)^{-\eta}}{P_t^C} = \beta E_t\left[\frac{(C_{t+1})^{-\eta}}{P_{t+1}^C}\right] \tag{5}$$

$$(M_t)^{-\sigma} = \frac{(C_t)^{-\eta}}{P_t^C \chi} \tag{6}$$

$$\frac{W_t}{P_t^C} = \frac{(L_t)^k}{(C_t)^{-\eta}} \tag{7}$$

Equations (5)-(7) are Euler, money demand and labor supply equations respectively (See section "a" of the Appendix for log-linearized versions).

The demand of representative household for energy is as follows (see section "b" of the Appendix for mathematical works):

$$C_t^G = \left(\frac{1-A}{A}\right)^A \frac{\alpha_o \left(E_t M_{t+1}\right)^{\frac{\sigma}{\eta}} \left(W_t\right)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}} \left(P_t^G\right)^{\frac{1-A(1-\eta)}{\eta}} \left(L_t\right)^{\frac{\kappa}{\eta}} \left(M_t\right)^{\frac{\sigma}{\eta}}} \tag{8}$$

---

[24] Euler equation:

$$\frac{(C_t)^{-\eta}}{P_t^C} = \beta E_t\left[\frac{(C_{t+1})^{-\eta}}{P_{t+1}^C}(1+i_t)\right] \tag{1}$$

Where i is the interest rate or nominal yields of bonds in time t, but since the representative household's utility is indifferent with bonds and their yields, here our Euler equation is different from the one above.

where $Log\alpha_0 = \frac{-b-\varepsilon-(A-1)z+Aa}{\eta} > 0$

Let's consider the following monetary equation:

$$E_t M_{t+1} = \Omega(E_t \pi_{t+1} - E_{t-1}\pi_t) \qquad (9)$$

where $E_t \pi_{t+1}$ and $E_t M_{t+1}$ are the expected values of the inflation rate and money supply of the next period, respectively. We rewrite the representative household demand for energy as follows:

$$C_t^G = \left(\frac{1-A}{A}\right)^A \frac{\alpha_o \left[\Omega(E_t\pi_{t+1} - E_{t-1}\pi_t)\right]^{\frac{\sigma}{\eta}} (W_t)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}} \left(P_t^G\right)^{\frac{1-A(1-\eta)}{\eta}} (L_t)^{\frac{\kappa}{\eta}} (M_t)^{\frac{\sigma}{\eta}}} \qquad (10)$$

*2.2.2. Firms*

Here, we have a representative firm whose production depends on the employment of labor, energy input and capital. This firm's production function may be written as:

$$Q_t = A_t L_t^{\phi} G_t^{\varpi} \overline{K} \qquad (11)$$

Where $Q_t$ is output, $L_t$ is labor measured in man-hours, $G_t$ is the flow of energy in barrels of crude oil, $\overline{K}$ is capital in USD, which is fixed amount, and t is time. $A_t$ is a time-varying exogenous technology parameter, and $\phi, \varpi$ are the output elasticities of labor and energy inputs respectively. As in Woodford (2003) we may think of capital as being allocated to each firm in a fixed amount, with capital goods never depreciating, never being produced, and (because they are specific to the firm that uses them) never being reallocated among firms; in this case, the additional argument of the production function may be suppressed. The estimated production function was restricted by requiring that the sum of the exponents $\phi, \varpi$ equal unity. The basic implications of such a "Cobb-Douglas" production function are constant returns to scale and partial elasticities of unity substitution. By assuming profit maximization behavior of the representative firm, it employs each of these inputs where their value of marginal production is equal to their respective prices. With the energy parameter, for instance, the representative firm employs energy at a rate where the following condition is fulfilled:

$$VMP_t^G = P_t^G \qquad (12)$$

Where $VMP_t^G$ denotes value of marginal production of energy and $P_t^G$ represents the energy price[25]. We obtain the following demand equations for labor and energy inputs, respectively:

$$L_t = \phi Q_t \left( \frac{W_t}{P_t^C} \right)^{-1} \tag{13}$$

$$G_t = \varpi Q_t \left( \frac{P_t^G}{P_t^C} \right)^{-1} \tag{14}$$

As in Woodford (2003), we assume that the supplier of each good chooses a price for it at each period, and is not constrained in any way by the price that has been charged for the good in the past. This supplier has complete information about current demand and cost conditions. As is typically found in a model of monopolistic competition, it is assumed that each supplier understands that his sales depend upon the price charged for his goods, according to the demand function[26]:

$$Q_t = Y_t \left( \frac{P_t^{NG}}{P_t^c} \right)^{-1} \tag{15}$$

The index of aggregate demand $Y_t$ corresponds simply to the representative household's choice of the index $C_t$. Using Eq. 13 and 14 we write the representative firm's real total cost function as follows:

$$TC_t = Q_t(\phi W_t + \varpi P_t^G) \tag{16}$$

The equation above shows that an increase in energy prices raises the representative firm's cost function family, including total cost and real marginal cost (see section "c" of the Appendix for derivatives).

On the other hand, the Phillips curve (See section "d" of the Appendix for mathematical works) will be as follows:

[25] Crude oil prices, in USD per barrel

[26] We assumed that the total output $Y_t$ in this economy consists of two subsectors, industrial output $Q_t$ and service output, which is assumed to have been determined out of our model. ($Y_t = Q_t$ + service sector output)

$$\pi_t = \left(\frac{1}{\psi}+\omega\right)\left(\iota p_{t-1}^{G}+(1-\iota)p_{t-1}^{NG}\right)-\frac{1}{\psi}\left(p_{t-2}^{c}\right)-\frac{\xi}{\psi}\left[(\omega+\sigma^{-1})\left(\hat{Y}_{t-1}-\hat{Y}_{t-1}^{n}\right)\right]+\varepsilon_t \tag{17}$$

Where $\varepsilon_t$ is the expectation shock term, identically distributed with mean zero and uncorrelated with the exogenous variables.[27]

Finally, since there is a state of equilibrium in our model, we have $Y_t = C_t^G + C_t^{NG}$. Using this equation the New Keynesian IS curve equation yields:

$$Y_t = \left(\frac{1-A}{A}\right)^{A} \frac{\alpha_o\left[\Omega(E_t\pi_{t+1}-E_{t-1}\pi_t)\right]^{\frac{\sigma}{\eta}}\left(W_t\right)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}}\left(P_t^{G}\right)^{\frac{1-A(1-\eta)}{\eta}}\left(L_t\right)^{\frac{\kappa}{\eta}}\left(M_t\right)^{\frac{\sigma}{\eta}}}+C_t^{NG} \tag{18}$$

Since $\alpha_o$ contains b, which is the Log of $\beta$ (the discount factor of the representative household's utility function), shows that IS is a function of interest rate as well.

The total energy demand in our model is equal to the summation of the representative household's energy consumption and the energy input of the firm, which is shown as $q_t^D$, so $q_t^D = C_t^G + G_t$. Now by substituting the household energy consumption and firm's energy input in this equation, and by assuming equilibrium in the labor market, we can obtain the total energy demand:

$$q_t^D = \left(\frac{1-A}{A}\right)^{A} \frac{\alpha_o\left[\Omega(E_t\pi_{t+1}-E_{t-1}\pi_t)\right]^{\frac{\sigma}{\eta}}\left(W_t\right)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}}\left(P_t^{G}\right)^{\frac{1-A(1-\eta)}{\eta}}\left(L_t\right)^{\frac{\kappa}{\eta}}\left(M_t\right)^{\frac{\sigma}{\eta}}}+\varpi Q_t\left(\frac{P_t^C}{P_t^G}\right) \tag{19}$$

Then we can write (See section "e" of the Appendix for mathematical works):

$$E_t\pi_{t+1}-E_{t-1}\pi_t = \frac{1}{\psi}\left[(\Delta\pi_t)-\xi(\Delta\vartheta_t)\right] \tag{20}$$

After this, by substituting Eq. 20 in Eq. 18 and Eq. 19 in order to release the IS curve and final energy demand, the following can be obtained:

$$Y_t = \left(\frac{1-A}{A}\right)^{A} \frac{\alpha_o\left(\frac{\Omega}{\psi}\left[(\Delta\pi_t)-\xi(\Delta\vartheta_t)\right]\right)^{\frac{\sigma}{\eta}}\left(W_t\right)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}}\left(P_t^{G}\right)^{\frac{1-A(1-\eta)}{\eta}}\left(L_t\right)^{\frac{\kappa}{\eta}}\left(M_t\right)^{\frac{\sigma}{\eta}}}+C_t^{NG} \tag{21}$$

[27] $\varepsilon_t$ obtained from the following equation:

$$\varepsilon_t = \xi\left[(\omega+\sigma^{-1})\left(\hat{Y}_t-\hat{Y}_t^{n}\right)+\iota\omega(p_t^G-\iota p_t^{NG})\right]-\xi E_t\left[(\omega+\sigma^{-1})\left(\hat{Y}_t-\hat{Y}_t^{n}\right)+\iota\omega(p_t^G-\iota p_t^{NG})\right] \tag{1}$$

$$q_t^D = \left(\frac{1-A}{A}\right)^A \frac{\alpha_o \left(\frac{\Omega}{\psi}\left[\left(\Delta\pi_t\right)-\xi\left(\Delta\vartheta_t\right)\right]\right)^{\frac{\sigma}{\eta}} \left(W_t\right)^{\frac{1}{\eta}}}{\left(P_t^{NG}\right)^{\frac{A(1-\eta)}{\eta}} \left(P_t^G\right)^{\frac{1-A(1-\eta)}{\eta}} \left(L_t\right)^{\frac{\kappa}{\eta}} \left(M_t\right)^{\frac{\sigma}{\eta}}} + \varpi Q_t \left(\frac{P_t^C}{P_t^G}\right) \tag{22}$$

Eq. 21 and Eq. 22 are final IS curve and final energy demand equations, respectively.

### *2.2.3. Energy producers:*

As for energy producer section, we followed Taghizadeh and Yoshino's (2014) model. Supposing that over the period t-1 to t, crude oil output or extraction of crude oil is given by $q_t^s$, we write the following equations:

$$Q_t^s = \sum_{t=0}^{T} q_t^S \tag{23}$$

$$R_t + Q_t^s = R_{t-1} + Q_{t-1}^s \tag{24}$$

$$R_t = R_{t-1} - q_t^s \tag{25}$$

Where $Q_t^s$ is the cumulative extraction at the end of period t, and $R_t$ is the proven crude oil reserves at period t. Eq. 25 states that the amount of proven oil is diminishing every year by $q_t^s$. Eq. 25 is under the condition that there is no new discovery of oil. The cost function is obtained from a convex function, depending negatively on the amount of remaining proven reserves. The so-called stock effect is mainly due to the pressure dynamics affecting petroleum extraction. This type of cost specification is also considered by Livernois and Uhler (1987), Farzin (1992), Favero et al. (1994), and more recently by Taghizadeh and Yoshino (2014). Here we represent modified version of it:

$$C_t(q_t^S, R_{t-1}) = \alpha\left(q_t^S\right) - \frac{1}{2}\beta(R_{t-1})^2 > 0, \alpha > 0, \beta > 0 \tag{27}$$

The first part of this cost function $\alpha\left(q_t^S\right)$ represents extraction cost, and the second part of it $\frac{1}{2}\beta(R_{t-1})^2$ shows scarcity cost. Crude oil suppliers will choose an extraction profile to maximize the discounted stream of profits over the life of the field.

$$Max\sum_{t=0}^{T}\theta^{t}\left[\pi_{t}(q_{t}^{S},R_{t-1})\right]\ 0\leq\theta<1 \tag{28}$$

$$\text{s.t. } (R_{t}-R_{t-1})=-q_{t}^{s} \tag{29}$$

$$\theta=1/(1+r+\omega);r>0 \tag{30}$$

Where $\theta$ is the subjective rate of discount, and $\omega$ is the risk premium. We write the profit equation for a crude oil producer, which is the function of expected possession price at time *t*, in relation to the output of crude oil:

$$\Pi_{t}=\theta\left[e_{t}E_{t-1}(P_{t}^{G})q_{t}^{S}-\alpha\left(q_{t}^{s}\right)+\frac{1}{2}\beta(R_{t-1})^{2}\right] \tag{31}$$

Where $E_{t-1}P_{t}^{G}$ is the expected real price of crude oil in USD per barrel, $e_{t}$ denotes the real effective exchange rate of USD, since the oil producer supplies the product to customers in the U.S. and receives USD in return. The exchange rate is the first channel through which monetary policies affect the supply side of the crude oil market. By assuming profit maximization behavior by the oil producer in oligopolistic market, the optimal oil supply equation is derived[28] as follows:

$$q_{t}^{S}=-\frac{e_{t}E_{t-1}(P_{t}^{G})+\beta(R_{t-1})-\alpha}{e_{t}E_{t-1}\left(\partial P_{t}^{G}/\partial q_{t}^{s}\right)} \tag{32}$$

As we know $\left(\partial P_{t}^{G}/\partial q_{t}^{s}\right)\leq 0$, means that when the supply of oil increases its price declines, and $\left(\partial q_{t}^{s}/\partial R_{t-1}\right)\geq 0$ means that larger oil reserves give a larger supply, and finally $\left(\partial q_{t}^{s}/\partial P_{t}^{G}\right)\geq 0$ means that when the price of crude oil rises, supply will grow larger.

The expected variable $E_{t-1}(P_{t}^{G})$ is formed rationally: $E_{t-1}(P_{t}^{G})=E_{t-1}(P_{t}^{G}|I_{t-1})$. $I_{t-1}$ is the information set in the period $t\text{-}1$, upon which expectations $E_{t-1}(P_{t}^{G}|I_{t-1})$ were based. Following McCallum (1976), the actual and expected prices are expressed as: $P_{t}^{G}=E_{t-1}(P_{t}^{G})+\eta_{s}$, where $\eta_{s}$ is a forecast error that is uncorrelated with $I_{t-1}$. In addition, as per Hausman et al., (1987) and Revankar & Yoshino (1990), we can obtain the estimated residual from our crude oil demand equation as the explanatory variable $\hat{u}_d$. We rearranged Eq. 32 by substituting for $E_{t-1}(P_t^G|I_{t-1})$. Later on in our empirical section, we need to add $\hat{u}_d$ to our supply equation, which acts as the information set.

$$q_t^S = -\frac{e_t E_{t-1}(P_t^G|I_{t-1}) + \beta(R_{t-1}) - \alpha}{e_t E_{t-1}\left(\partial P_t^G / \partial q_t^s\right)} \tag{33}$$

As the Hotelling rule states, the price of net marginal extraction cost of resources (here $\alpha$) is expected to rise with the discount rate, r, This is the second channel through which monetary factors have an effect on the energy supply side of our model. As previously stated, exchange rate is the first channel.[29] Therefore, the supply of crude oil is a function of the following: Expected price, proven crude oil reserves and monetary factors.

## *2.3. Monetary policies and crude oil prices*

Determining which side is affected more by oil prices makes it possible to clarify the ways in which monetary policy impacts the supply and demand sides of the oil market. It is stated by Bernanke et al. (1997) that the Federal Reserve raises interest rates too much in response to high oil prices, a practice that depresses economic activity beyond the negative effect of oil price shocks. Several papers, however, critically reevaluate Bernanke et al. (1997). For example, Leduc and Sill's (2004) findings approximated the Federal Reserve's behavior starting in 1979, showing that monetary policy contributes to an approximate 40 percent of drop in output following a rise in oil prices. Or, in a more recent research study, Anna Kormilitsina (2011) used an estimated dynamic stochastic general equilibrium model with the demand for oil to contrast the Ramsey optimal with estimated monetary policy. This study found that monetary policy amplified the negative effects of the oil price shock. In their 2014 research, Taghizadeh and Yoshino (2014) developed a global oil model and found significant impacts from U.S. money market rates as the key interest rate on the demand side of the global oil market, which raise oil prices even higher. Aggressive monetary policies led to low interest rates, credit demand augmentation, and aggregate

[29] Since oil is expected to be depleted at time $T$, it must be that $E_{T-1}(q_T^s) = E_{T-1}(R_{T-1} - R_T)$ and $E_T(q_{T+1}^s) = 0$. That is, in the period after the last barrel of oil is extracted, extraction of oil must be equal to zero. $\beta$ is a function of the interest rate, so the resulting implicit function for crude oil supply is : $q_t^S = n(P_t^G, i_t, e_t, R_{t-1})$ ; where $i_t$ is the interest rate at time t.

demand expansion, all of which served to heighten oil prices. According to this research, oil demand was significantly influenced by interest rates, a key factor of monetary policies.

Monetary policies affect oil prices through a number of channels, including interest rates and exchange rates. Channels of interest rate transmission could be completely described by classical monetarism, as well as in modern literature such as the Keynesian IS-LM model. Easing interest rates increase both the demand for credit and aggregate demand, including the demand for commodities. This increased demand for commodities also contains energy demand, especially for crude oil and derivatives because they are major energy carriers.

As for the exchange rate transmission channel, most oil sales throughout the world are denominated in U.S. dollars. This means that a depreciation of the U.S. dollar would make oil imports cheaper in non-dollar-denominated currencies, raising oil imports and oil demand. Another exchange rate channel is as follows: A depreciation of the U.S. dollar would cause an appreciation of non-dollar-dominated financial assets. The majority of global financial assets are in non-dollar-denominated currencies and would, in turn, raise world oil demand because of the wealth effect.

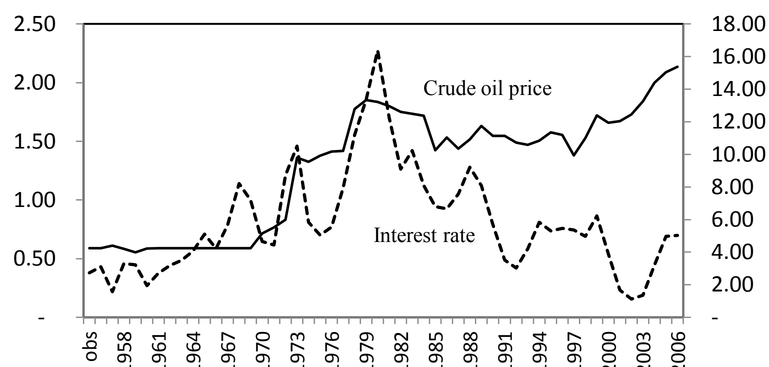


**Fig. 4: Interest rates and crude oil prices 1956 – 2011** Note: Crude oil prices are in logarithmic form. Source of crude oil prices: Average of U.K. Brent and U.A.E Fateh (Index, 2005=100). Interest rates are the U.S. money market rate, percent per annum. The left hand side scale is for the logarithm of crude oil prices and the right hand side scale is for interest rates. **Source of figure:** Taghizadeh and Yoshino (2014)

Figure 4 illustrates the relationship between interest rates and crude oil prices. As can be seen in this figure, the relationship between interest rates and crude oil prices is asymmetric. For the period of 1981-2011, average oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time, average interest rates subsided from 16.7 percent per annum in 1981 to about 0.1 percent per annum in 2011. (Taghizadeh and Yoshino, 2014)

In this chapter we clarify this impact on both oil demand and supply, and answer to the question of whether, as in Bernanke et al. (1997), interest rates need to be reduced in response to increasing oil prices, or, as in Hamilton and Herrara (2004), Anna Kormilitsina (2011), Taghizadeh and Yoshino (2014), Yoshino and Taghizadeh (2014) whether stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive.

# 3. Empirical Analysis

## *3.1. Data*

We use annual data from 1960 to 2011. As for the explanation of the data that we used for each variable, all are summarized in Table 2.

In order to evaluate the stationarity of all series, we used an Augmented Dickey–Fuller (ADF) test. The results that we found imply that consumption of non-energy, inflation rate, and GDP gap series were stationary on level during this period. This implies a stable structure that helped to maintain the consumption of non-energy around a stationary level. Most series, except the three above, were non-stationary in 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 with the exception of consumption of non-energy, inflation rate and GDP gap series, other 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. Hence, they will appear in our simultaneous equation model (SEM) in first differenced form.

## Table 2. Variables and data

| ***Notation*** | ***Variable*** | ***Data*** |
|---|---|---|
| $\pi_t$ | Inflation rate | U.S. consumer price inflation rate (all urban consumers) |
| $\hat{Y}_t - \hat{Y}_t^n$ | GDP Gap | Differences in U.S. GDP before and after HP[30] filter |
| $L_t$ | Labor Supply | Average weekly hours in private nonagricultural industries of the U.S. |
| $M_t$ | Household's money holding | U.S. Money supply (M1) |
| $W_t$ | Household's nominal wage per hour working | Average hourly earnings in private nonagricultural industries of the U.S. |
| $P_t^c$ | Consumer price index (CPI) | U.S. consumer price (all urban consumers) |
| $P_t^{NG}$ | Price of non- energy commodities | U.S consumer price index -all urban consumers - all items excluding food and energy |
| $P_t^G$ | Prices of energy (oil) | Average of U.K. Brent and U.A.E Fateh oil price indexes (2005=100) |
| $C_t^{NG}$ | Consumption of Non Energy commodities | U.S. real personal consumption expenditures excluding food and energy |
| $r_t$ | Interest rate | U.S. money market rate |
| $Q_t$ | Firms output | U.S industrial production index |
| $Y_t$ | GDP of oil importer country | U.S gross domestic product |
| $q_t^D$ | Total Energy (oil) demand | U.S crude oil consumption |

[30] Hodrick-Prescott

| | | |
|---|---|---|
| $q_t^s$ | Energy (oil) output or extraction | U.S crude oil consumption[31] |
| $e_t$ | Exchange rate (value of USD to energy exporter's currency) | USD effective exchange rate |
| $R_t$ | Amount of proven reserves of crude oil | World proven crude oil reserves[32] |
| $\hat{u}_d$ | Demand residual | Demand residual |
| $Z_{1973}$ $Z_{1979}$ | Dummy variables | Two Dummy variables for two major oil shocks 1973 and 1979 |

## *3.2. Empirical results*

It is necessary to run a regression in order to assess channels of transmission of oil price movements to macroeconomic variable, and to evaluate the impact of monetary factors such as interest rates and exchange rates on the oil market, as well. For this reason, we ran the regression for our SEM, which consists of 4 equations. These 4 equations are: (1) Energy demand, (2) Energy Supply, (3) IS curve and (4) Phillips Curve. For simplification, their implicit functions here mentioned below *(definitions of all variables used are explained in Table 2)*:

Energy Demand: $$q_t^D = q_t^D(P_t^G, P_t^{NG}, L_t, W_t, M_t, r_t, \hat{Y}_t - \hat{Y}_t^n, C_t^{NG}) \quad (34)$$

Energy Supply: $$q_t^s = q_t^s(P_t^G, e_t, r_t, R_{t-1}, \hat{u}_d, Z_{1973}, Z_{1979}) \quad (35)$$

IS Curve: $$Y_t = Y_t(Y_{t-1}, P_t^G, P_t^{NG}, W_t, L_t, r_t, M_t, Q_t) \quad (36)$$

New Keynesian Phillips curve (NKPC): $$\pi_t = \pi_t(\pi_{t-1}, \hat{Y}_t - \hat{Y}_t^n, P_t^G, P_t^{NG}) \quad (37)$$

The estimation of our SEM can be done by 1) two-stage least square (2SLS) 2) three-stage least square (3SLS) or 3) weighted two-stage least square (W2SLS). 2SLS, 3SLS and W2SLS are instrumental-variable estimation methodologies (Taghizadeh et al. 2013). We used the Akaike

[31] We assumed equilibrium in the crude oil market, so we let consumption be equal to output, and we used the same data for both. (Taghizadeh and Yoshino 2014)

[32] Proven reserves at any given point in time are defined by quantities of oil that geological and engineering information indicate with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions (Mohaddes 2012).

Information Criterion (AIC) to select the lag orders in which the maximum lag is set to 2 lags of each variable, and in order to get more rational results, we used the system method of estimation: a weighted two-stage least square (W2SLS).

Our results for oil demand price elasticity agree more with those from researchers that found low values for oil demand price elasticities, and suggest a demand price elasticity of -0.007 (significant). This means that an increase in oil prices by 100 basis points would reduce oil demand by 0.7 percent. The reason for this low elasticity is as follows: Because firms and consumers cannot change their production or consumption patterns immediately, the elasticity of their demand to oil prices is low, and from this assumption we expect that the effects of higher oil prices on GDP might be small, as well (at least initially).

## Table 3. Empirical Results[33]: 1962-2011

| Notation | CE | T-statistics | Notation | CE | T-statistics |
|---|---|---|---|---|---|
| ***Energy Demand*** $q_t^D$ | | | ***Energy Supply*** $q_t^s$ | | |
| $P_t^G$ | -0.007 | -5.02** | $P_t^G$ | 0.003 | 3.64** |
| $P_t^{NG}$ | -0.16 | -3.78** | $e_t$ | 0.28 | 1.10 |
| $L_t$ | -1.34 | -2.47* | $r_t$ | -0.02 | -2.62** |
| $W_t$ | 0.28 | 2.94** | $R_{t-1}$ | 0.53 | 0.99 |
| $M_t$ | 0.07 | 0.48 | $\hat{u}_d$ | 4.36 | 1.37 |
| $r_t$ | -0.07 | -5.40** | $Z_{1973}$ | 0.29 | 3.85** |
| $\hat{Y}_t - \hat{Y}_t^n$ | 0.02 | 0.10 | $Z_{1979}$ | 0.25 | 3.55** |
| $C_t^{NG}$ | 0.60 | 5.39** | | | |
| ***Demand side of Economy*** ***IS curve (*** $Y_t$ ***)*** | | | ***Supply side of Economy NKPC*** ***(*** $\pi_t$ ***)*** | | |
| $Y_{t-1}$ | 0.81 | 14.36** | $\pi_{t-1}$ | 0.95 | 9.61** |

[33] Included observations: 50. Total system (balanced) observations: 200
Estimation Method: Two-Stage Least Squares

| | | | | | |
|---|---|---|---|---|---|
| $P_t^G$ | -0.0008 | -2.01* | $\hat{Y}_t - \hat{Y}_t^n$ | -0.59 | -3.88** |
| $P_t^{NG}$ | -0.66 | -2.02* | $P_t^G$ | -<br>0.00004 | -0.55 |
| $W_t$ | 0.04 | 0.25 | $P_t^{NG}$ | 0.001 | 0.57 |
| $L_t$ | 0.30 | 3.77** | | | |
| $r_t$ | 0.0001 | 0.10 | | | |
| $M_t$ | 0.15 | 3.23** | | | |
| $Q_t$ | 0.34 | 2.10* | | | |

Note: CE, coefficient, * indicates significance at 5%, ** indicates significance at 1%

Our empirical results confirm this expectation, as the coefficient of oil prices in our IS curve equation comes to -0.0008, which is economically small and statistically significant. In this case, the oil price shocks will have slight impact on the U.S. GDP. However, the production of energy-intensive goods in this country may cause substantial reallocation of labor, which – if costly – can have a large impact on the production of this sector of economy.

For demand price elasticities, Gately and Huntington (2002) found between -0.12 and -0.64 for both OECD and non-OECD countries, and Krichene's (2006) results were between -0.03 and -0.08 for various countries in the short-run. His long-run price elasticity was significantly low: 0.05 in 1918–1999, 0.13 in 1918–1973 and almost zero during 1973–1999.

Mohaddes (2013) found -0.15 for the short-run price elasticity of global oil demand. More recently, Taghizadeh and Yoshino's (2014) results suggest a price elasticity for global oil demand of -0.08 (significant), -0.10 (significant), and -0.05 (significant) for 1960-2011, 1960-1980 and 1980-2011, respectively. We found a value of 0.003 for oil supply price elasticity. This elasticity was significant but economically smaller than demand elasticity, which indicates that supply is more rigid.

As for transmission channels of higher oil prices to GDP, our results are is in line with Hamilton (1988), suggesting that oil price shocks induce recessions mainly because of reduction on the demand side of the economy (the aggregate demand curve shifts more than the aggregate supply curve; Fig 3). However, Hamilton suggests that this decrease in demand is mainly due to an increase in uncertainty, along with a rise in the operating costs of certain durable goods. This increase reduces demand for durable goods and investments. Other papers that support our findings are: Lee and Ni (2002), which showed that oil price shocks mainly affect demand side of the economy, as well. Their paper suggests that oil price shocks influence economic activity possibly by delaying purchasing decisions of durable goods. Or Bernanke's research (2006) that proposed a viewpoint showing that an increase in energy prices slows economic growth primarily through its effects on consumer spending and demand side.

Our findings are in contrast with, Rasche and Tatom (1977), Bruno (1984), and more recently by DePratto et al. (2009), who claimed that energy prices affect the economy primarily through the supply side channel (Their findings are in line with Figure 2). They found that higher oil prices have temporary negative effects on both the output gap and on trend growth, and they did not find significant effects in the demand side. Their results support the notion that higher oil prices have effects similar to negative technology shocks, in that higher oil prices lower firm output in terms of value-added for a given input of capital and labor. Our results for the Phillips curve, which is representative of the supply side of the economy in our model, do not show any significant association between the inflation rate and higher oil prices. This conclusion rejects the hypothesis that high oil prices transmit to the economy through supply side (aggregate supply curve).

As stated earlier, Figure 3, shows that higher oil prices are transmitted to the economy mainly through demand side (Aggregate demand movements are greater than aggregate supply shifts). The main results are lower GDP and lower prices. Our empirical results, which fit Figure 3, arrive at the coefficient of -0.0008 for oil prices in our IS curve equation, which is economically small and statistically significant. This means that higher oil prices lead to a decline in GDP. On the other hand, however, the coefficient of oil prices in our Phillips curve is -0.00004, which is economically small and non-significant, but the fact that it is negative shows that higher oil prices reduce general price levels because of lower consumption (lower demand). These are all in line with Figure 3, and with our theoretical analysis.

Monetary policy, as mentioned earlier, tends to affect oil prices through two main channels: interest rates and exchange rates. Our regressions establish that interest rates play a significant role in affecting supply and demand for oil. For the demand side of the oil market in our model, the interest rate coefficient shows a value of -0.07. This means that a decrease in interest rates by 100 basis points would raise oil demand by 7 percent. This indicates that expansionary monetary policies lead to low interest rates and credit demand augmentation, which in turn raise the demand for oil because it becomes cheaper to get a loan for capital, raising demand for other input factors. This raises speculative demand, as well. In the supply side of the crude oil market, we also found a significant value of -0.02 for interest rates. Put simply, this means that a decrease in interest rates by 100 basis points would raise oil supply by 2 percent, a finding that is in line with Hotelling's (1931) theory, which states that lower interest rates reduce the marginal cost of production. Because the scarcity cost does not have a large effect, oil supply increases. This channel of transmission is clearly exhibited in Eq. 33 of our model. However, the increase in the demand side is larger than the increase in the supply side, so we can expect to have surplus demand in the market following easy monetary policies. The result is skyrocketing crude oil prices, which inhibit economic growth.

As for the exchange rate, results show that the impact of exchange rate depreciations on the oil market was not significant, and that the oil market actually remained constant during 1960-2011, in spite of exchange rate fluctuations. These results are in line with Taghizadeh and Yoshino (2014), which found that the oil market was stable to exchange rate fluctuations during the period of 1960-2011.

# 4. Conclusions

In the model that we developed, changes in the oil price transmitted to macro variables through supply (aggregate supply curve) and demand (aggregate demand curve). In particular, we allowed oil to shift the IS curve to proxy for temporary demand-side effects, and to affect the Phillips curve to capture inflationary effects through the supply side. This phenomenon creates destructive effects on the growth rate. In the empirical section, we conclude that oil price movements affect the economy through the demand channel (in line with Hamilton 1988 and Bernanke 2006) by reducing household consumption expenditures (aggregate demand movements are greater than aggregate supply shifts; Figure 3). Unlike some earlier studies (Rasche and Tatom 1977, Bruno

1984 and DePratto et al. 2009), we could not find statistically significant effects in the supply side (aggregate supply curve).

As for the effect of monetary policies on oil markets, we found that aggressive monetary policies led to low interest rates, credit demand augmentation, and aggregate demand expansion, which all raised oil prices. We found that oil demand was significantly influenced by interest rates, a key factor of monetary policies (in line with Anna Kormilitsina 2010, Taghizadeh and Yoshino 2014, Yoshino and Taghizadeh 2014), in contrast with Bernanke et al. (1997). Unlike some earlier studies, we found that low interest rates had an impact on oil supply expansion as well, which was statistically significant but economically smaller than their impact on the demand side of the oil market. The result from this interest rate phenomenon is skyrocketing crude oil prices, which inhibit economic growth. We argue that stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive.

As for elasticities in the oil market, our results for oil demand price elasticity agree more with the findings of researchers who arrived at low elasticity values. We also found that the supply of oil is more rigid to prices, comparing to the demand.

# Appendix

## *a) Euler, money demand, labor supply equations (log-linearized version)*

The log-linearized versions of equations (5)–(7) are shown as:

$$c_t = -\frac{b}{\eta} + E_t c_{t+1} + \frac{1}{\eta} E_t \pi_{t+1}; b = Log\beta, E_t \pi_{t+1} = E_t p^c_{t+1} - p^c_t \quad (1)$$

$$m_t = \frac{1}{\sigma} p^c_t + \frac{\eta}{\sigma} c_t + \frac{v}{\sigma}; v = Log\chi \quad (2)$$

$$l_t = \frac{1}{\kappa}(w_t - p^c_t - \eta c_t) \quad (3)$$

The lowercase letters denote the logarithms of the corresponding upper case variables. By solving these three equations for $c_t$ which is consumption in logarithmic form, the consumption equation yields:

$$c_t = \frac{-b+\nu}{\eta} + E_t c_{t+1} + \frac{1}{\eta} E_t \pi_{t+1} - \frac{\sigma}{\eta} m_t + \frac{1}{\eta} w_t - \frac{\kappa}{\eta} l_t \tag{4}$$

## b) Household energy consumption

Since earlier in Eq. 1 of section "a" of the Appendix we had written $E_t \pi_{t+1} = E_t (p^c_{t+1}) - p^c_t$, here we convert it back, and substitute the right hand side of it in Eq. 4 of section "a" of the Appendix in order to release energy prices and non-energy prices from $p^c_t$. We log linearize the CPI equation (Eq. 2) as follows:

$$p^c_t = \varepsilon - A\left(a - p^{NG}_t\right) + \left(A-1\right)\left(z - p^G_t\right); \varepsilon = Log\lambda, a = LogA, z = Log(1-A) \tag{1}$$

By substituting it and the expected value of Eq. 2 of section "a" of the Appendix for t+1 in Eq. 4 of section "a" of the Appendix, the logarithmic form of the household consumption equation yields:

$$c_t = \frac{-b - \varepsilon - (A-1)z + Aa}{\eta} - \frac{A}{\eta} p^{NG}_t + \frac{(A-1)}{\eta} p^G_t + \frac{\sigma}{\eta} E_t m_{t+1} - \frac{\sigma}{\eta} m_t + \frac{1}{\eta} w_t - \frac{\kappa}{\eta} l_t \tag{2}$$

Substituting the anti-log of Eq. 2 of section "b" of the Appendix into Eq. 2 of footnote 22, gives the demand of representative household for energy yields.

## c) Phillips curve (part 1)

Real marginal cost is written as follows:

$$s_t = (\phi W_t + \varpi P^G_t) \tag{1}$$

Following Woodford's (2003) analysis, we write the equation below, which shows the relationship between marginal cost of supply and output levels:

$$\hat{s}_t = \omega\hat{Q}_t + \sigma^{-1}\hat{Y}_t - (\omega + \sigma^{-1})\hat{Y}_t^n \tag{2}$$

Where $\omega > 0$ and $\sigma > 0$. Letting $\bar{Y}$ be the constant level of output in a steady state, and $Y_t^n$ be level of output in full employment, we define $\hat{Q}_t = \log(Q_t / \bar{Y})$, $\hat{Y}_t = \log(Y_t/\bar{Y})$, $\hat{Y}_t^n = \log(Y_t^n / \bar{Y})$, and $\hat{s}_t = \log(\mu s_t)$ ,where $\mu = \theta/(\theta - 1) > 1$ is the seller's desired markup. Substituting Eq. 2 in section "c" of the Appendix in the following inflation equation from Calvo (1983) produces the following results:

$$\pi_t = \xi\hat{s}_t + \psi E_t \pi_{t+1} \tag{3}$$

$$\pi_t = \left\lfloor \omega\hat{Q}_t + \sigma^{-1}\hat{Y}_t - (\omega + \sigma^{-1})\hat{Y}_t^n \right\rfloor \xi + \psi E_t \pi_{t+1} \tag{4}$$

Dividing Eq. 15 by $\bar{Y}$ and obtaining the Log-linearization of this equation results in the following:

$$\hat{Q}_t = \log\left[\frac{Y_t}{\bar{Y}}\left(\frac{P_t^c}{P_t^{NG}}\right)\right] = \hat{Y}_t + p_t^c - p_t^{NG} \tag{5}$$

The corresponding log-linear approximation to the aggregate price index is as follows:

$$p_t^c = \iota p_t^G + (1 - \iota) p_t^{NG} \tag{6}$$

Substituting the log linear aggregate price index (Eq. 6 of section "c" of the Appendix) along with Eq. 5 of section "c" of the Appendix into Eq. 4 of section "c" of the Appendix yields a New-Keynesian Phillips curve:

$$\pi_t = \xi\left[(\omega + \sigma^{-1})\left(\hat{Y}_t - \hat{Y}_t^n\right) + \omega(\iota p_t^G - \iota p_t^{NG})\right] + \psi E_t \pi_{t+1} \tag{7}$$

We followed Blanchard and Kahn (1980) method for rational expectations:

$$E_t \pi_{t+1} = \frac{1}{\psi}\pi_t - \frac{\xi}{\psi}\left[(\omega + \sigma^{-1})\left(\hat{Y}_t - \hat{Y}_t^n\right) + \omega(\iota p_t^G - \iota p_t^{NG})\right] \tag{8}$$

Then for the previous period we have:

$$E_{t-1}\pi_t = \frac{1}{\psi}\pi_{t-1} - \frac{\xi}{\psi}\left[(\omega + \sigma^{-1})\left(\hat{Y}_{t-1} - \hat{Y}_{t-1}^n\right) + \omega(\iota p_{t-1}^G - \iota p_{t-1}^{NG})\right] \tag{9}$$

This obtains the $E_{t-1}$ value of Eq. 7 of section "c" of the Appendix, which we can write in for the $E_t\pi_{t+1}$ results:

$$E_t\pi_{t+1} = \frac{1}{\psi}E_{t-1}\pi_t - \frac{\xi}{\psi}E_{t-1}\left[(\omega+\sigma^{-1})\left(\hat{Y}_t - \hat{Y}_t^n\right) + \omega(\iota p_t^G - \iota p_t^{NG})\right] \tag{10}$$

After substituting $E_{t-1}\pi_t$ from Eq. 9 of section "c" of the Appendix with Eq. 10 of section "c" of the Appendix and then setting Eq. 8 of section "c" of the Appendix and Eq. 10 of section "c" of the Appendix as equal the Phillips curve yields, however, it becomes apparent that this is not the final version of it and we need to do some more work on it.

## *d) Phillips curve (part 2)*

Initial version of Phillips curve:

$$\pi_t = \frac{1}{\psi}\pi_{t-1} - \frac{\xi}{\psi}\left[(\omega+\sigma^{-1})\left[\hat{Y}_{t-1} - \hat{Y}_{t-1}^n\right] + \omega(\iota p_{t-1}^G - \iota p_{t-1}^{NG})\right] + \varepsilon_t \tag{1}$$

From Eq. 6 of section "c" of the Appendix, we write the inflation rate in t-1 and substitute it in Eq. 1 of section "d" of the Appendix, making it so that the final Phillips curve yields the results in Eq. 17.

## *e) Equation 20. Derivations*

Considering Initial version of our Phillips curve (Eq.1 of section "d" of the Appendix) by solving for $E_t\pi_{t+1} - E_{t-1}\pi_t$ :

$$E_t\pi_{t+1} - E_{t-1}\pi_t = \frac{1}{\psi}\left(\pi_t - \pi_{t-1}\right) - \frac{\xi}{\psi}\left(\begin{matrix}\left[(\omega+\sigma^{-1})\left(\hat{Y}_t - \hat{Y}_t^n\right) + \iota\omega(p_t^G - \iota p_t^{NG})\right] - \\ \left[(\omega+\sigma^{-1})\left(\hat{Y}_{t-1} - \hat{Y}_{t-1}^n\right) - \iota\omega(p_{t-1}^G - \iota p_{t-1}^{NG})\right]\end{matrix}\right) \tag{1}$$

We assume the equation:

$$\left[(\omega+\sigma^{-1})\left(\hat{Y}_t - \hat{Y}_t^n\right) + \iota\omega(p_t^G - \iota p_t^{NG})\right] = \vartheta_t \tag{2}$$

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# Chapter 3: Monetary Policies and Oil Price Fluctuations Following the Subprime Mortgage Crisis[34]


## Abstract

This study examines how monetary policy affected crude oil prices after the subprime mortgage crisis. Our earlier research found that easy monetary policy had a significant impact on energy prices during the period of 1980–2011. This chapter finds that after the subprime mortgage crisis


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the weaker exchange rate of the United States (US) dollar caused by the country's quantitative easing pushed oil prices in US dollars upward over the period of 2009–2012, by causing investors to invest in the oil market and other commodity markets while the world economy was in recession in this period. This trend had the effect of imposing a longer recovery time on the global economy, as oil has been shown to be one of the most important production inputs.

Key Words: oil prices, monetary policies, subprime mortgage crisis, exchange rate

JEL Classification: E52, Q43, G01

## 1. Introduction

The subprime mortgage crisis began when the US housing bubble burst and sparked a global financial crisis in 2007 and 2008. Before the crisis, over a period of several years, housing prices had been increasing while interest rates remained low. Subprime mortgages were extensively available and refinancing was cheap. However, as interest rates increased and housing prices started to drop due to the huge housing supply, refinancing became more difficult and the risks embedded in subprime mortgages could no longer be hidden. In August 2007 these problems hit the global financial markets and caused enormous liquidity pressures within the interbank market. Due to the widespread dispersion of credit risk and the complexity of financial instruments, the mortgage crisis had a large impact on financial markets. In July 2007, Stock market indices began to see massive declines. Several large banks, and credit insurance and mortgage companies reported significant losses and dropped much of their market value. Because of this drop in global output and a reluctance to borrow from banks, commodity markets, including crude oil market demand, also experienced sharp drops and subsequently large price decreases.

In the United States (US), the Federal Reserve (Fed) held between $700–$800 billion worth of Treasury notes on its balance sheet before the recession. In order to mitigate some of the adverse effects of the crisis, in late November 2008 it began to purchase $600 billion in mortgage-backed securities. By March 2009, it held $1.75 trillion worth of bank debt, mortgage-backed securities, and Treasury notes, reaching a peak of $2.1 trillion in June 2010. Further purchases were halted as the economy began to improve, but resumed in August 2010 when the Fed decided that the economy was not growing robustly enough. After the halt in June, holdings started to fall naturally as debt matured, and were projected to fall to $1.7 trillion by 2012. The Fed's revised goal became to keep holdings at $2.054 trillion. To maintain this level, the Fed bought $30 billion in 2- to 10-year Treasury notes every month. In November 2010, the Fed announced a second round of quantitative easing, buying $600 billion of Treasury securities by the end of the Q2 2011. "QE2" became a ubiquitous nickname in 2010, used to refer to this second round of quantitative easing by US central banks (Authers, 2010). Retrospectively, the round of quantitative easing preceding QE2 was called "QE1" (Conerly, 2012). A third round of quantitative easing, "QE3," was announced on 13 September 2012. Additionally, the Federal Open Market Committee (FOMC) announced that it would likely maintain the federal funds rate near zero at least through 2015.

According to the International Monetary Fund (IMF), quantitative easing policies that were undertaken by the central banks of the major developed countries, as in the example of the US quantitative easing policies mentioned above, have contributed to a reduction in systemic risk following the crisis. The IMF states that these policies also contributed to improvements in market confidence and the bottoming out of the recession in the Group of 7 (G7) economies in the second half of 2009 (Klyuev et al., 2009).

However, there are several economists, such as Ratti and Vespignani (2013), who concluded that quantitative easing undertaken by the central banks of different countries following the 2007–2008 crisis played a large role in the fast recovery of commodity prices, especially with regard to the oil market. This trend had the effect of imposing a longer recovery time on the economy, as the oil has been shown to be one of the most important production inputs. This means that increasing oil prices are destructive for economic growth and tend to prolong economic recovery time. The hypothesis of this chapter is in line with the latter paper because we believe that quantitative easing policies undertaken by central banks in the US and other countries following the economic crisis rapidly pushed up commodity market prices. This rise includes crude oil prices, which caused a longer recovery time for the global economy.

Figure 1 shows movements during the period January 2007–October 2013 of the interest rate (US money market rate) and the crude oil price (simple average of the Dubai, Brent, and WTI crude oil prices in constant dollars). Expansionary monetary policy in the US led to a decrease in the US money market rate from 5.25% per annum in January 2007, to 2% per annum in June 2008. During the same period, crude oil prices saw an increase from around $53.35/barrel to beyond $131.70/barrel. We believe that a major cause of these skyrocketing prices was easy monetary policy.

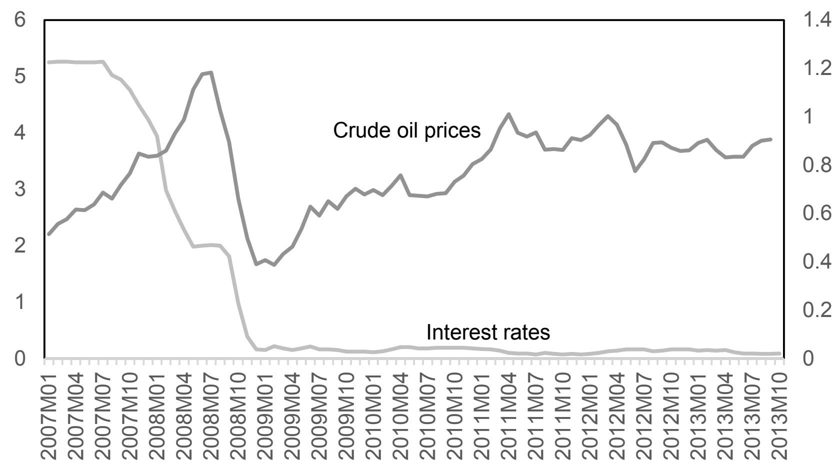


**Figure 1: Interest Rates and Crude Oil Prices, January 2007–October 2013** Note: Crude oil prices (right-hand scale) are in constant dollars obtained using the simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and West Texas Intermediate (WTI) crude oil prices in the New York market, deflated by the US consumer price index (CPI). Interest rates (left-hand scale) are the US money market rate, percent per annum.

Following the financial crisis of 2007–2008, a decline in global demand for crude oil caused oil prices to drop from $133.11 in July 2008 to below $42.01 in December 2008. After this dip, prices started to increase again. A portion of this elevation was due to increased demand stemming from a recovery in the global economy that increased demand, but we believe a significant reason for this sharp rise was the quantitative easing implemented by the monetary authorities. This easy monetary policy led to an elevation in crude oil demand, causing oil prices to increase rapidly. The result was that in May 2009, although the global economy had not recovered completely, crude oil prices almost surpassed their pre-crisis levels of January 2007. In this chapter, we answer to the question of whether monetary policy had a significant impact on the crude oil market following the subprime mortgage crisis.

This chapter is structured as follows. In the following section we review the literature. The third section details the theoretical background and the model, including: Section 3.1, monetary policy transmission channels to oil demand; Section 3.2, the effect of monetary policy actions on exchange rates; Section 3.3, definition of the real effective exchange rate (REER); Section 3.4, the theoretical framework; and Section 3.5, the model. The fourth section describes the empirical results, including: Section 4.1, data analysis; Section 4.2, structural parameter estimates; and Section 4.3, structural impulse response (IR) analysis. The fifth section contains the concluding remarks.

## 2. Review of the Literature

In the literature on energy economics, there are several research cases that have found a significant impact of monetary policy on energy markets, especially the crude oil market. Barsky and Kilian (2002) argue that changes in monetary policy regimes were a key factor behind the oil price increases of the 1970s, and show that the substantial increase in industrial commodity prices that preceded the increase in oil prices (1973–1974) is consistent with the view that rising demand based on increased global liquidity drove oil prices higher. Additionally, a more recent study by Taghizadeh and Yoshino (2014) demonstrated that global oil demand during the periods 1960–2011 and 1980–2011 was significantly influenced by monetary policy regimes. They showed that aggressive monetary policy stimulates oil demand, while supply remains inelastic to interest rates. The result is skyrocketing crude oil prices, which have the effect of inhibiting economic growth. On the other hand, Bernanke et al. (1997) showed that expansionary monetary policy could have largely eliminated the negative output consequences of the oil price shocks on the US economy. This view has, in turn, also been challenged by Hamilton and Herrera (2004), who argue that Bernanke, Gertler, and Watson's (BGW) empirical results suffer from model misspecification. Hamilton and Herrera reproduced the BGW experiment using a different model specification, and found that increases in the price of oil lead directly to contractions in real output. The tightening of monetary policy in the period that BGW examined played only a secondary role in generating the downturn.

There are several other recent studies that critically reevaluate the results of Bernanke et al. (1997). For example, Leduc and Sill (2004) examined the Federal Reserve's behavior starting in 1979, and show that monetary policy contributed to an approximate 40% drop in output following the rise in oil prices. The hypothesis of this chapter is in agreement with Barsky and Kilian (2002), Leduc and Sill (2004), Hamilton and Herrera (2004), Askari and Krichene (2010), Kormilitsina (2011), Ratti and Vespignani (2013), Taghizadeh and Yoshino (2013a, 2013b), and Taghizadeh and Yoshino's (2014) findings for the impact of monetary policy on crude oil prices. However, the main innovation of this chapter is that we will test another channel of monetary policy transmission, the exchange rate.

# 3. Theoretical Background and the Model

## *3.1. Channels of Transmission of Monetary Policy to Oil Demand*

Monetary policy affects oil demand through a number of channels, including interest rates and exchange rates. Channels of interest rate transmission could be completely described by classical monetarism, as well as in modern literature such as the Keynesian IS-LM model. Easing interest rates increases the demand for credit and increases aggregate demand, which includes the demand for commodities. This increased demand for commodities includes demand for energy, especially for crude oil and its derivatives because they are major energy carriers (Taghizadeh and Yoshino, 2014). Keynes (1936) examined the effects that lowered interest rates have on aggregate demand: expansionary monetary policy reduces the interest rate, and when the interest rate is lower than the marginal productivity of capital, it broadens investment demand until the marginal productivity of capital is equalized to a lower interest rate. This expansion of investment creates an accelerator-multiplier effect, causing aggregate demand to expand, which in turn amplifies demand for commodities and puts pressure on commodity prices. This can be generalized for energy carriers as well, especially crude oil. In the end, this process leads to increased pressure on oil prices. In other words, lower interest rates make borrowing cheaper, which increases demand in the commodities market, including the crude oil market.

As for the exchange rate transmission channel, most oil sales throughout the world are denominated in US dollars. This means that a depreciation of the US dollar makes oil imports cheaper in non-dollar-denominated currencies, raising oil imports and oil demand. Another exchange rate channel is that a depreciation of the US dollar causes an appreciation of non-dollar-dominated financial assets. The majority of world financial assets are denominated in non-dollar currencies, so a depreciation of the US dollar stimulates world oil demand through the wealth effect.

Figure 2 shows the REER and real crude oil price movements during the period January 2007–September 2013. The inverse relationship between these two variables is apparent in this figure. Generally, crude oil prices began to rise following depreciation of the US dollar, and dropped following an appreciation. For more information on the impact of exchange rate fluctuations on crude oil prices, see Reboredo (2012), Taghizadeh and Yoshino (2014), and Brahmasrene et al. (2014).

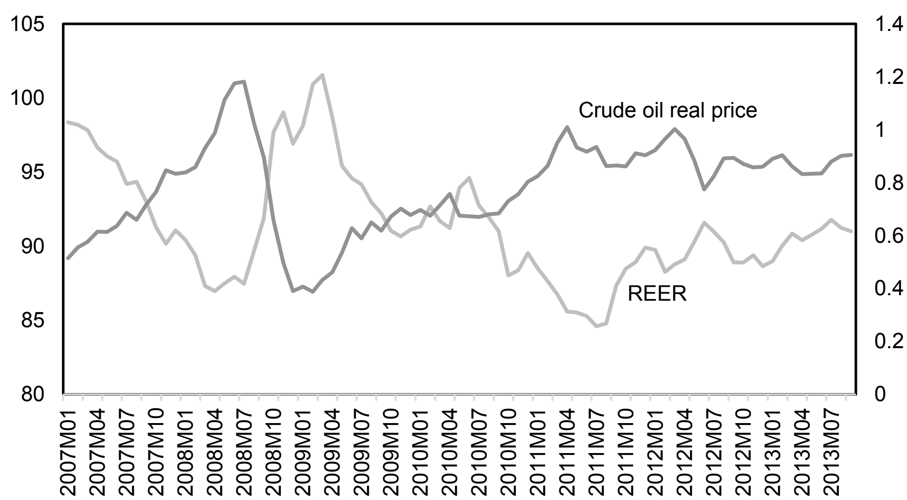


**Figure 2: Exchange Rate and Crude Oil Prices, January 2007–September 2013**

REER = real effective exchange rate. Note: Crude oil prices (right-hand scale) are in constant dollars obtained using 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). REER (left-hand scale) is for the US dollar. Source: International

Energy Agency (IEA) (2013); International Financial Statistics (IFS) (2013); The *Energy Data and Modeling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ)*.

Another way to verify our hypothesis can be seen in the figure bellow. Fig. 3 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.

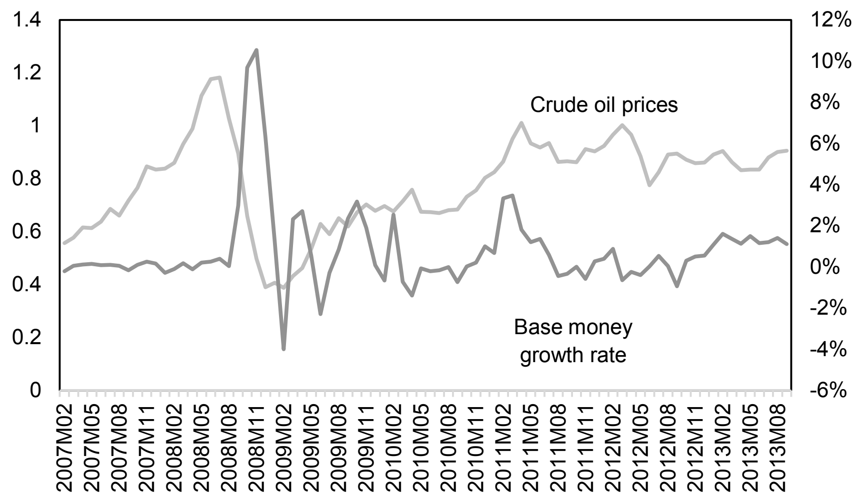


**Figure 3: Base Money and Crude Oil Prices, February 2007–September 2013** Note: Crude oil prices (left-hand scale) are in constant dollars obtained using a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, deflated by the US consumer price index (CPI). The base money growth rate (right-hand scale) is for the US, seasonally adjusted.

## *3.2. The Effect of Monetary Policy Actions on Exchange Rates*

The effect of monetary policy on exchange rates has been the subject of a large body of empirical research since the early 1990s. This research includes: Sims (1992), Clarida and Gali (1994), Eichenbaum and Evans (1995), Bonser-Neal et al. (1998), Bagliano and Favero (1999), Bitzenis and Marangos (2007), and Bahmani and Bahmani-Oskooee (2012).

Several of these empirical studies found that a tightening of US monetary policy is associated with an appreciation of the US dollar, while a loosening is associated with dollar depreciation. Using

VAR methodology, Eichenbaum and Evans (1995) find that contractionary shocks to monthly values of the federal funds rate, the ratio of non-borrowed reserves to total reserves, and the Romer and Romer (1989) index over the period 1974–1990 led to a sharp increase in the differential between US and foreign interest rates, as well as to a sharp appreciation in the US dollar. Clarida and Gali (1994), Evans (1994), and Lewis (1995) used similar methods to find that contractionary US monetary policy is associated with dollar appreciation. Bonser-Neal et al. (1998) found that increases in the federal funds rate target during the periods 1974–1979 and 1987–1994, which targeted interest rates, are associated with significant increases in the value of the dollar. Zettelmeyer (2004) studied the impact effect of monetary policy shocks on the exchange rates of three small open economies (Australia, Canada, and New Zealand) during the 1990s. The study found that a 100 basis point contractionary shock will force the exchange rate to appreciate by 2%–3% on impact. The association of interest rate hikes with depreciations that can sometimes be observed during periods of exchange market pressure, is mainly attributable to reverse causality.

While all of these studies estimate US dollar appreciation in response to contractionary monetary policy shocks, they report a different dynamic response pattern. Bonser-Neal et al. (1998), for example, estimate spot and forward rate responses consistent with standard overshooting models in the majority of the cases they examine. In contrast, Clarida and Gali (1994), Eichenbaum and Evans (1995), and Evans (1994) estimate that it can take from 1 to 3 years for the maximal effect of the policy shock to be felt on exchange rates. Bonser-Neal et al. (1998) also estimate that the impact of a policy shock is expected to increase over time, as in the case of the yen/US dollar exchange rate over the period 1974–1979. These latter results are clearly inconsistent with standard overshooting models. In overshooting models, contractionary US monetary policy causes the US dollar spot rate to temporarily appreciate beyond, or overshoot, its new higher equilibrium level. Future exchange rates are therefore expected to appreciate by less than the current spot rate in response to a tightening of monetary policy. Bonser-Neal et al. (2000) suggest that the standard overshooting model may be too restrictive to completely characterize the effects of monetary policy on exchange rates.

## *3.3. Definition of the Real Effective Exchange Rate (REER)*

The relative attractiveness of domestic goods compared to foreign goods depends primarily on their relative price. We can think of this relative price as the number of domestic goods that must be given up to acquire one foreign good. This relative price is called the "real exchange rate." This real exchange rate can be expressed in both bilateral and multilateral (or effective) terms. The multilateral real exchange rate (or the real effective exchange rate—the two terms are synonymous and are both in common use) is constructed from bilateral real exchange rates. It is simply the geometrically weighted average of the relevant set of bilateral real exchange rates. Note that a country's nominal and real exchange rates do not have to move in the same direction.

Figure 4 shows that the REER and nominal effective exchange rate (NEER) do not necessarily follow the same path. As can be seen from the definition of the real exchange rate, changes in the bilateral real exchange rate depend on two different factors: changes in the nominal exchange rate and changes in a country's price level relative to that of its trading partner. For example, in many developing countries that experienced high inflation during the 1980s and 1990s, it was not at all uncommon for their bilateral real exchange rates against the US dollar to appreciate significantly, while their nominal exchange rates were depreciating (Montiel, 2009), simply because their domestic inflation rates were so much higher than the inflation rate in the US.

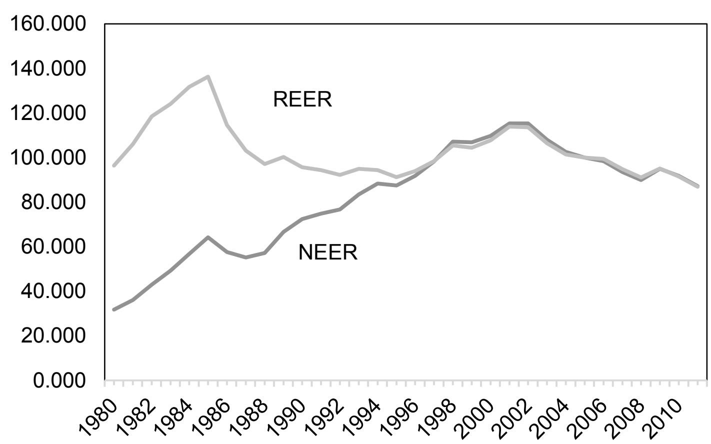


**Figure 4: Nominal Effective Exchange Rate (NEER) and Real Effective Exchange Rate (REER)** for the US Dollar, 1980–2011 Note: Both are consumer price index exchange rates, (2005=100).

Source: International Financial Statistics (IFS) (2013).

Effective exchange rate indices are constructed in three steps. First, the relevant bilateral exchange rates for a particular county are converted into indexes, using a common base year. Next, a set of weights is chosen to be applied to each of the bilateral indexes. Finally, the bilateral indexes are averaged together using these weights. While this may seem straightforward, there are several issues that have to be taken into consideration, such as geometric or arithmetic weighting, choice of weights, number of currencies, and the base year for weights.

### *3.4. Theoretical Framework*

In developing the theoretical framework of this chapter, we used Taghizadeh and Yoshino (2014) for inspiration. Our assumed oil importing country/region has a multi-input production function, with four production inputs:

$$y_t = f(K_t, N_t, q_{1t}^d, q_{2t}^d) \tag{1}$$

Where $y_t$ is total production (the monetary value of all goods produced in a year; GDP), $K_t$ is capital input (the monetary worth of all machinery equipment and buildings), $N_t$ is labor input (the total number of man-hours worked in a year), $q_{1t}^d$ is crude oil input (in barrels) and $q_{2t}^d$ is natural gas input (in cubic feet). An oil importer's profit equation is:

$$Max\pi_t^d = P_{yt}.y_t - i_t K_t - w_t N_t - e_t p_{1t} q_{1t}^d - e_t p_{2t} q_{2t}^d \tag{2}$$

Where $P_{yt}$ is the output price level, $w_t$ is the labor wage, $i_t$ is borrowed capital rent, $p_{1t}$ is the crude oil price in US dollars, $p_{2t}$ is the natural gas price in US dollars, and $e_t$ is the exchange rate. The Lagrange function is defined as:

$$L = \left(P_{yt} y_t - i_t K_t - w_t N_t - e_t p_{1t} q_{1t}^d - e_t p_{2t} q_{2t}^d\right) - \lambda\left[y_t - f(K_t, N_t, q_{1t}^d, q_{2t}^d)\right] \tag{3}$$

This produces the first order condition for crude oil:

$$\partial L/\partial q_{1t}^{d} = -\left[e_t p_{1t} + \left(\partial p_{1t}/\partial q_{1t}^{d}\right)e_t q_{1t}^{d}\right] + P_{yt}\left(\partial f/\partial q_{1t}^{d}\right) = 0 \tag{4}$$

More specific results can be obtained by adopting the Cobb-Douglas production function:

$$y_t = f(K_t, N_t, q_{1t}^{d}, q_{2t}^{d}) = b_t K_t^{\alpha} N_t^{\beta} \left(q_{1t}^{d}\right)^{\gamma_1} \left(q_{2t}^{d}\right)^{\gamma_2} \tag{5}$$

Where $\alpha, \beta, \gamma_1, \gamma_2$ are the output elasticities of capital, labor, crude oil, and natural gas, respectively. These values are constants determined by available technology, and $b$ is total factor productivity. We have assumed that capital comes from the competitive market and that the crude oil market is oligopolistic. For information regarding oligopolistic markets, we referred to Revankar and Yoshino (2008). By rewriting equation (4), accounting for our Cobb-Douglas production function, we get:

$$-\left[e_t p_{1t} + \left(\partial p_{1t}/\partial q_{1t}^{d}\right)e_t q_{1t}^{d}\right] + P_{yt}\gamma_1\left(y_t/q_{1t}^{d}\right) = 0 \tag{6}$$

In order to show that capital and labor inputs are functions of these variables, we rewrite equation (5) as follows:

$$y_t = b_t K_t^{\alpha}{}_{(i_t, y_t)} N_t^{\beta}{}_{(\frac{w_t}{P_{yt}}, y_t)} \left(q_{1t}^{d}\right)^{\gamma_1} \left(q_{2t}^{d}\right)^{\gamma_2} \tag{7}$$

and as we know:

$$q_{it}^{d} = f(p_{it}/P_{yt});_{(i=1,2)} \tag{8}$$

For estimation purposes we can express the oil demand function in simplified log-linear form as follows:[35]

$$\tilde{q}_{1t}^{d} = d_0 + d_1\tilde{p}_{1t} + d_2\tilde{p}_{2t} + d_3\tilde{y}_t + d_4\tilde{i}_t + d_5\tilde{e}_t + u_{dt} \tag{9}$$

where $\tilde{q}_{1t}^{d}$ is the logarithm of $q_{1t}^{d}$, $\tilde{p}_{it}$ is the logarithm of $(p_{it}/P_{yt});_{(i=1,2)}$, the coefficient $d_1$ is the price elasticity of crude oil demand, and $d_2$ is the substitution elasticity of natural gas, which is the main substitution for crude oil. To demonstrate the effect of changes in economic activity on the demand

[35] Since the labor wage does not have a significant impact on crude oil demand, we have omitted it from our demand equation.

for oil, we use the real GDP in logarithmic form: $(\tilde{y}_t = \log(y_t / P_{yt}))$. We also include two monetary policy factors: real interest rate $(\tilde{i}_t)$ and REER$(\tilde{e}_t)$. We expect negative values for both $d_4$ and the exchange rate coefficient ($d_5$), implying that a depreciation of the US dollar would increase demand for oil. $d_0$ is constant demand and $u_{dt}$ is the random error term. We can write the crude oil price equation as follows:

$$\tilde{p}_{1t} = \Pi_0 + \Pi_1 D_t^{excess} + \Pi_2 \tilde{p}_{2t} + \Pi_3 \tilde{y}_t + \Pi_4 \tilde{i}_t + \Pi_5 \tilde{e}_t + u_{pt} \tag{10}$$

where $D_t^{excess} = \tilde{q}_{1t}^d - \tilde{q}_{1t}^s$ denotes the excess demand in the crude oil market, which was obtained by deducting the crude oil supply from its demand. $\Pi_i; (i = 1,...,5)$ are the coefficients of variables in crude oil price equation, $\Pi_0$ is the constant and $u_{pt}$ is the random error term.

## *3.5. The Model*

The objective of this section is to examine the relationship between crude oil prices, natural gas prices, REER, GDP, and excess demand.[36] To assess this relationship, we adopt the K variable Structural Vector Autoregression (SVAR) as in Sims (1980), and start with the following VAR model:

$$Y_t = A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t \tag{11}$$

where $Y_t$ is a $(K \times 1)$ vector of variables and is comprised of $\tilde{e}_t, \tilde{y}_t, \tilde{p}_{2t}, D_t^{excess}, \tilde{p}_{1t}$. $A_i (i = 1, \ldots, p)$ are $(K \times K)$ fixed coefficient matrices, p is the order of VAR model and $u_t$ is a $(K \times 1)$ vector of VAR observed residuals with a 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 $\varepsilon_t$, as in Breitung et al. (2004) and Narayan (2013):

[36] In equation (10), it is shown that we included two monetary policy factors: real interest rate and REER in our crude oil price function, but since in the period that we focus on (January 2007–December 2013), the Federal Reserve and other monetary authorities' behavior kept the interest rates near zero, we limited our analysis to the exchange rate as the only channel for transmission of monetary policy to the crude oil market.

$$u_t = A^{-1}B\varepsilon_t \tag{12}$$

where, $B$ is a structural form parameter matrix. Substituting equation (12) into equation (11), and following minor operations, we obtain the following, which is the structural representation of equation (11):

$$AY_t = A_1^*Y_{t-1} + \ldots + A_p^*Y_{t-p} + B\varepsilon_t \tag{13}$$

where $A_{j(j=1,\ldots,p)}^*$ is a $(K \times K)$ matrix of coefficients in which $A_j = A^{-1}A_{j(j=1,\ldots,p)}^*$ and $\varepsilon_t$ is a $(K \times 1)$ vector of unobserved structural shocks, with $\varepsilon_t \sim (0, I_k)$. The structural innovation is orthonormal; that is, the structural covariance matrix, $\sum_{\varepsilon} = E(\varepsilon_t \varepsilon'_t{}')$, $I_K$ is the identification matrix. This model is known as the $AB$ model, and is estimated in the form below:

$$Au_t = B\varepsilon_t \tag{14}$$

The orthonormal innovation $\varepsilon_t$ ensures the identifying restrictions on A and B:

$$A\sum A' = BB' \tag{15}$$

Both sides of the expression are symmetric, which means that $K(K+1)/2$ restrictions need to be imposed on $2K^2$ unknown elements in A and B. At least $2K^2 - K(K+1)/2$ additional identifying restrictions are needed to identify A and B.

Considering the five endogenous variables that we have in our model, $\tilde{e}_t, \tilde{y}_t, \tilde{p}_{2t}, D_t^{excess}, \tilde{p}_{1t}$, the errors of the reduced form VAR are: $u_t = u_t^{\tilde{e}} + u_t^{\tilde{y}} + u_t^{\tilde{p}_2} + u_t^{D_{excess}} + u_t^{\tilde{p}_1}$. The structural disturbances, $\varepsilon_t^{\tilde{e}}, \varepsilon_t^{\tilde{y}}, \varepsilon_t^{\tilde{p}_2}, \varepsilon_t^{D_{excess}}, \varepsilon_t^{\tilde{p}_1}$, are the REER of the US dollar, real GDP of all OECD economies, natural gas real prices, excess demand in the world crude oil market, and crude oil real price shocks, respectively.[37] This model has a total of 50 unknown elements, and a maximum number of 15

[37] The Organisation of Economic Cooperation and Development (OECD) consists of the United States, much of Europe, and other developed countries. At 53% of world oil consumption in 2010, these large economies consume more oil than non-OECD countries. Due to having slower economic growth and more mature transportation sectors, the OECD countries have much lower oil consumption growth compared to non-OECD countries, but still have the larger share of world oil consumption. In this study, because of the importance of the OECD in global oil consumption and the homogeneity of the countries in this group (as they are

parameters can be identified in this system. Therefore, at least 35 additional identifiable restrictions are required to identify matrices A and B. The elements of the matrices that are estimated have been assigned $a_{rc}$. All 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 needs to be carried out in order to test whether the identification is valid.[38] The LR test is formulated with the null hypothesis that the identification is valid. Our system is in the following form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & a_{42} & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} u_t^{\tilde{e}} \\ u_t^{\tilde{p}_2} \\ u_t^{\tilde{y}} \\ u_t^{D_{excess}} \\ u_t^{\tilde{p}_1} \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{\tilde{e}} \\ \varepsilon_t^{\tilde{p}_2} \\ \varepsilon_t^{\tilde{y}} \\ \varepsilon_t^{D_{excess}} \\ \varepsilon_t^{\tilde{p}_1} \end{bmatrix} \qquad (16)$$

The first equation in this system represents the REER as an exogenous shock in the system. The second row in the system specifies real natural gas price responses to the REER. The third equation allows real GDP to respond contemporaneously to REER and gas price shocks. The fourth equation exhibits excess demand in crude oil market responses to REER and gas price shocks. The last equation depicts crude oil real prices. REER, natural gas prices, real GDP, and excess demand in the crude oil market are determinants of crude oil prices (see, *inter alia,* Askari and Krichene, 2010; Taghizadeh and Yoshino, 2013a, 2013b, and 2014; Taghizadeh et al., 2013). On the other hand, the focus of this chapter is to evaluate the impact of monetary policy on crude oil prices. REER is the monetary policy transmission channel in our model, and in order to capture its impact on crude oil prices, REER should be the most exogenous variable and crude oil price should be the most endogenous variable.

all advanced economies) we used the total GDP of the OECD members rather than GDP of the world or GDP of a certain country, as we are looking for an oil market as a whole rather than oil prices for a specific country.

[38] As in Narayan (2013), the LR statistic is computed as: $LR = T(tr(P) - \log(P) - K)$ where $P = A^{-1}B^{-T}B^{-1}A\sum$. The LR test is formulated with the null hypothesis that the identification is valid. The test statistic is asymptotically distributed with a chi-squared distribution, $\chi^2(q-K)$, where q is the number of identifying restrictions.

# 4. Empirical Results

## *4.1. Data Analysis*

We use monthly data from January 2007 to December 2013, the period leading up to and following the subprime mortgage crisis. Crude oil prices were obtained using simple averages 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. The reason we used Dubai crude oil prices in the Tokyo market is because Japan is the third largest importer of crude oil behind the US and the People's Republic of China. Natural gas prices are in constant US dollars obtained using a simple average of three major natural gas prices: the United States' Henry hub, United Kingdom's National Balancing Point (NBP), and Japanese imported LNG average prices. GDP is for the OECD members in constant US dollars, at fixed PPP, seasonally adjusted. All of the above three data series were deflated by the US consumer price index (CPI), as most crude oil and natural gas markets are denominated in US dollars. OECD GDP was also measured in US dollars. For the exchange rate series, we used the US dollar's REER (2005=100) Consumer Price Index. Henceforth, prices of crude oil, natural gas, and GDP are real values unless otherwise stated. The last variable, which is the excess demand for crude oil, shows the excess demand of crude oil in the global market. It was obtained by deducting the global crude oil supply from global crude oil consumption. We believe that by using global data, we can obtain more feasible results in order to generalize findings for most areas and countries. The sources of our 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), and the Monthly Energy Review of the* US Department of Energy (DOE).

In order to evaluate the stationarity of all series, we used an Augmented Dickey–Fuller (ADF) test. The results imply that with the exception of crude oil prices, which were stationary in the log-level, all other variables are non-stationary in the log-level. These variables include REER, real natural gas prices, real GDP of the OECD, and excess demand in the global crude oil market. However, when we applied the unit root test to the first difference of the log-level variables, we were able to reject the null hypothesis of unit roots for each of the variables. These results suggest that the REER, natural gas real prices, real GDP and excess demand in the crude oil market 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 the first differences level, they were integrated one order. Hence, they will appear in the SVAR model in first-differenced form.

### *4.2. The Structural Parameter Estimates*

The structural parameter estimates of the A and B matrices are presented in the table below. The LR test does not reject under-identifying restrictions at the 5% level, as the $\chi^2(1)$ test statistic is 3.62 and the corresponding p-value is 0.06, implying that identification is valid.

**Table 1: Structural Parameter Estimates of Matrices –A and B**

–A matrix

| | $\tilde{e}$ | $\tilde{p}_2$ | $\tilde{y}$ | $D_{excess}$ | $\tilde{p}_1$ |
|---|---|---|---|---|---|
| $\tilde{e}$ | 1 | 0 | 0 | 0 | 0 |
| $\tilde{p}_2$ | 0.01<br>(0.02) | 1 | 0 | 0 | 0 |
| $\tilde{y}$ | -1.31<br>(2.61) | 2.52<br>(0.96) | 1 | 0 | 0 |
| $D_{excess}$ | -1.47<br>(1.44) | -9.20<br>(7.53) | 0 | 1 | 0 |
| $\tilde{p}_1$ | -2.46<br>(0.58) | 7.71<br>(2.92) | -0.06<br>(0.13) | 0.10<br>(0.05) | 1 |

B matrix

| | $\tilde{e}$ | $\tilde{p}_2$ | $\tilde{y}$ | $D_{excess}$ | $\tilde{p}_1$ |
|---|---|---|---|---|---|
| $\tilde{e}$ | 0.01<br>(0.001) | 0 | 0 | 0 | 0 |
| $\tilde{p}_2$ | 0 | 0.002<br>(0.0002) | 0 | 0 | 0 |
| $\tilde{y}$ | 0 | 0 | 0.06<br>(0.005) | 0 | 0 |
| $D_{excess}$ | 0 | 0 | 0 | 0.16<br>(0.01) | 0 |
| $\tilde{p}_1$ | 0 | 0 | 0 | 0 | 0.06<br>(0.005) |

Note: Standard errors (SE) are presented in parentheses. T-statistics can be calculated as $(\hat{\alpha}/SE(\hat{\alpha}))$ where $\hat{\alpha}$ is the estimated coefficient. The critical values at the 5% and 1% levels are 1.96 and 2.58, respectively.

The signs and the significance of contemporaneous impacts on crude oil prices merit discussion because they have important policy and theoretical implications. To get an interpretation of the contemporaneous coefficients, the signs of the A matrices are reversed; this follows from equation (13) (see also Narayan, 2013). The key results are as follows. For this interpretation, the most important row in the –A matrix is the last row, which shows determinants of real crude oil prices over the period January 2007–December 2013, leading up to and following the subprime mortgage crisis. As is clear, the impact of REER for the US dollar on real crude oil prices was significant, and the sign of the coefficient is negative, implying that depreciation of the US dollar causes crude oil prices to rise. As assumed earlier, during January 2007–December 2013, US quantitative easing affected crude oil prices through the exchange rate channel. This means that the US dollar depreciated following the quantitative easing policies. This, in turn, made the oil prices cheaper in non-dollar-denominated currencies, resulting in higher demand and higher prices for crude oil in the global market. However, the global economy was in recession in that period, meaning a major part of the increased demand was speculative. Our estimations confirm this hypothesis.

Other findings reveal the impact of changes in natural gas prices on crude oil prices, which shows a positive correlation. This means that higher natural gas prices raise the prices of other substitute energy carriers, including crude oil. As for the impact of OECD GDP on crude oil prices, the sign of the coefficient shows a negative value. This is because in the period above, the global economy, especially the OECD, was in recession. However, this result is not significant. The last coefficient, which is the excess demand in the global market, shows a positive sign and is statistically significant, meaning that higher excess demand in the global oil market will raise crude oil prices. By running the Impulse Response analysis in Section 4.3, we are able to define the period in which each of these impacts was significant during January 2007–December 2013.

### *4.3. Structural Impulse Response (IR) Analysis*

A Structural Impulse response analysis is performed in order to provide further evidence on the dynamic response of crude oil real prices to REER, real natural gas prices, real GDP, and excess demand in crude oil market shocks.

Figure 5 shows the responses of real crude oil prices in our SVAR model to one-standard deviation structural innovations. In the left column are shown the responses of crude oil real prices to structural (positive) innovations in REER and real natural gas prices. The effects of an unanticipated positive shock to REER (appreciation of US dollars) on crude oil real prices are very persistent and highly significant, and can reduce real crude oil prices. An unanticipated positive innovation in real natural gas prices does not cause a significant effect on the real price of crude oil.

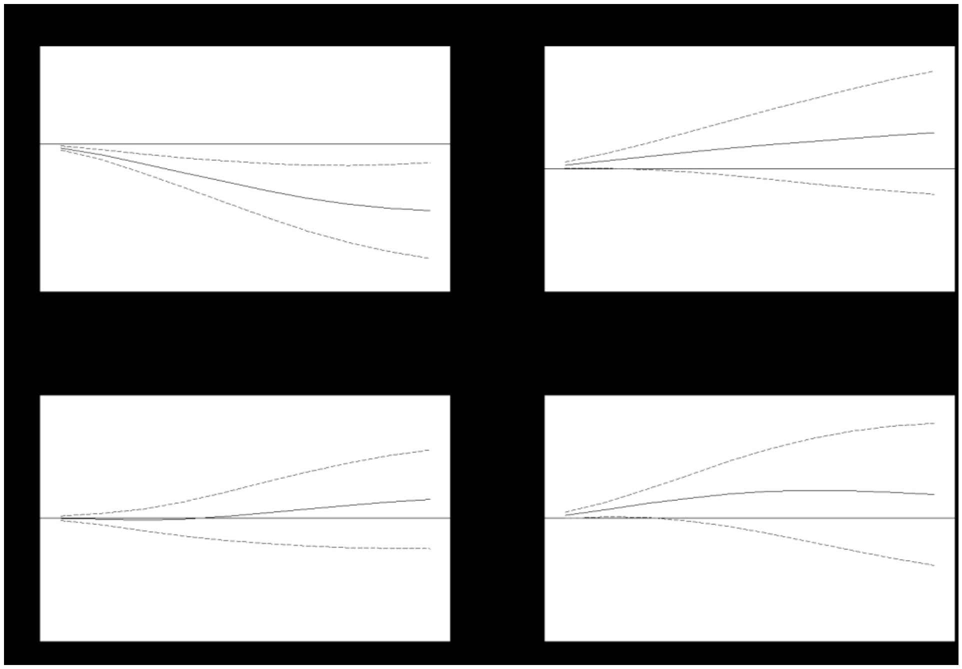

**Figure 5: The Impulse Response Effects of the Structural Shocks, May 2007–December 2012** Note: *p1* is crude oil real prices, *e* is the US dollar REER, *p2* is the real natural gas price, *y* is real GDP of the OECD members, *dexcess* is the excess demand of crude oil in the global market; all variables are in *first differences of their log forms*. The dashed lines represent one-standard-error confidence bands around the estimates of the coefficients of the impulse response functions. The confidence bands are obtained using Monte Carlo integrations.

In the right-hand column of Figure 5, a positive shock to the real OECD GDP has a positive effect on real crude oil prices that is statistically significant from the beginning for about 2 months. After this, the effects become non-significant. An unanticipated positive shock to excess demand of crude oil in the global market has a statistically significant positive effect on real crude oil prices, and builds up over the first 3 months. After this, it becomes insignificant.

# 5. Conclusions

This chapter evaluates how monetary policy affected crude oil prices leading up to and following the subprime mortgage crisis. This analysis concludes that aggressive monetary policy following the 2008 subprime mortgage crisis inflated oil prices, mainly through the exchange rate channel, by making oil cheaper in non-dollar-dominated currencies. Most of the world's crude oil demand is overshadowed by oil imports of non-producers or oil deficit producers. This means that a depreciation of the US dollar would make oil imports cheaper in non-dollar-denominated currencies, raising both demand for and prices of oil. Our results show that the sharp rise in crude oil prices up to early 2009 (until right after the crisis of 2007–2008) was not due to economic recovery, because the data shows the global economy still had not recovered at that time. In spite of this, however, crude oil prices rose sharply. We found that one of the reasons for this increase in crude oil prices is because of quantitative easing policies that the Federal Reserve and various central banks followed. This trend led to slower economic growth and imposed a longer recovery time for the global economy following the crisis. This research provides several other findings, among which are the relationship between gas prices and crude oil prices, and the impacts of GDP growth and excess demand in the crude oil market on crude oil prices. Our results of the dynamic response of crude oil prices to natural gas prices, GDP, and excess demand impacts during the period May 2007–December 2012 show that an unanticipated positive shock in natural gas real prices does not have a significant effect on the real price of crude oil. A positive shock to the real OECD GDP has a positive effect on real crude oil prices that is statistically significant from the beginning for about 2 months, after which the effects become insignificant. An unanticipated positive shock to excess demand of crude oil in the global market has a statistically significant positive effect on real crude oil prices and builds up over the first 3 months. After this 3-month period, these effects become insignificant.

Consequently, it is worthwhile to conclude that while US monetary policy focuses mainly on the US domestic economy, such as the unemployment rate, inflation, and the GDP gap, this chapter clearly shows that US monetary policy strongly affects global oil prices. This means that if the US continues its quantitative easing policy, then oil prices will continue to rise, and this will negatively affect global economic conditions.

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# Chapter 4: Economic Impacts of Oil Price Fluctuations in Developed and Emerging Economies[39]

## Abstract

This chapter assess the impact of crude oil price movements on two macro-variables, GDP growth rate and the CPI inflation rate, in three countries: U.S. 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

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[39] Another version of this chapter is available as:

Yoshino, N., and F. Taghizadeh-Hesary. 2014. 'Economic Impacts of Oil Price Fluctuations in Developed and Emerging Economies'. *IEEJ Energy Journal*. 9(3): 58-75.

# 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 1970's, 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 1970's. 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 by the 1970's 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.

In this research, we will assess and compare the impact of oil price fluctuations on the following macroeconomic factors: 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 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?

For this analysis, we chose to examine the period during the subprime mortgage crisis of 2008. Following the financial crisis of 2007-2008, crude oil prices dropped from US$ 133.11 in July 2008 to below US$ 42.01 in December 2008, due to decreased global demand. Shortly after this drop, however, they started to rise sharply again. We selected our analysis sub-periods to be before and after this event, and we will compare the results of these two sub-periods.

This chapter 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 explain our model, and in the fourth section we describe our empirical analysis. The fifth section contains this chapter'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[40] done 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[41] (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 its current 8% to 18%, exceeding its share of global population. This projection continues by saying 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.

[40] Asia/World Energy Outlook 2013
[41] Equal to about 6186 Million barrels of oil equivalent (Mboe)

## *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.

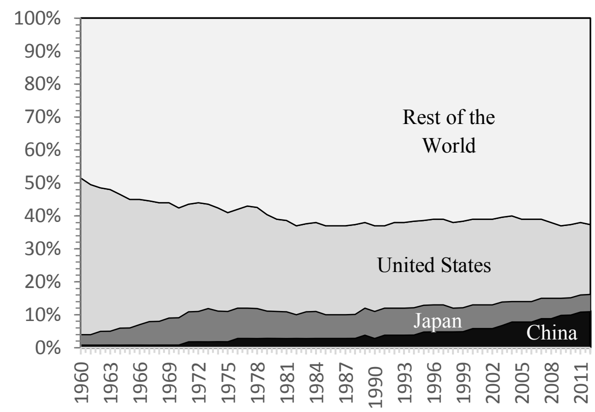


**Figure 1. Share of three major oil consumers in global oil consumption, 1960-2012 Source:** Annual statistical bulletin of the Organization of the Petroleum Exporting Countries (OPEC), 2013

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

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 an 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 approvals to return to 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 to 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 this 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[42].

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 Americans’ world more easily connected. Almost all of 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.[43] The EIA estimates U.S. proven oil reserves to be about 23 billion barrels.

[42] U.S. Energy Information Administration (EIA), Monthly Energy Review (January 2014)
[43] Energy Overview, Institute for Energy Research (IER)

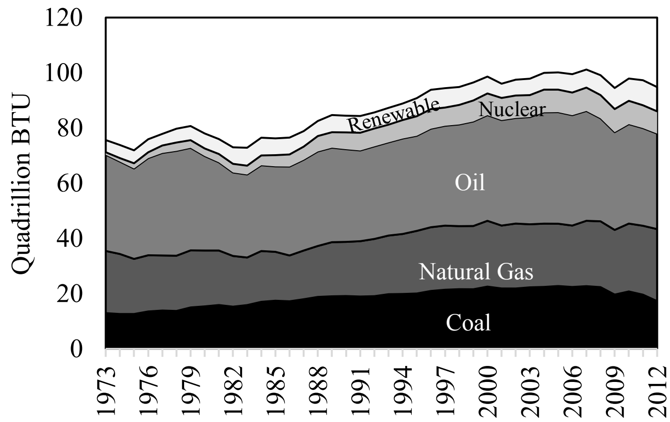


**Figure 2. US primary energy consumption by source, 1973-2013 Note:** Natural gas consumption is excluding supplemental gaseous fuels.

**Source:** U.S. 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. Model

The main objective of this research is to assess the impact of crude oil price movements on two macroeconomic variables: GDP growth rate and CPI inflation rate. In developing this model we used Taghizadeh and Yoshino (2013a) as a reference. In their model, they assumed that oil price movements 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 impact on the crude oil market (Taghizadeh and Yoshino 2013a; 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 exchange rate are monetary policy variables that have an impact on the crude oil market (Taghizadeh and Yoshino 2013a; 2013b; 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.[44]

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 K variable Structural Vector Autoregression (SVAR) model and start with following VAR model:

$$Y_t = A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t \qquad (1)$$

Where $Y_t$ is a $(K \times 1)$ vector of variables. $A_{i\,(i=1,\ldots,p)}$ are $(K \times K)$ fixed coefficient matrices, p is the order of the VAR model and $u_t$ is a $(K \times 1)$ 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, $\varepsilon_t$, as in Yoshino and Taghizadeh (2014):

$$u_t = A^{-1} B \varepsilon_t \qquad (2)$$

Where, $B$ is a structural form parameter matrix. Substituting Eq. (1) into Eq. (2) and following minor operations, we get the following equation, which is the structural representation of our model:

$$AY_t = A_1^* Y_{t-1} + \ldots + A_p^* Y_{t-p} + B\varepsilon_t \qquad (3)$$

[44] Taghizadeh and Yoshino (2014) used two monetary policy factors in their global crude oil model: real interest rate and Reel Effective Exchange Rate (REER). But since in the second sub-period that we focus on it (2000m08 – 2013m12), Federal Reserve and some other monetary authorities' behaviour kept the interest rates near to zero, so we added Money Supply variable instead of interest rate in our analysis.

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

$$Au_t = B\varepsilon_t \tag{4}$$

The orthonormal innovations, $\varepsilon_t$ ensure the identifying restriction on A and B:

$$A\sum A' = BB' \tag{5}$$

Both sides of the expression are symmetric, which means that $K(K+1)/2$ restrictions need to be imposed on $2K^2$ unknown elements in A and B. At least $2K^2 - K(K+1)/2$ additional identifying restrictions are needed to identify A and B. Next, we examine the six endogenous variables that we have in our model: $m_t, e_t, p_{2t}, p_{1t}, \pi_t, y_t$ , which are money supply, exchange rate, natural gas price, crude oil price, CPI, and GDP. The errors of the reduced form VAR are : $u_t = u_t^m + u_t^e + u_t^{p_2} + u_t^{p_1} + u_t^{\pi} + u_t^y$ The structural disturbances, $\varepsilon_t^m, \varepsilon_t^e, \varepsilon_t^{p_2}, \varepsilon_t^{p_1}, \varepsilon_t^{\pi}, \varepsilon_t^y$ , 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 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:

Matrix A | Matrix B

$$\begin{array}{c} \\ m_t \\ e_t \\ p_{2t} \\ p_{1t} \\ \pi_t \\ y_t \end{array}
\begin{array}{c} \begin{array}{cccccc} m_t & e_t & p_{2t} & p_{1t} & \pi_t & y_t \end{array} \\
\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ 0 & a_{32} & 1 & 0 & 0 & 0 \\ 0 & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & 0 & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \end{array}
\begin{bmatrix} u_t^m \\ u_t^e \\ u_t^{p_2} \\ u_t^{p_1} \\ u_t^{\pi} \\ u_t^y \end{bmatrix} =
\begin{array}{c} \begin{array}{cccccc} m_t & e_t & p_{2t} & p_{1t} & \pi_t & y_t \end{array} \\
\begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} \end{bmatrix} \end{array}
\begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^e \\ \varepsilon_t^{p_2} \\ \varepsilon_t^{p_1} \\ \varepsilon_t^{\pi} \\ \varepsilon_t^y \end{bmatrix} \qquad (6)$$

The first equation in this system represents the money supply as an exogenous shock in the system[45]. The second row in the system specifies exchange rate responses to money supply shocks[46]. 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 impact on the GDP; (see, *inter alia,* Taghizadeh and Yoshino 2013a, Taghizadeh et al. 2013). The main purpose of this chapter is to measure and compare $a_{54}$ & $a_{64}$ which are the impact 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.

# 4. Empirical Results

As mentioned earlier, the increase in oil prices that began in 2001, the sharp decline that followed the 2008 subprime mortgage crisis, and the immediate recovery that they experienced shortly after have renewed interest in the effects of oil prices on the Macroeconomy. For this reason, we selected a period which covers significant fluctuations mentioned above. We ran regressions for

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

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

our SVAR for each of these three countries during the two sub periods 2000m1-2008m07 and 2008m8-2013m12, and compared the findings.

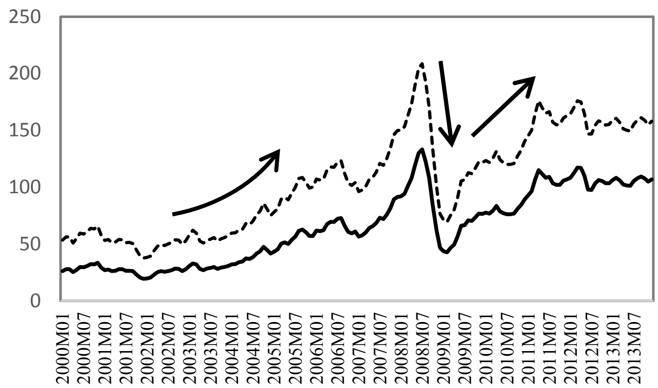


**Figure 3. Crude oil price movements 2000m1 -2013m12** Note: The square dotted line is the real price and the solid line is the nominal price. Crude oil prices are a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market all in USD. Real crude oil prices obtained by deflating crude oil prices using the U.S. consumer price index (CPI) (2005=100). Source: The *Energy Data and Modeling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ)* and International Financial Statistics (IFS) 2013.

Figure 3 shows the crude oil price movements during the entire period covered by this chapter. Following the financial crisis of 2007-2008, due to a decline in global demand for crude oil, prices dropped from USD 133.11 in July 2008 to below USD 42.01 in December 2008, and then started to increase again sharply.

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. GDP of all 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 Modeling 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 in log-level, all other variables are non-stationary in 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. Hence they will appear in the SVAR model in first differenced form. This means that instead of CPI, we will have 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.

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.

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). The main cause for this is the appreciation of the Chinese Yuan. Slightly After the sub-prime mortgage crisis, oil prices started to increase sharply. This happened because of a mild recovery in the global economy and huge quantitative easing (QE) policies of the US and other country's monetary authorities (Yoshino and Taghizadeh 2014). At the same time, the Chinese Yuan appreciated compared to other currencies, which means that 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.

**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 impact of oil price fluctuations on GDP growth, $-a_{54}^{i}(i = CN, JP, US)$ shows 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. 3.* indicates significance at 5%, ** indicates significance at 1%.

Japan's elasticity of 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. The disaster made this country fully depended on imports of fossil products, especially on crude oil. 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 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. This positive elasticity 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 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 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 GDP growth rate to 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.

The impact of oil price fluctuations on US and Japanese GDP is much milder than in China. On the other hand, however, Chinese CPI sees smoother rates of inflation in oil shocks compared to the US and Japan, because of the higher growth rate in Chinese economy, which shifts the AS curve forward and avoids higher prices in oil shocks. In Japan's case, the AS curve has been almost constant recently, and in the US it is seeing only a small forward shift.

# 5. Conclusions

In this chapter, 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 drastically. CPI elasticity reduced, however, because of 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 sub-prime 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 (Yoshino and Taghizadeh 2014). 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.

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# Chapter 5: Impact of Energy prices and the Effectiveness of the Easing Monetary policy in Japanese Economy[47]

## Abstract

Japan has reached the limits of conventional macroeconomic policies. Recently Bank of Japan (BOJ) in order to overcome the deflation and achieve sustainable economic growth, set the inflation target at 2 percent and implement aggressive monetary policy to achieve this target as soon as possible. Although prices started to rise after the BOJ implemented monetary easing, but main reason for this price elevation may not come directly from easy monetary policy, but other sources such as higher oil prices. Expensive oil prices in Japanese yen which is result of depreciated Japanese yen is one of the main causes of the inflation. Moreover, result of this chapter shows that quantitative easing may not stimulate the Japanese economy. Aggregate demand which includes private investment did not increase significantly in Japan when the interest rate is lowered. Private investment displays this unconventional behavior because of uncertainty about the future and ageing population. We believe that remedy of Japanese economy is not monetary policy. The government needs to look for serious structural changes and growth strategies.

Keywords: easing monetary policy, Japanese economy, zero interest rate policy, Abenomics, energy prices

[47] Another version of this chapter is available as:

Yoshino, N., and F. Taghizadeh-Hesary. Forthcoming, 2014. 'Effectiveness of the Easing Monetary policy in Japanese Economy incorporating Energy Prices'. *ADBI Working Paper* 492. Tokyo: Asian Development Bank Institute.

# 1. Introduction

In the early 1990s, Japan's real estate and stock market bubble burst and the economy went into a tailspin. Since then, Japan has suffered from sluggish economic growth. Two decades later, the collapse of Lehman Brothers in September 2008 and the global financial crisis threatened the entire world economy. In March 2011, a catastrophic earthquake and tsunami struck north-eastern Japan. Japan's government budget deficit to GDP ratio breached 200% in 2010, mainly because of the high share of pension fund payments in government spending, and the efficiency and effectiveness of public investment was called into question. The Japanese economy required a stimulus to escape from this pattern of long-term sluggish growth. In December 2012, the Liberal Democratic Party won a general election, making Shinzo Abe prime minister of Japan, a post that he had held in 2007. "Abenomics" refers to the economic policies advocated by the prime minister after the election, which were designed to revive the sluggish economy with "three arrows:" (i) fiscal consolidation, (ii) more aggressive monetary easing by the Bank of Japan, and (iii) structural reforms to boost Japan's competitiveness and economic growth. (Yoshino and Taghizadeh, 2014a) The Bank of Japan settled on an inflation target of 2% by implementing easing monetary policy.

In this chapter we want to focus on the aggressive monetary easing and supposed to answer to two questions: firstly, does the Japanese aggregate demand which includes private investment increase significantly when the interest rate is lowered following by easing monetary policy? Secondly, does the inflation in Japan got impact from aggressive monetary easing of the Bank of Japan or it causes by other reasons for example higher oil prices? In order to do so, in first section, we will initially describe the reasons for Japan's stagnant economy, secondly we shed light on the recent monetary policy of the BOJ and finally we will explain that How Higher Energy Prices Created Inflation in Japan?. In second section we will develop our model. Third section is for the empirical works and the fourth section contain this chapter's concluding remarks.

## *1.1. Reasons for Japan's stagnant economy after burst of bubble*

The sudden imposition of a tight monetary policy in 1990 pushed land and stock prices down about one-third from their peak level. The annual real growth rate of the economy was below 2 percent for most of the 1990s. The unemployment rate went up to almost 5 percent in 2002 and 2003. Paul Krugman argues that Japan is currently in a liquidity trap, a situation in which monetary policy is ineffective in lowering interest rates. However, our empirical analysis indicates that the problems of the Japanese economy stem from other sources. We will state our diagnosis here and then substantiate it in the sections that follow.

Aggregate demand which includes private investment did not increase significantly in Japan when the interest rate is lowered. Private investment displays this unconventional behavior because of uncertainty about the future and ageing population, this means that monetary policy was not effective.

The large foreign direct investment (FDI) of Japan to other Asian countries, shifted the investment-saving (IS) curve to the left, as shown in Figure 1. In such circumstances, because monetary policy is ineffective, Fiscal policy should be used to shift the IS curve back to the right so that the economy can recover. The dilemma, however, is that despite the huge increase in government investment, the IS curve has not shifted enough to the right. This was because that the effectiveness of public works drastically diminished, compared to high growth period. (Yoshino and Nakahigashi, 2000)

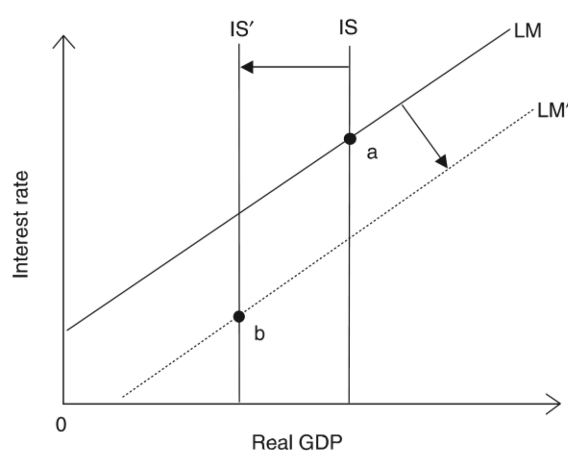


**Figure 1. The ineffectiveness of monetary policy in Japan**

Source: Yoshino and Sakakibara (2002)

Public investment had produced low simulative effects on GNP because it had been distributed ineffectively. The bulk of public investment increased concentrated in the countryside, and the facts are that public investment had a much smaller impact on rural areas than on urban areas and that public investment in the agricultural sector had been much less effective than public investment in the industrial and service sectors. The result of this increasing rural and agricultural bias in the allocation of public investment is that the multiplier of public investment had declined sharply from about 2.5 to only about 1 in recent times (Yoshino, Kaji, and Kameda, 1998). This means that such public investment only increased the budget deficits; it could not bring about a recovery of the Japanese economy.

Several other factors have contributed to the stagnant economy in last two decades:

After burst of the bubble, there was a credit crunch, because banks had been less willing to make investment loans for several reasons. Falling land prices had made private banks reluctant to grant loans because of the anticipated fall in the value of collateral. The prudential measures introduced in 1998 for tougher bank examination, as well as the higher capital requirements, forced banks to reduce the number of loans they made. The growing proportion of NPLs in the banks' loan portfolios had caused the banks to reduce their loans to build up their loss provisions. The failures of several large financial institutions had also reduced the availability of loans.

Capital flows had become more interest rate sensitive. The lower interest rate in Japan had encouraged out flow of financial investment to the United States and other countries (Yoshino and Sakakibara, 2002)

The level of consumption has decreased. The fall in the propensity to consume has been mainly a result of workers' concerns about possible layoffs. In addition, the fall of asset prices has lowered consumption, including that of the corporate sector, because of the wealth effect. Another reason for the decrease in the level of consumption is the demographic issues. Japan's biggest problem is its ageing population. The number of elderly and retired people is rising, and the younger generation is shrinking, and usually elderly people consume less comparing to younger generation.

### *1.2. Recent monetary policy of the Bank of Japan*

Recently the government and the Bank of Japan (BOJ) delivered a joint statement on overcoming deflation and achieving sustainable economic growth on 22 January 2013. The BOJ set the price stability target at 2% (year-on-year rate of change in the consumer price index). On 4 April 2013, the BOJ announced that, based on a decision by the Monetary Policy Meeting, it would purchase Japanese government bonds, effective 5 April 2013. This decision was taken at the first Monetary Policy Meeting after Haruhiko Kuroda had taken up his post as the new governor of the BOJ. Approximately JPY 7.5 trillion per month of Japanese government bonds (2-year bonds, 5-year bonds, 10-year bonds, 20-year bonds, 30-year bonds, 40-year bonds, floating-rate bonds, and inflation-indexed bonds) would be purchased and increasing the monetary base, in contrast to previous attempts at an expansionary monetary policy which mainly focused on buying short-term government bonds (Yoshino and Taghizadeh, 2014a). Although prices started to rise after the BOJ implemented monetary easing,[48] but it could not raise the investment and the aggregate demand. And the inflation stem from other sources such as higher energy prices that happened because of depreciated Japanese Yen after easing monetary policy[49].

### *1.3. How Higher Energy Prices Create Inflation?*

A simple aggregate supply and demand model will clarify the analysis of how higher energy prices which was result of depreciated Yen could create inflation in Japan:

[48] For more information about the impact of monetary policy on oil prices see inter alia, Taghizadeh and Yoshino 2013a; 2014; Yoshino and Taghizadeh 2014c.

[49] 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 an immediate shutdown of about 10GW 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 approvals to return to 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 and caused inflation. Increases to 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 value. Japan consumed over 4.7 million barrels per day (bbl/d) of oil in 2012. The increased cost of imported energy had significant negative impact on Japanese economy. (For more information regarding the impact of higher energy prices on the economy see, *inter alia*, Taghizadeh and Yoshino 2013b; Taghizadeh et al. 2013)

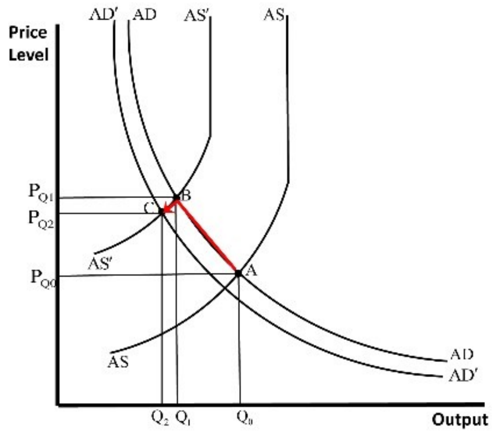


**Figure 2. How higher energy prices create inflation?** Note: We are assuming that there is a technological progress that is why the output level in full employment also increased.

Source: Yoshino and Taghizadeh (2014b).

In Figure 2, the economy initially is in equilibrium with price level PQ0 and real output level Q0 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 Q1. 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 (PQ1), given the nominal wage rate. This moves the economy to the level of output (Q1) and price level (PQ1). This point is indicated in Figure 2 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 PQ1 and sets them to PQ2 as the final equilibrium price. This lowers the output levels due to less consumption in the economy, from the previous point of Q1 to Q2. This point is indicated in Figure 2 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. Consequently, output and prices move along an adjustment path such as that indicated by the arrow in Figure 2. Figure 3 is an evidence for the aforementioned in Japanese economy.

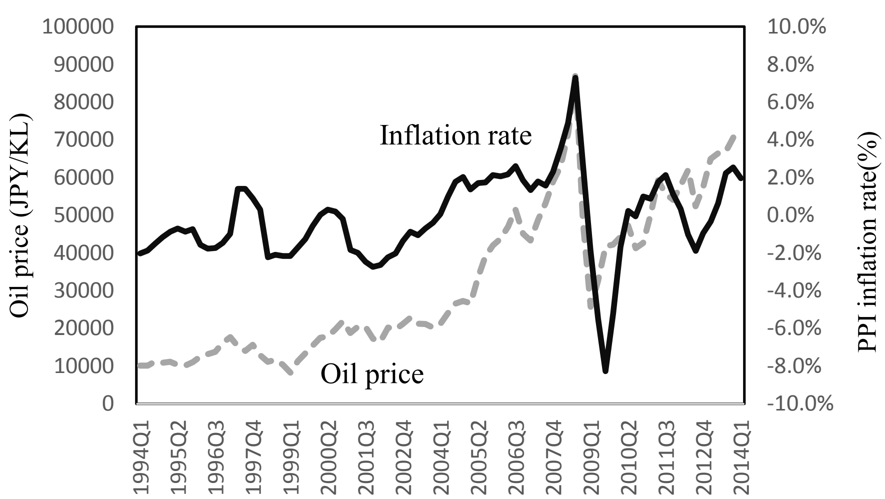


**Figure 3. Oil price and Inflation rate in Japan** Note: Inflation rate is producer price index (PPI) growth rate for all commodities based on year-on-year change. Oil price stands for the average CIF imported crude oil price of Japan, in Japanese Yen per kilo liter.

Source: Bank of Japan database and The Energy Data and Modelling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ).

Figure 3 shows the co-movements of Inflation rate in Japan and import price of crude oil in Japanese yen. As it is clear in most cases they followed same path and graphically it declares that there is a large association between these two variables. Rising of oil prices during the period of

1994Q1-2014Q1 caused by various reasons. In earlier quarters it caused by higher crude oil demand especially from the side of emerging economies such as China, India, Brazil and the Middle East which brew up the global oil prices. In Most recent quarters especially when BOJ implemented series of easy monetary policy, this elevation happened because of the depreciation of Japanese yen infront of other currencies, which made the oil import more expensive in Japanese yen, and may had high impact on the inflation rate.

# 2. Model

The New-Keynesian (NK) approach to monetary policy analysis has emerged in recent years as one of the most influential and prolific areas of research in macroeconomics.[50] It has provided us with a framework that combines the theoretical rigor of Real Business Cycle (RBC) theory with Keynesian ingredients like monopolistic competition and nominal rigidities. The framework has also became the basis for the new generation of models being developed at central banks, and increasingly used for simulation and forecasting purposes (see Gali, Smets and Wouters, 2012).

In this section, we will try to develop a model with NK approach which includes both aggregate supply (Phillips Curve), aggregate demand side and monetary policy blocks, in order to capture impact of monetary policy and oil price shocks on the economy. The Aim that we follow is to answer to these question that i) if easy monetary policy could stimulate the GDP in Japan? and ii) whether aggressive monetary policy of the BOJ raised the aggregate demand and caused inflation, or the inflation in Japan stemmed from other sources such as higher oil prices, which shifts the aggregate supply to left and makes inflation?

Here we write the three equations that constitute the simplest possible version of our NK model, and in subsequent section we use these equations simultaneously in order to run our empirical works. The first equation in our simultaneous equation model (SEM) is New-Keynesian Phillips Curve (NKPC), can be derived from the aggregation of the price-setting decisions by firms,

[50] See Gali and Gertler (2007) for quick introduction to the NK framework. The Textbooks by Woodford (2003) and Gali (2008) provide a more comprehensive treatment and analysis of the NK model.

combined with an equation describing the relationship between marginal cost and the level of activity (Gali), it takes the form bellow:

$$\pi_t = \alpha_\pi E_t\{\pi_{t+1}\} + \alpha_y(y_t - \bar{y}_t) + \alpha_{oil} p_t^{oil} + \alpha_{gas} p_t^{gas} + u_t \tag{1}$$

where $\pi_t$ is the inflation rate, $E_t\{\pi_{t+1}\}$ is the expected inflation rate, $(y_t - \bar{y}_t)$ represents deviations of (log) output from (log) steady state (or trend level), $p_t^{oil}$ and $p_t^{gas}$ are crude oil and natural gas prices respectably which are two main energy carriers and two production inputs, and changes in their prices could affect the general level of prices, and $u_t$ is a cost-push shock.

The second key block of the model relates the output gap positively to its expected one-period ahead value, negatively to the real interest rate, and positivity to the exchange rate ($e_t$). When the domestic currency depreciates, exchange rate will increase, this will tend to increase in export and decrease of import, which will let the output to increase, and it is in favor of the left hand of equation 2, The real interest rate is defined as the difference between the long-term nominal interest rate ($i_t^{LN}$) and the expected inflation rate ($E_t\{\pi_{t+1}\}$). The resulting equations is given by:

$$(y_t - \bar{y}_t) = -\frac{1}{\beta_i}\left(i_t^{LN} - E_t\{\pi_{t+1}\}\right) + \beta_y E_t\{(y_{t+1} - \bar{y}_{t+1})\} + \beta_e e_t \tag{2}$$

The third equation in the model is a means of block describing how monetary policy is conduced. The simplest possible such description is given by a version of the so-called "Taylor rule", which takes the form:

$$i_t^{SN} = \gamma_0 + \gamma_\pi \pi_t + \gamma_y(y_t - \bar{y}_t) + v_t \tag{3}$$

where $i_t^{SN}$ is the short-term nominal interest rate and $v_t$ is the monetary shock.

Since the interest rate in equation 2 is long-term interest rate and the interest rate in equation 3 is short-term one, in order to be able to run SEM, we need to add one more block, which is called "bridge equation". It takes the form bellow:

$$i_t^{LN} = \lambda_0 + \lambda_i i_t^{SN} \tag{4}$$

Considering above, the resulting SEM is given by:

$$\begin{pmatrix} \pi_t = \alpha_\pi E_t\{\pi_{t+1}\} + \alpha_y(y_t - \bar{y}_t) + \alpha_{oil} p_t^{oil} + \alpha_{gas} p_t^{gas} + u_t \\ (y_t - \bar{y}_t) = -\frac{1}{\beta_i}\left(i_t^{LN} - E_t\{\pi_{t+1}\}\right) + \beta_y E_t\{(y_{t+1} - \bar{y}_{t+1})\} + \beta_e e_t \\ i_t^{SN} = \gamma_0 + \gamma_\pi \pi_t + \gamma_y(y_t - \bar{y}_t) + v_t \\ i_t^{LN} = \lambda_0 + \lambda_i i_t^{SN} \end{pmatrix} \tag{5}$$

Model 5 enables us to capture impact of higher energy prices (oil and gas) and the output gap on the inflation rates. Moreover simultaneously it allows to see impact of monetary policy on output gap. This means that by doing the empirical works in section 3 of this chapter on the aforementioned model, we would be able to answer to these two questions that i) easy monetary policies of BOJ has any impact on the output level in this country? ii) Does the easy monetary policy caused the inflation in Japan or whether it stemmed from other sources such as higher oil prices?

# 3. Empirical works

## *3.1. Identification of SEM*

One of the significant issues in simultaneous equations is identification, meaning that we must first determine whether the equation is identified or not. If the equation is not identified, then estimating its parameters is meaningless. This is because the estimates obtained will have no interpretation, and therefore will not provide any useful information. Two popular ways for checking whether equations are identified or not are i) rank condition and the ii) order condition. The order condition is a necessary but not sufficient condition for identification. The rank condition is both a necessary and sufficient condition for identification.

The order condition is a simple counting rule that could be used to determine if one structural equation in a system of linear simultaneous equations is identified. Define as following: G = total number of endogenous variables in the model, K = total number of variables (endogenous and exogenous) excluded in the equation being checked for identification. The order condition is as follows:

If $K = G - 1$ the equation is exactly identified

If $K > G - 1$ the equation is overidentified

If $K < G - 1$ the equation is unidentified

Bellow shows result of order condition for Eqs. 1-4 of our SEM:

Eq. 1: G=4, K= 3, $K = G - 1$, Equation 1 is exactly identified

Eq. 2: G=4, K= 3, $K = G - 1$, Equation 2 is exactly identified

Eq. 3: G=4, K= 4, $K > G - 1$, Equation 3 is overidentified

Eq. 4: G=4, K= 5, $K > G - 1$, Equation 4 is overidentified

Results of order condition shows that simultaneous equations are identified, however as mentioned earlier the order condition is a necessary but not sufficient condition for identification and there is one more step to go, which is rank condition.

The rank condition tells us whether the structural equations we are checking for identification can be distinguished from a linear combination of all structural equations in the simultaneous equation system. Results of rank condition shows that our simultaneous equations are identified, hence we can start the next steps of empirical works.

### *3.2. Data Analysis*

We use quarterly data from 1994Q1 to 2014Q2, the period that we selected for this analysis includes the era which BOJ had taken zero interest rate policy. In 2001Q4 the short-term interest rate which is a monetary policy interest rate of the BOJ, became almost zero. This forced us to separate the period of our analysis into two sub-periods, the first period is from 1994Q2 to 2001Q4, that the value of short term interest rate was significant and more than zero, and the second period is from 2002Q1 to 2014Q2, that BOJ had taken zero interest rate monetary policy in it, and short term interest rate was almost zero in most of the time.

Inflation rates that we used in our survey is the growth rate of producer price index (PPI) of Japan for all commodities based on year-on-year change. Output gap is the variation of real GDP of Japan from GDP in full employment for this country. In order to estimate the GDP of full employment, we have done Hodrick Prescott filter on the real GDP. Price of oil stands for the average CIF imported crude oil price of Japan, in Japanese Yen per kilo liter. Price of gas is for the average CIF Imported LNG price of Japan in Japanese yen per ton. As for short-term interest rate, call rates (average of uncollateralized overnight rate) of Japan used. For the long-term interest rate we used Japanese government bond (JGB) interest rate. And finally for the exchange rate we used US dollar/Japanese Yen spot rate average in the quarter, in Tokyo market. Sources of data are, Trade Statistics of Japan, Bank of Japan database and The Energy Data and Modelling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ).

To evaluate the stationarity of all series, we used an Augmented Dickey–Fuller (ADF) test. The results imply that with the exception of short-term interest rate, inflation rate and GDP gap, which were stationary, all other variables are non-stationary. These variables include crude oil price, gas price, long-term interest rate and the exchange rate. However, when we applied the unit root test to the first difference of the variables, we were able to reject the null hypothesis of unit roots for each of the variables. These results suggest that the crude oil price, gas price, long-term interest rate and the exchange rate 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 the first differences level, they were integrated of order one. Hence, variables will be appeared in our SEM in first differences form.

In the next step, in order to identify the cointegrating vectors among the variables, we conduct a cointegration analysis using Johansen's technique by assuming a linear deterministic trend and in two cases, with intercept and with intercept and trend. Results suggests to accept the null hypothesis of non-cointegrating variables, this means that there is no cointegrating vectors among the variables.

### *3.3. Empirical results*

It would be necessary to run a regression in order to assess the impact of BOJ easy monetary policy and higher energy prices on the Japanese economy. For this reason, we ran the regression for our SEM using the weighted two-stage least squares (W2SLS) method. Results are summarized in Table 1. W2SLS is an instrumental-variable estimation methodology, for instruments we used lagged values of the two exogenous variables that we have in this survey which are oil price and gas price. We used the Akaike Information Criterion (AIC) to select the lag orders in which the maximum lag is set to 3 lags of each variables.

## Table 1. Empirical results

| | *Notation* | 1994Q2 - 2001Q4 | 2002Q1 - 2014Q2 |
|---|---|---|---|
| **Phillips curve** | | | |
| ***Inflation rate*** $\pi$ | | | |
| Lagged inflation rate | $\pi_{(-1)}$ | *0.89(4.08)*** | *-0.36(-1.12)* |
| GDP gap | $(y-\bar{y})$ | *0.69(2.18)** | *-0.24(-0.45)* |
| Crude oil price | $p^{oil}$ | *0.06(3.27)*** | *0.07(2.59)*** |
| Gas price | $p^{gas}$ | *0.03 (0.45)* | *0.05(1.17)* |
| **Aggregate Demand** | | | |
| ***GDP gap*** $(y-\bar{y})$ | | | |
| *Long-term real interest rate* | $(i^{LN}-\pi)$ | *-0.02(-4.71)*** | *-0.02(-1.09)* |
| *Lagged GDP gap* | $(y_{(-1)}-\bar{y}_{(-1)})$ | *-0.33(-1.66)* | *0.42(1.52)* |
| *Exchange rate* | $e$ | *0.09(2.18)** | *0.07(1.17)* |
| **Taylor Rule** | | | |
| ***Short-term interest rate*** $i^{SN}$ | | | |
| *Inflation rate* | $\pi$ | *1.21(0.67)* | *1.94(2.16)** |
| *GDP gap* | $(y-\bar{y})$ | *4.76(2.72)*** | *3.89(3.01)*** |
| **Bridge equation** | | | |
| ***Long-term real interest rate*** $i^{LN}$ | | | |
| *Short-term interest rate* | $i^{SN}$ | *3.50(3.16)*** | *4.44(2.67)** |

T-statistics are in parentheses, * indicates significance at 5%, ** indicates significance at 1%s

The first part of empirical results is for the Phillips curve which is the aggregate supply function. Vertical axis of the Phillips curve is inflation rate and the horizontal axis is $(y-\bar{y})$ which is the GDP gap. Usually aggregate supply curve is upward slopping, that means GDP gap and rate of inflation should have positive relation. Our results for 1994Q2-2001Q4 is in accordance with upward slopping aggregate supply, this means larger GDP gap tended to higher inflation rate in the first period. When the economy is in inflationary environment, then that will accelerate current inflation more, so in this situation lagged inflation should have positive impact on the current inflation rate, which is correct in the first period of our analysis. However after 2002, Japan was facing with deflation and the GDP gap was falling down, so these two numbers are not significant in the second period of our analysis, which is valid. This means current year's inflation was not affected by lagged inflation rates, secondly because economy was in recession, so GDP gap was negative and had no impact on the inflation rate. On the other hand, increasing crude oil price shift up aggregate supply curve, because it is inflationary pressure from import of oil, then the positive sign of crude oil price in both period is correct. This finding is in accordance to what is happening now in Japanese economy. As mentioned earlier, the second arrow of Abenomics is aggressive easing monetary policy. Although after launching this policy inflation created, but we believe it stemmed mainly from other sources, especially from higher oil prices. Following by easy monetary policy of the BOJ, Japanese yen started to depreciate heavily, this raised prices of crude oil and other sources of energy which are all importing products, hence it has high pressure on Japanese manufactures by pushing up their production costs, and subsequently created the inflation. Our Empirical analysis also supports this assertion, Because in second period sign of output gap in Phillips curve equation was not significant, it means the easy monetary policy could not raise the investment, and nor the aggregate demand, but these easy monetary policy pushed up oil prices in Japanese yen, which is a negative sign for Japanese manufacturers.

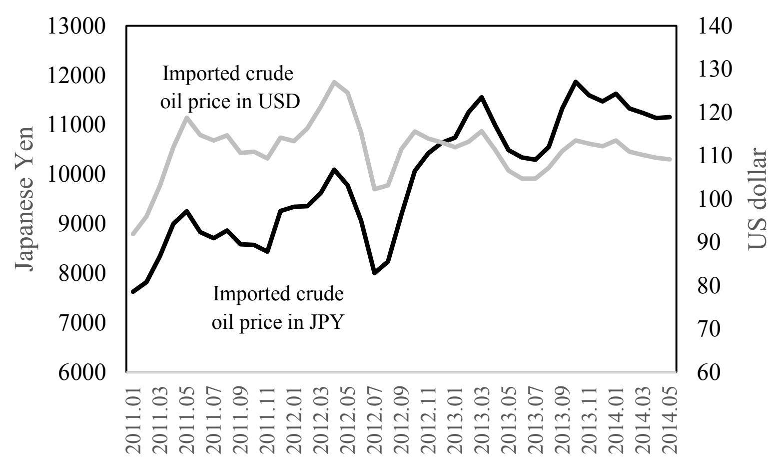


**Figure 4. Crude oil import price of Japan** Note: Import prices are CIF price of Japan. CIF Price of Japan is converted into dollars by the monthly average of exchange. Source: Japan Exports & Imports (Ministry of Finance)

Figure 4 compares trend of CIF Japan price of oil in US dollars and in Japanese yen. As it is clear because of depreciated yen which is result of easy monetary policy, the black line (imported crude oil prices in JPY) which was bellow gray (imported crude oil price in USD) line passed it and moved upward.

As for the gas price impact on the inflation rate it was not significant in both periods. The reason that the value for oil was significant in both period but gas was not, is that oil is the main sources of energy in the energy basket of Japan. Figure bellow shows share of oil, gas and other energy carriers in energy basket of Japan during Jan 1994 – June 2014.

As it is clear in Figure 5 the main energy carrier which has the largest share in energy basket of Japan is oil and petroleum products. In the first period of our analysis (1994Q1-2001Q4) average share of oil and petroleum products in primary energy demand of Japan was almost 54 percent, although in the second period (2002Q1-2014Q2) this share diminished to about 48 percent, but it is still quite large and is still the largest energy carrier in Japanese energy basket. That's why oil price fluctuations had high impact on macro-variables of Japan including the inflation rate in both period.

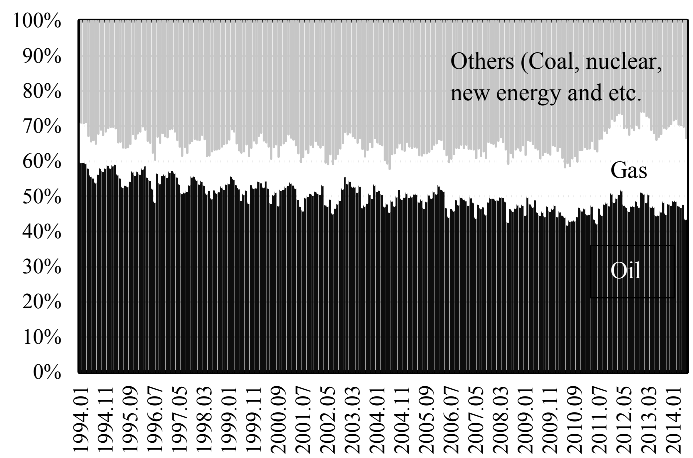


**Figure 5. Share of different energy sources in Japanese energy basket (Jan 1994 – June 2014)** Note: shares calculated by the calorie of energy sources. Oil in this figure is imported crude oil + imported petroleum products. Gas is imported LNG. Other energy carriers are coal, nuclear power, hydropower, new energy power, and etc.

Source: General Energy Statistics, Agency of Resources and Energy, Ministry of Trade, Economy and Industry of Japan, METI

But the reason that gas price fluctuations did not have significant impact on inflation rate of Japan, is because share of this energy carrier is still smaller comparing to oil. Share of gas in first period was 11 percent and in the second period it raised to 17 percent. Following by the March, 2011 earthquake and catastrophic Tsunami in Japan which tends to shut down of all nuclear power plants in the country, LNG import increased drastically and it is still increasing, so in future, till Japan supposed to keep the nuclear power plants off, we expect that LNG prices also have a significant effect on macro-variables of the country.

Next part of Table 1 shows the results for the aggregate demand. When real interest rate goes down, then investment should go up, so the sign of interest rate in the empirical findings should be negative. In both periods it shows negative, however after 2002, because of long-term recession, even when the interest rate became lower, investment was not so accelerating, so it supposes the vertical IS curve (Figure 1). Lagged GDP gap in both period did not have significant impact on the current value of GDP. Exchange rate affects to export and import. If value of domestic currency appreciate infront of foreign currencies, exchange rate decreases, it reduce the export and raise the import, which means aggregate demand should go down. So the sign of exchange rate in this equation should be positive. In this example both periods shows positive signs for the exchange rate, however only in the first period it is significant value.

The third part of empirical results is for the Taylor rule which depends on inflation and GDP gap. If the inflation rate keeps on going up, then the central bank will tighten the monetary policy, so the inflation rate should has positive sign (Yoshino et al., 2014). In both periods it is positive however only in the second period it is significant. Next part of Taylor rule is GDP gap. From 1994Q2 - 2001Q4 GDP gap was widening, when current GDP is higher than full employment GDP, that means acceleration of the economy, then central bank is try to tighten its money market, so GDP gap in Taylor rule should have positive sign. After 2002, Japan was facing with recession, so $y - \bar{y}$ became negative, then central bank wants to lower the short-term interest rate, again GDP gap in Taylor rule should have positive sign.

# 4. Conclusions

Currently Bank of Japan is trying to achieve inflation target of 2 percent by quantitative easing in order to overcome the deflation and achieve a sustainable economic growth. However the present rate of inflation may come from several different factors, such as higher oil price that pushed up the rate of inflation. Based on our empirical results, after 2002Q1, aggregate demand was not affecting by current and lagged value of the GDP gap. That means the inflation targeting of Japan may not be caused by recovery of the Japanese economy but an increase of the oil price,[51] so that means stagflation. In order to avoid such stagflation Japan needs growth strategies and changing the economy of the ageing population so that is one of the policies here. Secondly monetary policy does not have strong impact in this movement, because from 2002Q1 - 2014Q2, long-term real interest rate does not have significate impact on aggregate demand. So the government Japan needs to look for structural changes and growth strategies rather than focusing on the monetary policy.

[51] This finding is in accordance to what Taghizadeh and Yoshino (2014b) found. They found that higher oil prices creates larger inflation in advanced economies (U.S. and Japan in their survey) comparing to emerging economies (China in their survey). The reason is that in emerging economies aggregate supply is shifting to forward because of higher growth in outputs, so it avoid high inflations in oil shocks.

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# III. Concluding remarks

In this thesis we examined the impact of monetary policy on the crude oil market. Moreover we have done surveys for the impacts of oil shocks on various economies incorporating monetary policies.

In first chapter we examined the global crude oil market over the period of 1960-2011. We analyzed the properties of oil markets and determinants of crude oil prices during this period. In order to reach worthwhile analytical results, we have done our estimations during the main period above and two sub-periods, 1960-1980 and 1980-2011. The reason for classifying in this way is that, while most price volatilities during 1970s have supply reasons, we believe in the second period, crude oil prices skyrocketed mainly due to another type of inflating pressure. We argued that this second period, with the exception of Persian Gulf War (1990-1991) oil price shock, had another reason for its price expansion, which was on the demand side instead of the supply side. In this research, we explained that in most cases, this uninterrupted price increase was caused by expansionary monetary policies that led to low interest rates, credit demand augmentation, and aggregate demand expansion, which heightened oil prices. We found that global oil demand was significantly influenced by interest rates, but the impact of exchange rate depreciations on oil demand was not significant, and supply actually remained constant. Aggressive monetary policy stimulates oil demand, while supply is inelastic to interest rates. The result is skyrocketing crude oil prices, which inhibit economic growth. We argue that stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive.

At the same time, we reviewed crude oil price determinants and price properties, as well as elasticities during the main period and two sub-periods. We found that price elasticity of crude oil demand decreased in the second sub-period, because the crude oil market administrated a large structural change after the 1970s oil shocks: high energy-taxation in oil importing countries, the establishment of the Strategic Petroleum Reserve (SPR), and a raise in share of other energy carriers such as natural gas in the energy baskets of energy importing countries. These factors all contributed significantly to the reduction in demand elasticity. For the income elasticity of demand, our findings suggests significant elasticity during 1960-2011 and 1980-2011. Unlike earlier research studies, we found that oil supply is elastic to prices in short-run, and during the second sub-period, the price elasticity increased compared to the first sub-period. Our attempts to test the hypothesis of equilibrium vs. disequilibrium in the oil market showed that crude oil prices adjust instantly and the results declare the existence of equilibrium in the oil market during the total period of 1960-2011.

In second chapter we developed a New-Keynesian general equilibrium model for the oil market. In the model that we developed, changes in the oil price transmitted to macro variables through supply (aggregate supply curve) and demand (aggregate demand curve). In particular, we allowed oil to shift the IS curve to proxy for temporary demand-side effects, and to affect the Phillips curve to capture inflationary effects through the supply side. This phenomenon creates destructive effects on the growth rate. In the empirical section, we conclude that oil price movements affect the economy through the demand channel (in line with Hamilton 1988 and Bernanke 2006) by reducing household consumption expenditures (aggregate demand movements are greater than aggregate supply shifts). Unlike some earlier studies (Rasche and Tatom 1977, Bruno 1984 and DePratto et al. 2009), we could not find statistically significant effects in the supply side (aggregate supply curve).

As for the effect of monetary policies on oil markets, we found that aggressive monetary policies led to low interest rates, credit demand augmentation, and aggregate demand expansion, which all raised oil prices. We found that oil demand was significantly influenced by interest rates, a key factor of monetary policies (in line with Anna Kormilitsina 2010, Taghizadeh and Yoshino 2014, Yoshino and Taghizadeh 2014), in contrast with Bernanke et al. (1997). Unlike some earlier studies, we found that low interest rates had an impact on oil supply expansion as well in this period, which was statistically significant but economically smaller than their impact on the demand side of the oil market. The result from this interest rate phenomenon is skyrocketing crude oil prices, which inhibit economic growth. We argue that stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive. As for elasticities in the oil market, our results for oil demand price elasticity agree more with the findings of researchers who arrived at low elasticity values. We also found that the supply of oil is more rigid to prices, comparing to the demand.

In third chapter, we evaluated that how monetary policy affected crude oil prices leading up to and following the subprime mortgage crisis. This analysis concludes that aggressive monetary policy following the 2008 subprime mortgage crisis inflated oil prices, mainly through the exchange rate channel, by making oil cheaper in non-dollar-dominated currencies. Most of the world's crude oil demand is overshadowed by oil imports of non-producers or oil deficit producers. This means that a depreciation of the US dollar would make oil imports cheaper in non-dollar-denominated currencies, raising both demand for and prices of oil. Our results show that the sharp rise in crude oil prices up to early 2009 (until right after the crisis of 2007–2008) was not due to economic recovery, because the data shows the global economy still had not recovered at that time. In spite of this, however, crude oil prices rose sharply. We found that one of the reasons for this increase in crude oil prices is because of quantitative easing policies that the Federal Reserve and various central banks followed. This trend led to slower economic growth and imposed a longer recovery time for the global economy following the crisis. This research provides several other findings, among which are the relationship between gas prices and crude oil prices, and the impacts of GDP growth and excess demand in the crude oil market on crude oil prices. Our results of the dynamic response of crude oil prices to natural gas prices, GDP, and excess demand impacts during the period May 2007–December 2012 show that an unanticipated positive shock in natural gas real prices does not have a significant effect on the real price of crude oil. A positive shock to the real OECD GDP has a positive effect on real crude oil prices that is statistically significant from the beginning for about 2 months, after which the effects become insignificant. An unanticipated positive shock to excess demand of crude oil in the global market has a statistically significant positive effect on real crude oil prices and builds up over the first 3 months. After this 3-month period, these effects become insignificant.

Forth chapter, 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 drastically. CPI elasticity reduced, however, because of 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 sub-prime 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 (Yoshino and Taghizadeh 2014). 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.

And the fifth or last chapter, analyzed the effectiveness of the easing monetary policy in Japanese economy incorporating energy prices. Currently Bank of Japan is trying to achieve inflation target of 2 percent by quantitative easing in order to overcome the deflation and achieve a sustainable economic growth. However the present rate of inflation may come from several different factors, such as higher oil price that pushed up the rate of inflation. Based on our empirical results, after 2002Q1, aggregate demand was not affecting by current and lagged value of the GDP gap. That means the inflation targeting of Japan may not be caused by recovery of the Japanese economy but an increase of the oil price, so that means stagflation. In order to avoid such stagflation Japan needs growth strategies and changing the economy of the ageing population so that is one of the policies here. Secondly monetary policy does not have strong impact in this movement, because from 2002Q1 - 2014Q2, long-term real interest rate does not have significate impact on aggregate demand. So the government Japan needs to look for structural changes and growth strategies rather than focusing on the monetary policy.

Consequently, it is worthwhile to conclude that while US monetary policy focuses mainly on the US domestic economy, such as the unemployment rate, inflation, and the GDP gap, results of this thesis clearly show that US monetary policy strongly affects global oil prices and pushes them up. This means that if the US continues its quantitative easing policy, then oil prices will continue to rise, and this will negatively affect global economic conditions.