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# **The Oil Price and Aggregate Economic Activity: Evidence from Canada**

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## **Abstract**

In recent years, Canada has become one of the largest oil exporters in the world. As a result, how the volatility of oil price links to the growth of Canadian economy has received more and more attention. In this paper, the transmission of linear and non-linear oil price shocks to the Canadian macroeconomy is evaluated in the light of the existing research results and the specific situation of Canada. This paper investigates the impact of oil price fluctuations on real GDP and other economic variables in Canada, using multivariate vector autoregressive (VAR) linear and nonlinear models. Both models consist of real oil price and real GDP as two major variables of interest as well as intermediate variables such as real effective exchange rate (REER), real wage, inflation, and short and long-term interest rates.

The result of this paper suggests that the oil price has significant effects on many real economic variables, especially real GDP, REER and inflation. Furthermore, in the non-linear model, evidence shows that a drop in oil prices has a greater impact on real GDP than the rise in oil prices. In the short term, rise in oil prices has a positive effect on the economy. While in the long-run, the effect turns to be permanently negative.

***Key Words: Oil Price Fluctuations, Real GDP, Multivariate VAR model, Canada.***

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# 1 Introduction

Since the Second Industrial Revolution, oil has been rapidly infiltrating into the national economy in various industries. After the World War II, the proportion of oil on total global energy consumption was around 40%, occupying the world's first place. In the foreseeable future, crude oil will continue to be a key element and input to many sectors of the economy in Canada and the rest of the world.

However, the geographical distribution of oil is extremely imbalanced around the world, which results in a series of oil crises and economy turmoil (see Appendix 2). The influence of oil price fluctuations on the global economy has caused many concerns in political, academic and business circles. Researchers have begun to investigate the driving forces and effects of international oil price fluctuations in order to timely and effectively work out the countermeasures with the purpose of eliminating the adverse effects of oil price shocks and ensuring the stability of the global economy and global political situation.

The main objective of this study is to shed light on the channels through which oil price shocks transmit into the Canadian economy. Oil is at the heart of Canada's energy industry and an important contributor to Canada's economy (see Appendix 3). This study will help both the public and the policy makers to better understand the direction and the magnitude of the effects of oil price fluctuations on Canadian economic activity.

This study uses multivariate VAR linear and nonlinear models to quantify the influence of oil price fluctuations on real GDP and other economic variables in Canada. It relies on the Granger causality tests, impulses response and forecast error variance decomposition methods. The result of Granger causality tests show a one-way causal relationship from the international oil price fluctuations to Canadian GDP growth. Impulse response functions analysis shows that the peak effects on real GDP, real effective exchange rate (REER), inflation, real wage, short-term interest rate and long-term interest rate to disturbances in international oil price occur between the second and fourth quarters. A rise in the oil price is good for the Canadian economy in the short term but can cause negative reactions in the long-run. In addition, the analysis of forecast error variance indicates that the contribution of oil price volatility to real GDP is 8.6% in the long-run, which can be interpreted as the evidence of the dependence of economic growth on international oil prices.

The rest of the study is organized as follows. The second section is the literature review, which summarizes the research achievements on this topic since the 1970. The third section discusses the methodology and the data used in this research. The fourth section discusses the empirical results. The last section gives the conclusions of this paper.

## **2 Literature Review**

Since 1970s, two consecutive oil shocks and stagflations in the developed economies have attracted the attention of many economists to study the effect of each international oil price shock on the macroeconomy. Initially, in most academic research, economists considered the oil price volatility as an exogenous variable. However, more and more characteristics of the macroeconomy showed a relation with oil price fluctuations. Moreover, it was discovered that the effect of oil price fluctuation on the macroeconomy could not be explained by the share of oil in production inputs, thus economists began to put more emphasis on the endogenous and exogenous problems of oil price shocks. That is, on the one hand, the volatility of oil price could be internalized from the macroeconomy. On the other hand, oil price shocks could affect production efficiency and macroeconomic activities.

### **2.1 Theoretical Literature Review**

The theoretical research on the relation between oil and economic growth mainly focuses on the transmission channels from the fluctuations of oil price to economic activities, as well as on the role of monetary policy in the effects of oil price on macroeconomy. In addition, some scholars tried to prove that there is no significant relationship between oil price volatility and macroeconomic performance.

There are many transmission channels through which oil price influences on economic activities, and researchers and economists have conducted in-depth studies. Pierce and Enzler (1974) argued that an increase in oil price would lead to an increase in money demand. Since the monetary authorities could not increase money supply in time to meet the rising money demand, it would result in higher interest rate and slower economic growth. Dohner (1981) argued that increases in oil prices reduced the world total consumption demand, leading to a downward pressure on real interest rates. The decrease in real interest rates would stimulate investment growth and partially offset the decline in consumption. As a result, aggregate demand would be kept unchanged.

Later economists also considered the influences on labor market. Loungani (1986) found that long-term fluctuations of oil prices could lead to changes on the production structure and on the unemployment rate. If oil prices remain at a high level for a long period, firms would be encouraged to carry out reforms and adopt new production methods to cut down investment in oil, which would redistribute capital and labor among sectors. Hamilton (1988) established a neoclassical model of unemployment and economic cycles. He pointed out that due to frictions in the labor market, the unemployed labor force, which was brought about by the rising oil price, could not be immediately transferred to other sectors. As a result, the falling employment rate would lead to an economic recession. Brown and Yucel (1999) viewed the rise of oil prices as a typical

supply shock reducing potential production. They believed higher oil prices would decrease production, and drive up the real interest rate and price level.

In the 1980s and 1990s, the reverse causality between oil prices and the real economy faded. Scholars began to question the validity of the pure supply shock model and turned to explore more transmission mechanisms, for example, the response of monetary policy. Dotsey and Reid (1992) argued that the rise in oil price and the tightening of monetary policy were (for example, rise in interest rates) statistically significant explanations for the economic downturn. Bernanke et al. (1997) separated the direct and indirect impacts of oil price shocks, and found that the effects on the real economy from oil price shocks should mainly be attributed to the contraction of monetary policy. Blanchard and Gali (2007) illustrated that at the time when oil price fluctuations had a great shock to the macroeconomy, other different large shocks may also happen, for example, increases in other commodity prices in the 1970s. Kilian (2009) argued that oil price increases may have different effects on the real price of oil depending on the different underlying causes of the price increase. The real price of oil consists of crude oil supply shocks, shocks to the global demand for all industrial commodities, and demand shocks that are specific to the global crude oil market. These different underlying causes would generate different effect on the macroeconomy, so we should just start from oil price changes directly and observe their effects. Kilian believed that we should endogenize the oil price variable rather than assuming exogenously given oil prices.

Moreover, Charnavoki and Dolado (2014) confirmed Kilian's argument that real commodity prices were driven by various global shocks, instead of by any particular one.

## **2.2 Empirical Literature Review**

Empirical studies have shown the close correlation between oil price fluctuations and macroeconomic performance. Hamilton (1983) concluded that there is a negative relationship between oil price shocks and the macroeconomy. Since widespread concerns about oil price influence consumption and investment decisions, economic growth is further affected. Burbidge and Harrison (1984) analyzed the impulse response of oil price changes by establishing a VAR model. Their conclusions supported the view that the rise in international oil prices could bring about a recession.

In 1986, the international oil price plummeted, but it did not have a positive effect on the real economy of the major industrial countries in the world. This economic phenomenon motivated researchers to study the asymmetric properties of the impact of oil prices on the macroeconomy. Mork (1989) found that if Hamilton's analytical framework was extended to 1986, it was statistically significant that increasing in oil prices had a negative effect on real production output, while the positive coefficient was relatively small and statistically insignificant. The results proved that the impact of oil price rises or falls on the macroeconomic was asymmetric. Mork et al. (1994) computed bivariate correlations as well as partial correlations within a reduced-form

macroeconomic model to analyze the relationship between asymmetric oil price movements and GDP fluctuations for seven different countries, including oil exporting countries such as Canada, the United Kingdom and Norway. They found that these countries, with the exception of Norway, had a significant negative macroeconomic response in the face of rising oil prices. Lee et al. (1995) argued that an oil price stable economic environment might be more severely influenced by oil price shocks, in comparison to economic environments in which oil price movement were more irregular and frequently.

In addition to studying the relationship between oil prices and US economic growth, many economists have studied the situation of oil exporters. Olomola (2006) used the VAR model for the Nigerian economy and found that contrary to previous empirical results, positive oil price shocks would not significantly affect Nigeria's output and inflation. However, oil price shocks were proved to significantly affect the real exchange rate. The author argued that oil price shocks might result in a wealth effect, causing real exchange rates to appreciate, and squeeze out the tradable sector, leading to the "Dutch disease". The "Dutch disease" indicated that the increase in the development of oil sector resulted in a decline in other sectors. Farzanegan and Markwardt (2008) used VAR models for the Iranian economy and found that both positive and negative oil price shocks significantly increased inflation. They confirmed a strong positive relationship between positive oil price changes and industrial output growth. Aliyu (2009) empirically

assessed the impact of oil price shocks on real macroeconomic activities in Nigeria. By using linear and nonlinear specifications for Granger causality test and multivariate VAR analysis, he found that the positive impact of oil price increases on real GDP growth was greater than the adverse effect of oil price decreases. In addition, Wald and Granger multivariate and bivariate causality tests showed that the oil price coefficients for linear and asymmetric specifications are statistically significant. Moreover, he found that there is a relationship between oil price shocks and real GDP and other macroeconomic variables. Algahtani (2016) found that there is a significant positive relationship between oil price and GDP in Saudi.

Economists also put several oil exporters in one paper to compare the different response of the economies to oil price shock. Korhonen and Mehrotra (2009) used structural VAR models to assess the impact of oil price shocks on real exchange rates and output in four large oil-producing countries: Iran, Kazakhstan, Venezuela and Russia. They found that higher real oil prices were associated with higher output, but that supply shocks were the most important driver of real output in all four countries. At the same time, oil shocks did not account for a large share of real exchange rates. Berument et al. (2010) examined how oil price shocks affected production growth in 16 selected MENA countries, including some net oil exporters. The results showed that a standard deviation shock in oil prices had a statistically significant positive effect on the growth of several

major net oil-exporting economies: Algeria, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Syria and the United Arab Emirates.

Nusair (2016) used a nonlinear co-integration autoregressive distribution hysteresis (NARDL) model to examine the impact of oil price shocks on the real GDP of Gulf Cooperation Council (GCC) countries. The results provided evidence of asymmetry in all cases. The results show a significant positive impact of oil price increases on real GDP in all cases. On the contrary, negative changes in oil prices only were significant in Kuwait and Qatar, suggesting that decreases in oil prices lead to decrease in real GDP in some countries. Overall, the results implied that the positive oil price shocks have a larger impact on real GDP than negative oil price changes.

### **2.3 Literatures Focusing on Canadian Case**

In this part, I focus on the literature related to the Canadian case. Burbidge and Harrison (1984) used monthly data for the period from January 1961 to June 1982 in a seven variable VAR model to test the effect of oil price increases in Canada. The results showed that the impact of oil price shocks on the price level is substantial, but their impact on industrial production is limited. In addition, they studied the effects of two types of shocks, namely, oil price increase after 1973 and after 1979 separately, and found that the first type had substantial effects while the second one did not. Mork et al. (1994) examined the correlation between oil price movements and Canadian GDP. The

correlation between GDP and the rise in real oil prices was significantly negative, and the correlation with the drop in oil prices was significantly positive. Moreover, the case of Canada showed the evidence of asymmetry.

Later, economists adopted more advanced econometric models. Based on a Vector Error Correction Model (ECM), Khademvatani (2003) used quarterly data (1984-2002) to analyze the asymmetry between crude oil prices shocks and aggregate activities. He proved that there are a long-run and equilibrium relationship between GDP and oil prices. In contrast with most literature, he found the symmetry between crude oil price fluctuations and overall economic performance to be significant. At the same time, he was unable to reject an asymmetric relationship of Canada's economy and crude oil price shocks. The symmetric response of the overall economy derived from the change of the short-term interest rate from monetary policy or from the natural response of aggregate demand and supply. Kilian (2005) estimates the impact of external shocks on the global oil production on the Canadian economy. The results showed that the disruption of external oil supplies led to a temporary decline in real GDP growth, which concentrated in the second year after the shock. Moreover, there was strong evidence of stagflation in Canada compared to other G7 countries. Cologni and Manera (2008) used a structural cointegration VAR model to analyze the response of economic activity to oil price shocks. They found that the direct impact of higher oil prices on output is positive.

However, the temporary increase of oil prices also puts inflationary pressure on Canada, as after one year, the consumer price index increased by 0.881%.

Recent studies also remarked the significance of the asymmetry of the correlation between oil prices and the Canadian economy. Rahman and Serletis (2012) used Canadian quarterly data from 1974:I to 2010:I to demonstrate a significant asymmetry between production growth and real oil prices. In addition, they suggested that the increase in uncertainty over changes in real oil prices was related to low economic growth in Canada. Their finding is consistent with the argument of Elder and Serletis (2009, 2010). Charnavoki and Dolado (2014) used structural dynamic factor models and VAR techniques to study the effects of different real commodity price shocks on a set of macro variables in Canada. They found that positive global demand and negative commodity-specific shocks led to higher commodity prices. However, only the latter shock led to the Dutch disease and expenditure effects. Instead, positive global demand shocks stimulated real output and real spending in the Canadian industry. Donayre and Wilmot (2015) argued that asymmetry was significant during recessions but not that obvious during expansions. They also found that the fall in inflation rates due to the negative impact of oil price shocks was greater than the rise in inflation rates after the positive oil price shocks, particularly during periods of low output growth.

## 3 Methodology

### 3.1 Multivariate VAR Model

To study the impact of oil price fluctuations on Canadian output and other macroeconomic variables, this paper proposes a multivariate VAR model. The VAR model is widely used to analyze the time series data and to test the dynamic impact of one variable on the others.

Sims (1980) was the first to simplify the standard macroeconomic model into a model of multiple dynamic systems. He proposed VAR model, in which all variables are regarded as endogenous variables. The assumption that all variables are related to each other in the model avoids arbitrarily restricting the relationships among economic variables, so that the VAR model can capture overall economic relationships. At the same time, VAR models are much simpler to estimate, thus they are nowadays widely used to study a number of macro issues.

The foundation of our multivariate VAR model derives from the classic research on the relationship between oil prices and macroeconomy, and uses Granger causality tests, impulse responses and variance decomposition analysis. I also complete unit root tests and determine the optimal lag order before estimating the VAR model. In particular, I reproduce the main research methods of Jiménez-Rodríguez and Sánchez (2005), because of the following two reasons. Firstly, Jiménez-Rodríguez and Sánchez (2005) introduced

a general methodology which was based on the analysis of oil importers and also worked well for oil exporters. Secondly, Jiménez-Rodríguez and Sánchez (2005) included Canada into their research targets and their research framework performed well for the Canadian case. The differences of our model lie in that, firstly, compared to the sample of Jiménez-Rodríguez and Sánchez (2005)(1972:III-2001:IV), my data are more updated and consider the oil price fluctuations after 2001, which generated a considerable impact on the Canadian economy. Secondly, for the non-linear model, I select an asymmetric specification for Canadian case, since Jiménez-Rodríguez and Sánchez (2005) studied for seven OECD countries, while I am only interested in Canada, and in their paper, they find the asymmetric specification dominates the other non-linear specifications. Thirdly, when defining the variables and data, I consider the characteristics of Canada and select a more appropriate dataset for our paper. Fourthly, I adjust the ordering of variables before computing the impulse response functions to better focus on the effect of an innovation in oil prices.

### 3.1.1 Linear VAR Model

A typical unrestricted VAR model,  $VAR(p)$  can be expressed as:

$$y_t = c_1 y_{t-1} + c_2 y_{t-2} + \dots + c_p y_{t-p} + Hx_t + \varepsilon_t \quad (3.1)$$

$$t = 1, 2, \dots, T$$

Suppose we have  $k$  time series variables,  $y_t$  is a  $k$ -dimensional column vector of endogenous variable that we intend to explain in the model,  $x_t$  is an exogenous variable of  $d$ -dimensional column vector of exogenous variables,  $p$  is the lag order,  $T$  is the length of the sample,  $c_1, \dots, c_p$  and  $H$  are matrices of coefficients that we need to estimate.  $\varepsilon_t$  is a  $k$ -dimensional disturbance vector, modeled as a white noise process. For the elements of  $\varepsilon_1, \dots, \varepsilon_T$ , they may be correlated contemporaneously, but they can't be correlated with their own lag value or the variables on the right-hand side of the equation. The covariance matrix of  $\varepsilon_t$  is a  $(k \times k)$  positive definite matrix.

This paper starts with a simple unrestricted VAR model to examine the effect of an oil price shock to Canadian real economic variables. So,  $y_t$  is defined as the column vector composed of the values of oil price and a set of selected macroeconomic indicators, for a total of  $k$  variables.  $p$  is determined by the time range that this paper is intended to study.

### **3.1.2 Non-linear VAR Model - Asymmetric Specification**

Based on the previous literature, especially after the sharp decline of international oil prices in 1986, linear VAR models could not explain the correlation between oil prices and fluctuation in the world economics. In fact, the impact of decreases in oil prices on economic activity were found to have smaller positive effects than predicted by linear models (Jiménez-Rodríguez and Sánchez, 2005). So, economists proposed

non-linear VAR models to study the effects of oil prices shocks. Up to now there are mainly three specifications of non-linear models that shape the effect of oil price fluctuations on macroeconomic variables, namely, an asymmetric specification, a scaled specification and a net specification (Jiménez-Rodríguez and Sánchez, 2005).

In this paper, I use the asymmetric specification as the main method for the non-linear model. In Aliyu (2009), a Wald test showed that the coefficients of an asymmetric specification were significant. The asymmetric specification splits the direction of the oil prices, treating increase and decrease in oil price as two different variables. Its theoretical basis is the dispersion hypothesis raised by Lilien (1982). This hypothesis is dependent on the standpoint that changes in oil prices can disturb the equilibrium in the resource allocation among various sectors. In particular, Lilien (1982) argues that the reallocation of resources to each sector results in adjustment costs. The rise (decline) in oil price increases (decreases) the production costs of the sectors that use oil, further leading to the expansion (contraction) of the energy efficiency-based sectors relative to the energy-intensive sectors. Moreover, given the high adjustment cost of resources reallocation among sectors in the short term, the adjustment between energy-efficiency and energy-intensive sectors will lead to a loss of aggregate output, thus exacerbating the economic contraction in times of oil price increases. Later research including Loungani (1986), Davis (1987) and Hamilton (1988) also held this view.

For more details in the model set-up, I follow Mork's asymmetric specification, in which increases and decreases in the price of oil are considered as separate variables. I denote  $o_t$  as the rate of change in real oil prices in period  $t$ ,  $o_t^+$  as the rate of increase in real oil prices in period  $t$  and  $o_t^-$  as the rate of decrease in real oil prices in period  $t$ . When real oil decreases (increases),  $o_t^+$  ( $o_t^-$ ) is defined to be zero, i.e.,

$$o_t^+ = \begin{cases} o_t & \text{if } o_t > 0 \\ 0 & \text{if } o_t \leq 0 \end{cases}$$

$$o_t^- = \begin{cases} o_t & \text{if } o_t < 0 \\ 0 & \text{if } o_t \geq 0 \end{cases}$$

So, in the non-linear model, I add two variables of  $o_t^+$  and  $o_t^-$  in replace of the single oil price variable in the linear model. There are eight endogenous variables in the non-linear model, including oil price increase  $o_t^+$ , oil price decrease  $o_t^-$ , real GDP, real wage, REER, inflation rate, short-term interest rate and long-term interest rate. I will use these variables to perform the multivariate VAR model.

## 3.2 Data and Variables

The sample period in this paper goes from 1981:I to 2016:IV, for a total of 144 quarterly observations (see Appendix 1 for detail). Seven variables are factored in the model: real GDP, real oil price, real effective exchange rate (REER), inflation rate, short and long-term interest rates, and real wage; the variables are plotted in Figure 1. This paper uses real GDP and real oil prices as the main variables to estimate the correlation

between oil prices and the macroeconomy. Also, this study considers other variables since they can transfer the effect of an oil price shock to the real economy. For example, the exchange rate can affect imports and exports, which are part of GDP. Real wages can induce changes in the labor market. Below is a brief description of each variable.

Real GDP is considered at both the production level and price level. Real GDP is expressed in log form. The inflation rate is measured by the consumer price index (CPI). A short-term interest rate and a long-term interest rates are added as indicators for the monetary sector.

The real oil price is expressed in logarithmic form. It is defined as the log of the West Texas Intermediate (WTI) spot price converted from US dollars to Canadian dollars using the quarterly exchange rate and, it is deflated by the Canadian Producer Price Index (PPI). Here we do not use the UK Brent oil price as Jiménez-Rodríguez and Sánchez (2005), because the US are the most important trade counterparty of Canada and I believe that the WTI oil price will be more relevant for my study<sup>1</sup>. The choice of the oil price variable follows the method of Mork et al. (1994), which adopted a trade-off

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<sup>1</sup> While I am searching for the data of oil price, I indeed noticed that there is WCS(Western Canadian Select), but the problem is that WCS was launched in DEC 2014, and the data that are available only started from 2009, which is not enough for our paper. Thus, I use WTI.

measurement between the corrected price from price-control schemes in the United States and Canada (Mork, 1989). Furthermore, the authors adopted a simple US dollar world price (Burbidge and Harrison, 1984), and used world oil prices for all countries but converted them to each countries' currencies by means of the market exchange rate. This method was then recognized and used by subsequent economists. Thus, my results using the same method will be comparable to the previous literatures.

The real wage is the log of the nominal wage divided by the Consumer Price Index (CPI). It is the only proxy for the labor market in the model. Notice that my proxy for real wage is different from the one for Canada in Jiménez-Rodríguez and Sánchez (2005). I use unit labor cost, i.e., the cost of the labor input required to produce one unit of output, which equals labor compensation in current dollars divided by real output; this is because I want to measure the whole cost of labor at the point of production. Jiménez-Rodríguez and Sánchez (2005) also use this proxy for European countries.

In order to capture the economy's competitiveness, the REER is chosen as a proxy for the exchange rate. According to the International Monetary Fund (IMF), REER is defined as the nominal effective exchange rate adjusted for the relative price level or index of cost between the domestic country and the foreign country. It is the product of the weighted geometric mean of the ratio of the domestic price level (or index of cost) to the foreign country's price level (or index of cost), and the nominal effective exchange

rate. A rise in the REER represents an increase in the relative value of the domestic currency, while a fall represents a real depreciation of the local currency. Since the REER takes into account not only changes in the currencies of a country's major trading partners, but also the inflation factor, it can more accurately reflect the external value of a country's currency and the competitiveness of the country.

### 3.3 Unit Root Tests

The premise of classical regression analysis is that the time series of data are stationary. The non-stationary nature of the data often leads to spurious regressions, which are characterized by a high correlation between two variables that might not have any causal relationships.

In this paper, I apply three unit root tests: the *ADF* test, the *Dickey – Fuller GLS (ERS)* test, and the *Phillips – Perron PP* test to examine the stability of the data, as reported in Table 1. A *Dickey – Fuller GLS (ERS)* test is essentially an *ADF* test, but it has significantly greater power than the *ADF* test because that in the case of the *Dickey – Fuller GLS (ERS)* test, the time series is transformed via a generalized least squares (GLS) regression before performing the test. A *Phillips – Perron (PP)* test can be viewed as the Dickey-Fuller statistics that have been made robust to serial correlation and autocorrelation. The *Phillips – Perron (PP)* test has two main advantages. Firstly, the *PP* test is robust to general forms of

heteroskedasticity in the error terms. Secondly, it does not require the user to specify a lag length for the regression. One drawback of the PP test is that it only works well in large samples.

The null hypothesis of these three unit root tests are the same- a unit root is present. The results in Table 1 show that the first differences of all variables are stationary<sup>2</sup>. As an example, the value of "GDP in First Difference" in ADF(Model with intercept) is -6.7715, which is smaller than -3.4768 (the corresponding 1% critical value), thus I am able to reject the null hypothesis. Thus, I define  $y_t$  as the first log-differences of real GDP, real oil price, real wage, and first differences of the inflation rate, REER, short-term interest rate and long-term interest rate<sup>3</sup>.

### 3.4 Optimal Lag Order Selection

When selecting the lag order, one needs to consider a trade-off between sufficient lag terms and degrees of freedom. This paper mainly applies the Likelihood Ratio test (LR), FPE (Final Prediction Error), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC) and Hannan-Quinn Criterion (HQ) to determine the

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<sup>2</sup> My conclusion about the stationary is consistent across all tests except for the DFGLS test (Model with intercept case), where the first differences of long-term interest rate is not stationary, only the second differences of long-term interest rate is stationary.

<sup>3</sup> In the models, log-differences of real GDP, real oil price, real wage are represented by DLGDP, DLOP, DLW, respectively. First differences of the inflation rate, REER, short-term interest rate and long-term interest rate are represented by DInf, DREER, DSI, DLI, respectively.  $o_t^+$  and  $o_t^-$  are represented by Oi and Od, respectively.

appropriate lag order. The tests results are summarized in Table 2. The best lag length is selected by Likelihood Ratio test whenever there is inconsistency between the different tests. Based on the results reported in Table 2, I select the lag order of four.

## **4 Empirical Results**

### **4.1 Causality Tests**

In this section, I investigate the direct and indirect causality among oil prices and other variables in the model, with an emphasis on the importance of the impact of oil prices on real economic activities. This paper performs three tests for the linear and nonlinear models mentioned above.

This research firstly examines the effect of oil prices on real GDP in the linear and non-linear VAR models. The analysis is performed using Wald statistics, the null hypothesis is that in the equation of GDP, the coefficients of all lag values of the oil price variable are all zero. The results of the Wald Statistics for both linear and non-linear models are presented in Table 3. The results indicate that for the linear VAR model, we are able to reject the hypothesis that oil price does not directly affect real GDP at a 5% significance level. Also, for the non-linear VAR model, the results are statistically significant at the 5% critical level for both oil price increases and decreases. As an example, the p-value for oil price increases is 0.0396, which is smaller than 0.05. The

results mean that both increases and decreases in oil prices have a direct impact on real GDP.

Secondly, this section examines the effects of the oil price variable on all the other variables except itself. The analysis is performed using a Likelihood Ratio test, where the null hypothesis is that in all the equations except that of oil prices, the coefficients of all the lag values of the oil price variable are jointly zero. Rejection of the null hypothesis means that oil prices affect real GDP through another variable in the VAR model. The results are summarized in Table 4. This table indicates that we are able to reject the null hypothesis in the linear model, increase in oil price and decrease in oil price variables in the non-linear model do not have an impact on all the other variables except themselves at a significance level of 5%. Therefore, I need to retain these three variables in our models for further research.

Thirdly, this section conducts three multivariate Granger-causality tests, which examine whether other variables in the system Granger-cause oil prices, whether the oil price variable Granger-causes the other variables, and whether there is any relationships between the oil price variable and other variables in the model. The results of the three multivariate Granger-causality tests are summarized in Table 5. The null hypothesis of the first test is that all other variables in the model do not affect the oil price variable. As shown, I fail to reject the null hypothesis in the linear model, which suggests that other

variables are likely to not affect the oil price variable. However, in the non-linear case, I am able to reject the null hypothesis at the 5% critical level, which suggests that other variables are likely to affect the oil price variable. I then test the null hypothesis that the oil price variable does not affect other variables in the VAR model. As shown, I am able to reject the null hypothesis at a 5% significance level in both the linear and non-linear models, which suggests that the oil price variable does affect the other variables. This result is consistent with the result of Jiménez-Rodríguez and Sánchez (2005). The null hypothesis of the last test is that there is no relationship between oil prices and the other variables in the model. As shown, this test permits me to reject the null hypothesis at the 5% critical level in both linear and non-linear models, which indicates that there is a relationship between oil prices and the other variables. This result is also consistent with the work of Jiménez-Rodríguez and Sánchez (2005).

To conclude, the results of the three causality tests indicate that the relationships between oil prices and other economic variables are generally significant at the 5% significance level, which implies that in most of the cases, oil prices and real variables have a specific causal relationship.

## **4.2 Impulse Responses**

In this section, I use impulse response functions to track the impact of one variable and identify the responsiveness of the other dependent variables in the VAR system. In

the model, I focus on the impact of an oil price shock to the real economic variables. Before calculating the impulse response, I assume a specific ordering of the variables, and use a Cholesky decomposition to compute the impulse response functions. The ordering suggests that the oil price does not respond to all other variables' shocks, but other variables are allowed to respond to the oil price shocks. Given that I am interested in how an innovation in oil prices can affect the macroeconomy, it seems more appropriate to place the oil price as the leading variable. Then, as a largely exogenous variable in most of the related literature, real GDP is ranked as the second variable. The rest follows as: real wage, REER, inflation rate, short-term interest rate and long-term interest rate.

In addition to orthogonalized impulse response functions, this paper also uses accumulated impulse responses to identify the effects of oil price shocks on the whole system. Figures 2 and 3 present the results of the orthogonalized impulse-responses of the six variables other than oil prices to a Cholesky one standard deviation innovation in real oil prices for linear and non-linear models. Tables 6 and 7, and Figures 4 and 5 present the accumulated responses for linear and non-linear models. For both impulse response functions, I use two analytic standard errors bands (see 4.2.3 Results from the Impulse Response Function for more detail).

There are three aspects that I would like to illustrate from the impulse response analysis. Firstly, I report the impulse response of both GDP and other real economic variables because of the result discussed in section 4.1 that it's statistically significant that oil prices can affect GDP growth through a third variable. Thus, I would like to study if there are any variables which are significantly affected by oil prices and investigate the underlying transmission mechanism. Secondly, I summarize the results of both linear and non-linear models not only for differentiating the effects of positive and negative oil price shocks, but also for comparing the soundness of these two models and determining the better one. Thirdly, I use both orthogonalized impulse-response functions and accumulated impulse response functions, because I would like to analyze the directions in which other variables react to an innovation to oil prices, and the relative and absolute magnitudes of the responses.

In the following subsections, I extend my research on the above three questions and summarize the main results emerging from the impulse response functions.

#### **4.2.1 Implied Indirect Relationship between Oil Price and GDP**

From Table 6 of the accumulated impulse response to oil price changes in the linear model, I can conclude that in addition to GDP, the oil price variable has a relatively obvious influence on inflation. So, inflation could be the third variable that bridges real oil prices and real GDP. As previous economists have argued, the high oil prices would

increase the cost of production, thus driving up the overall price level of goods. Gradually, the inflation rate would increase. The increasing price level would in turn stress people to set a higher expectation of future inflation. Therefore, people would cut down their consumption, which would further hurt real production and GDP.

In the non-linear model, however, the story is different. The biggest impact of oil price changes occurs to the short-term interest rate, followed by the long-term interest rate and inflation, which implies that when we consider the two directions of oil price changes separately, monetary factors are significantly affected. Monetary policy and its corresponding indicators are important channels that transmit the effects of oil price shock, to real GDP, which is consistent with the argument that previous economists have put forward.

#### **4.2.2 Implied Model Selection**

This paper uses two models to investigate the effect of oil price fluctuations on real GDP growth. However, given the specific time frame that we choose, i.e. 1981-2016, which is different from the previous literature, it is worth further analyzing the more appropriate model to explain the causality between oil prices and GDP. Firstly, one possibility is compare the confidence bands<sup>4</sup> of the real economic variables' responses to

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<sup>4</sup> The confidence band represents two standard errors of the point estimate as computed by Eviews, and the standard errors are reported in parentheses below the responses. In this paper we use asymptotic standard errors.

oil prices. As shown in Figures 2 to Figure 5, the non-linear model displays more narrow confidence bands, which implies that the non-linear model is preferred in terms of precision of the estimates. I use AIC, BIC and HQ statistics to compare the two models and determine the dominant one. Table 8 presents the outcomes of the AIC and BIC statistics. The test statistics of non-linear model are higher than that of linear model, which suggest that the non-linear model has an obvious advantage over the linear model in explaining the relationship between oil prices and GDP.

### **4.2.3 Results from the Impulse Response Functions**

Figure 2 and Figure 3 display the orthogonalized impulse-response functions for the linear and the non-linear models. In the short run, the impact of oil price increases in the linear model is positive, and this is different from results of Kilian (2005), which imply a temporary reduction in Canadian real GDP at horizons of 4 to 9 quarters. My research shows that a rise in oil price rises is favorable to the Canadian economy in the short term, and that income effects likely outweigh the negative impact of the positive factors, given that Canada is a net oil exporter. The positive effect reaches the highest point in the second quarter. However, after one year, the impact becomes negative, and then fades out in around three years. The short-run effect on the real wage, inflation and the REER is negative, positive, and positive, respectively. Specifically, I observe a positive effect on inflation in the first 2 quarters, which is in line with the result of Kilian (2005) that

Canada has a relatively short period of increase in inflation following an oil price shock compared to other G7 countries. One mechanism that may help to explain this result is that in the short run, more specifically, within one year, the increase in oil prices stimulates the economy, driving up inflation and strengthening the competitiveness of its currency. But given the stickiness of nominal wages, the real wage is negatively affected.

On the contrary, the non-linear model in Figure 3 implies that the effects of oil price increases and decreases are negative at all horizons. When considering the extent of the effect, the negative effect of an oil price increase is monotonically increasing. The negative effect of an oil price decrease starts to decrease after 3 quarters and converts to a positive effect in 2 quarters. This result suggests that benefits from oil price decreases only exist for a short period of time, and that negative effects dominate at longer horizons. Overall, the magnitude of the impact of an oil price increase is relatively larger. Other variables' responses to oil price increases and decreases are symmetric in terms of both direction and magnitude.

Tables 6 and Table 7, and Figures 4 and 5 present the accumulated impulse response functions for the linear and non-linear models. In the linear model, an increase in oil prices is predicted to have a positive effect on real GDP, and this effect reaches a peak in two years, then vanishes after three years. In terms of the magnitude of the effect of oil price shocks on the other six variables included in the VAR model, it is worth

mentioning that the long-term effects on GDP, real wages and interest rates tend to be very small. However, for the REER and the inflation rate, the effects seem to be positive and long-lasting. The real exchange rate appreciation induced by positive oil shocks, which emerges from our model, is consistent with the result of Jiménez-Rodríguez and Sánchez (2004). In my model, REER has the largest response to oil price shocks. Charnavoki and Dolado (2014) added the nominal exchange rate into their model, and concluded that this real appreciation was almost fully due to the appreciation of the nominal exchange rate. All variables' responses reach the highest point in two to four quarters.

As for the non-linear model, the effect of a positive oil price shock is smaller than in the linear model and presents to be negative ever after the shock. In the long-run, the negative effect tends to be permanent. An oil price decrease also induces a negative effect on GDP. My results are consistent with the results of Mork et al. (1994), who find that the impact of oil price increases on GDP is significantly negative and the impact of oil price decreases on GDP is significantly positive. After four quarters we can observe a decrease in the magnitude of the negative effects. The results can be explained by the arguments proposed by Donayre and Wilmot (2015). These authors suggested that the positive effect of a higher oil price for an oil exporter could come with a delay since the extraction and production in the oil industry are restricted by long-run investments. The long-term effect of a negative oil price shock is smaller than that of a positive oil price

shock, which is consistent with the finding of Aliyu (2009) and Nusair (2016). Thus, the results of the paper provide some evidence of an asymmetric relationship between oil price shocks and the macroeconomy, as in Rahman and Serletis (2012), Elder and Serletis (2009, 2010) and Donayre and Wilmot (2015). For real wages, both an increase and a decrease in oil prices have positive effects. Interestingly, for all other variables except real GDP and the real wage, i.e. the REER, short-term and long-term interest rates and inflation rate, the response to oil price increases and decreases is symmetric in terms of both direction and magnitude.

### **4.3 Forecast Error Variance Decomposition**

Table 9 and Table 10 present the results of the variance decomposition, which tells us how the effect from unexpected shocks are explained by different variables. Variance decomposition generally shows that in the case of both symmetric and asymmetric specifications, oil price shocks are a considerable source of real economic fluctuations. For the linear model, the result for GDP's variance decomposition are reported in Table 9. The table shows that oil price shocks have the largest contribution to the variance of GDP at any time horizon, accounting for around 4.99% in the short run and 8.6% in the long-run. In addition, oil prices also contribute significantly to the other variables' forecast error variance. For example, it is the largest source of variance for the REER and for inflation.

The results of the forecast error variance decomposition for the non-linear model are shown in Table 10. According to these results, oil price decreases are the largest source of GDP variance, accounting for 8.0% percent in the long-run. It's worth noticing that in the first two quarters, the effect of oil price decrease is not that obvious, only accounting for 1.2%. In the fourth quarter, the contribution of oil price decreases jump to 7.5%, exceeding the contribution of oil price increases. For the short-term interest rate and the REER, oil price decreases also contribute the largest proportion to the respective variances, which is consistent to the pattern obtained from the linear model. For the rest of the variables, oil price decreases drive a considerable portion of variance of these variables. For all variables, oil price decreases contribute more than oil price increases.

#### **4.4 Stability Test**

I use the Quandt-Andrews Breakpoint Test to examine the stability of the oil price coefficients in the VAR models. The results are presented in Table 11.

The Quandt-Andrews Breakpoint Test is developed from the Chow Breakpoint Test, and aims at examining if there are one or more unknown structure breakpoints for a certain form of the equation. In order to analyze whether there are structural changes between two time points containing  $k$  sample points, or between observations  $T_1$  and  $T_2$ , the Chow Test needs to be performed separately at each observation point. On the other hand, the Quandt-Andrews Test will integrate the  $k$  values obtained by the Chow test into

a test statistic which allows them to test the null hypothesis that there is no break point between  $T_1$  and  $T_2$ .

The statistics of the Quandt-Andrews Breakpoint Test include three categories: (i), the largest statistic defined as the maximum value of the  $k$  F-statistics obtained by the Chow Test; (ii), the Avg statistic defined as the average value of the  $k$  F-statistics obtained by the Chow Test; (iii), the Exp statistic defined as the expectation of the  $k$  results. The results in Table 11 indicates that there is no evidence that any of the oil price coefficients in the GDP equations is unstable at the 10% significant level.

## **5 Conclusions**

In recent years, the Canadian economy experienced a recovery period, which reflected a tight correlation with energy. It is important to study the contribution of oil price to the economic development of Canada. This paper empirically studies the relationship between oil price and macroeconomic variables in Canada. Consistent with the previous research, I find that the effect of oil price shocks on GDP is significant. Overall, the findings of the paper are the following.

Firstly, the results of the Granger causality tests show that the price of oil is the one-way Granger cause of the six economic variables we studied. The economic

development of Canada is still very dependent on the international oil market, and its economic growth rate is easily influenced by the fluctuations of oil prices.

Secondly, this study uses impulse response functions to examine the response of real economic variables to changes in oil prices. The results indicate that all economic variables reach their maximum response to oil prices in the second to fourth quarters and do not respond immediately in the current period. This is possibly due to the time lag of three to four months from changes in oil prices to changes in the price of oil trade contracts, and then to changes in macroeconomic variables. I first analyze the impact of oil price changes on real GDP, and find that in the short term, oil shocks are beneficial to oil-producing countries such as Canada, and the income effect brought about by rising oil prices is far greater than the negative impact due to adjustment costs. As a result, the impact of international oil prices actually leads to a positive response of real GDP, which reaches the maximum in the second quarter. However, the rise in short-term real GDP masks many unfavorable factors for economic growth, such as deteriorating terms of trade and delays in the process of political and economic reform. This poses a threat to Canada's long-term economic growth. So, in the long-run, the accumulated response of GDP to oil price increases is negative. It is worth mentioning that I also find that the REER has a large response to the changes in oil prices. The rise in oil prices is bound to expand the energy sector in Canada, where oil extraction, mining and transportation require substantial capital investment to further expand oil production and exports. The

rise in oil prices brings with it a huge number of petrodollars in Canada, which stimulates the rise of oil exports, and causes appreciation pressure on the Canadian dollar.

Finally, this paper uses forecast error variance decomposition to analyze the contribution of international oil price changes to business cycle variations of domestic economic variables. I find that the contribution of international oil prices to the variance of real GDP reaches 8.6%, while the contribution to the REER and inflation is around 27% and 14%, respectively. It can be concluded that the contribution of the fluctuations of oil prices to the forecast variance of Canadian economic variables is significant, which further proves the dependence of Canadian economic growth on international oil prices.

At the same time, my research methodology has a disadvantage, i.e., I do not separate oil price shocks according to their underlying causes, as proposed by Kilian (2009). The choice to focus on overall oil price shocks was due to a because of the limitation of information.

## Appendix 1: Data Sources

GDP: Gross domestic product, expenditure-based, quarterly (dollars x 1,000,000) ,  
Statistics Canada, Table 380-0064

Real Effective Exchange Rates: index 2010=1, quarterly, not seasonally adjusted,  
<https://fred.stlouisfed.org/series/CCRETT01CAQ661N>

Nominal oil price: WTI oil price, price per barrel of WCS oil in US dollars,  
<http://economicdashboard.alberta.ca/OilPrice>

Real oil price: WTI oil price times exchange rate, then divided by PPI

Nominal wage: Unit labor cost, seasonally adjusted, quarterly (index,2007=100),  
Statistics Canada, Table 383-0012

Real wage: nominal wage divided by CPI

Short term interest rates: per cent per annum,  
<https://data.oecd.org/interest/short-term-interest-rates.htm#indicator-chart>

Long term interest rates: per cent per annum,  
<https://data.oecd.org/interest/long-term-interest-rates.htm#indicator-chart>

Producer Prices Index(PPI): Economic activities: total manufacturing for Canada, index  
2010=1, quarterly, not seasonally adjusted,  
<https://fred.stlouisfed.org/series/PIEAMP01CAQ661N>

Consumer Prices Index(CPI): Total, all items for Canada, index 2010=1, quarterly, not  
seasonally adjusted, <https://fred.stlouisfed.org/series/CPALCY01CAQ661N>

Exchange rate: Canada / U.S. Foreign Exchange Rate, quarterly, not seasonally adjusted,  
<https://fred.stlouisfed.org/series/CCUSSP01CAQ650N>

## **Appendix 2: Review of Oil Price History**

Judging from the historical data on international oil prices, almost all the political, military, and disaster events related to major oil-producing countries have led to dramatic changes in oil prices, which further triggered macro-economic effects on a wide range of oil-importing countries and other oil-exporting countries. Below is a brief review of the remarkable events related to oil price fluctuations and the recent trend. The pattern of oil prices from 1970 to present is plotted in Figure A.

### **First Oil Crisis (1973-1974)**

In October 1973, Egypt, Syria and 12 Arab countries launched an unexpected military attack against Israel, which marked the outbreak of the Fourth Middle East. Later, the United States and The Netherlands provided support to Israel. Consequently, the Organization of Arab Petroleum Exporting Countries declared the implementation of an oil embargo against a series of western countries. In December, several major Arab members of the OPEC declared to withdraw the pricing rights on crude oil. Consequently, international oil prices rose rapidly from less than 3 dollars per barrel to around 12 dollars in 1974. This was called the "First Oil Crisis".

According to statistics from the International Monetary Fund (IMF), during the war period of 1973-1974, oil prices rose by 258%. The surge in oil prices had a major impact

on the western developed economies. For example, in Europe, GDP fell by 2.5%. A remarkable slowdown in economic growth occurred in all industrialized countries, with the main countries experiencing severe stagflation, causing a swift decrease in the world GDP growth rate from 6.9% to 1.9%.

### **Second Oil Crisis (1978-1980)**

At the end of 1978, the Iranian revolution broke out, leaving the society in great turmoil. The daily output of oil declined sharply, with Iran banning the export of oil for 60 days, which triggered the Second Oil Crisis. It was estimated that there was an oil shortfall of 5 million barrels per day on the global market, representing about 10% of the total world consumption. The tight supply induced market panic and prompted a massive run on crude oil, causing oil prices to rise more sharply. In 1980, the Iraqi Air Force shelled Iran, and the Iran-Iraq war broke out. The war brought to a complete halt of the production and export of oil from Iraq and Iran. Oil production fell quickly from 5.8 million barrels per day to less than 1 million barrels per day, leading to a shortfall of about 5.6 million barrels per day in the global oil market.

At the same time, a split occurred within OPEC, with Saudi Arabia advocating a freeze on oil prices and even implementing a large unilateral increase in output to hold down prices, while most OPEC members preferred to follow the market for a price

increase. As a result, major oil-exporting countries raised the price in turns, driving a jump from 13 dollars per barrel in 1979 to 41 dollars per barrel at the end of 1980.

As in the previous oil crisis, the economies of the major industrial countries in the western world experienced stagflation, a general slowdown in output growth and a sharp rise in unemployment. The oil-importing developing countries also faced economic recessions and high inflation. The United States government estimates that its GDP fell by about 3% during this oil crisis.

### **Third Oil Crisis (1990)**

In the early 1990s after the Iraqi invasion of Kuwait, a multinational force, led by the United States, launched a military action named "Desert Storm" against Iraq. The Gulf War led directly to the disruption of Iraq's oil supply, and the third oil crisis erupted, with oil prices rising sharply from 14 dollars per barrel to 42 dollars per barrel, more than quadrupling in just three months. The United States and the United Kingdom's economies began to falter, dragging down global GDP growth rates to less than 2% in 1991.

In response to the oil disruption, the International Energy Agency (IEA) started implementing emergency response plans, releasing up to 2.5 million barrels of crude oil reserve on the market each day. The OPEC was rapidly increased production as well, so oil prices collapsed. As a result, compared with the previous two oil crises, during this

time the increase in oil prices did not last long and the impact on the global economy was much smaller.

### **Oil Price Fluctuations Since 2000**

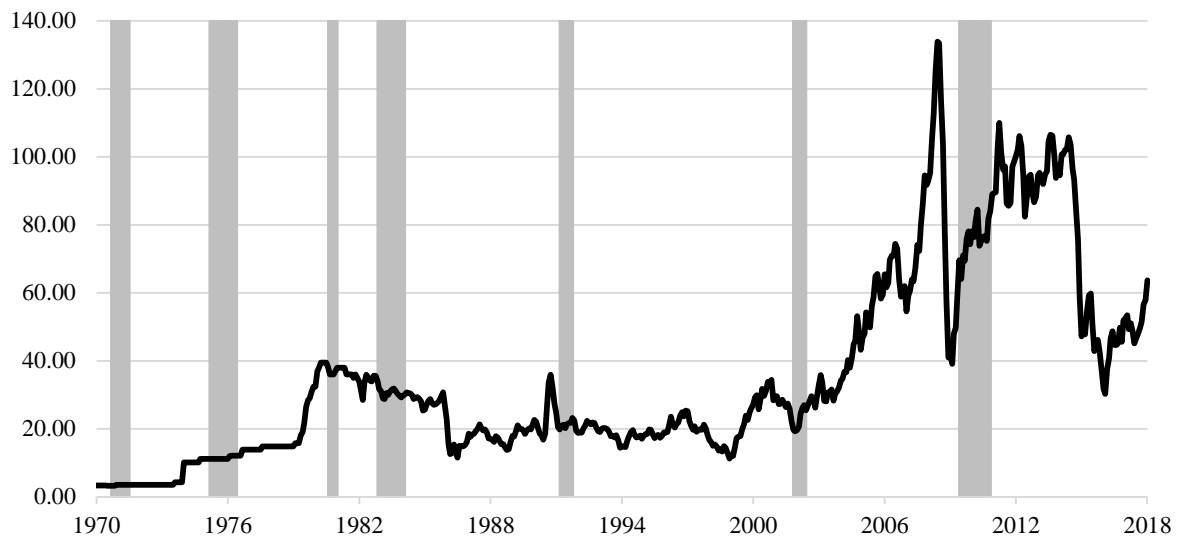
Prior to 2003, international oil prices had been volatile in a tight range of low levels, and even declined slightly during 2002. After the outbreak of the war in Iraq in March 2003, international oil prices began to enter a stage of steady rise. In September 2004, oil prices exceeded 50 dollars per barrel from less than 30 dollars per barrel before the war. From August to September 2005, the United States encountered one of the worst natural disasters in history - hurricane Katrina and Rita attacked the southern United States within just one month. Not only some low-lying areas were flooded, but almost all the US refineries in the Gulf of Mexico area were shut down. International oil speculation took the opportunity to push oil prices to a new high of 70 dollars per barrel. In September 2007, due to growing tensions in the relationship between the United States and Iran, as well as the fact that market worried about the decline in US crude oil stocks, international oil prices broke through 80 dollars per barrel. On February 22, 2008, Turkish troops crossed the border in a take military action against Kurdistan Workers' Party in northern Iraq, directly pushing the closing oil price in the New York market to a new high of 98.81 dollars per barrel. Just a few days later, oil price broke through the 100 dollars per barrel mark, and then rose to the highest point of 147 dollars per barrel.

After July 2008, the price of oil entered a period of adjustment. Marked by the bankruptcy of Lehman Brothers, the sub-prime crisis in the United States officially evolved into an international financial crisis, and the oil price went into a free fall. In less than four months, oil plummeted from 147 dollars per barrel to around 40 dollars per barrel, and eventually dropped to 33 dollars per barrel in early 2009. The reasons for this of more than 70% fall can be attributed to the following two factors. On the one hand, under the shock of the financial crisis, the global economy was going through a recession, so oil demand was cut down. On the other hand, before the financial crisis, the oil futures market experienced a period of vigorous development, and the trend of oil financialization was increasingly obvious. After the outbreak of the financial crisis, many famous financial institutions went bankrupt or were acquired. Financial institutions investing in the international oil markets also suffered heavy losses. As a result, they pumped back their investment in the oil futures market, thus exacerbating the decline in oil prices in the second half of 2008.

In the following years, the global economic recovery triggered a rebound in oil demand, so oil prices began to resume the upward trajectory. At the beginning of 2009, the price of oil was about 33 dollars per barrel, while in 2010, it hovered around 70 to 90 dollars per barrel. In June 2010, due to dramatic changes in the US economic situation and the European Sovereign Debt Crisis, the US dollar experienced a new round of turbulence fall. The depreciation of the US dollar and the expectations of inflation drove

a large amount of capital into the commodities markets, which sparked a new increase in international oil prices. From 2011 to 2014, oil price continued to fluctuate between 90 dollars per barrel to 130 dollars per barrel. By 2014, global crude oil production continued to climb. Iran and Libya resumed the export of crude oil. In addition, the United States and Iraqi's oil production increased sharply. In June 2014, OPEC decided not to cut production, so oil prices plunged by nearly 50%. The United States cancelled their 40-year ban on crude oil exports in December 2015. In January 2016, the sanctions on Iran were officially lifted, and Iran was allowed to sell oil internationally again. Iran's addition of 500,000 barrels per day of crude oil to the already oversupplied market put more pressure on the price of oil, which fell below 30 dollars per barrel. Since 2017, oil prices have recovered slowly, still hovering at 50 dollars per barrel. Figure 1 shows the fluctuations of oil price, measured by the West Texas Intermediate (WTI) spot price. The shading area represents the period of US economic contractions.

Figure A: Oil Price Fluctuations Since 1970



Note: Shaded regions represent the main global recessions.

Source: Federal Reserve Bank of St. Louis, NBER

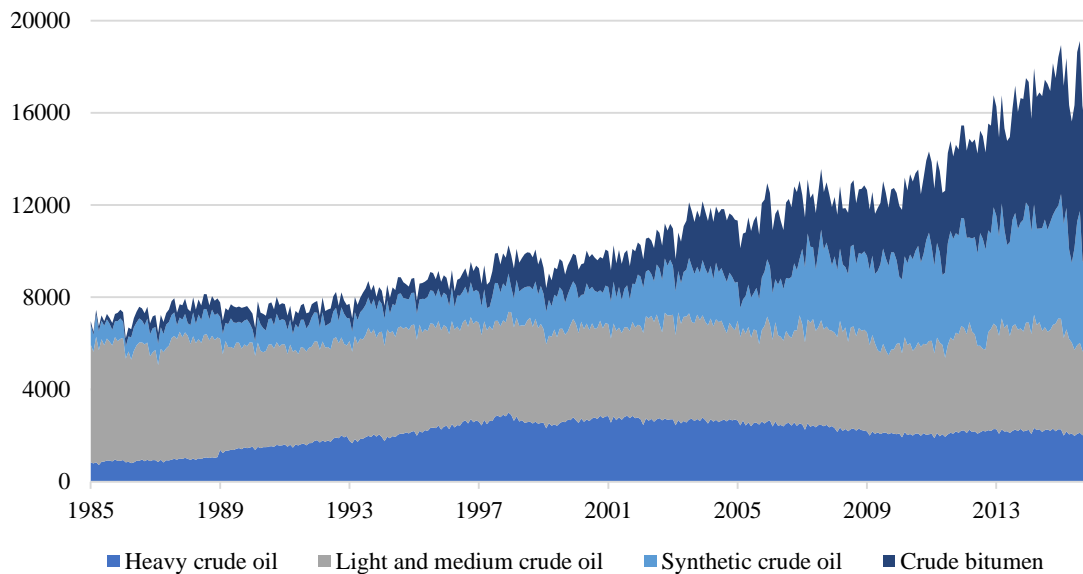
### **Appendix 3: Overview of Canada's Oil Resource**

As an important part of the global economy, Canada has considerable crude oil production capacity, especially oil sands. The analysis of the impact of the volatility of oil prices on the Canadian economy is a topic of great interest. Some provinces in Canada, such as Alberta, British Columbia and Saskatchewan, are on the supply side of oil energy for the Canadian economy, while the country also imports significant oil from the United States, Saudi Arabia and other countries. Therefore, explaining the symmetry or asymmetry between fluctuations in oil price and their overall effect on economic activity can be a complicated issue. In addition, while there are many contributions on the asymmetric or symmetric correlation between energy and the macroeconomy for the United States, the studies involving the Canadian economy are rare (Mork et al., 1994).

As of 2016, following Venezuela and Saudi Arabia, Canada has the third largest oil reserves in the world, which amount of 10% of the world's total reserves. Meanwhile, Canada is also the fourth largest oil-producing country in the world, ranked after the United States, Saudi Arabia and Russia, accounting for 5% of the world's total production. Oil (including crude oil, natural gas liquids and synthetic crude) is the most important source of Canadian energy supply and an important part of Canada's production, accounting for 2.2% of GDP in 2016. In 2016, Canadian oil production reached 3.9

MMb/d, with 62% coming from oil sands. Figure B shows the oil production categorized by oil types in Canada.

Figure B: Canadian Crude Oil Production by Type, 1985-2015

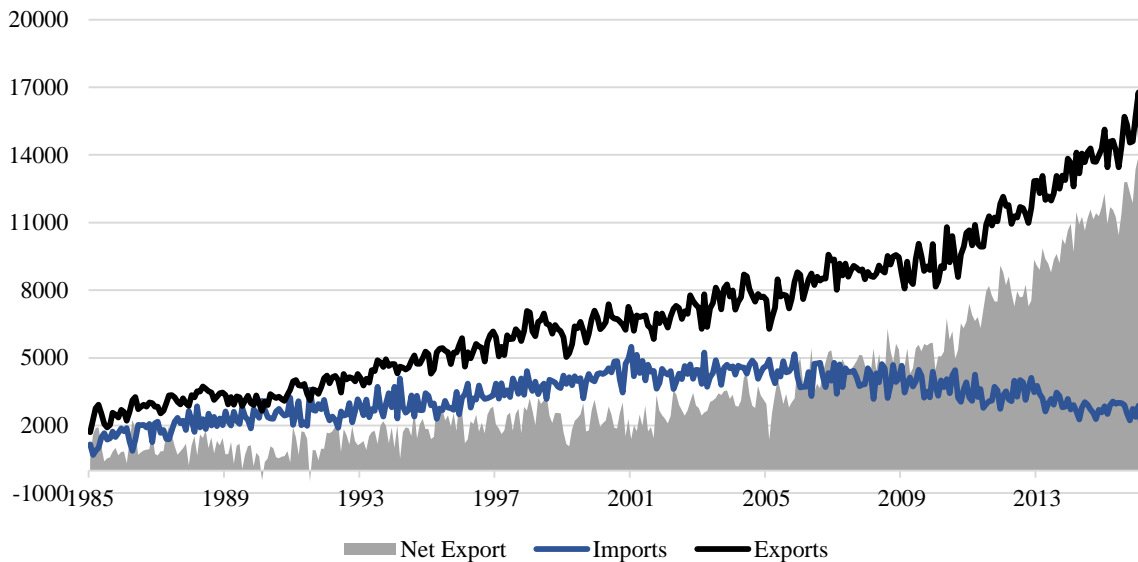


Source: Statistic Canada

With respect to oil exports, Canada ranks third following Saudi Arabia and Russia, accounting for 8% of global exports. In 2016, 80.4% of the crude oil produced in Canada was for export, with an export volume of 3.1 MMb/d. Local oil production is increasing, and more and more oil sands and new offshore production are driving this trend. In 2016, 99% of Canada's exported crude oil was transported to the United States, representing 41% of crude oil imports and 20% of refinery crude imports in the United States, respectively. Small quantities were shipped to other markets such as Asia and Europe. Oil production

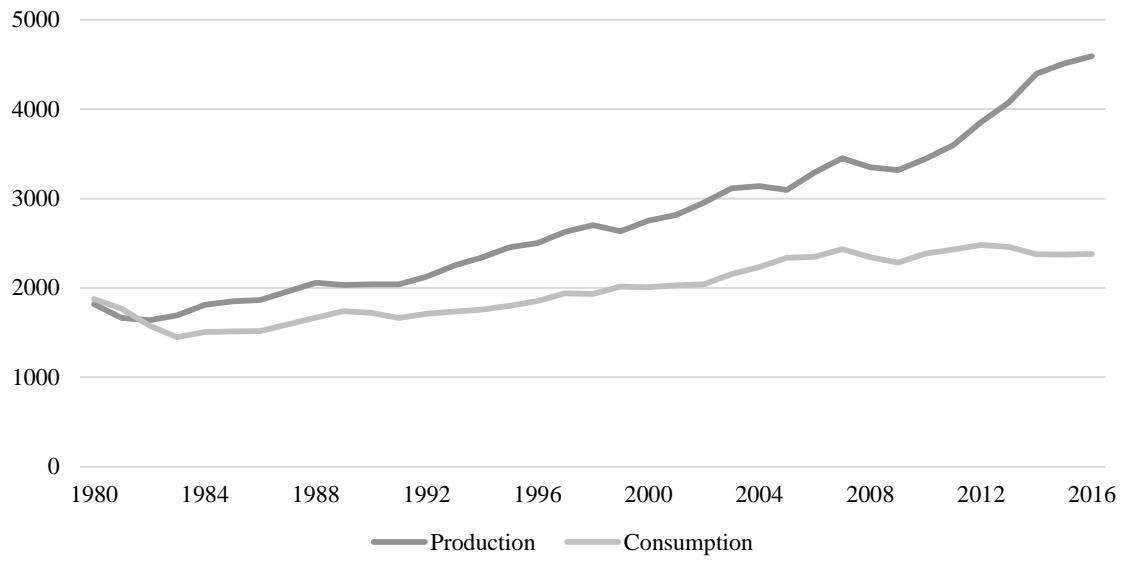
in Canada can also be used to reduce the country's own import demand. In 2016, crude oil imports dropped to 1.9 MMb/d. Crude oil imports are from multiple countries, including the United States (62%), Saudi Arabia (9%), Algeria (9%), Nigeria (8%), and Norway (4%). Eastern Canadian refineries, which usually rely on global oil imports, have been absorbing more US oil, thus displacing more expensive imports. Figure C shows oil imports and exports for Canada, and Figure D shows the oil production and consumption in Canada.

Figure C: Oil Import and Export of Canada, 1985-2016



Source: Statistic Canada

Figure D: Oil Production and Consumption of Canada, 1980-2016



Source: US Energy Information Administration

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## Tables and Figures

Table 1: Results of Unit Root Test

	Model with intercept			Model with trend and intercept			Model without intercept	
	ADF	DFGLS	PP	ADF	DFGLS	PP	ADF	PP
<b>Output and exchange rate variables</b>								
GDP in Levels	-0.455	2.301	-0.560	-2.242	-2.203	-1.959	4.069	-0.560
GDP in First Difference	-6.772***	-5.879***	-6.780***	-6.749***	-6.550***	-6.757***	-6.772***	-6.780***
GDP in Second Difference	-11.536	-0.620	-28.864	-11.502	-1.844	-29.576	-11.536	-28.864
REER in Levels	-1.822	-1.843	-1.725	-1.819	-1.844	-1.723	-1.819	-1.723
REER in First Difference	-9.123***	-7.561***	-9.062***	-9.098***	-8.677***	-9.037***	-9.151***	-9.062***
REER in Second Difference	-9.099	-11.502	-35.486	-9.069	-10.447	-35.299	-9.128	-35.561
<b>Price variables</b>								
Real Oil Price in Level	-2.029	-1.491	-1.883	-2.553	-1.721	-2.387	-0.616	-0.613
Real Oil Price in First Difference	-9.890***	-9.591***	-9.818***	-9.871***	-9.875***	-9.798***	-9.920***	-9.850***
Real Oil Price in Second Difference	-9.228	-9.156	-33.747	-9.155	-8.863	-33.594	-9.228	-33.933
Real Wage in Levels	-2.538	-0.250	-2.558	-1.789	-0.913	-1.723	-1.145	-1.148
Real Wage in First Difference	-11.398***	-11.113***	-11.389***	-11.612***	-11.662***	-11.648***	-11.347***	-11.349***
Real Wage in Second Difference	-9.277	-0.380	-91.322	-9.254	-2.079	-109.142	-9.310	-91.325
Inflation in Levels	-4.556***	0.186	-4.306***	-5.205***	-0.907	-3.505	-3.932***	-8.578***
Inflation in First Difference	-8.453***	-4.294***	-8.625***	-8.773***	-7.896***	-9.287***	-8.281***	-8.578***
Inflation in Second Difference	-8.355	-8.306	-35.770	-8.379	-9.731	-35.324	-8.360	-35.995

Table 1: Results of Unit Root Test (continued)

<b>Monetary variables</b>								
Short-term interest rate in Level	-2.383	0.260	-2.390	-4.164***	-1.828	-3.402	-2.736***	-2.584
Short-term interest rate in First Difference	-9.915***	-1.877*	-9.947***	-9.998***	-3.676***	-10.004***	-9.770***	-9.841***
Short-term interest rate in Second Difference	-7.671	-1.815	-21.217	-7.649	-3.752	-21.096	-7.696	-21.323
Long-term interest rate in Level	-1.201	0.654	-1.253	-4.457***	-4.265***	-3.545	-2.205	-2.093
Long-term interest rate in First Difference	-10.178***	-1.468	-10.124***	-10.181***	-2.728*	-10.123***	-9.935***	-9.909***
Long-term interest rate in Second Difference	-13.735	-13.513***	-21.550	-13.680	-13.347	-21.488	-13.792	-21.645

Note: Note: One/two/three asterisks mean a p-value less than 10%/5%/1%.

Critical values used for each test are listed as followed:

		1%	5%	10%
Model with intercept	ADF	-3.4768	-2.8818	-2.5777
	DFGLS	-2.5813	-1.9431	-1.6152
	PP	-3.4765	-2.8817	-2.5776
Model with trend and intercept	ADF	-4.0240	-3.4418	-3.1455
	DFGLS	-3.5296	-2.9880	-2.6980
	PP	-4.0235	-3.4416	-3.1453
Model without intercept	ADF	-2.5813	-1.9431	-1.6152
	DFGLS	-2.5813	-1.9431	-1.6152
	PP	-3.4765	-2.8817	-2.5776

Table 2: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1053.13	NA	6.85E-16	-15.05	-14.90*	-14.99
1	1140.23	164.28	3.96e-16*	-15.60*	-14.42	-15.12*
2	1175.25	62.37	4.87E-16	-15.40	-13.18	-14.50
3	1213.78	64.87	5.73E-16	-15.25	-12.00	-13.93
4	1264.00	79.48*	5.78E-16	-15.27	-10.98	-13.52

Note: Each test is at the 5% significance level.

\* indicates lag order selected by the criterion.

Table 3: Wald Test

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$H_0$ : the coefficients of all the lag values of oil price are jointly zero in the equation of GDP.

---

Results for linear and non-linear models:

		Chi-square	Probability
<b>Linear</b>	DLOP	14.7321	0.0053***
	Oi	10.05061	0.0396**
<b>Non-linear</b>	Od	17.029	0.0019***

Note: One/two/three asterisks mean a p-value less than 10%/5%/1%.

Log-differences of real oil price is represented by DLOP.

Table 4: Likelihood Ratio Test

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$H_0$ : in all the equations except that of oil price, the coefficients of all the lag values of oil price are jointly zero

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Results for linear and non-linear models:

		Chi-square	Probability
<b>Linear</b>	DLOP	41.89096	0.0133**
	Oi	61.9790	0.0002***
<b>Non-linear</b>	Od	49.60588	0.0072***

Note: One/two/three asterisks mean a p-value less than 10%/5%/1%.

Log-differences of real oil price is represented by DLOP.  $o_t^+$  and  $o_t^-$  are represented by Oi and Od, respectively.

Table 5: Multivariate Granger-Causality Tests

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$H_0$ : all other variables in the VAR model do not affect the oil price variable.

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Results for linear and non-linear models:

		<b>Chi-square</b>	<b>Probability</b>
<b>Linear</b>	DLOP	14.21137	0.9417
<b>Non-linear</b>	Oi	75.3856	0***
	Od	101.9977	0***

---

$H_0$ : the oil price variable does not affect other variables in the VAR model.

---

Results for linear and non-linear models:

		<b>Chi-square</b>	<b>Probability</b>
<b>Linear</b>	DLOP	41.89096	0.0133**
<b>Non-linear</b>	Oi & Od	75.7199	0.0065***

---

$H_0$ : there is no relationship between oil prices and other variables in the VAR model.

---

Results for linear and non-linear models:

		<b>Chi-square</b>	<b>Probability</b>
<b>Linear</b>	DLOP	48.40884	0.0315**
<b>Non-linear</b>	Oi & Od	76.1425	0.0051***

Note: Log-differences of real oil price is represented by DLOP.  $o_t^+$  and  $o_t^-$  are represented by Oi and Od, respectively.

Table 6: Accumulated Effect of Cholesky One Standard Deviation Real Oil Price Shock

Innovation for Linear Model						
Quarter	DLGDP	DLW	DREER	DINF	DSI	DLI
<b>2</b>	0.001192 (0.00049)	0.012504 (0.00176)	-0.001631 (0.00056)	0.191196 (0.04470)	-0.009586 (0.05385)	0.089173 (0.03976)
<b>4</b>	0.004729 (0.00168)	-0.001519 (0.00125)	0.012341 (0.00491)	0.384575 (0.10505)	0.089504 (0.13181)	0.083708 (0.09756)
<b>6</b>	0.002705 (0.00229)	0.000058 (0.00145)	0.012434 (0.00597)	0.202509 (0.12192)	0.105103 (0.17300)	0.070694 (0.11097)
<b>8</b>	0.002837 (0.00262)	-0.000242 (0.00154)	0.011701 (0.00622)	0.295292 (0.12701)	0.094623 (0.19595)	0.098314 (0.10621)
<b>10</b>	0.002479 (0.00271)	-0.000243 (0.00159)	0.012572 (0.00617)	0.335975 (0.13155)	0.081712 (0.20403)	0.100370 (0.09738)
<b>12</b>	0.002007 (0.00271)	-0.000057 (0.00163)	0.012934 (0.00628)	0.299013 (0.13383)	0.057773 (0.20291)	0.082850 (0.09631)

Note: Standard errors are reported in in parentheses below the responses.

Log-differences of real GDP, real oil price, real wage are represented by DLGDP, DLOP, DLW, respectively. First differences of inflation rate, REER, short-term interest rate and long-term interest rate are represented by DInf, DREER, DSI, DLI, respectively.

Table 7: Accumulated Effect of Cholesky One Standard Deviation Real Oil Price Shock

## Innovation for Non-linear Model

Quarter	DLGDP		DLW		DREER	
	OI	OD	OI	OD	OI	OD
<b>2</b>	-0.001123 (0.00091)	-0.003167 (0.00088)	0.000131 (0.00086)	0.001554 (0.00084)	-0.005454 (0.00305)	0.003296 (0.00300)
<b>4</b>	-0.002390 (0.00163)	-0.001587 (0.00159)	0.000482 (0.00116)	0.001107 (0.00113)	-0.007115 (0.00476)	0.011108 (0.00459)
<b>6</b>	-0.004127 (0.00217)	-0.001259 (0.00202)	0.001580 (0.00134)	0.001547 (0.00123)	-0.007115 (0.00590)	0.011108 (0.00540)
<b>8</b>	-0.004898 (0.00264)	-0.002055 (0.00226)	0.001351 (0.00160)	0.002972 (0.00134)	-0.008557 (0.00666)	0.009254 (0.00551)
<b>10</b>	-0.005486 (0.00302)	-0.002863 (0.00237)	0.001781 (0.00189)	0.002778 (0.00150)	-0.009131 (0.00739)	0.009652 (0.00554)
<b>12</b>	-0.006203 (0.00334)	-0.003320 (0.00242)	0.002137 (0.00211)	0.002841 (0.00157)	-0.008983 (0.00806)	0.009670 (0.00566)

Quarter	DINF		DSI		DLI	
	OI	OD	OI	OD	OI	OD
<b>2</b>	0.067095 (0.07513)	-0.160393 (0.07376)	-0.161415 (0.08333)	0.036039 (0.08201)	-0.053459 (0.06571)	0.060999 (0.06501)
<b>4</b>	0.096234 (0.10309)	-0.090722 (0.10037)	-0.161415 (0.12450)	0.036039 (0.12162)	-0.055795 (0.09568)	0.062016 (0.09338)
<b>6</b>	-0.022170 (0.11509)	0.027450 (0.10782)	-0.260270 (0.16465)	0.184753 (0.15455)	-0.078493 (0.10840)	0.112586 (0.09986)
<b>8</b>	0.007556 (0.12945)	-0.033950 (0.11397)	-0.258715 (0.20058)	0.230173 (0.17489)	-0.047609 (0.11774)	0.113098 (0.09657)
<b>10</b>	0.046350 (0.14710)	-0.023288 (0.12121)	-0.261396 (0.22672)	0.196314 (0.18079)	-0.034173 (0.12832)	0.113856 (0.09465)
<b>12</b>	0.009829 (0.16121)	0.022776 (0.12387)	-0.269170 (0.24510)	0.171413 (0.17919)	-0.034608 (0.13743)	0.112532 (0.09533)

Note: Standard errors are reported in in parentheses below the responses.

Log-differences of real GDP, real oil price, real wage are represented by DLGDP, DLOP, DLW, respectively. First differences of inflation rate, REER, short-term interest rate and long-term interest rate are represented by DInf, DREER, DSI, DLI, respectively.  $o_t^+$  and  $o_t^-$  are represented by Oi and Od, respectively.

Table 8: Relative Performance of The Models

	<b>AIC</b>	<b>BIC</b>	<b>HQ</b>
<b>Linear</b>	-15.6739	-11.3052	-13.8986
<b>Non-linear</b>	-3.04693	2.634493	-0.73816

Table 9: Variance Decomposition for the Linear Model – Oil Price Contribution

<b>Period</b>	<b>2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>
<b>GDP</b>	4.99	5.33	8.92	8.67	8.59	8.64
<b>REER</b>	29.29	28.60	28.04	27.90	27.90	27.87
<b>Wage</b>	4.85	7.55	9.14	9.10	9.08	9.08
<b>Inflation</b>	13.20	12.69	14.81	14.49	14.24	14.30
<b>Short-term Interest Rate</b>	0.11	0.18	0.27	0.47	0.51	0.54
<b>Long-term Interest Rate</b>	2.58	2.79	3.00	3.04	3.03	3.08

Note: The table reports the contribution of oil price shocks to the forecast error variance decomposition for different variables.

Table 10: Variance Decomposition for the Non-linear Model – Oil Price Contribution

Contribution from oil price increase:

	<b>2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>
<b>GDP</b>	1.90	3.18	5.51	5.81	5.92	6.24
<b>REER</b>	5.54	5.22	5.59	5.57	5.57	5.56
<b>Wage</b>	0.61	1.37	2.75	2.68	2.82	2.90
<b>Inflation</b>	1.36	2.03	3.47	3.38	3.45	3.54
<b>Short-term Interest Rate</b>	3.69	3.13	3.11	3.05	3.03	3.02
<b>Long-term Interest Rate</b>	0.90	1.06	1.10	1.36	1.40	1.40

Contribution from oil price decrease:

<b>Period</b>	<b>2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>
<b>GDP</b>	1.22	7.51	7.12	7.36	7.89	8.09

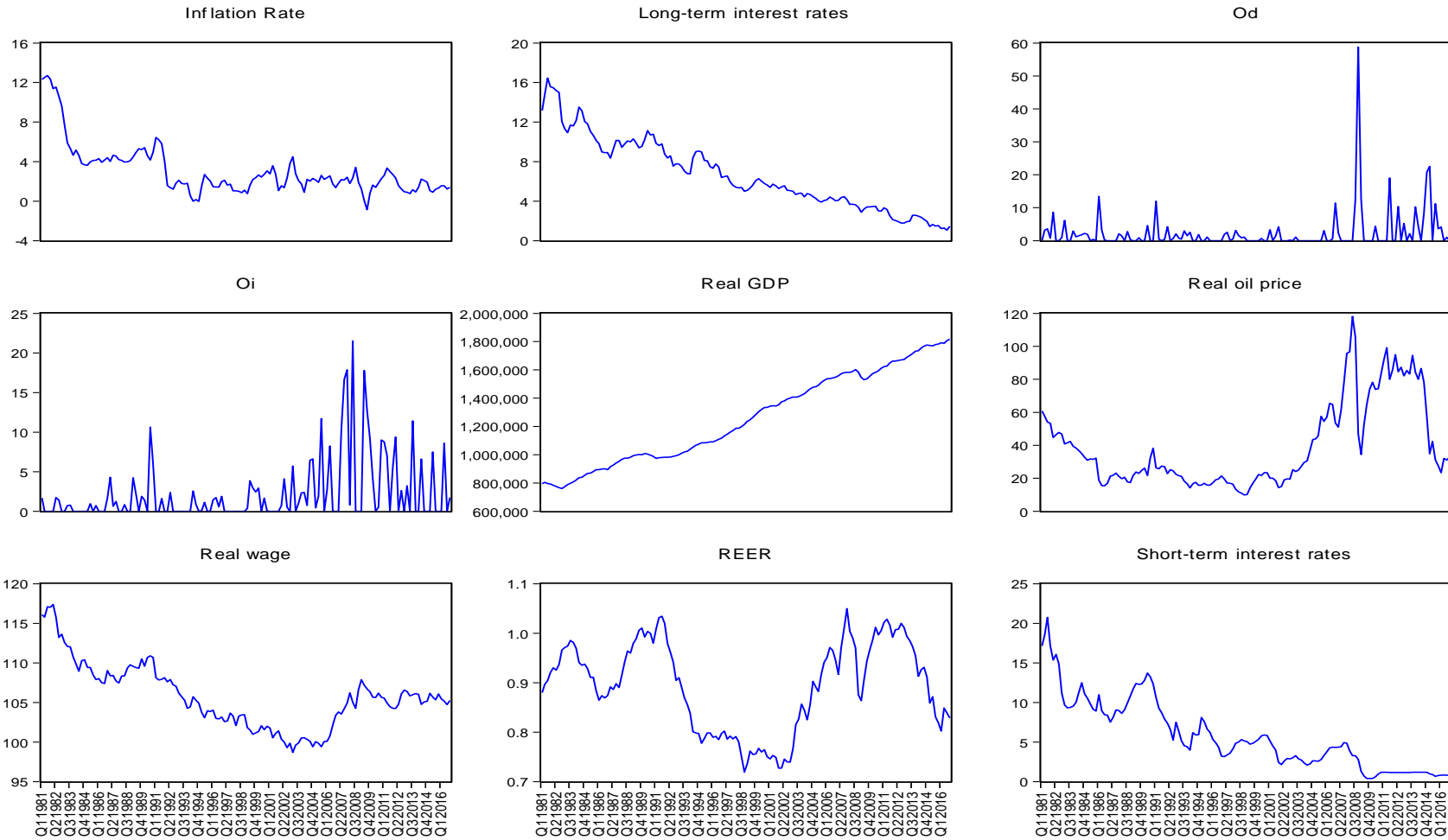
<b>REER</b>	2.00	7.08	7.27	7.50	7.53	7.52
<b>Wage</b>	3.25	2.87	3.44	5.32	5.31	5.28
<b>Inflation</b>	3.51	3.87	6.82	6.73	6.53	6.70
<b>Short-term Interest Rate</b>	3.47	4.07	6.17	6.38	6.42	6.49
<b>Long-term Interest Rate</b>	4.08	3.72	4.35	4.32	4.31	4.31

Note: The table reports the contribution of oil price shocks to the forecast error variance decomposition for different variables.

Table 11: Result of the Quandt-Andrews Breakpoint Test

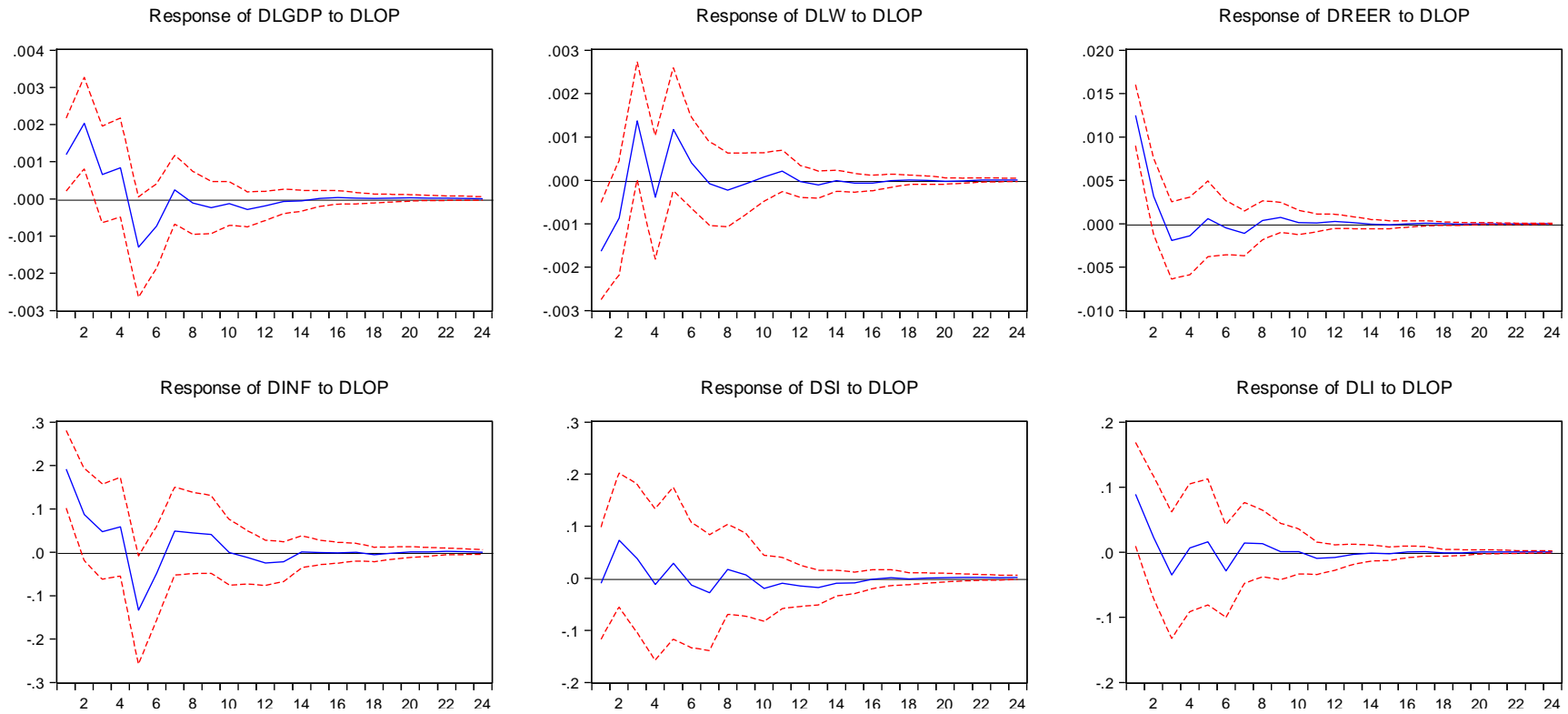
	<b>Statistic</b>	<b>Value</b>	<b>Prob.</b>
<b>Linear model</b>	Maximum LR F-statistic (Obs. 113)	2.656278	0.5102
	Maximum Wald F-statistic (Obs. 113)	5.312556	0.5102
	Exp LR F-statistic	0.409745	0.6340
	Exp Wald F-statistic	0.905359	0.5808
	Ave LR F-statistic	0.742104	0.5653
	Ave Wald F-statistic	1.484209	0.5653
<b>Nonlinear model - oi</b>	Maximum LR F-statistic (Obs. 109)	5.092912	0.0879
	Maximum Wald F-statistic (Obs. 109)	10.18582	0.0879
	Exp LR F-statistic	1.377698	0.0800
	Exp Wald F-statistic	3.021864	0.0604
	Ave LR F-statistic	2.413025	0.0427
	Ave Wald F-statistic	4.82605	0.0427
<b>Nonlinear model - od</b>	Maximum LR F-statistic (Obs. 48)	1.699694	0.8273
	Maximum Wald F-statistic (Obs. 48)	3.399387	0.8273
	Exp LR F-statistic	0.290087	0.8008
	Exp Wald F-statistic	0.639623	0.7571
	Ave LR F-statistic	0.528409	0.7542
	Ave Wald F-statistic	1.056818	0.7542

Figure 1: Endogenous Variables Used in the VAR Analysis



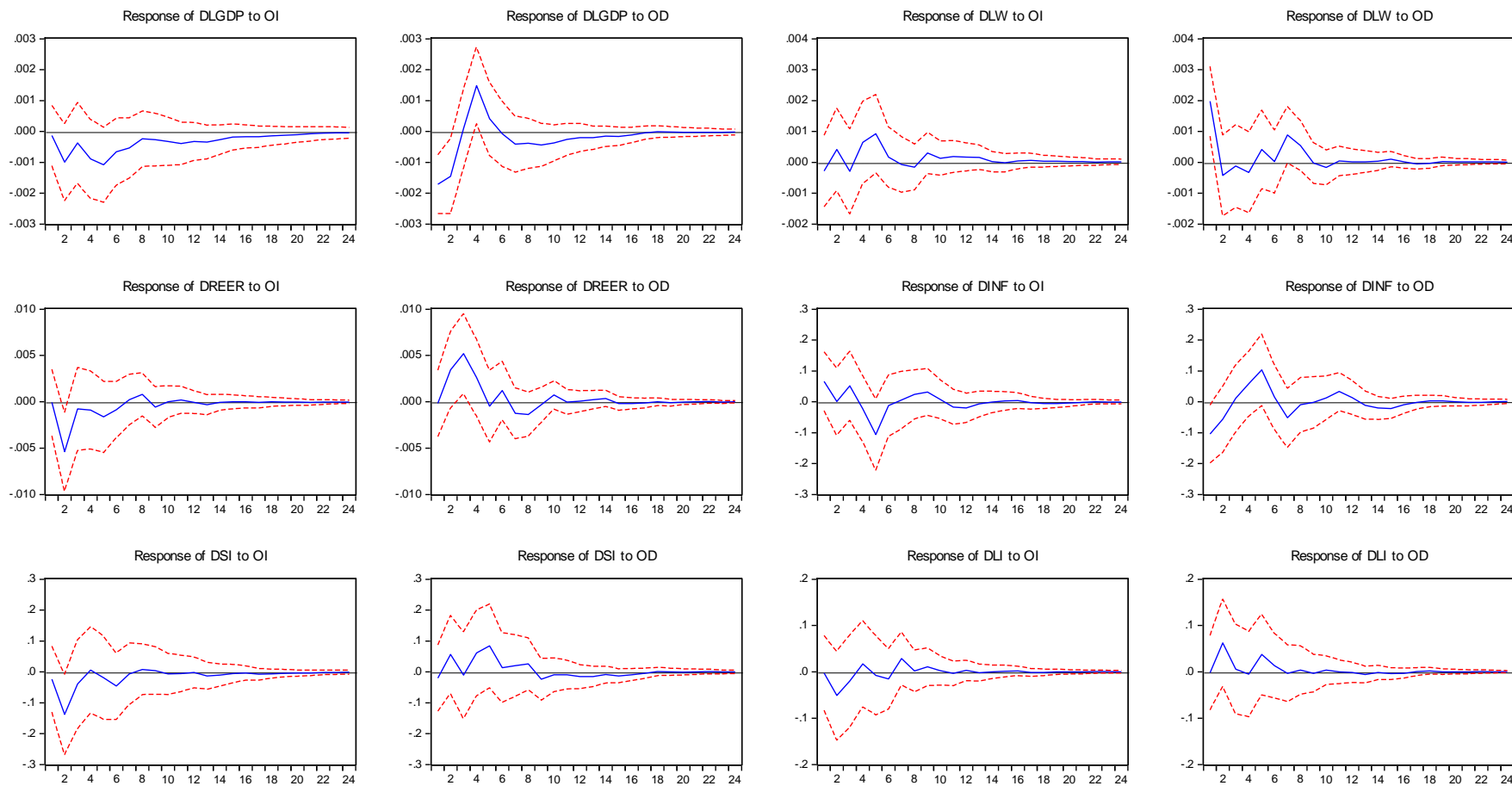
Note: Real GDP data are expressed in million Canadian dollars; real oil price and real wage data are in Canadian dollars.

Figure 2: Response to a Cholesky One Standard Deviation Innovation in Real Oil Prices for the Linear Model



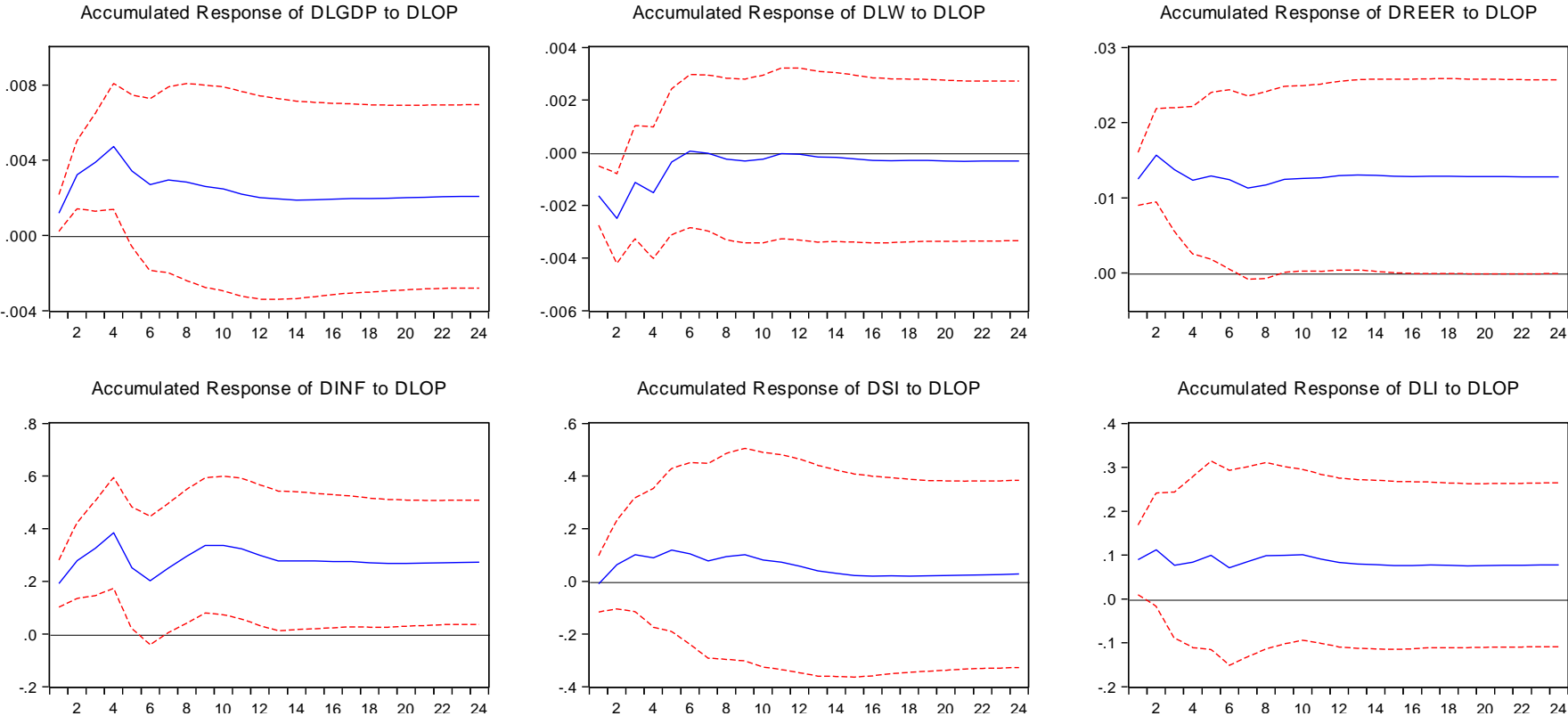
Note: Solid blue lines: point estimates; dotted red lines: one standard error bands. Log-differences of real GDP, real oil price, real wage are represented by DLGDP, DLOP, DLW, respectively. First differences of the inflation rate, REER, short-term interest rate and long-term interest rate are represented by DInfl, DREER, DSI, DLI, respectively.  $\sigma_t^+$  and  $\sigma_t^-$  are represented by Oi and Od, respectively

Figure 3: Response to a Cholesky One Standard Deviation Innovation in Real Oil Prices for the Non-linear Model



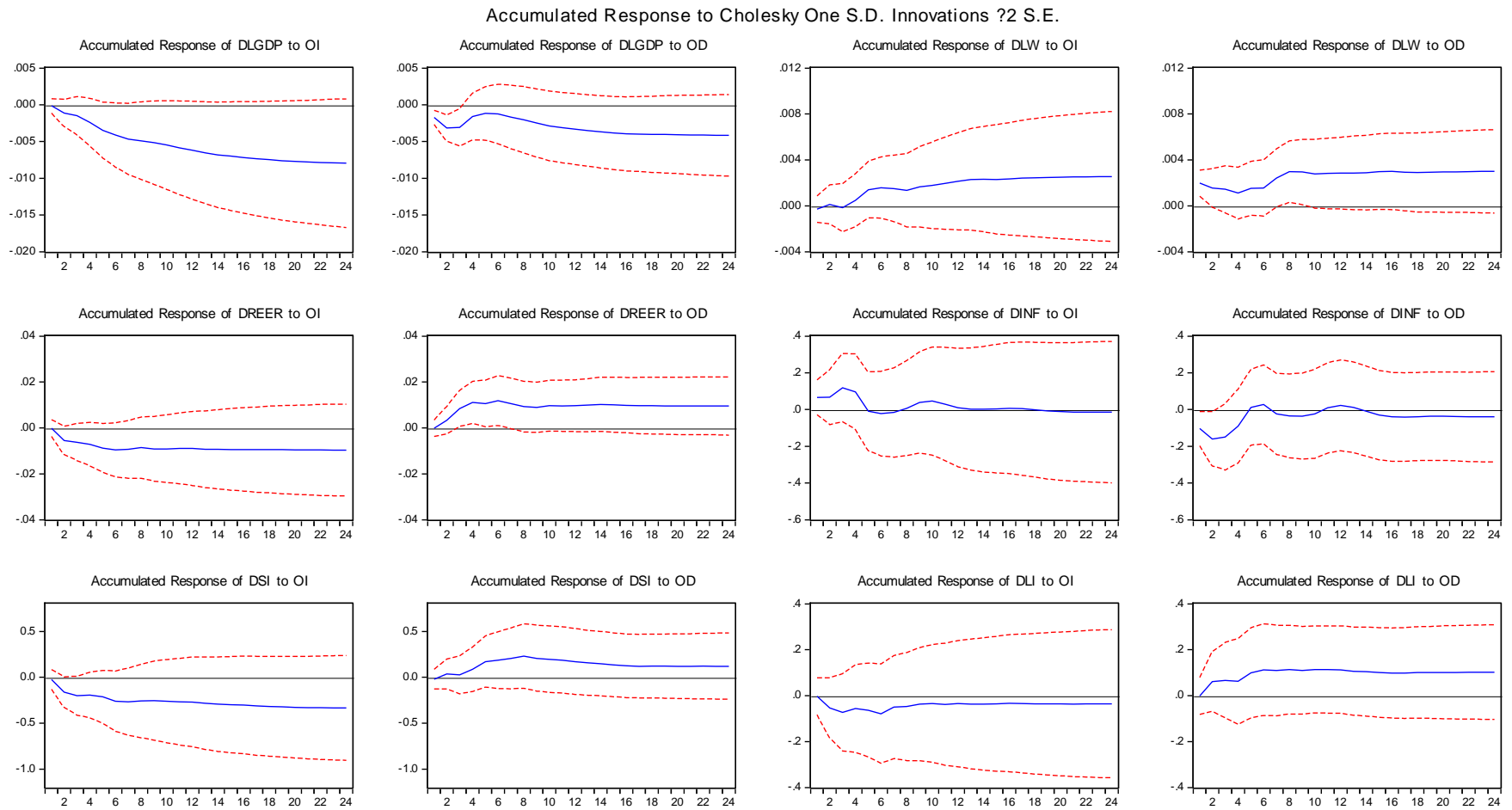
Note: Solid blue lines: point estimates; dotted red lines: one standard error bands. Log-differences of real GDP, real oil price, real wage are represented by DLGDP, DLOP, DLW, respectively. First differences of the inflation rate, REER, short-term interest rate and long-term interest rate are represented by DInf, DREER, DSI, DLI, respectively.  $\sigma_t^+$  and  $\sigma_t^-$  are represented by Oi and Od, respectively

Figure 4: Accumulated Response to a Cholesky One Standard Deviation Innovation in Real Oil Prices for the Linear Model



Note: Solid blue lines: point estimates; dotted red lines: one standard error bands. The actual numbers are given in Table 6.

Figure 5: Accumulated Response to a Cholesky One Standard Deviation Innovation in Real Oil Prices for the Non-linear Model



Note: Solid blue lines: point estimates; dotted red lines: one standard error bands. The actual numbers are given in Table 7.

