THE IMPACT OF OIL PRICES ON CANADIAN ECONOMIC ACTIVITY

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ABSTRACT

In this paper, a series of vector autoregression (VAR) models are developed to empirically evaluate the effects of higher oil prices on macroeconomic performance in Canada. Macroeconomic performance is measured using two benchmarks, namely GDP and GDI. This study shows that oil price increases have a negative impact on real GDP and a positive effect on real GDI. Although in economic theory, GDP should equal GDI, in reality these two measures differ. The significant upsurge in real commodity prices over the last decade, coupled with the lower cost of imported consumer goods from emerging markets, have led to large improvements in our terms of trade and generated large gains in real income. This is not accounted for under real GDP calculations. Therefore, when analyzing the effects of higher oil prices on the Canadian economy, this paper finds that real GDI may be a more appropriate variable to use instead of real GDP and concludes that higher oil prices are ultimately good for the economy.

1. INTRODUCTION

The relationship between oil price shocks and economic growth is a significant issue for Canadians. Much interest since the 1970s has focused on whether lagged oil price changes help predict the economy. The seminal study of Hamilton (1983) demonstrated that sustained increases in the price are responsible for almost every post-World War II U.S. recession. Since then, other researchers have extended Hamilton's basic findings using alternative data and estimation procedures to explore this link for various countries. Although the bulk of empirical research focuses on the effects of oil price changes on U.S. economic activity, few studies have examined the effects in Canada. The rapid acceleration in prices between 2003 and 2008, and the sharp decline that followed, has sparked a renewed interest in the role oil prices have on economic growth.

The transmission through the Canadian economy from significant run-ups in oil prices is certainly a complicated one. Some regard Canada's wealth of natural resources as a great endowment. Indeed, the crude oil industry has played a pivotal role in the development of Canada's economy. Using a multi-sector general equilibrium model, Dissou (2010) showed that an oil shock would have positive aggregate impacts on the Canadian economy. Given that this country is an oil exporter, the mainstream view is that Canada enjoys an overall economic prosperity with higher oil prices and suffers a net hit with declines.

Despite this mainstream view, a growing number of economists and analysts seem to suggest that sharp shocks in oil prices have considerable consequences on the economic performance in Canada (Allan, 2012). They look at the global commodity boom and make the grave diagnosis of "Dutch Disease", ignoring any benefits such as higher incomes and greater economic security. Beine, Bos, and Coulombe (2012) as well as Shakeri, Gray and Leonard

(2012) found limited evidence of this phenomenon; nonetheless, lingering concerns related to the natural resource booms remain (e.g., regional effects). Other findings show that the Canadian economy responds differently to an oil price shock depending on two factors— the initial macroeconomic conditions and, more importantly, the nature of the oil price increase. For example, in a 2011 working paper, the Bank of Canada showed that a 10% increase in the price of oil driven by an oil specific demand could shave 0.8 percentage points off Canadian real GDP growth in the short run (Baumeister, Peersman, and Van Robays, 2009). Based on these studies, it would seem that even for a major oil exporting economy like Canada, higher prices may not always be better. As prices rise beyond a certain level, the economic benefits to Canada can become crowded out by the increasing costs incurred by oil consuming industries like manufacturing and transportation. Furthermore, a sustained and significant rise in the value of oil could hinder Canadian economic growth by rousing inflation and cutting spending. Yet signs of economic prosperity seem to abound in spite of persistently high oil prices. Economic activity across the country appears stable with inflation remaining at approximately two percent.

The problem with these studies is that they only focus on one measure of economic activity, namely, real GDP. Although advances in productivity shore up our economy and improve our standard of living, in an open economy like Canada's, the volume of output is not the only source of real income. The trading value of that output, that is, the terms of trade, is just as important. Assessing living standards with GDP overlooks this critical dimension because it is only concerned with production. Consequently, economic benefits stemming from higher oil prices and other commodities don't necessarily show up in the data for GDP. On the other hand, real GDI, which measures Canadians' buying power, is an alternative yet important way to measure true economic performance, especially in economies trading on international markets.

Although conceptually, GDP should equal GDI, they are not equal in reality. These two measures have diverged since 2003. The substantial rise in real commodity prices since the beginning of 2003 and the reduced prices for imported consumer goods from emerging-market economies have resulted in a significant improvement in our terms of trade, and generated large gains in real income. GDI can capture these gains in addition to production. As a result, this may be a better variable to use because rising oil prices have contributed to an improvement in our terms of trade which is an important effect not accounted for in the calculation of real GDP. Canadians are better off as commodity prices increase. They can purchase a larger volume of imported goods and services with their exports.

In this paper, a series of vector autoregression (VAR) models are developed to investigate the importance of energy price changes on Canadian GDP. The present paper extends the existing empirical literature by examining the effects of oil price increases on GDI as well. Overall, it can be said that there is a crucial relationship between oil price shocks and economic growth. The effect of this relationship depends on which variable of economic activity is used. A productivity measure, like GDP for example, shows that an oil price increase negatively affects Canada in the short term. Focusing on real GDI, however, which includes the effect of the resource booms on purchasing power, paints a different economic picture. An oil price increase leads to positive economic growth. GDI better represents how the rapid increases in resource prices in recent times have affected economic prosperity in Canada.

Before the model is outlined, a brief review of the importance of crude oil is discussed in section 2. Later, factors affecting oil prices are listed as well as the theoretical impacts of oil prices on the economy. Transmission mechanisms are outlined in section 3. A review of the academic literature is outlined in section 4. Methodology is described in section 5 while empirical results are analyzed in section 6 through 8. Key insights and concluding remarks are summarized in section 9.

2. IMPORTANCE OF CRUDE OIL IN CANADA

Crude oil is an essential raw material, used in the production process of many industries. For example, it is used to produce heat, operate machinery and fuel vehicles and airplanes. Its components are used to manufacture almost all chemical products, such as plastics, detergents, paints, and even medicines.

According to a report released by the Natural Resources of Canada (Izzard, 2010), the oil industry is a major driver of Canada's economy:

- TSX Group is a leader in the oil & gas sector - more oil & gas companies are listed on the Toronto Stock Exchange (TSX) and TSX Venture Exchange than any other exchange in the world.
- Oil and Gas is a significant industry in Canada with companies accounting for about 5% of Canada's Gross Domestic Product (GDP).
- In 2008, the oil and gas extraction industry invested $54 billion in capital expenditures.
- Oil and Gas industry affects millions of Canadians either through employment or ownership in shares of companies such as RRSPs.

Canada's Position in Global Oil Production

According to the IEA Oil Market Report (Aug. 2012), Canada is the sixth largest oil producer (see Table 1). NRCan projects that by 2015, Canada may jump to the 4th largest oil producer because of the growing oil sands production.

Table 1: World's Top Oil Producers, 2011

Rank	Country	Million barrels per day
1	Russia	10.6
2	Saudi Arabia	9.0
3	United States	8.2
4	China	4.1
5	Iran	3.6
6	Canada	3.5
7	Mexico	2.9

Source: IEA Oil Market Report, August, 2012

As Table 2 indicates, Canada's proven oil reserves are the second largest in the world following only Saudi Arabia. This represents about 13% of the world's total oil reserves. It would take more than 150 years to extract these reserves (Izzard, 2010). As technology advances, some of Canada's additional oil sands resources that are currently unrecoverable will certainly become economic to extract and produce.

Table 2: World's Top Oil Reserves, 2011

Rank	Country	Reserves (billion barrels)	OPEC Member
1	Saudi Arabia	262.4	Yes
2	Canada	174.7	No
3	Iran	137.6	Yes
4	Iraq	115.0	Yes
5	Kuwait	104.0	Yes
6	Venezuela	99.4	Yes
7	U.A.E	97.8	Yes

Source: IEA Oil Market Report, August, 2012

3. TRANSMISSION MECHANISMS: FROM OIL PRICES TO ECONOMIC OUTPUT

A sustained increase in the value of oil (relative to historical prices) can impact the Canadian economy through a number of supply- and demand-side channels, in both positive and negative ways. It is therefore important to have a clear view of the potential transmission mechanisms. From a theoretical perspective, oil-price changes affect the performances of macroeconomic variables through the following six transmission channels. These are brief examples as the primary focus of this paper is on assessing the empirical relationship between oil prices and Canadian economic performance.

<u>1. Supply-side shock effect</u>

As oil prices increase, the marginal cost of production also increases. This induces firms to lower output thereby decreasing profits. Oil supply shocks are the single most important driving force behind oil price fluctuations.

<u>2. Sector adjustment effect</u>

Higher crude oil prices are a boom for Canada's resource-rich provinces, particularly in Alberta and Saskatchewan. They stimulate production and investment. This, in turn, leads to higher employment and wages. In fact, these provinces are projected to grow the fastest in 2012 and 2013 according to RBC forecasts[1].

On the other hand, industrial provinces, like Ontario and Quebec, are more vulnerable to oil price shocks. Oil-intensive sectors like manufacturing and transportation face an increase in production costs, potentially slowing economic activity.

<u>3. Inflation effect</u>

An increase in oil prices directly impacts inflation as measured by the All-items Consumer Price

[1] http://www.rbc.com/economics/quicklink/pdf/provtbl.pdf

Index (CPI). Consumers, households and businesses alike face increasing costs. The extent to which rising oil prices translate into higher overall inflation depends on its sustainability.

4. Exchange rate effect

A link between the appreciation of the Canadian dollar and the rise in oil prices may exist. Persistent strength of the Canadian dollar may pose challenges for exporters, in particular those in the manufacturing industry.

5. Wealth effect

Energy accounts for 9.4 per cent of a household's consumption basket (Kremmidas, 2011). As a result, higher energy costs can hurt Canadians. However, those provinces rich in oil enjoy higher incomes and greater wealth from boosted energy prices. This can offset some of the increase in their energy costs. Also, Canada's major stock exchange, the TSX, is comprised of a large amount of energy stocks (oil and gas companies account for about 27 per cent of the TSX's market capitalization). This has the potential to boost profits at many energy companies when oil prices rise. Subsequently mutual funds that specialize in energy stocks yield higher returns which in turn benefits many Canadian investors and pension funds.

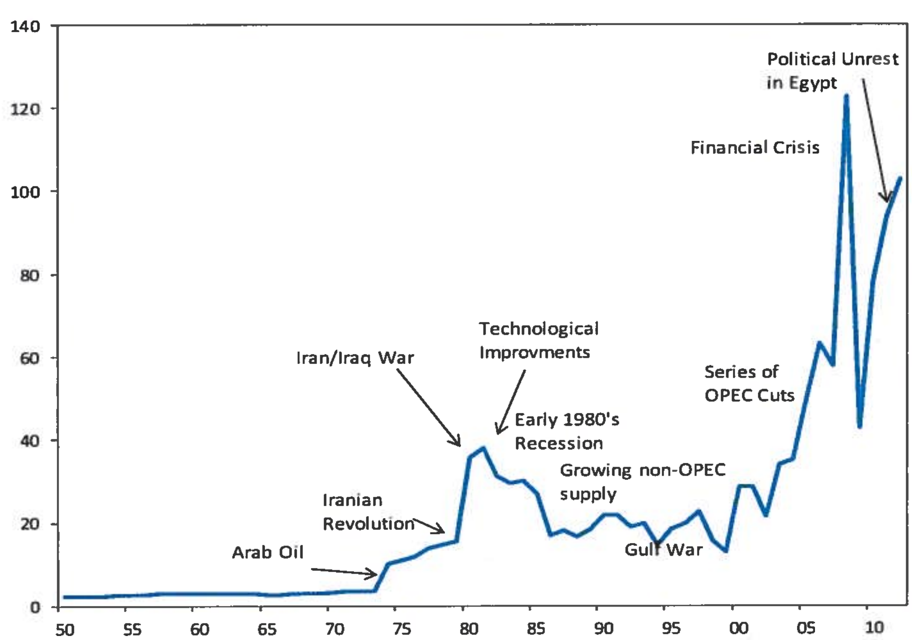
Although these are a selection of some of the possible mechanisms via which the price of oil may influence the Canadian economy, it can be very difficult to disentangle which, if any, of these channels are most important. Consequently, this research focuses on the empirical relationship between Canadian output and the price of oil.

4. LITERATURE REVIEW

The relationship between oil prices and economic activity has long been analyzed using several approaches. A distinction can be made between empirical studies with little economic theory, and theoretical studies with little empirical work.

Early research showed a negative linear relationship between oil prices and real economic activity. That is, an increase in oil prices would deter economic growth, while a decrease would improve it. These studies include Rasche and Tatom (1981), Darby (1982), Hamilton (1983), Burbidge and Harrison (1984), and Gisser and Goodwin (1986) just to name a few. However, this relationship became increasingly questioned by the mid-1980s. This period was marked with sudden drops in energy prices yet an increase in economic activity did not follow. Subsequently, Hooker (1996) found that the relationship between oil prices and the macroeconomy was weak and showed that the estimated linear relationship began to lose significance. Figure 1 shows a time series plot of real oil prices. Oil prices stayed relatively constant up to the early 1970s after which time they exhibited an upward trend. The 1986 oil price shock marks the first time there was a major oil price decrease. Even further, the 1990s and 2000s show a period of both large oil price increases and large oil price decreases.

Figure 1: WTI Annual Crude Oil Prices



To address this seeming breakdown in the oil-economy relationship, several empirical studies showed that energy prices had a nonlinear effect on the macroeconomy instead of a linear effect as was initially assumed. Thus, oil price increases should lead to negative growth, while the effect of falling oil prices was not known. Mork (1989) found an asymmetric relationship where increases and decreases in the price of oil were defined as separate variables. Hamilton (1996) introduced a net oil price increase transformation to re-establish the negative relationship and to analyze Granger causality between the two variables.

Theoretic literature in support of a nonlinear relationship includes Lilien (1982) who developed what is known as the dispersion hypothesis. According to this theory, high unemployment can occur as a result of sectoral shifts in demand and because the reallocation of labour is sticky. An increase in oil prices would lead to a contraction in those sectors that are heavily dependent on oil, creating an expansion in the energy-efficient sectors. However, because the cost of reallocating resources is high in the short run, this would lead to an overall loss in output. While this loss further intensifies the economic contraction when oil prices increase, it will mitigate the economic expansion when oil prices decrease, subsequently leading to the asymmetric effect. Another theoretical justification for nonlinearities in the oil price-macroeconomy relationship comes from the asymmetric response of the monetary authorities to oil price increases and decreases. It has been argued that central banks respond more aggressively to rises in crude oil prices than it does to decreases of the same magnitude (Natal, 2009).

By the beginning of the 21st century, a general agreement seemed to have emerged regarding the nonlinear nature of the relationship between oil prices and the macroeconomy, which in turn was thought to address the problem of structural instability found in the linear models in the post-1986 era (Herrera, Lagalo, and Wada, 2010). However economic activity in recent years appears to have been more resilient to oil price fluctuation than it was in the 35 years following World War II. Subsequently, recent literature suggests that if there is in fact a negative relationship between oil prices and real activity, its magnitude is likely to be small (Jones et al., 2004). Even still, work by Kilian and Vigfusson (2011a) has questioned whether oil price innovations really do have an asymmetric effect on GDP growth. In particular, they prove that the methodology commonly used in the empirical literature to assess the possible asymmetry in the response of economic activity to oil price shocks may lead to inconsistent parameter estimates due to a censoring bias.

Lastly, a remarkable schism is observable between recent empirical studies that suggest that oil price changes have very limited effects, and the effects predicted in by various Central Banks. For example, in a 2011 working paper, the Bank of Canada showed that a 10% increase in the price of oil driven by an oil specific demand could shave 0.8 percentage points off Canadian real GDP growth in the short run (Baumeister, Peersman, and Van Robays, 2009).

Clearly, explaining relationship of oil price changes and aggregate economic conditions could be a controversial debate—especially for a country like Canada, where some provinces such as Alberta, Saskatchewan, and Newfoundland thrive on a higher value for oil. The bulk of available literature has investigated the relationship between energy prices and aggregate economic activities in the United States while the research of this type is not as widely done about Canada's economy. Table 3 below summarizes some key findings.

Table 3: Summary of Key Papers Assessing the Relationship Between Oil Prices and Economic Activity

Author	Year of Study	Countries observed	Conclusions
Hamilton	1983,1996, 2003	USA	Significant negative relationship
Burbridge and Harrison	1984	5 OECD countries	Substantial initial impact
Jiménez-Rodríguez and Sánchez	2005	Several	Significant negative relationship
Papapetrou	2001	Greece	Significant negative causal relationship
Hooker	1996	USA	Changing and unstable oil price-macroeconomic relationship
Lardic and Mignon	2006	USA and Europe	Asymmetric relationship
Barsky and Kilian	2001, 2004	USA	Limited impact of oil price shocks
Kilian	2009	USA	Little or no impact of oil price shocks
Dissou	2010	Canada	Positive aggregate impacts

5. METHODOLGY

When constructing a model with more than one time series, it is imperative to account for the interdependence between the variables. One way of doing this is to estimate a vector autoregression (VAR) model as suggested by Sims (1980). The VAR approach is easy to estimate and is designed to avoid problems of endogeneity. Furthermore, studies modelling the economic impacts of oil price shocks on the economy, have also employed the VAR methodology. In addition to studying the impact of oil prices on real GDP growth using the VAR approach, this study extends on current literature by looking at the impact of oil prices on real GDI growth. An analysis of the impulse response function (IRF) of oil price movements on economic activity is also conducted. Impulse response functions essentially map out, over time, the expected responses of economic activity to a shock in oil prices within VAR equations. The IRFs therefore becomes crucial in the analysis of oil price shocks.

An approximation of the possible effects of higher oil prices on real economic growth can be determined with this simple pth-order VAR, denoted as:

$$\Delta \ln(y_t) = \propto + \sum_{i=1}^{n} [\beta_i \Delta \ln(y_{t-i}) + \delta_i \Delta \ln(o_{t-i})] + e_t \quad (1)$$

In this analysis, y_t is a measure of economic growth. The most popular variable to use, and indeed what most empirical studies have focused on, is the log change in real GDP. For this reason, it will be used in this study as well. Later, an alternative measure of economic growth will be employed, namely real GDI and the results will be compared. The variable, o_t, is the period-over-period rate of change in oil price.

We begin by modelling a linear specification to the VAR in equation (1). The linear specification models oil price increases and decreases with the same symmetric effect. That is, if increases in oil price are expected to have a negative impact on the level of economic activity then decreases should have a positive impact.

Further, based on past empirical work and economic arguments, two nonlinear transformations of oil prices are also analyzed. The first type of nonlinear transformation follows Mork's (1989) asymmetric oil price change where increases and decreases in the price of oil are determined as separate variables. The asymmetric specification differentiates between the positive rate of change in the oil price, o_t^+, and its negative rate of change, o_t^-, which are classified as follows:

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

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

where o_t is the rate of change in the real oil price. This asymmetric model can be understood using the dispersion hypothesis mentioned in the literature review.

The second nonlinear transformation is the net specification proposed by Hamilton (1996). In this context, the explanatory relationship between oil prices and GDP is nonlinear in that (1) oil price increases matter only if they exceed the maximum oil price in recent years and that (2) oil price decreases are absolutely insignificant. The net oil price increase (NOPI), as Hamilton outlined, is equal to the percent change between the oil price in the current quarter and the highest price in the previous 4 quarters. If the difference is positive, then that observation is used. On the other hand, if the difference is negative then an observation of zero is used. For example, in the fourth quarter of 2010 (December 2010), the spot price of WTI crude oil was $85.03 per barrel. Over the previous 4 quarters, the maximum crude oil price was $78.62 per barrel, an increase of 8.1 percent. If the price of WTI was $78.62 per barrel or less in 2010:Q4 (a zero or negative percentage change), the observation used for that quarter would have been zero. This kind of nonlinear transformation serves to filter out increases in the price of oil that simply represent corrections for recent decreases. That is, increases that did not exceed the maximum price observed in the past 12 months are censored at zero. In addition, it mutes any oil price decreases by setting the value of the variable to zero when a decline takes place. This transformation has been widely used in literature to better understand the macroeconomic effects and that is why it is employed here as well.

5.1 Nominal Price of Oil versus Real Price of Oil

One key difference separating existing literature is whether the price of oil is specified in real or in nominal terms. Although many empirical studies use real price of oil in their work, many other studies have focused on the nominal price of oil. For example, Hamilton's nominal

NOPI variable has become one of the most widely used specifications in literature studying the relationship between the price of oil and the U.S. economy. Hamilton (2010) justifies this by arguing that economic agents of oil products choose to respond to changes in the nominal price of oil rather than the real price of oil because this is the price that is readily and easily known.

Another leading argument in support of nominal oil prices is that they are likely exogenous with respect to macroeconomic conditions in Canada (i.e., the price of oil is determined on a global market and Canada is a relatively small player). Before 1973, the nominal price of oil often remained constant for long periods at a time. As a result, changes in the real price simply accounted for inflation adjustments that were endogenous to the economy (Killian and Vigfusson, 2011b). But this does not justify the use of the nominal price of oil after 1973. Inflation innovations would instantly be incorporated in the nominal price of oil because the nominal price of oil would have been free to adjust to inflation pressures (Gillman and Nakov 2009). Although the nominal price of crude oil receives much attention, I believe the variable most relevant for economic modeling is the real price of oil. Because of positive inflation, the same shock to the nominal price would create a decreasing effect on real variables over the time horizon. Furthermore, the focus on real oil price changes also makes sense because an increasing number of empirical studies are focusing on the real price of oil. For example, Kilian and Vigfusson (2009) used the real price of oil for their model, in addition to many others like Mork (1989), Elder and Serletis (2010), and Herrera, Lagalo and Wada (2010).

5.2 Choice of Oil Price Variable

While the objective of this paper is to understand the link between oil prices and economic growth, choosing the right oil price variable remains difficult as there exist different prices across various markets and countries. However, the selection of the oil price variable to use in the model is an important one. Empirical results, for example, can vary depending on what oil price series chosen (Kilian and Vigfusson 2011b). While there has been limited studies that focus on Canada, obvious choices for the oil price series include the price of West Texas Intermediate crude oil, the Edmonton Par, Western Canadian Select, or the average unit value-cost of imported crude to Canada. There is no general agreement on which price of oil to use.

When assessing the impact of oil shocks to GDP in the U.S., Hamilton (2010) argued that the producer price of crude oil is a better proxy than the unit value-cost of imported crude oil because the producer price is correlated with price of gasoline. This argument has some merit, but then it can be argued that the retail price of gasoline should be used instead, because it is itself a good representation of the retail price of energy faced by economic agents (Edelstein and Kilian 2009). This is indeed the variable used in the empirical work of Edelstein and Kilian (2009), in Ramey and Vine (2010) and in some of the results shown in Hamilton (2010). But as Mork (1989) noted, the imported oil price has been subjected to government regulation and may not be representative of true market conditions.

Therefore, I define oil prices in real terms, multiplying the WTI spot price by the CDN/US exchange rate and deflating it by the Canadian Consumer Price Index. One may argue that Western Canadian Select, the key benchmark for Canadian medium and heavy oil, would be a better proxy to determine the effects on economic growth. However, the WTI is more comparable across international studies and the correlation between the growth rate for the WTI spot price and the rate of growth for the Canadian benchmark is high (0.87) across the period of analysis.

5.3 Sample Period

The sample period used in the regression analysis is another important specification in modeling. Empirical studies assessing the impact of real output to oil price innovations have focused on a number of different sample periods yielding different results. It is immediately evident in Figure 1 that prior to 1970, the nominal price of oil was fairly constant due to regulation by the Texas Railroad Commission.

Because of this, regression models would not be appropriate for constructing the responses of real output to oil price shocks during the pre-1970 period. Little information is contained in oil price innovations prior to 1970; as such, impulse responses constructed from such models may be invalid, especially when assessing the evidence for asymmetric real output responses. This is because a large number of observations for the Hamilton's NOPI variable are zeroes before 1970. Furthermore, all of the major oil price shocks have occurred after this time period. It is therefore preferable to restrict the analysis to the post-1970 period. Therefore, the analysis begins in 1970.

6. TESTS AND EMPIRICAL RESULTS

In this section the empirical results are presented and analyzed for the linear and the two nonlinear models described in the previous section. Moreover, the impulse response functions obtained from the estimated VAR models are also expounded. First, in subsection 6.1, the stochastic properties of the variables considered in the model are investigated by testing for stationarity. Subsection 6.2 examines the optimal lag to be undertaken. In subsection 6.3, Granger causality is analyzed. Next, in 6.4, the results are formally presented and the performance of the different specifications compared. Then, the results of the impulse-response functions are discussed in subsection 6.5.

6.1 Stationarity

A stationary time series is one whose statistical properties such as mean, variance, and covariance are all constant over time. Before understanding the impact oil price innovations have on economic output, it is important to investigate whether the variables are stationary; The use of non-stationary data in causality tests may lead to spurious regressions (Stock and Watson, 1989). The assumption of stationarity is necessary for econometric estimators and has far-reaching implications for modeling and forecasting. Fundamentally, undertaking any VAR techniques become invalid without testing for stationarity first. As a result, before proceeding with further econometric analysis, it must be verified if the log GDP series as well as the log WTI series are in fact stationary. The data in levels seem to exhibit non-stochastic properties. Indeed, most economic time series are characterized by deterministic nonstationary properties rather than a stochastic process (Nelson and Plosser, 1982). If this is also the case for these particular variables, the next step is to take the first difference until the data becomes stationary. Therefore, in order to achieve stationary representations of the VAR models, two types of unit root tests are conducted, namely the ADF test and the KPSS test.

Dickey and Fuller (1979) developed a test to determine whether a unit root exists in autoregressive models. The decision rule therefore becomes the following:

Null Hypothesis: non-stationarity due to unit root

Alternative Hypothesis: stationarity

Kwiatkowski et al. (1992) provided an alternative test, the KPSS test, for testing the null hypothesis of stationarity against the alternative hypothesis of a unit root. In order to supplement the ADF test in this study, the KPSS test was also performed. The difference between the ADF and the KPSS test is that while the former obtains the test statistic under the null of nonstationarity, the latter assumes the null of stationarity to run the test. As a result, the KPSS test serves as a good complement for the ADF test.

The estimated statistics of the ADF and KPSS stationary tests are presented in Appendix A. Table 4 presents a summary and shows that the results are consistent.

Table 4: Model with Constant and Trend

Results of Unit Root Test

Variables	ADF statistic (in levels)	ADF statistic (in first difference form)	KPSS statistic (in levels)	KPSS statistic (in first difference form)
GDP	0.86	3.88***	0.054**	0.037
Oil Price	1.85	4.85***	0.151**	0.052

*Note: The rejection of the null hypothesis at 10%,5%, and 1% critical levels are denoted with *, ** and *** respectively*

As can be seen the t-statistic of 0.863 for the coefficient of the lagged level of GDP is insignificant even at the 10% confidence level and therefore the hypothesis that GDP has a unit root cannot be rejected. The same test is conducted for the oil price variable.The t-statistic of 1.85 for the coefficient of the lagged level is insignificant even at the 10% confidence level and therefore we cannot reject the unit root hypothesis. The non-stationary variables were transformed by taking their first differences in order to exhibit stationarity, indicating the mean, variance and covariance of the time series are independent of time. Similarly, the results of the alternative KPSS test shown do not reject the hypotheses that logGDP in level are stationary in levels but the results in the first-difference form imply that the null hypothesis cannot be rejected. Consequently, all analysis is performed using first differenced data.

6.2 Choice of the lag p

An important component in the specification of VAR models is choosing the lag length. VAR estimations can be sensitive to the lag structure of variables. While a sufficient lag length helps to reflect the long-term impact, adding to it can result in collinearity problems and lower the degrees of freedom. Therefore, a key question is how many lags should be included in this VAR model aimed at understanding the impact of oil price shocks. A decision can be based on one or more so-called information criteria.

The golden rule in regression analysis is that the model should be as parsimonious as possible (Enders, 2004). From standard regression theory a VAR(p+1) will fit the data better than a VAR(p). Although every additional variable increases the fit of any regression, there is a tradeoff and this improved fit comes at the cost of $p \times k$ additional parameters (where p is the number of lags and k is the number of regressors).

The information criteria are measures which formalize this trade-off. The two most common information criteria are the Akaike Information Criterion (AIC) and the Schwarz-Bayesian Criterion (SBC). The optimal lag length is the one that minimizes either the AIC and SBC. Both AIC and SBC gave very different suggestions for the optimal lag length (Appendix B). Therefore, I have chosen to adopt the parsimonious model with lag length 1 as suggested by the SBC as well as 4 lags. The VAR(4) benchmark model has also been used by Hamilton (2003), Alquist, Kilian and Vigfusson (2011), and Ravazzolo and Rothman (2012), among others, facilitating comparisons with existing results in the literature.

Table 5: Identifying the Optimal Lag Length

	Linear Oil Price Specification		Asymmetric Specification		NOPI	
Number of Lags	AIC	SC	AIC	SC	AIC	SC
1	4.23	**4.39**	**7.16**	**7.46**	2.12	**2.27**
2	4.24	4.49	7.20	7.69	2.15	2.40
3	4.27	4.60	7.25	7.92	**2.10**	2.43
4	**4.21**	4.62	7.25	8.11	2.11	2.52
5	4.22	4.71	7.32	8.36	2.16	2.65
6	4.23	4.80	7.38	8.61	2.20	2.77
7	4.28	4.94	7.48	8.89	2.23	2.89
8	4.32	5.06	7.53	9.13	2.28	3.02
9	4.36	5.18	7.61	9.39	2.33	3.14
10	4.35	5.25	7.64	9.61	2.30	3.20
11	4.35	5.33	7.67	9.81	2.28	3.26
12	4.39	5.46	7.69	10.02	2.31	3.38

6.3 Granger Causality

A question that frequently arises in time series analysis is whether or not one economic variable can help forecast another economic variable. One way to address this question was first proposed by Granger (1969) and later popularized by Sims (1972). The Granger causality test uses a time series data based approach in order to determine causality. For the purpose of this paper, the test is utilized to determine whether the past values of oil are useful for predicting GDP. The null hypothesis, evaluated at a confidence level of 5%, is that the past p-values of oil prices do not help in predicting the value of GDP growth. An F-test is used to determine whether the coefficients of the lagged values of oil prices are jointly zero. While the causal relationship of oil prices and macroeconomic productivity has been extensively examined through Granger causality, inferences from the test results need to be made with caution. Granger causality does not imply direct causality but simply means that a variable such as oil prices contains useful information to predict GDP.

In this section we try to find out if Canadian GDP is dependent on oil prices. In order to shed more light on these links, we carry out Granger causality tests to demonstrate that causality exists from oil price shocks to GDP growth. The results are revealed in the appendix. A table below also summarizes the F-stats and p-values:

Table 6: Granger Causality

	F stat	P value
Linear	3.6769	0.0061
Asymmetric	2.0659	0.0038
NOPI	2.9815	0.0028

Several observations can be made from the table. First, the hypothesis that the oil price shocks does not Granger cause real GDP growth is rejected across all model specifications. According to the results, causality runs from oil prices to GDP in Canada. The granger causality test shows the probability of the null hypothesis "Oil prices does not Granger cause Canadian GDP" is small. The use of Granger causality-type tests allow us to conclude that the interaction between oil prices and macroeconomic variables is found to be significant. Therefore oil prices shocks help to predict the real GDP growth.

6.4 Interpretations

Table 7 shows the VAR(1) regression results from the equation in section 5. Additional results are contained in Appendix C.

Table 7: Estimate coefficients of the impact on real GDP growth-1lag

Item	Linear	Asymmetric	Net Oil Price
Constant	0.406**	0.527 ***	0.424**
GDP rate change in			
t-1	0.484***	0.543***	0.484***
Oil price rate change in			
t-1	0.000	-0.001	-0.005
Memo Item:			
Number of observations	154	154	154
Residual standard error	0.652	0.627	0.650
Adjusted R-squared	0.242	0.297	0.250
F-test for joint insignificance (p-value)	7.05E-11	9.38E-10	5.29E-10

NOTE: ***, **,*, . , denotes significance at the 0.1, 1, 5, and 10 percent levels, respectively. The sample period is 1970:Q1-2011Q4

Following Hamilton's approach, a VAR(4) was also regressed, with the results summarized below.

Table 8: Estimate coefficients of the impact on real GDP growth-4lags

Item	Linear	Asymmetric	Net Oil Price
Constant	0.423**	0.527 ***	0.481**
GDP rate change in			
t-1	0.562***	0.543***	0.541***
t-2	-0.134	-0.145	-0.157 .
t-3	0.234**	0.239**	0.252**
t-4	-0.162*	-0.192*	-0.15 .
Oil price rate change in			
t-1	0.001	-0.001	-0.003
t-2	-0.005	-0.010	-0.012*
t-3	0.002	-0.005	0.004
t-4	-0.011**	-0.007	-0.008
Memo Item:			
Number of observations	154	154	154
Residual standard error	0.614	0.627	0.612
Adjusted R-squared	0.33	0.30	0.33
F-test for joint insignificance (p-value)	6.31E-11	9.38E-10	5.35E-10

NOTE: ***, **,*, . , denotes significance at the 0.1, 1, 5, and 10 percent levels, respectively. The sample period is 1970:Q1-2011Q4

From table 8, it seems that lagged oil price changes have a negative impact on GDP, particularly the asymmetric and NOPI specifications. The largest negative impact occurs in the fourth quarter after the shock. Although this VAR(4) model is commonly used to predict future GDP growth, the adjusted R-square is quite low for a time series model. Furthermore, the estimated coefficients for lagged oil prices are not statistically significant. This result is rather typical because of the high idiosyncratic volatility usually observed in quarterly growth rates. As van Dijk et al. (2007) stated, it remains difficult to fully understand and interpret time series models, especially nonlinear ones, by looking at the estimated coefficients of the model parameters only. Nevertheless, the hypothesis that the lags of the oil price changes have no collective impact on the pace of growth of aggregate economic output can be clearly rejected as the p-values for the joint test of insignificance is close to zero.

Table 9 indicates that the accumulated responses of GDP growth to a positive oil price shock. The linear and nonlinear models are similar. Over the entire sample period the sum of the energy coefficients on real GDP growth was highly significant, though modest. An oil price shock has a negative accumulated negative effect on GDP growth. Moreover, the nonlinear specifications yield larger negative accumulated impacts on GDP growth than in the linear case.

Table 9: Accumulated Response of GDP Growth

	Sum of oil price coefficients	F-statistic	P-value
Linear	-0.013	9.185	6.31E-11
Asymmetric	-0.023	6.784	9.38E-10
NOPI	-0.019	8.173	5.35E-10

6.5 Impulse Response Function

As described in the previous section, the individual estimates of the VAR model are not easy to interpret. These difficulties in the interpretation lead economists to look at impulse response functions in order to understand the economic implications of the VAR model. The results of the impulse response function essentially map out the dynamic response of a one standard deviation shock of oil on GDP. This type of analysis therefore becomes crucial in this study of oil price shocks.

Figures 3, 4, and 5, display the impulse response functions (IRF). Let us start the analysis of results by evaluating the relative performance of the different linear and nonlinear specifications. While the linear model assumes that oil price changes are symmetric, nonlinear specifications account for differential impacts of oil shocks that come from the same magnitude but different sign. There is a similar pattern of impulse response functions for all models. It is observed that the real impact of oil prices is negative in the short-term but eventually levels off in the long run. All these impacts are removed after about 10 periods.

IRF generated from the VAR model using linear specification of oil price shocks to GDP leads to an initial slight increase for two periods after which growth becomes negative. What is even more interesting is the upper band dips to negative territory leading to the conclusion that oil prices unambiguously leads to a negative effect on GDP in the short term before eventually levelling off. The fluctuations tend to die out after the 10^{th} period.

Next, looking at the asymmetric specification, it is observed that GDP growth is positive after an oil price shock. After the 4^{th} period however, GDP growth turns negative and lasts for 5 periods.

Turning to the net oil price specification, the largest negative short-run influence takes place in the 5^{th} period. The impact of the shock becomes very small after the 8^{th} period, dying out almost completely after that. The precision of the estimation of the impulse responses can be determined by assessing the confidence bands. Here, there is a large spread between the upper and lower confidence bands indicating that the estimation may not be quite precise. Furthermore, the upper confidence band remains positive, never dipping below zero. The linear specification yields a more accurate representation than the nonlinear model which is in contradiction to other findings.

In sum, using GDP as a variable for economic growth seems to indicate that higher oil prices have a significant adverse impact on economic performance in the short term, though their impact in the longer term is more muted. The impact on the rate of GDP growth is felt mostly within the first five periods as production is driven down, undermining both domestic consumption and investment. With all 3 specifications, losses start to diminish in the following periods as production of non-oil goods and services recovers.

Figure 3: Linear Specification

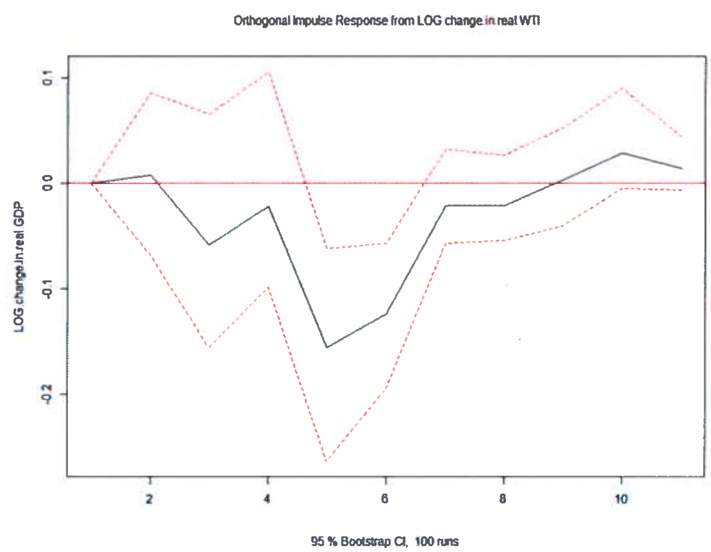


Figure 4: Asymmetric Specification

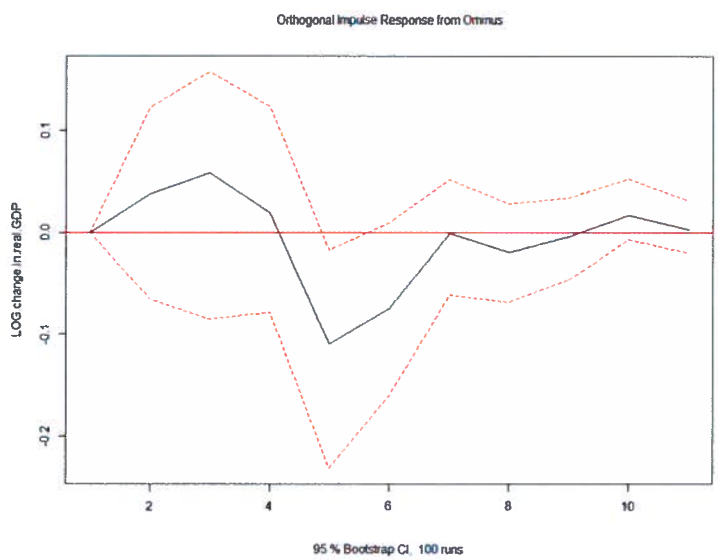
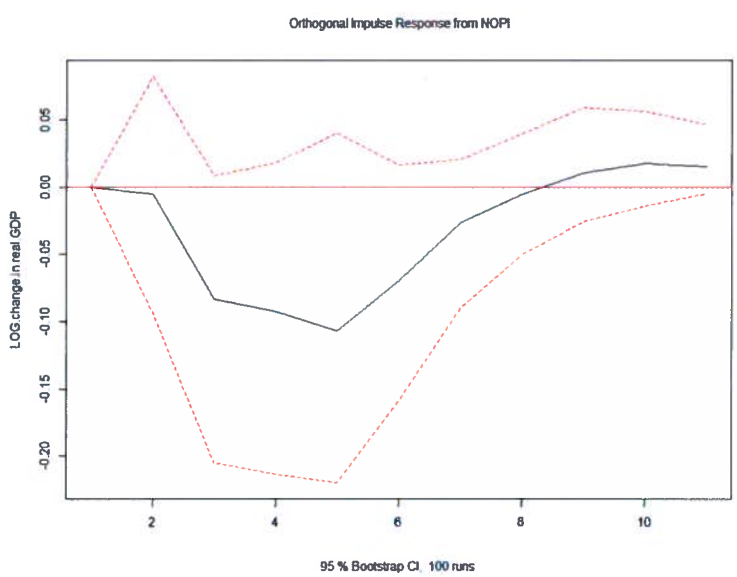


Figure 5: NOPI Specification



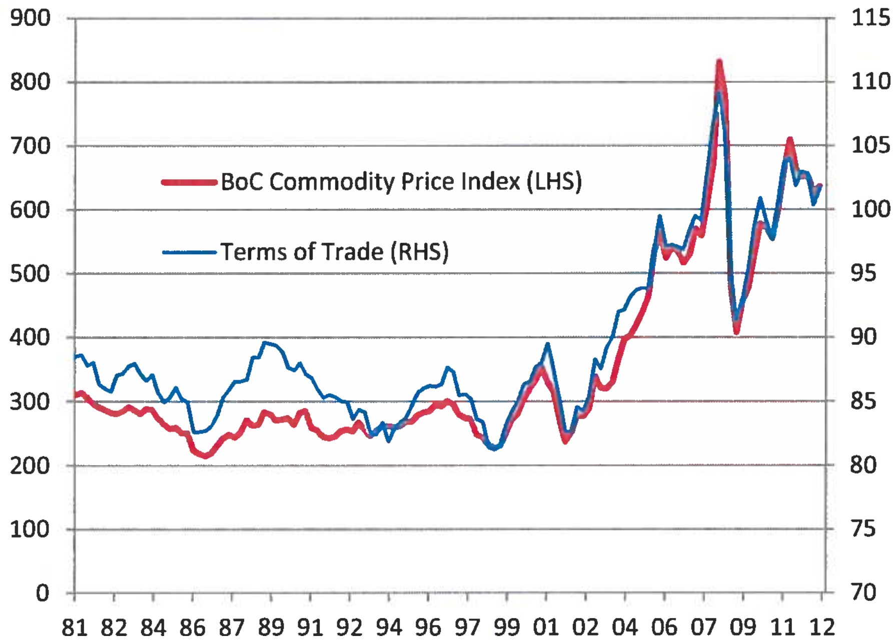
7. AN ALTERNATIVE MEASURE OF ECONOMIC GROWTH

It was shown in the last section that using the GDP variable as a measure of economic activity leads to the conclusion that changes in the oil price decrease short term economic growth. In this section, an alternative measure of economic activity will be explored, namely real GDI.

7.1 Divergence between GDP and GDI

GDP calculates macroeconomic activity by final expenditures, while GDI measures this by the incomes generated from producing GDP (Kohli, 2006). In national economic accounting, GDP and GDI should theoretically be equal-- a penny spent by one is a penny earned by another. While this assumption holds for countries with a small proportion of trade, it is likely not true for a country such as Canada that is open to the world. In reality, the two measures are not equal and may not always paint the same economic picture. GDP and GDI differ because of how exports and imports are treated. Real GDP deflates imports and exports separately, while real GDI deflates net exports by final domestic demand prices (Macdonald, 2007). From 2002 real GDI has been outpacing real GDP due to the terms-of-trade improvements. Oil is now our most important export commodity by value and rising commodity prices have likely played a pivotal role in improving our terms of trade (Figure 6).

Figure 6: Terms of Trade and Commodity Prices



Overall wellbeing has increased, having a major impact on consumption, investment and import activity in recent years. This effectively catapults real incomes and boosts domestic spending even if output as measured by GDP remains constant. As argued by Diewert and Morrison (1986) an improvement in the terms of trade can be likened to technological progress. Despite all this, terms of trade have not received much consideration as a source of economic improvement.

This country's percentage of GDP derived from trade is significant and therefore changes in the relative price of exports and imports can have two important consequences (Roy, 2004). Firstly, movements in the terms of trade alter the number of imports that can be purchased with a given level of exports. This can therefore be thought of as productivity growth, improving our material wellbeing. Economic agents are better off because they are able to consume more goods and services from their available resource base. Secondly, a stronger exchange rate captures increases in nominal income stemming from higher value of net exports. Moreover, the stronger Canadian dollar has eased the pressure of increased domestic spending on aggregate demand by dampening net exports, thus helping to keep overall supply and demand in check, and inflation pressures subdued. For the overall economy, then, the flexible exchange rate acts as a "shock absorber".

These two effects are the trading gains that Canada realizes when the relative price of oil and other commodities increases. By adjusting real GDP for trading gains it is possible to track the overall wellbeing by measuring real purchasing power of income. This is referred to as real gross domestic income (GDI). Because of Canada's large trade volumes, the measure of real GDI is potentially a more relevant indicator of Canada's economic performance than real GDP.

In short, real GDI has presented a much more favourable picture of the Canadian economy for some time now. GDI has increased real wealth and income, and thus propelled spending by consumers, governments, and businesses. More importantly, from this study's perspective, potential benefits from our oil exports are likely captured more fully by real GDI compared with real GDP. This is because it represents the change in the volume of goods and services that can be purchased with the income earned through production (real GDP).

7.2 Economic Importance of this Divergence

This divergence between real GDP and real GDI raises a substantial and significant issue and it is not clear which variable gives a better representation of economic activity in Canada. It depends on whether one is interested in a measure of production or a measure of purchasing power.

Although GDP is widely used to assess economic activity, some economists think that GDI is a more reliable indicator (e.g., Nalewaik, 2010). In addition, MacDonald (2007) found that between 2002 and 2005, real GDP increased by 8.3%, while real gross domestic income rose by 13.4%, a difference of 5.1 percentage points. This means that for every $2 of extra income earned by Canada, about $3 worth of extra goods and services could be purchased simply because of trading gains.

Comparisons of economic performance depend greatly on what measurement is used. An output variable, like GDP, for example, shows a resource exporting nation like Canada lagging behind the United States. Focusing on real GDI, however, which includes the effect of the resource boom on purchasing power, shows Canada gaining ground. GDI better represents how the rapid increases in resource prices in recent times have affected the economic prosperity of Canadians.

In summary, real GDI is an alternative yet important way to measure true economic income, especially in trade-focused economies such as Canada. Trade-focussed economies are more susceptible to significant fluctuations in terms of trade and increasing terms of trade can contribute substantially to real income growth. As real GDP underestimates real income growth when major changes occur in the terms of trade, GDI is potentially a more appropriate variable to use when studying the effect of oil prices on the Canadian economy.

8. TESTS AND EMPIRICAL RESULTS

In this section of the analysis, the empirical results of the model are presented, this time using GDI as a measure of economic performance. Again, Granger causality is analyzed in section 8.1 to understand the relationship between GDI and oil prices. In section 8.2 the results are formally presented and compared with the GDP model. Finally, the impulse response functions obtained from the estimated VAR models are discussed in section 8.3.

8.1 Granger Causality

As before, Granger causality tests are carried out to demonstrate that causality exists from oil price shocks to GDI growth. A table below summarizes the F-stats and p-values:

Table 10: Granger Causality

	F- stat	P- value
Linear	3.47	0.009
Asymmetric	3.84	0.004
NOPI	4.74	0.001

The hypothesis that the oil price shocks does not Granger cause real GDI growth is rejected across all model specifications. According to the results, causality runs from oil prices to GDI in Canada. The Granger causality test shows the probability of the null hypothesis "Oil prices does not Granger cause Canadian GDI" is small. Therefore it can be concluded that oil prices shocks help to predict the real GDI growth.

8.3 Interpretations

Table 11 shows the VAR(4) regression results from equation (1) now using GDI as a measure of economic performance. Var(4) is demonstrated here for ease of comparison.

Table 11: Estimated coefficients of the impact on real GDI growth

Item	Linear	Asymmetric	Net Oil Price
Constant	0.423**	0.372 ***	0.528 ***
GDI rate change in			
t-1	0.264**	0.924 **	0.241 **
t-2	0.252**	1.005	0.261 **
t-3	0.168*	0.499 *	0.168 *
t-4	0.096	0.840	0.112
Oil price rate change in			
t-1	0.005*	0.001	0.011*
t-2	0.006*	0.028 **	0.011**
t-3	0.001*	0.007 *	0.003
t-4	0.000	0.003	-0.008 .
Memo Item:			
Number of observations	154	154	154
Residual standard error	0.4124	0.4116	0.406
Adjusted R-squared	0.78	0.71	0.79
F-test for joint insignificance	2.20E-16	2.12E-09	2.20E-16

NOTE: ***, **,*, . , denotes significance at the 0.1, 1, 5, and 10 percent levels, respectively. The sample period is 1970:Q1-2011Q4

These results show that an environment of elevated oil prices proves to be beneficial for Canada, This is in contradiction to the results in the previous GDP model. It seems that GDI growth in all specifications responds positively for the most part to an increase in oil prices. In addition, the adjusted R-square is much higher. The hypothesis that the lags of the oil price changes have no collective impact on the pace of growth of aggregate economic output can be clearly rejected as the p-values for the joint test of insignificance is close to zero. Indeed, high energy prices, irrespective of the specification yields higher GDI. The evidence seems to suggest that increases in the oil price do not hinder the economy in the short run. GDI seems to present a more complete picture of Canada's economic performance–as it is a measure of purchasing power of income.

8.4 Impulse Response Function

Figures 7, 8, and 9 below show the results of the impulse response functions of GDI to positive oil shocks. Overall, positive shocks do not show negative effects on the economy. An oil windfall improves economic performance. The GDI growth rate responds positively to all oil price specifications

Figure 7: Linear Specification

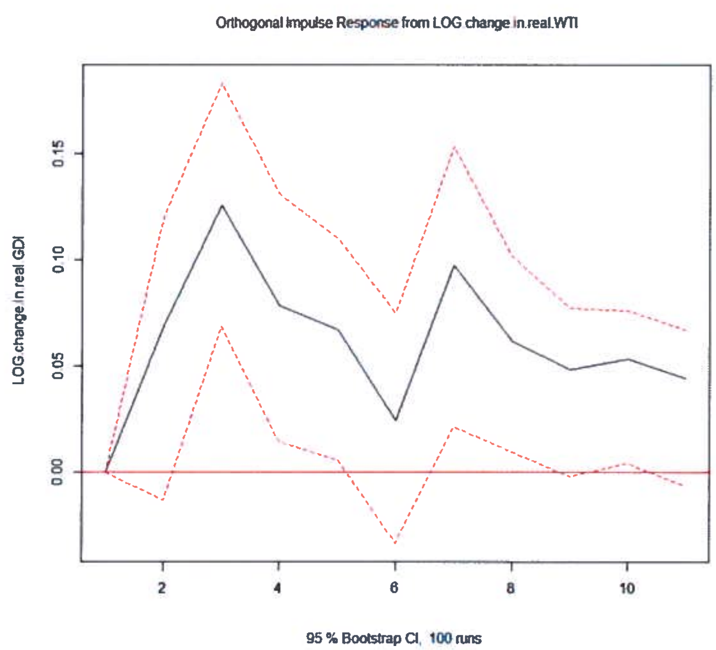


Figure 8: Asymmetric Specification

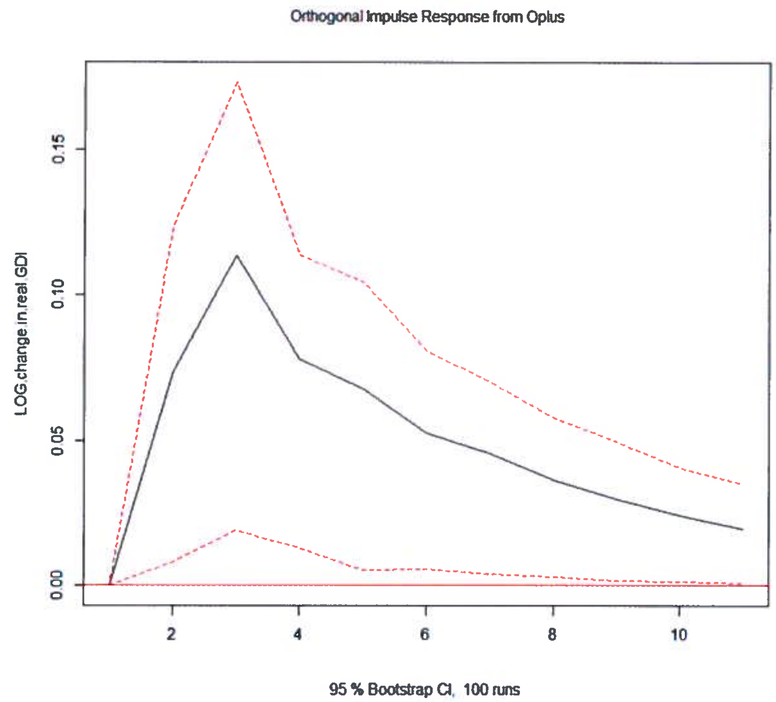
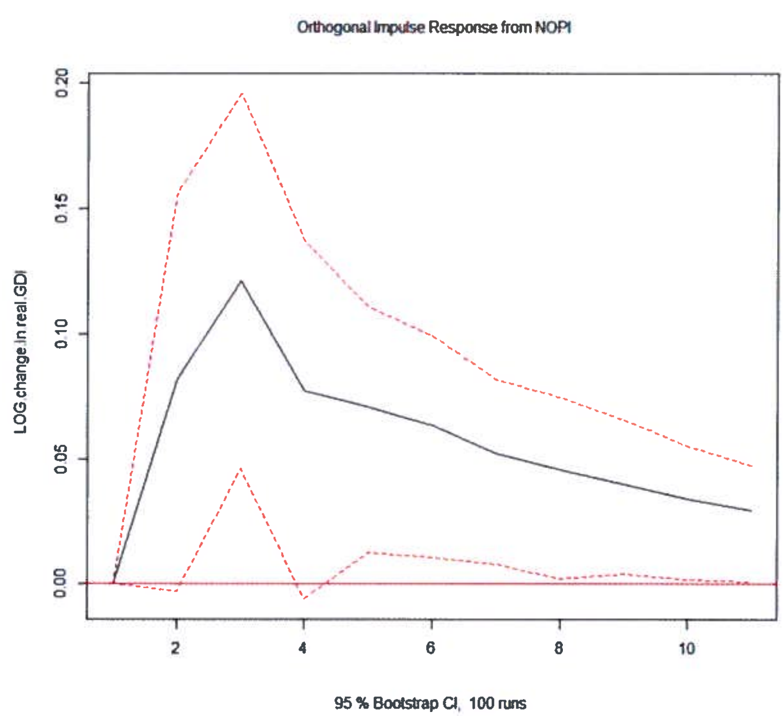


Figure 9: NOPI Specification



9. CONCLUSION

This paper studies the effects of oil price shocks on the real economic activity in Canada. The impact of oil prices on GDP and GDI was analyzed in terms of vector autoregressions by using 3 specifications, namely a linear model and two leading nonlinear specifications proposed in the literature.

Statistics Canada has (at least) two ways to measure economic activity. The first, and most widely used benchmark, is GDP where the value of all the goods and services produced in the economy are determined. The other is GDI, where income received in the economy, including wages, interest and profits are calculated. Although economic theory states that these two values should be the same, reality dictates that they are not. These two measures have diverged since 2003. The significant upsurge in real commodity prices over the last decade, coupled with the lower cost of imported consumer goods from emerging markets, have led to large improvements in our terms of trade, and generated large gains in real income.

To investigate the links between oil prices and macroeconomic performance, Granger causality tests were conducted. These tests supported the existence of causality running from oil prices to both GDP and GDI.

The impulse response functions were used to analyze the impact of shocks to the price of oil. A preferred specification could not be found as they all yielded similar results in both categories of economic performance. In spite of this, it can be said that there is a crucial relationship between oil price increases and economic growth. The effect of this relationship depends on which variable of economic activity is used, GDP or GDI, not on the oil price specification. Using real GDP as the dependent variable leads to the conclusion that higher oil prices ultimately hurt the economy in the short run. Models using GDP as a measure of economic growth cannot take in account the improvements in the terms of trade and therefore may produce misleading results.

In contrast, using real GDI as the dependant variable leads to the conclusion that higher oil prices are better for our economy. The magnitude of the gain from a given price increase depends on oil's contribution to national income and the degree of dependence on imported refined oil. This means that a rise in prices directly increases real domestic income through higher earnings from oil exports, though based on the impulse response functions, part of this gain would be later offset by losses from lower demand for manufacturing exports.

GDI is potentially a better indicator of economic wellbeing than GDP and this is the measurement that should be used when conducting empirical studies on the impact of higher oil prices on Canadian economic performance.

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A.1 Stationary Tests - Log GDP (LEVELS)

1. Augmented Dickey-Fuller Test Unit Root Test

Call:
```
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)
```

Min	1Q	Median	3Q	Max
-0.0183622	-0.004	0.0004745	0.0040545	0.0185805

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.004	0.001	3.097	0.002	**
z.lag.1	-0.520	0.115	-4.524	0.000	***
tt	0.000	0.000	-1.048	0.296	
z.diff.lag1	0.097	0.112	0.863	0.390	
z.diff.lag2	-0.052	0.104	-0.503	0.616	
z.diff.lag3	0.197	0.100	1.978	0.050	*
z.diff.lag4	-0.001	0.089	-0.007	0.995	
z.diff.lag5	-0.036	0.082	-0.441	0.660	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.006311 on 143 degrees of freedom

Multiple R-squared: 0.2971Adjusted R-squared: 0.2627

F-statistic: 8.633 on 7 and 143 DF, p-value: 8.18e-09

Value of test-statistic is: -4.5241 6.8348 10.2522

Critical values for test statistics:

	1pct	5pct	10pct
tau3	-3.99	-3.43	-3.13
phi2	6.22	4.75	4.07
phi3	8.43	6.49	5.47

2. KPSS Unit Root Test

```
Test is of type: tau with 13 lags.

Value of test-statistic is: 0.0543

Critical value for a significance level of:
                10pct  5pct 2.5pct  1pct
critical values 0.119 0.146  0.176 0.216
```

A.2 Stationary Tests - Log GDP (First Difference)

1. Augmented Dickey-Fuller Test Unit Root Test

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:

Min	1Q	Median	3Q	Max
-0.0164705	-0.0045812	0.0004745	0.0036834	0.0220291

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.000	0.001	0.078	0.938	
z.lag.1	-2.343	0.308	-7.596	0.000	***
tt	0.000	0.000	-0.117	0.907	
z.diff.lag1	1.049	0.270	3.879	0.000	***
z.diff.lag2	0.659	0.230	2.867	0.005	**
z.diff.lag3	0.593	0.186	3.194	0.002	**
z.diff.lag4	0.338	0.132	2.554	0.012	*
z.diff.lag5	0.124	0.082	1.511	0.133	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.006715 on 142 degrees of freedom

Multiple R-squared: 0.6703, Adjusted R-squared: 0.654
F-statistic: 41.24 on 7 and 142 DF, p-value: < 2.2e-16

Value of test-statistic is: -7.5959 19.2444 28.8656

Critical values for test statistics:

	1pct	5pct	10pct
tau3	-3.99	-3.43	-3.13
phi2	6.22	4.75	4.07
phi3	8.43	6.49	5.47

2. KPSS Unit Root Test

```
Test is of type: tau with 13 lags.

Value of test-statistic is: 0.0375

Critical value for a significance level of:
                10pct  5pct 2.5pct  1pct
critical values 0.119 0.146  0.176 0.216
```

A.3 Stationary Tests- Log WTI (LEVELS)

1. Augmented Dickey-Fuller Test Unit Root Test

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:

Min	1Q	Median	3Q	Max
-0.57681	-0.05531	0.01238	0.05152	0.41413

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.002	0.022	-0.091	0.928
z.lag.1	-1.160	0.229	-5.071	0.000
tt	0.000	0.000	0.407	0.685
z.diff.lag1	0.387	0.209	1.850	0.067
z.diff.lag2	0.190	0.190	1.003	0.318
z.diff.lag3	0.200	0.163	1.222	0.224
z.diff.lag4	0.111	0.139	0.797	0.427
z.diff.lag5	-0.052	0.120	-0.438	0.662
z.diff.lag6	0.028	0.096	0.294	0.769
z.diff.lag7	0.040	0.074	0.536	0.593

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.1223 on 139 degrees of freedom

Multiple R-squared: 0.4602, Adjusted R-squared: 0.4252
F-statistic: 13.17 on 9 and 139 DF, p-value: 4.63e-15

Value of test-statistic is: -5.0711 8.6438 12.9356

Critical values for test statistics:

	1pct	5pct	10pct
tau3	-3.99	-3.43	-3.13
phi2	6.22	4.75	4.07
phi3	8.43	6.49	5.47

2. KPSS Unit Root Test

```
Test is of type: tau with 13 lags.
Value of test-statistic is: 0.1514
Critical value for a significance level of:
                10pct  5pct 2.5pct  1pct
critical values 0.119 0.146  0.176 0.216
```

A.4 Stationary Tests - Log WTI (First Difference)

1. Augmented Dickey-Fuller Test Unit Root Test

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:

Min	1Q	Median	3Q	Max
-0.56843	-0.06438	0.01523	0.06561	0.44254

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.013	0.024	-0.527	0.599	
z.lag.1	-4.246	0.588	-7.218	0.000	***
tt	0.000	0.000	0.453	0.651	
z.diff.lag1	2.641	0.545	4.849	0.000	***
z.diff.lag2	1.961	0.481	4.081	0.000	***
z.diff.lag3	1.444	0.399	3.622	0.000	***
z.diff.lag4	1.006	0.318	3.162	0.002	**
z.diff.lag5	0.501	0.233	2.150	0.033	*
z.diff.lag6	0.228	0.149	1.530	0.128	
z.diff.lag7	0.075	0.075	0.993	0.323	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.1331 on 138 degrees of freedom

Multiple R-squared: 0.7536, Adjusted R-squared: 0.7376
F-statistic: 46.91 on 9 and 138 DF, p-value: < 2.2e-16

Value of test-statistic is: -7.2184 17.3859 26.0785

Critical values for test statistics:

	1pct	5pct	10pct
tau3	-3.99	-3.43	-3.13
phi2	6.22	4.75	4.07
phi3	8.43	6.49	5.47

B. Results For Lag Selection

Linear Specification

AIC(n)	HQ(n)	SC(n)	FPE(n)
4	1	1	4

Criteria	1	2	3	4	5	6	7	8	9	10	11	12
AIC(n)	4.23	4.24	4.27	4.21	4.22	4.23	4.28	4.32	4.36	4.35	4.35	4.39
HQ(n)	4.30	4.34	4.40	4.38	4.42	4.46	4.55	4.62	4.69	4.72	4.75	4.83
SC(n)	4.39	4.49	4.60	4.62	4.71	4.80	4.94	5.06	5.18	5.25	5.33	5.46
FPE(n)	68.62	69.46	71.58	67.72	67.81	68.85	72.52	75.55	78.35	78.11	78.04	81.57

Asymmetric Specification

AIC(n)	HQ(n)	SC(n)	FPE(n)
1	1	1	1

Criteria	1	2	3	4	5	6	7	8	9	10	11	12
AIC(n)	7.16	7.20	7.25	7.25	7.32	7.38	7.48	7.53	7.61	7.64	7.67	7.69
HQ(n)	7.29	7.39	7.52	7.60	7.74	7.88	8.06	8.18	8.34	8.44	8.54	8.64
SC(n)	7.47	7.69	7.92	8.11	8.36	8.61	8.89	9.13	9.39	9.61	9.81	10.02
FPE(n)	1289.74	1333.79	1402.74	1413.29	1513.67	1613.97	1792.25	1891.70	2060.99	2132.26	2200.39	2275.95

NOPI Specification

AIC(n)	HQ(n)	SC(n)	FPE(n)
3	1	1	3

Criteria	1	2	3	4	5	6	7	8	9	10	11	12
AIC(n)	2.12	2.15	2.11	2.11	2.16	2.20	2.23	2.28	2.33	2.30	2.28	2.31
HQ(n)	2.18	2.25	2.24	2.27	2.36	2.44	2.50	2.58	2.66	2.67	2.68	2.74
SC(n)	2.28	2.40	2.43	2.52	2.65	2.77	2.89	3.02	3.14	3.20	3.26	3.38
FPE(n)	8.30	8.60	8.23	8.24	8.65	9.06	9.33	9.83	10.26	10.05	9.84	10.18

C.1 (a) Linear Specification

GDP 4 Lags

VAR Estimation Results:

=========================

Endogenous variables: LOG.change.in.real.GDP, LOG.change.in.real.WTI

Deterministic variables: both

Sample size: 154

Log Likelihood: -755.402

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.563	0.079	7.168	0.000	***
LOG.change.in.real.WTI.l1	0.001	0.004	0.149	0.881	
LOG.change.in.real.GDP.l2	-0.134	0.088	-1.533	0.128	
LOG.change.in.real.WTI.l2	-0.005	0.004	-1.256	0.211	
LOG.change.in.real.GDP.l3	0.234	0.088	2.670	0.008	**
LOG.change.in.real.WTI.l3	0.002	0.004	0.430	0.668	
LOG.change.in.real.GDP.l4	-0.163	0.077	-2.108	0.037	*
LOG.change.in.real.WTI.l4	-0.012	0.004	-3.229	0.002	**
const	0.424	0.130	3.249	0.001	**
trend	-0.001	0.001	-0.915	0.362	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.6139 on 144 degrees of freedom

Multiple R-Squared: 0.3647, Adjusted R-squared: 0.325

F-statistic: 9.185 on 9 and 144 DF, p-value: 6.305e-11

C.1 (b) Linear Specification

GDP 1 Lag

VAR Estimation Results:
=========================
Endogenous variables: LOG.change.in.real.GDP, LOG.change.in.real.WTI
Deterministic variables: both
Sample size: 157
Log Likelihood: -785.271

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.485	0.070	6.907	0.000	***
LOG.change.in.real.WTI.l1	0.000	0.004	0.021	0.984	
const	0.406	0.122	3.329	0.001	**
trend	-0.001	0.001	-0.760	0.448	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.6521 on 153 degrees of freedom

Multiple R-Squared: 0.2568, Adjusted R-squared: 0.2422
F-statistic: 17.62 on 3 and 153 DF, p-value: 7.045e-10

C.2 (a) Asymmetric Specification

GDP 4 Lags

VAR Estimation Results:
=========================
Endogenous variables: LOG.change.in.real.GDP, OPlus, OMinus
Deterministic variables: both
Sample size: 154
Log Likelihood: -1218.846

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.542	0.083	6.505	0.000	***
Oplus1	-0.003	0.006	-0.503	0.616	
Ominus1	0.005	0.006	0.729	0.467	
LOG.change.in.real.GDP.l2	-0.158	0.092	-1.723	0.087	.
Oplus2	-0.013	0.006	-2.237	0.027	*
Ominus2	0.004	0.006	0.648	0.518	
LOG.change.in.real.GDP.l3	0.252	0.091	2.778	0.006	**
Oplus3	0.004	0.006	0.694	0.489	
Ominus3	-0.001	0.007	-0.160	0.873	
LOG.change.in.real.GDP.l4	-0.150	0.080	-1.877	0.063	.
Oplus4	-0.008	0.006	-1.329	0.186	
Ominus4	-0.016	0.006	-2.415	0.017	*
const	0.482	0.171	2.814	0.006	**
trend	-0.001	0.001	-0.904	0.368	

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.6118 on 140 degrees of freedom

Multiple R-Squared: 0.3865, Adjusted R-squared: 0.3295
F-statistic: 6.784 on 13 and 140 DF, p-value: 5.354e-10

C.2 (b) Asymmetric Specification

GDP 1 Lag

VAR Estimation Results:

=========================

Endogenous variables: LOG.change.in.real.GDP, OPlus, Ominus

Deterministic variables: both

Sample size: 157

Log Likelihood: -1263.743

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.468	0.074	6.337	0.000	
Oplus1	-0.003	0.006	-0.542	0.588	
Ominus2	0.004	0.007	0.604	0.546	
const	0.448	0.135	3.310	0.001	**
trend	-0.001	0.001	-0.751	0.454	

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '
1

Residual standard error: 0.6531 on 152 degrees of freedom

Multiple R-Squared: 0.2593, Adjusted R-squared: 0.2399

F-statistic: 13.31 on 4 and 152 DF, p-value: 2.552e-09

C.3 (a) NOPI Specification

GDP 4 Lags

VAR EstimationResults:
=========================
Endogenous variables: LOG.change.in.real.GDP, NOPI
Deterministic variables: both
Sample size: 154
Log Likelihood: -669.967

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.543	0.081	6.733	0.000	***
NOPI.l1	-0.001	0.007	-0.104	0.917	
LOG.change.in.real.GDP.l2	-0.145	0.090	-1.610	0.110	
NOPI.l2	-0.010	0.007	-1.545	0.125	
LOG.change.in.real.GDP.l3	0.240	0.091	2.650	0.009	**
NOPI.l3	-0.005	0.007	-0.762	0.447	
LOG.change.in.real.GDP.l4	-0.193	0.079	-2.435	0.016	*
NOPI.l4	-0.007	0.007	-1.131	0.260	
const	0.528	0.141	3.738	0.000	***
trend	-0.001	0.001	-1.222	0.224	

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.6266 on 144 degrees of freedom

Multiple R-Squared: 0.3381, Adjusted R-squared: 0.2967
F-statistic: 8.173 on 9 and 144 DF, p-value: 9.375e-10

C.3 (b) NOPI Specification

GDP 1 Lag

VAR Estimation Results:
=========================
Endogenous variables: LOG.change.in.real.GDP, NOPI
Deterministic variables: both
Sample size: 157
Log Likelihood: -695.099

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDP.l1	0.484024	0.068817	7.034	6.29E-11	***
NOPI.l1	-0.00513	0.006713	-0.765	0.445591	
const	0.424191	0.123972	3.422	0.000798	***
trend	-0.00097	0.001165	-0.832	0.4066	

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.6509 on 153 degrees of freedom

Multiple R-Squared: 0.2596, Adjusted R-squared: 0.2451
F-statistic: 17.89 on 3 and 153 DF, p-value: 5.29e-10

D.1 Linear Specification

GDI 4 Lags

VAR Estimation Results:

=========================

Endogenous variables: LOG.change.in.real.GDI, LOG.change.in.real.WTI

Deterministic variables: both

Sample size: 154

Log Likelihood: -693.688

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDI.l1	0.265	0.085	3.127	0.002	**
LOG.change.in.real.WTI.l1	0.005	0.002	2.182	0.031	*
LOG.change.in.real.GDI.l2	0.253	0.085	2.964	0.004	**
LOG.change.in.real.WTI.l2	0.007	0.003	2.579	0.011	*
LOG.change.in.real.GDI.l3	0.168	0.084	1.999	0.048	*
LOG.change.in.real.WTI.l3	0.001	0.003	0.526	0.600	
LOG.change.in.real.GDI.l4	0.096	0.082	1.177	0.241	
LOG.change.in.real.WTI.l4	-0.001	0.003	-0.316	0.752	
const	0.408	0.177	2.304	0.023	*
trend	-0.003	0.001	-2.071	0.040	*

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4124 on 144 degrees of freedom

Multiple R-Squared: 0.7959, Adjusted R-squared: 0.7831

F-statistic: 62.39 on 9 and 144 DF, p-value: < 2.2e-16

D.2 Asymmetric Specification

GDI 4 Lags

VAR Estimation Results:
========================
Endogenous variables: LOG.change.in.real.GDI, Oplus, Ominus
Deterministic variables: both
Sample size: 154
Log Likelihood: -1165.808

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDI.l1	0.250	0.086	2.917	0.004	**
Oplus.l1	0.008	0.004	2.057	0.042	*
Ominus.l1	0.003	0.004	0.650	0.517	
LOG.change.in.real.GDI.l2	0.260	0.086	3.020	0.003	**
Oplus.l2	0.011	0.004	2.715	0.007	**
Ominus.l2	0.002	0.004	0.589	0.557	
LOG.change.in.real.GDI.l3	0.181	0.085	2.131	0.035	*
Oplus.l3	0.000	0.004	0.088	0.930	
Ominus.l3	0.002	0.004	0.524	0.601	
LOG.change.in.real.GDI.l4	0.095	0.083	1.156	0.250	
Oplus.l4	-0.004	0.004	-0.980	0.329	
Ominus.l4	0.002	0.004	0.504	0.615	
const	0.373	0.180	2.073	0.040	*
trend	-0.003	0.001	-2.001	0.047	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.4129 on 140 degrees of freedom

Multiple R-Squared: 0.8011, Adjusted R-squared: 0.7826
F-statistic: 43.37 on 13 and 140 DF, p-value: < 2.2e-16

D.3 NOPI Specification

GDI 4 Lags

VAR Estimation Results:

========================

Endogenous variables: LOG.change.in.real.GDP, NOPI
Deterministic variables: both
Sample size: 154
Log Likelihood: -600.724

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	
LOG.change.in.real.GDI.l1	0.242	0.085	2.851	0.005	**
NOPI.l1	0.011	0.004	2.553	0.012	*
LOG.change.in.real.GDI.l2	0.261	0.084	3.096	0.002	**
NOPI.l2	0.012	0.004	2.684	0.008	**
LOG.change.in.real.GDI.l3	0.168	0.084	2.007	0.047	*
NOPI.l3	0.003	0.005	0.679	0.498	
LOG.change.in.real.GDI.l4	0.112	0.081	1.382	0.169	
NOPI.l4	-0.008	0.004	-1.826	0.070	.
const	0.363	0.175	2.067	0.041	*
trend	-0.003	0.001	-1.900	0.059	.

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.406 on 144 degrees of freedom

Multiple R-Squared: 0.8023, Adjusted R-squared: 0.7899
F-statistic: 64.91 on 9 and 144 DF, p-value: < 2.2e-16