Oil Price Shocks and the Macroeconomy of Nigeria: A Non-linear Approach

Aliyu, Shehu Usman Rano

Bayero University Kano, Nigeria

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S.U.R. Aliyu[1]

Abstract

Nowadays, the impact of oil price shocks is pervasive as it virtually affects all facets of human endeavor. As such, it is pertinent that we should know the relationship between oil price shocks and the macroeconomy. Therefore, this paper assesses empirically, the effects of oil price shocks on the real macroeconomic activity in Nigeria. Granger causality tests and multivariate VAR analysis were carried out using both linear and non-linear specifications. Inter alia, the latter category includes two approaches employed in the literature, namely, the asymmetric and net specifications oil price specifications. The paper finds evidence of both linear and non-linear impact of oil price shocks on real GDP. In particular, asymmetric oil price increases in the non-linear models are found to have positive impact on real GDP growth of a larger magnitude than asymmetric oil price decreases adversely affects real GDP. The non-linear estimation records significant improvement over the linear estimation and the one reported earlier by Aliyu (2009). Further, utilizing the Wald and the Granger multivariate and bivariate causality tests, results from the latter indicate that linear price change and all the other oil price transformations are significant for the system as a whole. The Wald test indicates that our oil price coefficients in linear and asymmetric specifications are statistically significant.

JEL Classification Codes E32, E37

Key words: Oil Shocks, Macroeconomy, Granger Causality, Asymmetry, Vector Autoregressive

1.1 Introduction

As an oil exporter and importer of refined petroleum products, Nigeria is potentially vulnerable to oil price volatility. A large body of research suggests that oil price volatility tends to exert a positive effect on the GDP growth for a net oil exporting country and a negative effect on net oil importing countries. Theoretical literature has identified the transmission mechanisms through which oil prices affect real economic activity to include both supply and demand channels. The supply side effects relate to the fact that crude oil is a basic input to production and commerce, and hence an increase in oil price leads to a rise in production and distribution costs that induces firms to lower output. Changes in oil price also entail demand-side effects on consumption and investment. Consumption is affected indirectly through its positive relation with disposable income while investment is adversely affected indirectly because such increase in oil price also

[1]. Shehu Usman Rano Aliyu, *PhD,* is an Associate Professor in the Department of Economics, Bayero University, Kano and also worked as a visiting scholar on Sabbatical leave in the Research Department of Central Bank of Nigeria. Email: susaliyu@yahoo.co.uk, Mobile: +2348037875246.

affects firms' input prices and thereby increasing their costs. Oil price changes also influence foreign exchange markets and generate stock exchange panics, higher interest rate, produce inflation and eventually lead to monetary and financial instability[2].

The economic importance of oil price shocks was examined utilizing the neoclassical theory in attributing the macroeconomic significance to such events. Empirical studies attempted to estimate the linear negative relationship between oil prices and real activity in oil importing countries. Earlier attempts include: Rasche and Tatom (1981), Darby (1982), Hamilton (1983), Burbidge and Harrison (1984), Hamilton (1983), for instance, identifies a robust relationship between oil price increases and subsequent economic downturns for majority of the post-World War Two recessions in the United States (US) economy. Afterwards, Mork (1989), Lee, Ni and Ratti (1995), Hamilton (1996 & 2003), Jimenez-Rodriguez (2002), Jimenez-Rodriguez and Sanchez (2004) and more recently, Gounder and Bartleet (2007) all introduced non-linear transformations of oil prices to re-establish the negative relationship between increases in oil prices and economic downturns, as well as to analyze Granger causality between both variables.

The Nigerian economy, which for so long has been criticized for its monocultural nature relies heavily on export of crude oil. The Nigeria's oil statistics shows that the country has an estimated 36.2 billion barrels of oil reserve which places the country as the second largest in terms of oil reserve in the entire African continent. The Nigerian oil sector accounts for over 95 percent of export earnings and about 85 percent of government revenues. Its contribution to GDP, however, stood at 21.9 and 19.4 percent in 2006 and 2007 respectively. EIA (2009) estimates Nigeria's effective oil production capacity to be around 2.7 million barrels per day (bbl/d). Serious drop in oil production levels[3], which affects exports and the plummeting of world oil prices[4] in the late 2008 have resulted in huge revenue gaps for the country. Equally, the

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[2] According to Jimenez-Rodriguez and Sanchez (2004) some of these indirect effects may involve economic policy reactions. For instance, authors like Bohi (1989) and Bernanke and Watson (1997) argue that economic downturns observed after oil price shocks are caused by a combination of direct impacts of the shocks themselves and the monetary responses to them. McKillop (2004) adds that such could lead to higher interest rates, inflation and even a plunge into recession.

[3] Incessant crisis in the oil producing region left Nigeria with a huge gap between actual output and OPEC allocated quota. Attacks on oil infrastructure, kidnapping of expatriates working in oil companies and shut-in production, for instance, in the year 2008 have caused monthly oil production to drop to a range between 1.8 million bbl/d and 2.1 million bbl/d.

[4] According to the *Oil and Gas Journal (2009)* oil prices dropped from over $140 to less than $70 per barrel.

country is exposed to oil price shocks through massive importation of the refined petroleum products since the collapse of local refineries in the late 1980's. Currently, the country imports almost 85 percent of refined products for its local consumption. The near collapse of the power generation and distribution industry in the country further accentuates the acute shortage of energy. The burden on the government to provide energy resources at subsidized rate became very unwieldy and between 1999 and 2008, the federal government of Nigeria has reduced its subsidy approximately 9 times. This adversely affects production, consumption and investment decisions and hence the rate of economic growth.

The growth path of the country has been very rough over the years. During the oil boom era, roughly 1970-78, GDP grew positively by 6.2 percent annually - a remarkable growth. However, in the 1980s, GDP had negative growth rates. In the period 1988-1997 which constitutes the period of Structural Adjustment Programme (SAP), which entails economic liberalization, the GDP responded to economic adjustment policies and grew at a positive rate of 4.0 percent. Agriculture, industry and manufacturing, oil and gas sectors had greater dominance in the composition of the Nigeria's GDP. The year 1989 – 1998 was the most turbulent period in the history of the country's growth pattern. Real GDP grew only by an average of 3.6 percent, against the population growth rate of 2.8% during the same period. Inflation, poverty, exchange rate were all at alarming rates. Foreign direct investment, which is a necessary engine of growth, was stifled because of unconducive enabling environment. Between 1999 and 2008, the country's growth performance improved significantly. GDP growth rate averaged 7.8% during the decade solely due to the growth of non-oil sector which grew by 9.5 percent. In this regard, however, oil sector constitutes both a drag on growth and a source of instability in GDP growth pattern. According to Obadan (2009), of the 3 large sectors, production, wholesale and retail and oil and gas, only the latter exerts a negative influence by up to 4.49 percent of GDP, in spite of its great potentials in relation to manufacturing and its large share of GDP at 23.2 percent.

Against this background, the paper attempts to empirically examine the impact of oil price shocks on economic growth utilizing the linear and non-linear approaches. To date no study, to our knowledge, has been undertaken to estimate these effects on the Nigerian economy. Estimating the consequences of oil price shocks on growth is particularly relevant in the case of Nigeria since, as a small open economy, it has no real influence on the world price of oil, whereas it is greatly influenced by the effect of oil price variability both as an oil exporter and importer of refined petroleum products. The rest of the paper is structured as follows: section two presents an overview of the empirical literature on the link between oil price and economic growth, with particular emphasis on the development of oil price shocks measures reflecting indirect transmission mechanisms. The models, data and methodology employed are discussed in section three while the penultimate section presents the estimated results. The final section concludes the impact of oil price shocks on growth in Nigeria.

2.1 An Overview of Literature and Theoretical Issues

The macroeconomic literature has identified three primary routes to the asymmetry between oil price changes and GDP responses: the sectoral shifts hypothesis (costly rearrangement of factors across sectors that are affected differently by the oil price change); the demand composition route; and the investment pause effect (along the lines of the irreversible investment model, in which households and firms defer major purchases in the face of uncertainty). Thus, studies linking oil prices to the macroeconomy through these channels: sectoral shifts or labor market dispersion (Loungani, 1986; Davis and Mahidhara, 1997; Carruth, Hooker and Oswald 1998; Finn, 2000; Davis and Haltiwanger, 2001), consumption or demand decomposition route (Hamilton 1988, 2003; Bresnahan and Ramey 1992, 1993; Lee and Ni, 2002) and investment uncertainty (Bernanke, 1983; Dixit and Pindyck, 1994; International Monetary Fund, 2005). Others include the consequences for inflation (Pierce and Enzler, 1974; Mork, 1981; Bruno and Sachs, 1982); suggest that indirect transmission mechanisms may be the crucial means by which oil price shocks have macroeconomic consequences.

Oil price shocks, thefrefore, receive considerable attention for their presumed macroeconomic consequences. Hamilton (1983, 1985) is among the early economist to convince policymakers and economist as well that oil price increases generally, and not just the OPEC supply disturbances of the 1970s, are important contributors to recessions. In fact the 'oil crises' of the 1970s and early 1980s gave rise to both inflation and unemployment at the same time, (Bruno and Sachs, 1985; Helliwell, 1988, Hooker, 2002). Nevertheless, at the same time that Hamilton's arguments were gaining acceptance, the evidence for them was breaking down: Lee, Ni and Ratti (1995), Hooker (1996), and others have shown that oil prices typically fail to Granger cause macro variables when data samples are extended past the mid-1980s. Specifically, decline in oil prices in the second half of the 1980s were found to have smaller positive effects on economic activity than predicted by linear models. Hooker (1999) several authors rightly argue that the breakdown in Hamilton's argument reflects the greater power to reject misspecified equations[5] brought by the increased variation in oil prices in the 1980s and 1990s.

Mork (1989), Lee, Ni and Ratti (1995) and Hamilton (1996) introduces non-linear transformations of oil prices to re-establish the negative relationship between increases in oil prices and economic downturns, as well as to analyze Granger causality between both variables. Mork (1989), for instance allow for an asymmetric response of the US economic activity to oil price changes by specifying increases and decreases in the real price of oil as separate variables. His findings were that the effects of oil price increases are different from those of decreases, and that oil price decreases are not statistically significant. Mory (1993) also found an asymmetric relationship for the US, and argues that the oil-induced dislocations posited by Loungani (1986) and Hamilton (1988) would be recessionary whether triggered by price increases or decreases.

Lee, Ni and Ratti (1995) focus on volatility, maintaining that "an oil shock is likely to have greater impact in an environment where oil prices have been stable than in an environment where oil price movement has been frequent and erratic" because price changes in a volatile environment are likely to be soon reversed. An asymmetry is found to exist between the effects of positive and negative normalized shocks in all sample periods. Positive non-normalized shocks in real oil price are strongly related to negative real growth and positive unemployment. Negative normalized shocks are not statistically significant. A generalized autoregressive conditional heteroscedasticity (GARCH) model is utilized to construct the conditional variation of oil price changes used to normalize unexpected movements in real oil price. These results are consistent with the view that the effect of a change in real oil price depends upon whether it is an unusual event rather than merely an adjustment in response to a change in the previous month.

[5] Until the mid-1980s econometric studies on the subject used to estimate linear models linking oil prices and real activity. These studies according to Jimenez-Rodriguez and Sanchez (2004) include: Rasche and Tatom (1981), Darby (1982), Hamilton (1983), Burbidge and Harrison (1984), and Gisser and Goodwin (1986). While all these contributions consider the case of the US, Darby (1982) and Burbidge and Harrison (1984) also analyzed other developed countries (Japan, Germany, the UK, Canada, France, Italy, and the Netherlands in the former case, and Japan, Germany, the UK and Canada in the latter).

Findings further show that the oil price shock variable is highly statistically significant in explaining GNP growth and unemployment over different sample periods, even when matched in a VAR against other functions of real oil price.

Bernanke, Gertler and Watson (1997) study the role of monetary policy as the central issue rather than a factor contributing to discontinuity in the oil price-GDP relationship. Evidences from their impulse response functions show that had the Fed maintained the funds rate at the pre-shock level, most of the GDP response to oil price over the 1973, 1979-80, and 1990 episodes would have been avoided. This suggests that most, if not all, of the reduction in GDP during the recessions following those episodes was attributable to monetary policy rather than the oil price shocks themselves. Hamilton and Herrera (2001) re-examine Bernanke, Gertler and Watson (1997), and arrive at a diametrically opposite conclusions about the relative contributions of monetary policy and oil price shocks to the recessions following the 1973, 1979-80, and 1990 oil price shocks. From their analysis of the impulse response functions, they discover that the potential of monetary policy to avert the contractionary consequences of an oil price shock is not as great as suggested by the analysis of Bernanke, Gertler, and Watson. Rather, oil shocks appear to have a bigger effect on the economy than suggested by their VAR, and we are unpersuaded of the feasibility of implementing the monetary policy needed to offset even their small shocks.

Backus and Crucini (2000) consider the issue of terms of trade and the volatility of oil price in the US economy. They find evidence that heightened terms of trade volatility is significantly related to increased oil price volatility, as opposed to fluctuations in nominal or real exchange rates that are both insignificant with respect to the terms of trade volatility

Jimenez-Rodriguez and Sanchez (2004) assess empirically the effects of oil price shocks on the real economic activity of the main industrialized countries using both linear and non-linear models. Evidence of a non-linear impact of oil prices on real GDP was established. Specifically, their results show that oil price increases exert more impact on GDP growth than that of oil price declines. Interestingly, evidences show that among oil importing countries, oil price increases have a negative impact on economic activity in all cases but Japan. UK’s economy, according to them exhibits a surprising behavior: while it is expected that an oil price shock has positive effects on the GDP growth for a net oil exporting country, an oil price increase of 100% actually leads to a loss of British GDP growth rate of more than 1% after the first year in all specifications. This does not come as a surprise because an extensive literature has highlighted that this unexpected result has to do with the fact that oil price hikes led to a large real exchange rate appreciation of the pound, which in the literature was described as the Dutch disease.

Gounder and Bartleet (2007) argue that the demand-side impacts of energy crisis suggest that an energy price shock can result in higher inflation and higher unemployment. In fact the ‘oil crises’ of the 1970s and early 1980s gave rise to both inflation and unemployment at the same time, and this is known as the ‘stagflation’ phenomenon. Earlier, Mork, Olsen and Mysen (1994), Bruno and Sachs (1985) Helliwell (1988) Hooker (2002) opine that the theoretical result that energy price shocks may trigger an external inflation spike has been pervasive in the literature. As inflation results from oil price movements and is not caused by an increase in domestic money supply, it can have negative consequences for real balances. Similarly, other important studies, including DeLong (1997), Barsky and Kilian (2001), Hooker (1999), and Clarida, Gal´i and Gertler (2000), suggest that different monetary policy (particularly prior to the oil shocks) could have substantial impact on inflation.

In a recent comparative study by Jin (2008) on the impact of oil price shocks and exchange rate volatility on economic growth, he shows that the oil price increases exerts a negative effect on economic growth of Japan and China – although the latter is an oil producing country, and a positive effect on economic growth of Russia. Specifically, a 10% permanent increase in international oil prices is associated with a 5.16% growth in Russian GDP and a 1.07% decrease in Japanese GDP. On the one hand, an appreciation of the real exchange rate leads to a positive GDP growth in Russia and a negative GDP growth in Japan and China. Aliyu (2009) shows in a unidirectional relationship that oil price shock Granger cause real GDP in the Nigerian economy while results from the long-run vector error correction model reveal that oil price shocks and appreciation in the level of real exchange rate exert positive impact on real economic growth. His model and Jin’s, however, were based on the Hamilton’s (1983) linear specification, which assumes symmetric oil-real GDP relationship.

Table 1: Macroeconomic Impacts of Energy Price Shocks: Results from Empirical Studies

Study	Data	Methodology	Significance
Hamilton (1983)	USA; Quarterly 1949-1972	VAR (Y, OP, MP, IP, UN, W, INF)	Yes
Burbidge and Harrison (1984)	US, Japan, Germany, UK, Canada; Monthly 1961-1982	VAR (Y, OP, MP, IP, R, W, INF)	Yes
Gisser and Goodwin (1986)	USA; Quarterly 1961-1982	OLS (Y, OP, MP, FP, UN, I, INF)	Yes
Mork (1989)	USA; Quarterly 1949-1988	VAR (Y, OP, MP, IP, UN, W, INF)	Yes
Mory (1993)	USA; Annual 1952-1990	OLS (Y, OP, MP, GOV)	Yes
Lee, Ni and Ratti*,* (1995)	USA; Quarterly 1949-1992	VAR (Y, OPV, MP, IP, UN, W, INF)	Yes
Ferderer (1996)	USA; Monthly 1970-1990	VAR (Y, OPV, OPV MP)	Yes
Hooker (1996*a*)	USA; Quarterly 1947-1974	VAR (Y, OP, MP, IP, INF)	Yes
Hooker (1996*b*)	USA; Quarterly 1974-1994	VAR (Y, OP, MP, IP, INF)	No
Hooker (1999)*	USA; Quarterly 1979-1998	ECM (Y, TB, UN, OP, IP)	Yes
Hamilton (1996)	USA; Quarterly 1948-1994	OLS (Y, OP, MP, INF, IP)	Yes
Darrat *et al.,*(1996)	USA; Quarterly 1960-1993	VAR (Y, OP, MP, FP, W, R)	No
Lee, Ni and Ratti.*,* (2001)	Japan; Monthly 1960-1996	VAR (Y, OPV, MP, INF, R, CP, GOV)	Yes
Cunado and Perez de Gracia (2003)	15 European Countries; Quarterly 1960-1999	VAR (Y, OP, INF)	Yes
Jimenez-Rodriguez and Sánchez (2005)	9 OECD Countries; Quarterly 1972-2001	VAR (Y, OPV, INF, R, W, EX)	Yes
Gounder and Bartleet (2007)*	New Zealand; Quarterly 1989-2006	VAR (Y, OPV, W, EX INF)	Yes
Jin (2008)*	Russia, Japan and China Quarterly; 1999-2007	VECM (Y, EX, OP)	Yes
Aliyu (2009)*	Nigeria; Quarterly 1986-2007	VECM (Y, EX, OP)	Yes

*Adapted from Gounder and Bartleet (2007) and *improved*

Notes: VAR is Vector Autoregression, Y is economic growth, MP is Monetary Policy, OP is oil prices, IP is import prices, UN is unemployment, W is wages, INF is inflation, R is interest rate, I is investment, OPV is oil price volatility, CP is commodity prices, GOV is Government expenditures, EX is exchange rate, TB is treasury Bill rate. 'Is Energy Significant?' indicates whether the coefficient on the energy price variable is significant. Note that the ordering of variables within the brackets does not reflect the order of the VAR within the corresponding study.

Table 1, which was adapted from Gounder and Barleet (2007) and improved by this paper, presents the summary of the empirical studies so far in the area. Furthermore, Jones, Leiby and Paik (2004) classify into three broad categories, the findings of empirical studies in the oil-real

GDP relationships. Firstly, that the most thorough research to date has found that post-shock recessionary movements of GDP are largely attributable to the oil price shocks, not to monetary policy. Secondly, two nonlinear and asymmetric specifications of oil price shocks have been found that yield stable oil price-GDP relationships over the entire post-World War II period. Thirdly, detailed empirical research has shown that considerable reallocation of labor occurs after oil price shocks, amounting to as much as 11 percent of the labor force in manufacturing, and similar extents outside manufacturing. Against this background, this paper seeks to add value into the body of empirical research by applying both the linear and non-linear models to assess the nature of oil-real GDP relationships in the Nigerian economy. The empirical models as developed Mork (1989), Lee, Ni and Ratti (1995) and Hamilton (1996) are presented in the next section.

3.1 Methodology of the Paper

Our model uses real oil prices and real GDP growth since our main objective is to analyze the effects of the former variable on the latter. The paper uses only one measure of economic activity, namely, real GDP, thus, doing without a separate role for unemployment – Jimenez-Rodriguez and Sanchez (2004). The paper follows the literature in measuring the real oil price, which excludes taxes. Monthly data from January, 1980M1 to December, 2007M12 is used for all variables in the country. Data of nominal GDP was obtained from the CBN (Central Bank of Nigeria) Statistical Bulletin and the consumer price index (CPI) from the same source is used as a deflator to compute the real GDP figures. Monthly series of oil price was sourced from the IMF website which is the price of internationally traded variety of crude (UK Brent) in US dollars. The analysis converts all variables into logarithmic form and their trends shown in Figures *a* and *b,* in the appendix suggest the existence of strong links among the variables.

We consider the following vector autoregression model of order p (or simply, VAR (p)):

$$y_t = c + \Sigma\, \Phi_i\, y_{t-i} + \varepsilon_t \qquad (3.1)$$

where y_t is a (n × 1) vector of endogenous variables, $c = (c_1..., c_5)'$ is the (5 × 1) intercept vector of the VAR, Φ_i is the ith (5 × 5) matrix of autoregressive coefficients for $i = 1, 2, ..., p$, and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, ..., \varepsilon_{5t})'$ is the (5 × 1) generalization of a white noise process.

In order to assess the impact of shocks on endogenous variables, we examine both the orthogonalized and accumulated impulse-response functions, using Cholesky (dof adjusted) decomposition. The paper assumes the following ordering of the five variables used in the VAR: real GDP, oil price, real money supply, real exchange rate and government spending/GDP. This is necessary because the orthogonalization method involves the assignment of contemporaneous correlation only to specific series. Thus, the first variable in the ordering is not contemporaneously affected by shocks to the remaining variables, but shocks to the first variable do affect the other variables in the system; the second variable affects contemporaneously the other variables (with the exception of the first one), but it is not contemporaneously affected by them; and so on. In addition to estimating the impulse response and variance decomposition, the bivariate and multivariate Granger causality tests were also carried out in order to ascertain whether there is a statistically significant relationship between oil prices and the important macroeconomic variables.

Using the specification provided in equation 3.1, the paper, further conducts tests for stationarity of the series using Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) tests as follows:

$$\Delta y_t = \alpha_0 + \alpha_1\, y_{t-1} + \alpha_1\, trend + \Sigma\, \beta_j\, \Delta\, y_{t-j} + \mu_t \qquad (3.2)$$

The models estimated employ both the linear and non-linear oil price transformations to examine various short run impacts. The two non-linear price measures utilized in the paper follow Mork's (1989) *asymmetric specification*, in which increases and decreases in the price of oil are considered as separate variables, and Hamilton's (1996) *net specification*[6], where the relevant oil price variable is defined to be the net amount by which these prices in quarter *t* exceed the maximum value reached in the previous four quarters.

[6] Unlike Hamilton (1996), who uses nominal oil price, Mork (1989) and Lee, Ni and Ratti (1995) use the real price of oil. This present paper follows the former approach.

The *asymmetric* specification models the positive and negative oil price changes separately. That is, the oil price shock variable is included in the regression framework as follows, where o_t is the rate of change of oil price in period t:

$$o_t^+ = \begin{cases} o_t & \text{if } o_t > 0 \\ 0 & \text{otherwise} \end{cases} \qquad (3.2a)$$

$$o_t^- = \begin{cases} o_t & \text{if } o_t < 0 \\ 0 & \text{otherwise} \end{cases} \qquad (3.2b)$$

According to Gounder and Barleet (2007) the distinction between equations (3.2a) and (3.2b) has a theoretical basis in the sectoral shifts hypothesis developed by Lilien (1982), which suggests that both positive and negative price changes may alter the marginal product of factor inputs and spur the sectoral reallocation of various resources on the supply side of the economy. On the other hand, investment and consumption uncertainty that may arise in a climate of volatile oil prices have been suggested by Bernanke (1983), among others, to be the important means by which oil prices can affect economic growth. This idea motivates several non-linear price measures first developed by Hamilton (1996) and Lee, Ni and Ratti (1995).

The Hamilton's (1996) non-linear transformation, which he calls *net oil price increase* (NOPI) is defined to be the amount by which (the log of) oil prices in quarter t, p_t, exceed the maximum value over the previous 4 quarters; and 0 otherwise. That is:

$$\text{NOPI} = \max \{0, o_t - \max \{o_{t-1}, o_{t-2}, o_{t-3}, o_{t-4}\}\} \qquad (3.3)$$

Hamilton's definition is also asymmetric in the specific sense because it captures oil price increase-type shocks while neglecting the impact of oil price declines. This is inspired by the earlier evidence that oil price decreases had played a smaller role in the US business cycle. Thus, transforming the price variable in this manner focuses on those price increases that occur after a period of relative stability, placing less emphasis on price changes that occur during periods of existing price volatility.

Lee, Ni and Ratti., (1995) and Hamilton (1996) develop another measure, which they call the *scaled oil price* to account for the fact that oil price increases after a long period of price stability have more dramatic macroeconomic consequences than those that are merely corrections to greater oil price decreases during the previous quarter Lee, Ni and Ratti (1995) model the conditional volatility of oil prices using Generalized Autoregressive Conditional Heteroscedasticity, i.e. AR(4)-GARCH(1,1) process as follows:

$$o_t = \alpha_0 + \alpha_1 o_{t-1} + \alpha_2 o_{t-2} + \alpha_3 o_{t-3} + \alpha_4 o_{t-4} + e_t \tag{3.4}$$

$$e_t \,\middle|\, I_{t-1} \sim N(0, h_t)$$

$$h_t = \gamma_0 + \gamma_1 e^2_{t-1} + \gamma_2 h_{t-1} \tag{3.5}$$

$$\text{SOPI} = \max(0, \hat{e}_t / \sqrt{\hat{h}_t}) \tag{3.6a}$$

$$\text{SOPD} = \min(0, \hat{e}_t / \sqrt{\hat{h}_t}) \tag{3.6b}$$

o_t is Mork's series (in quarterly growth rates) updated through the present. SOPI is then computed using the estimated *e*'s and *h*'s given in equations (3.6a) and (3.6b). The parameters of the GARCH model (3.4) and (3.5) are obtained via maximum likelihood on Mork's series. The recursions to create SOPI use the estimated unconditional variance and its square root, respectively, for the initial values of $\hat{h}_t$ *and* $\hat{\varepsilon}_t$. SOPI stands for *scaled oil price increases*, while SOPD for *scaled oil price decreases*. The scaled oil price measure is, however, not used in the paper.

4.1 Empirical Results

In this section we analyze the empirical results for the linear and the two non-linear models described in the previous section. Firstly, we run the unit root tests in subsection 3.1 using the ADF and the PP techniques as specified in equation (3.2). It has often been argued that macroeconomic data is characterized by a stochastic trend, and if untreated, the statistical behavior of the estimators is influenced by such trend. The treatment involves differencing the data to determine the level of cointegration. Besides, only stationary variable are applicable to the VAR-based methodology. Next, in subsection 3.2, we carried out the Wald tests for the joint significance of the oil price coefficients in the VAR model and the bivariate and multivariate

Granger causality tests to determine the direction of causality in the oil price-real GDP and other macroeconomic relationships. Lastly, using the specification in equation (3.1) presented in the previous section, we analyze the impulse functions and the accumulated responses and error variance decompositions. Stock and Watson (2001) observe that the impulse responses and the variance decompositions are more informative than the estimated variable coefficients and the R^2 statistics in the VAR. Meanwhile,

3.1 Unit root tests

The estimation of equation (3.2) with constant and trend yields the results presented in Table 1. The regressions were run for all the series at both level and first difference and, with constant and trend in the equation. As usual, the appropriate lag level applied in the unit root test follows the SIC criterion. Results show that except for the nonlinear oil price measures, all the other five variables – including the nominal oil price, are nonstationary at level. Meaning, the hypothesis of unit root could not be rejected at the 1 percent level. We, however, reject the null hypothesis at the 1 percent level for the three nonlinear oil price measures, namely, NOPI, asymmetric oil price increase and asymmetric oil price decrease. The nominal oil price, real GDP, ratio of government expenditure to GDP and real money supply are only stationary at the first difference level.

Table 2: Unit Root Tests

	Level		*First Difference*		
Variable	ADF Test Statistic	PP Test Statistic	ADF Test Statistic	PP Test Statistic	ADF/PP C.V
oilp	-0.913	-0.503	-13.8*	-13.5*	-3.98 (3.42)
NOPI	-14.3*	-14.2*	-11.1*	-58.2*	-3.98 (3.42)
asy_increase	-14.8*	-14.8*	-11.2*	-76.9*	-3.98 (3.42)
asy_decrease	-14.1*	-14.1*	-11.9*	-76.6*	-3.98 (3.42)
rgdp	-0.727	-3.30	-5.04*	-14.2*	-3.98 (3.42)
mss	-1.79	-3.40	-6.61*	-3.56*	-3.98 (3.42)
gov_gdp	-3.59**	-3.31	-3.92**	-7.54*	-3.98 (3.42)

* (**) indicate significance at 1 and 5 percent respectively.
Note: Lag length was chosen in line with the Schwarz information criterion which imposes a larger penalty for additional coefficients. It is given by SC = $2l/T + (k \log T)/T$. where l is the log likelihood, T is the number of observations and k is the number of coefficients.

The only difference is the *gov_gdp* variable, which according to the ADF statistic, the variable is only stationary at the 5 percent level both in level and at first difference of the series. The PP result is, however, very clear and hence the variable is taken at first difference on the basis of the PP test.

3.2 Testing for significance and Granger-causality

The paper investigates the relationship between oil prices and the macroeconomic variables of the model with emphasis on the impact of oil prices on real activity. We run tests for both linear and non-linear specifications of oil price models. In the first place, the Wald test, which tests the null hypothesis that all of the oil price coefficients are jointly zero in the GDP equation of the VAR model, was carried out. Table 2 reports the results of the Wald, multivariate and bivariate Granger causality test statistics and the *p*-values. The Wald test statistic indicates that we accept the hypothesis that the different oil prices variables in the linear and non-linear models are statistically significant at the 10 percent or better level whereas the net oil price specification is not. This implies that oil prices, with the exception of NOPI, have a significant direct impact on real activity in the Nigeria economy.

Second, the second line results display the multivariate Granger causality or block exogeneity[7] test. We first run the test to test the null hypothesis that the oil price variable under consideration is Granger caused by the remaining variables of the system. Results – though not reported here, tell us to reject the null hypothesis except in the linear specification. However, real money supply, for instance, among other variables significantly cause NOPI, while asymmetric price increases and decreases each, among other variables, causes one another. Focusing on the causality between oil price and all the other variables in the VAR, results show that the null hypothesis could be safely rejected at the 10 and 1 percent levels for the NOPI and asymmetric price decrease, but, not for the linear and asymmetric increases. Lastly, the bivariate Granger causality test results reported in the third line in Table 2 show that all the oil price measures, including the linear specification, Granger cause real GDP the 5 percent or better level. By way

[7] Alternatively, the block exogeneity test also considers whether the coefficients on all of the lags of all variables other than the dependent variable are jointly different from zero. On the basis of this, the results further confirm the findings from the Wald test on the significance of the oil price coefficients particularly in the non-linear specification.

of summing up, the results show that the interaction between oil prices and macroeconomic variables in Nigeria is generally significant with the direction of causality going in at least one direction across all the oil price specifications.

Table 3:

Wald Test and Granger Multivariate and Bivariate Causality Test

Test Statistic	Model			
	Linear	NOPI	Asy_increase	Asy_decrease
Wald test	9.435*** (0.091)	6.223 (0.285)	86.89* (0.000)	90.67* (0.000)
Block exogeneity (Multivariate Granger causality)	2.762 (0.251)	4.727*** (0.094)	5.909 (0.206)	34.65* (0.000)
Bivariate Granger Causality	7.923* (0.000)	5.656* (0.004)	11.123* (0.000)	5.852* (0.003)

Source: Author's calculation
Note: the hypothesis for the Wald test is H0: oil price coefficients are jointly equal to zero in the GDP equation of the VAR model. The Granger causality test tests the hypothesis that a given oil price measure does not Granger cause real GDP.
One/two/three asterisks denote significance at 1, 5 and 10 percent, respectively.

3.3 Impulse response functions and accumulated responses

Under this item we examine the effects of oil prices on real GDP growth using both the orthogonalised impulse-response functions and accumulated responses for the linear, net and the non-linear specifications of the model. Figures 1, 3 and 5 present the orthogonalized impulse responses functions of GDP growth to one standard deviation oil price shock for the three specifications while Figures 2, 4 and 6 report the accumulated impulse responses of real GDP to a 1 percent oil price shock. Another important channel is the effect of oil price shock on the level of real exchange rate. As a net oil exporter[8], Nigeria's real exchange rate appreciates when oil price hike facilitates higher inflow of foreign exchange into the economy. Although this may

[8] See Figure 16 in the appendix.

sound good for the economy, it, however, has serious implications on real economic activities and the foreign scene due to the heavy reliance of the economy on foreign inputs. Figure 7, 9 and 11, and Figures 8, 10 and 12 display both the orthogonalized impulse responses functions and the accumulated responses of the *rer* to a 1 percent oil price shock across the three oil price specifications, respectively.

3.3.1 Impulse response functions: Linear Specification

The orthogonalized impulse response functions and the accumulated responses are examined as presented in Figure 1 and 2, respectively. The responses of real GDP to a 100 percent oil price innovations from the orthogonalized impulse response functions are generally weak across all the time horizons. From 0.6 percent, for instance, in the second month following the shock, it turns into negative in the fifth and the sixth months, and subsequently, the impact asymptotes to zero exactly one year after the shock. This suggests that the impact of the net oil price shock on real GDP in Nigeria is relatively short-lived. The accumulated impulse responses of the same 100 percent magnitude reveal that the impact is positive on the level of real GDP throughout the 24 months. Table 4 results show that real GDP grows by 0.88 percent in the first six months following the shock, by almost 1 percent in one year and a little above 1 percent in two years, that is 24 months after the shock. In terms of relating the findings to those reported by earlier studies, the results tally very well with the coefficient of oil price shock of 0.77 reported by Aliyu (2009) using a linear oil price model for the Nigerian economy. Similarly, Jimenez-Rodriguez and Sanchez (2004) reported a negative impact of oil price shock to the tune of 1.1 percent for European Union countries after eight quarters following the shock and a positive impact of 0.89 and 1.1 percent for Norway and Japan, respectively. This is despite the fact that Japan is an oil importing country. Furthermore, Gounder and Bartleet (2007) reported a cumulative effect of 0.7 percent of GDP growth for New Zealand.

3.3.2 Impulse response functions: Asymmetric and Net Specifications

The impulse responses for the non-linear or asymmetric and net oil price specifications are presented in Figures 3 – 6. Starting with the net oil price specification, the impulse responses from the orthogonalized functions as presented in Figure 3 reveal that real GDP in Nigeria responds positively to oil price innovations by up to 1.5 percent in the first six months following the shock. This, however, turns into negative in the eleventh month and persists throughout the time horizon. It was 1.1 percent exactly one and a half years after the shock and up to 4.2 percent two years after the shock. The accumulated responses were however, more robust. From the summary presented in Table 4, the six months post innovation responses – a 100 percent, reaches up to 5.7 percent, and was 6.4 percent 12 months after. Real GDP, however, responds negatively exactly 14 months after the shock and persists up to the end of the time horizon. Comparing the two results using Figures 3 and 4, while the turning point in the former case, that is, the orthogonalized impulse responses, occurred in the eleventh month after the shock, it occurred in the fourteenth month in the latter's case. These findings are consistent with that of Lee, Ni and Ratti (1995) for GNP growth in the US, and Jimenez-Rodriguez and Sanchez (2005) for France, Italy, Norway and Canada. Furthermore, Gounder and Bartleet (2007), for instance, found that the largest negative impact of NOPI innovations to GDP occurred in the third quarter and remains negative over 2 years in new Zealand.

Table 4:

Accumulated Response of real GDP to a one percent oil price shock

Model	After			
	6 months	12 months	18 months	24 months
Linear	0.0088	0.0098	0.0100	0.0101
NOPI	0.0568	0.0644	-0.0381	-1.0431
Asymmetric Increase	0.0139	0.0188	0.0290	0.0355
Asymmetric Decrease	-0.0114	-0.0040	-0.0027	-0.0054

Source: Author's calculation

The asymmetric specification's orthogonalized and accumulated impulse responses functions are presented in Figures 5 and 6, respectively. As we can see, the orthogonalized responses of real GDP to asymmetric oil price increase and price decrease demonstrate a cyclical pattern as depicted in Figure 5. In all, the negative and positive impact of asymmetric oil price shocks to real GDP is less than 1 percent across the time horizons. The accumulated responses, however, were more robust and consistent. Table 4 shows that the accumulated responses of a 100 percent asymmetric oil price innovations is positive for asymmetric price increase and negative for asymmetric oil price decrease throughout the time horizons. As expected, the positive impact of the former on real GDP outweighs the negative impact of the latter. Real GDP responds by almost 2 percent one year after the shock and by up to 3.5 percent two years later. In somewhat lesser degree, the accumulated responses show that real GDP contracts by 1.1 percent in the first six months following asymmetric oil price decrease innovations, further down by less than a half of a percent, that is, by 0.4 percent in the twelfth month and a little above a half of a percent, that is, 0.54 percent in the twenty-fourth month. The result shows that Nigeria benefits more from asymmetric oil price increases[9] than it suffers from asymmetric price decreases. The findings are consistent with what was reported by Jimenez-Rodriguez and Sanchez (2005) for Norway. Their study further shows that although UK is a net oil exporting country, it exhibits a surprising behavior because an oil price increase of 100% actually leads to a loss of British GDP growth rate of more than 1% after the first year in all their specifications[10]

Comparing the three models, results from the Wald test suggest that the coefficients of linear and asymmetric specifications are jointly significant and different from zero while those of NOPI are not. Although evidence of a strong linear relationship has been established both on the basis of bivariate Granger causality test and accumulated impulse responses functions, post Hamilton's (1983) studies have demonstrated that oil-real GDP relationship is not symmetric and so results could not be relied upon. Although the post innovation's shock of the net oil price specification to real GDP in the first one year is enormous and surpasses that of other specifications, it, as well, deflates real GDP in the same fashion. The asymmetric specification with more consistent and significant accumulated responses coefficients persists steadily on real GDP growth

[9] The country's external reserves position, for instance, stood at US $62,082.86 as at September, 2008, the naira exchange rate stabilizes up to November of the same year before the emergence of the adverse effects of global financial meltdown. Additionally, the country's achieves over 24 months of imports equivalent for the first time all due to persistent oil price increase until the last quarter of 2008.

[10] The authors attributed this fact to what is known in the literature as the *'Dutch disease'*, that is, a phenomenon whereby oil price hikes led to a large real exchange rate appreciation of the pound. Despite significant inflow of oil revenue into the country, policymakers in Nigeria have stubbornly maintained exchange rate at sufficiently low level to forestall stability and minimize adverse effect on foreign trade and capital flows.

following asymmetric oil price increases and a modest real GDP loss as a result of oil price decreases is most dependable.

Assessing the real exchange rate responses to oil price innovations is another important channel for understanding the impact of oil price shock on the overall macroeconomy. Table 5 reports both the orthogonalized responses functions and the accumulated responses of the real exchange rate to oil price innovations across all the specifications. The first line reports the accumulated responses coefficients whereas the second line reports those of the orthogonalized responses functions. Generally, there is a consensus across the models except the net specification – in the short and medium terms, that oil price innovations in Nigeria result in real exchange rate depreciation. This shows that although Nigeria is a net oil exporting country, large inflow of oil revenue does not lead to exchange rate appreciation. This is not unconnected to the fact that Nigeria had embarked on SAP since July, 1986, and a major component of the programme is the deregulation of the foreign exchange market.

Table 5:

Orthogonalized Impulse and Accumulated Responses in *rer* to a one percent oil price shock

Model	**After**			
	6 months	12 months	18 months	24 months
Linear	-0.0059 (-0.0022)	-0.0130 (-0.0008)	-0.0155 (0.0002)	-0.0163 (-0.0000)
NOPI	0.0058 (0.0026)	0.0462 (0.0093)	0.0580 (-.0105)	-0.2538 (-0.0873)
Asymmetric Increase	-0.0086 (-0.0000)	-0.0286 (-0.0029)	-0.0607 (-.0069)	-0.1138 (-0.0113)
Asymmetric Decrease	-0.0011 (-0.0002)	-0.0034 (-0.0010)	-0.0078 (-.0015)	-0.0151 (-0.0015)

Source: Author's calculation

The results show that the accumulated responses reports larger real exchange rate depreciation than the orthogonalized responses. Between the specifications, while the asymmetric specification was more consistent and persists steadily throughout the time horizon, net oil innovations result in higher degree of exchange rate depreciation by up to 25.4 percent for a 100 percent oil price innovations. Thus, from the analysis of impulse responses of oil price innovations to real GDP and the real exchange rate in Nigeria, it is clear that while the economy's real GDP grows as oil price hikes – this applies to all the models except NOPI, the country's real exchange rate depreciates to consolidate the gains from oil price increases while at the same time insulating the country's foreign trade from deterioration.

3.4 Variance Decomposition Analysis

Under this section, the forecast error variance decomposition tells us exactly how much of the unanticipated changes of the variables are explained by different shocks. The variance decomposition generally suggests that oil price shocks, except the linear specification, are considerable source of volatility for some in the case of asymmetric specification and virtually all the variables in the model in the case of NOPI specification. Figures 13 through 15 present the results of the forecast error variance decomposition of the real GDP. Figure 13 shows that the linear oil price accounts for less than 1 percent of real GDP's variability. Contemporaneously and over the time horizon, real GDP drives its own variance by over 93 percent. Monetary policy innovations, in addition, account for up to 5 percent of real GDP variability.

In the NOPI specification, oil price innovations, for instance, account for up to 14.3, 8.8 and 18.9 percent of the variance of the real GDP in the sixth, twelfth and twenty-fourth months, respectively. Besides, oil price innovations significantly drive the variance of other variables in the model. Lastly, the combined share of the asymmetric oil price increase and decrease account for more than 5 percent of the variance of the real GDP. This is also significant considering the fact that Dotsey and Reid (1992) found that oil prices explain between 5% and 6% of the variation in GNP, while Brown and Yucel (1999) show evidence that oil price shocks explain little of the variation in output. Jimenez-Rodriguez and Sanchez (2005) estimates from the decomposition of the forecast error variance show that oil price shock account for 8 percent of Germany's output variability, 9 percent in the UK, and 5 percent in Norway.

4.1 Conclusion and Recommendations

This paper assesses the effects of oil price shocks on the Nigeria's macroeconomy between 1980M1 and 2007M12. The main focus is on the relationship between oil prices and real GDP. The main instruments of data analysis are the Granger block exogeneity and the vector autoregression techniques. In addition, ADF and PP techniques were employed to check the time series characteristics of the data. In line with the specifications proposed in the literature, three different specifications were developed in the paper, namely; linear net and asymmetric specifications.

As a first step, the ADF and PP tests show while all oil price transformations, namely; NOPI, asymmetric increase and decrease are stationary in their own levels, others – *rgdp*, *oilp*, *mss*, *rer* and *gov_gdp* are stationary at first difference. These inform how the variables were entered into the VAR model while the ordering of the variables follows both the intuition of the researcher and in line with the Cholesky laid down criteria. Results from the Granger causality tests, block exogeneity and pairwise causality, permit us to conclude that the interaction between all the oil price transformations, including the linear oil price variable, and macroeconomic variables in general and real GDP is found to be significant, with the direction of causality going, in the latter case, in at least one direction.

The results from vector autoregressions are broadly consistent with the expectation that the real GDP of net oil exporting economies benefit from increases in oil prices in both linear and non-linear models. We find evidence of more significant positive effect of asymmetric oil price increase in Nigeria than adverse effect of asymmetric oil price decrease on the level of real GDP. Equally, the results from linear and net specification fall within the bound reported by similar studies in the area. The Wald test confirms the significance of the linear oil price coefficients in the VAR and those of asymmetric specification. With regard to the size of the responses, accumulated responses happen to be more accurate and consistent in delivering the expected changes in the variable of interest, here being the level of real GDP. In addition, although net oil price specification tends to yield higher real impact of oil price shock, non-linear or asymmetric specification yields more robust and consistent coefficients, which situate well within the bounds reported by empirical studies in the area. Specifically, our results from the non-linear specification show that Nigeria as a net oil exporter benefits more from asymmetric oil price increases in terms of real GDP growth than it suffers from asymmetric price decreases.

Our variance decomposition analysis indicates that net oil price shocks and to some extent asymmetric shocks are together with monetary shocks, considerable sources of volatility in real GDP. Overall, it can be said that there is a crucial relationship between oil price shocks and economic growth and other macroeconomic variables. This is reinforced by the finding that oil prices cause depreciation of the real exchange rate of the naira, a finding which is consistent with net oil exporting country like Nigeria.

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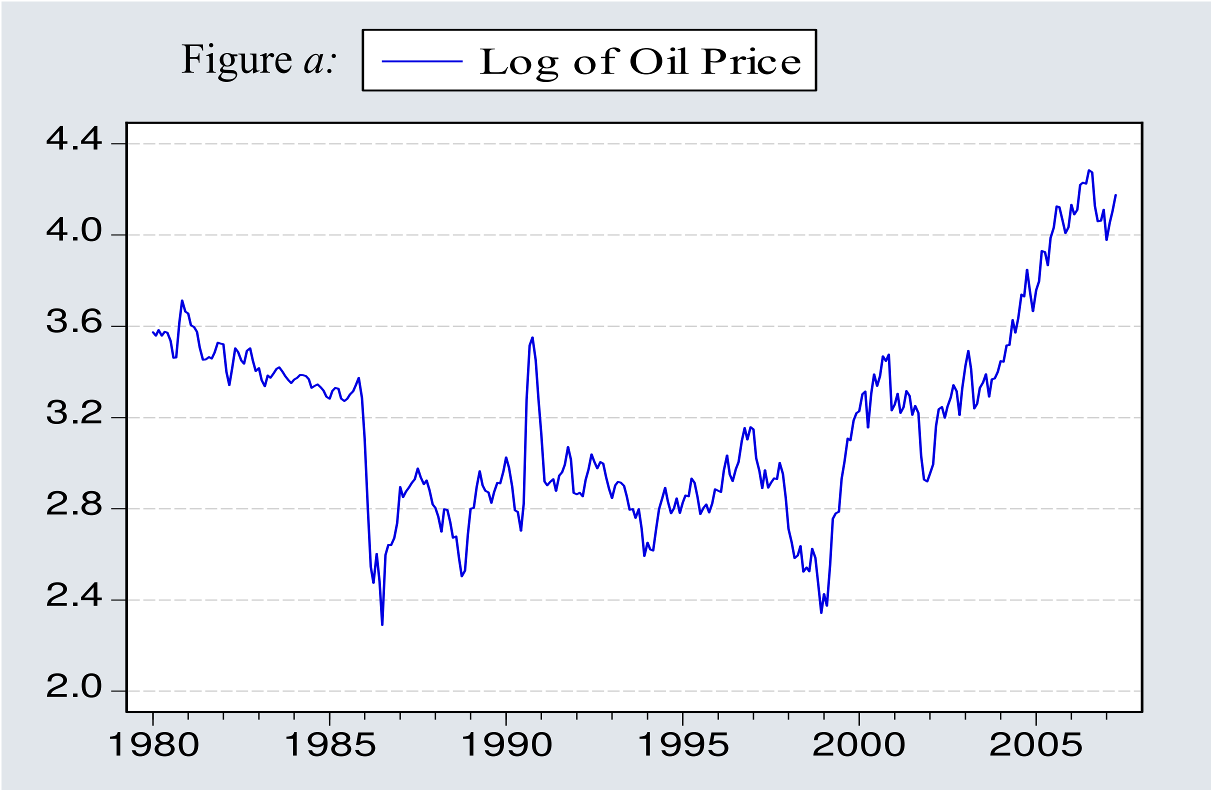


Figure a:
Log of Oil Price
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1980
1985
1990
1995
2000
2005

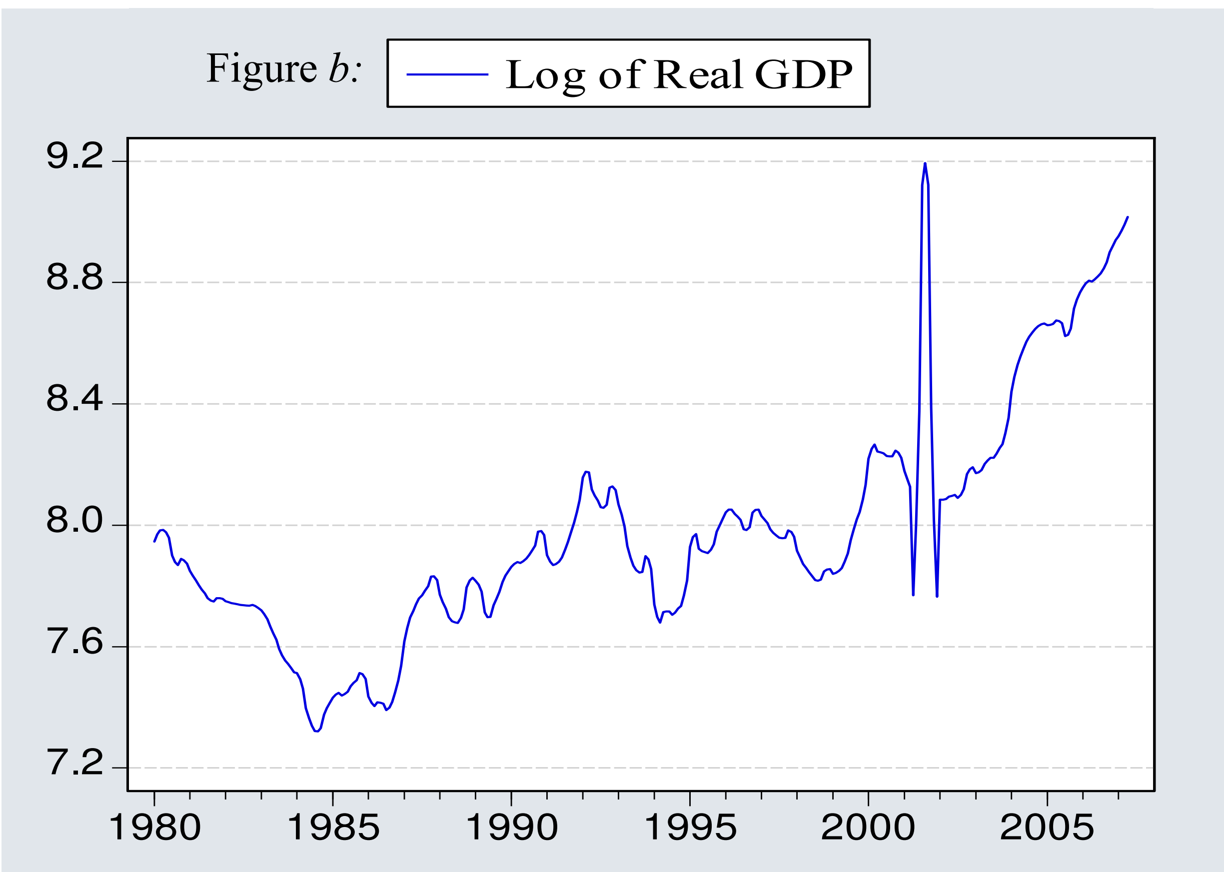


Figure b:
Log of Real GDP
9.2
8.8
8.4
8.0
7.6
7.2
1980
1985
1990
1995
2000
2005

Figure 1
Orthogonalised impulse-response function of rgdp
to a one-standard-deviation oil price innovation
(Linear Specification)

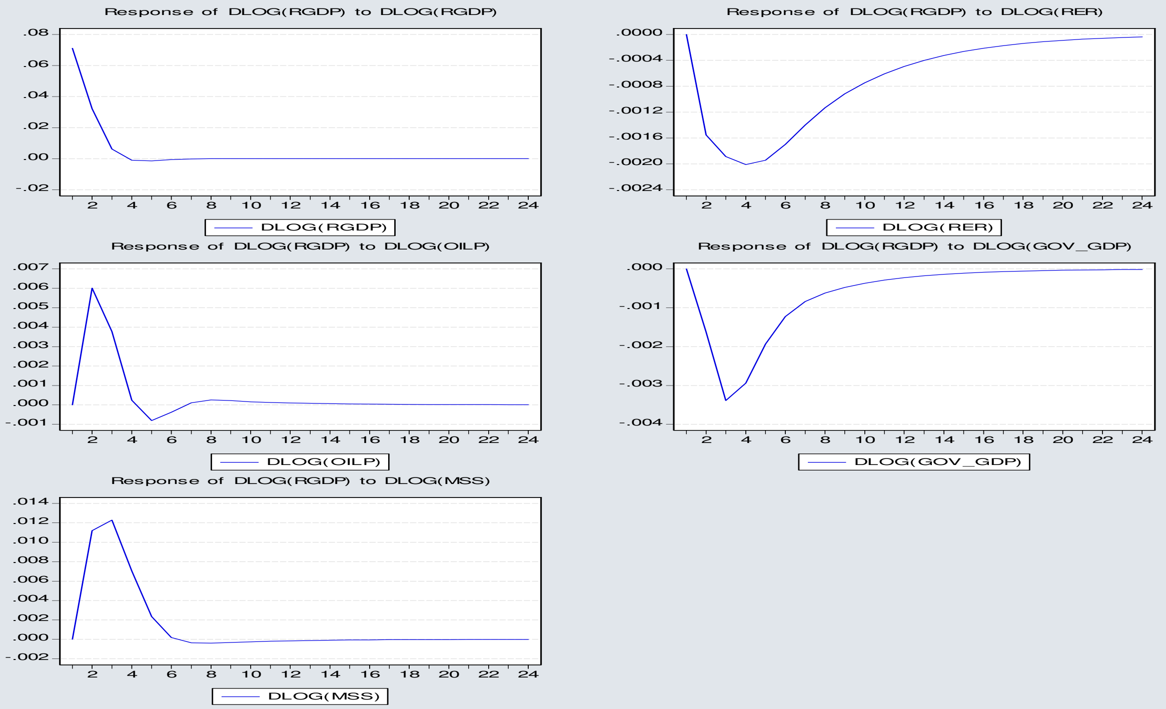


Figure 2
Accumulated Responses of rgdp to a 1% oil price shock
(Linear Specification)

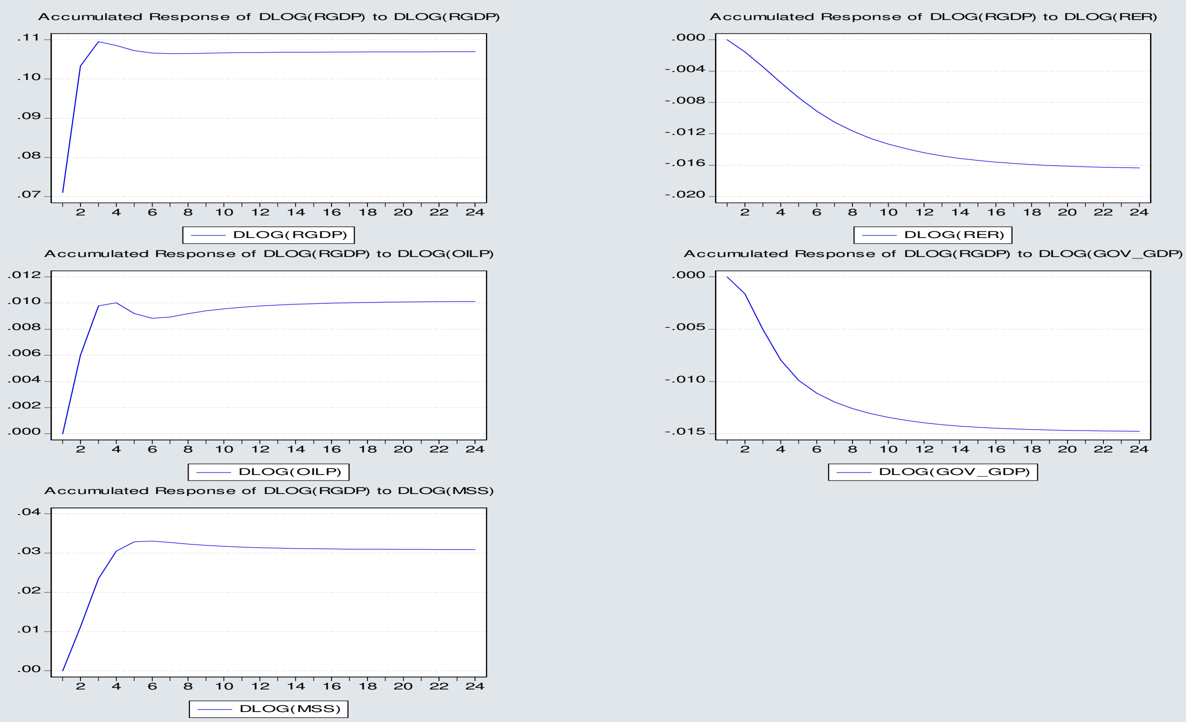


Figure 1
Orthogonalised impulse-response function of real GDP
to a positive one-standard-deviation oil price innovation
(Linear Specification)

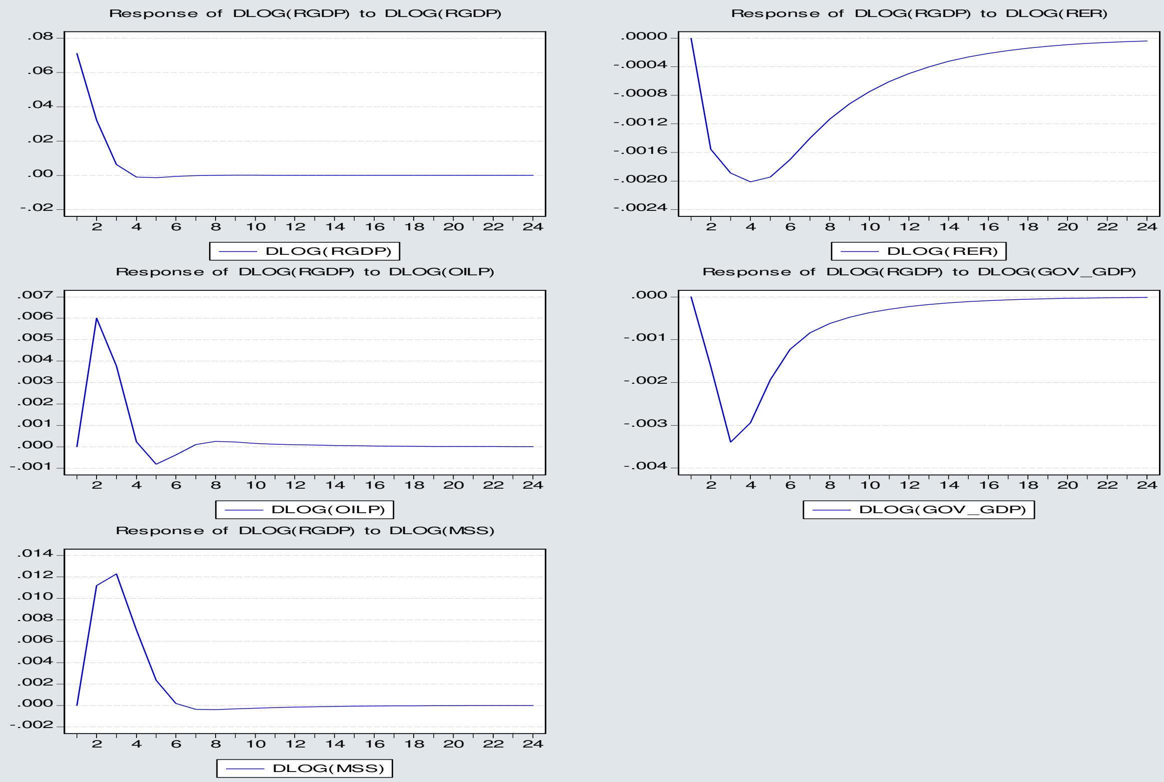


Figure 2
Accumulated Responses of Real GDP to a 1% oil price shock
(Linear Specification)

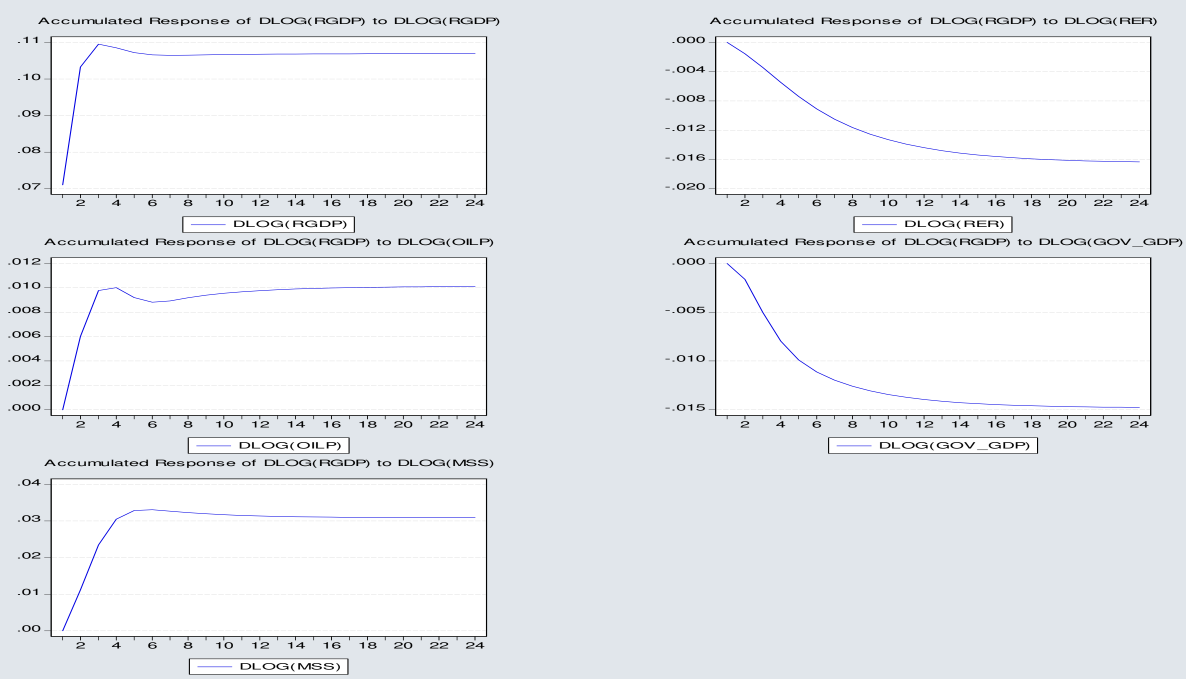


Figure 3
Orthogonalised impulse-response function of real GDP to a positive one-standard-deviation oil price innovation
(NOPI Specification)

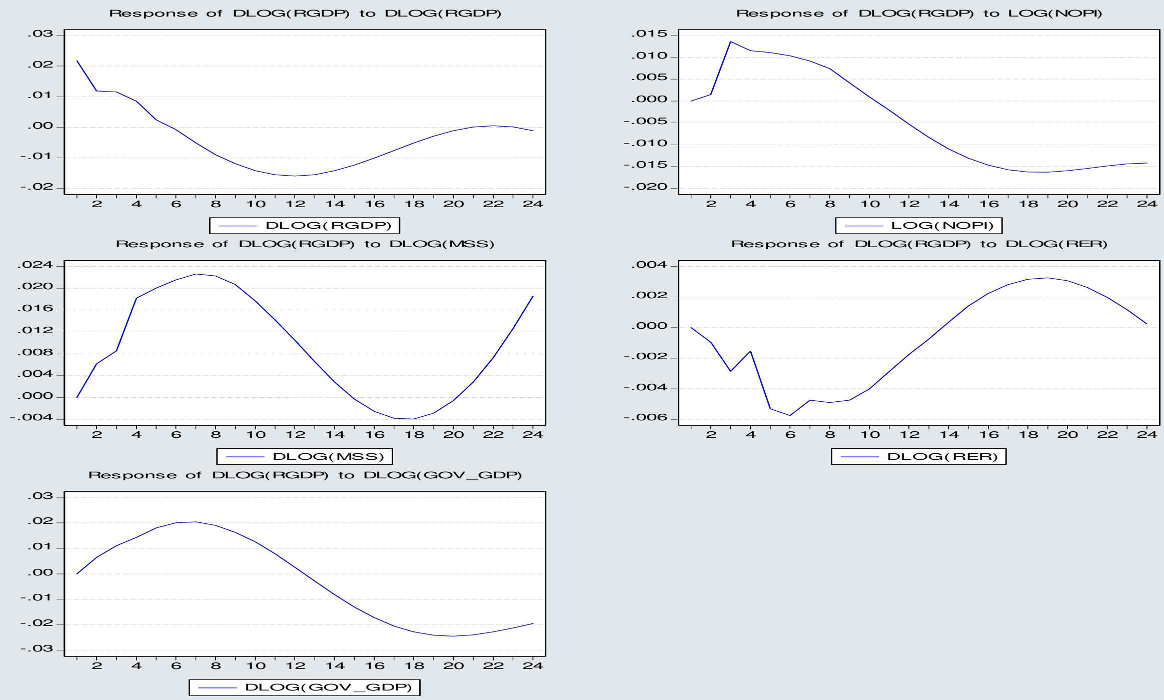


Figure 4
Accumulated Responses of Real GDP to a 1% oil price shock
(NOPI Specification)

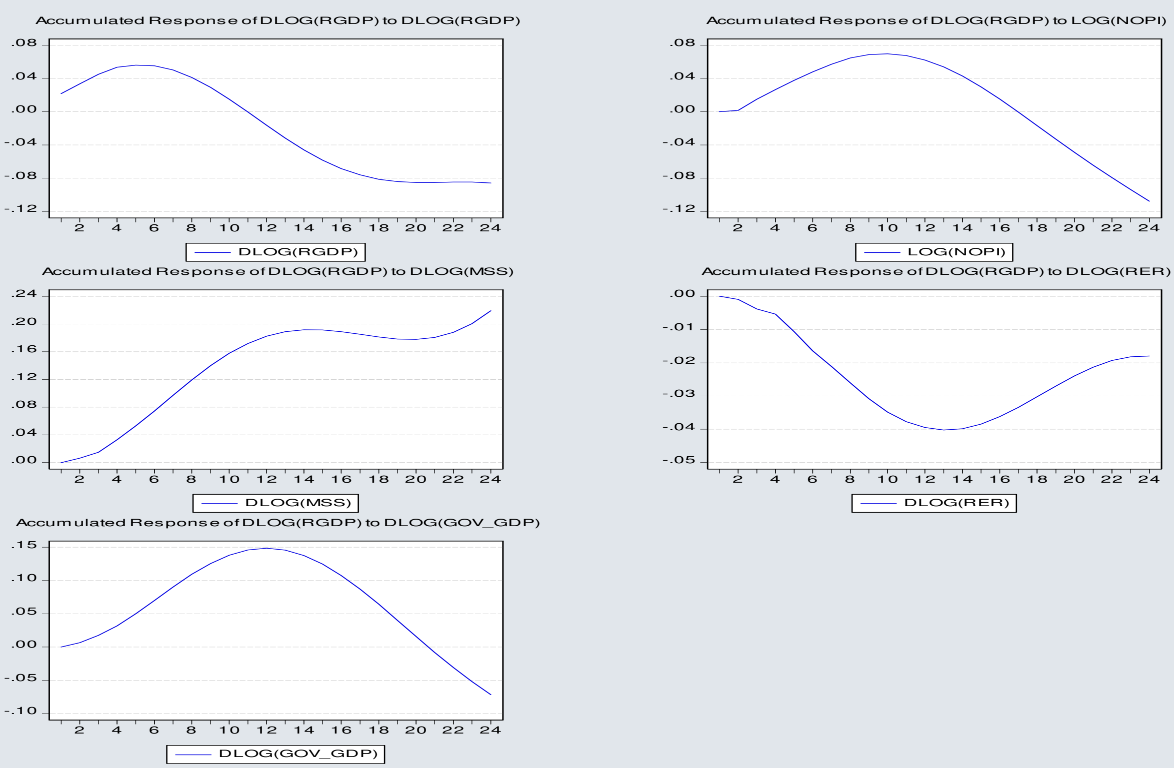


Figure 5
Orthogonalised impulse-response function of real GDP
to a positive one-standard-deviation oil price innovation
(Asymmetric Specification)

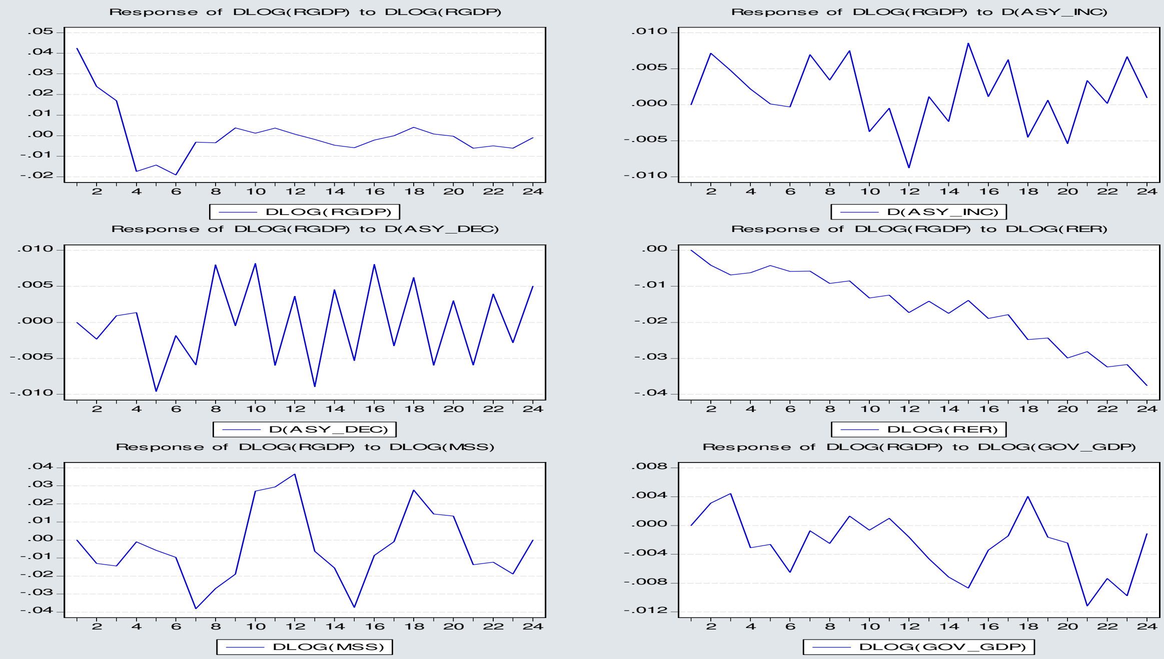


Figure 6
Accumulated Responses of Real GDP to a 1% oil price shock
(Asymmetric Specification)

Figure 7
Orthogonalised impulse-response function of rer to a positive one-standard-deviation oil price innovation
(Linear Specification)

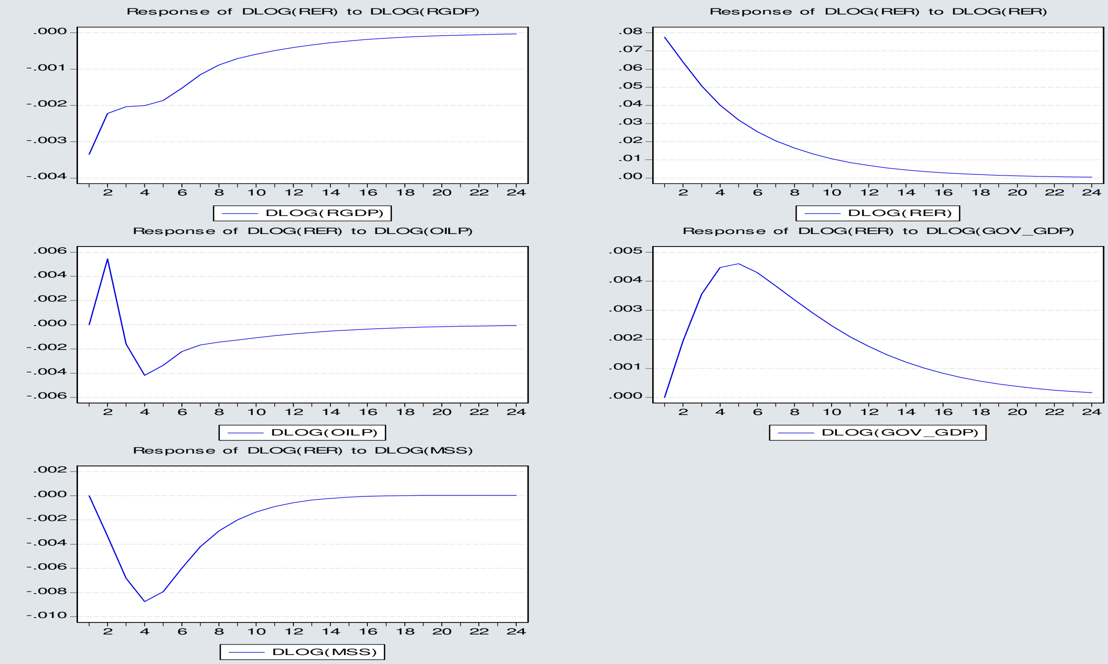


Table 8
Accumulated Response of the rate of change in rer to a 1% oil price shock
(Linear Specification)

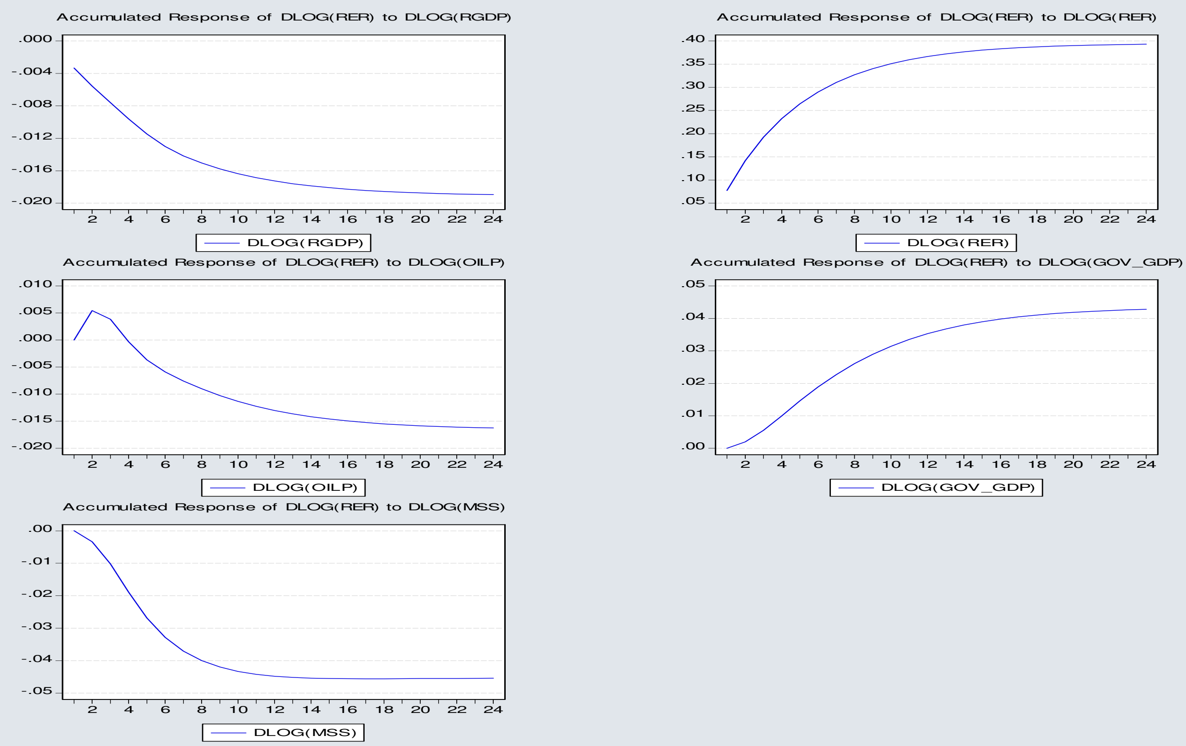


Figure 9
Orthogonalised impulse-response function of rer to a one-standard-deviation oil price innovation (NOPI Specification)

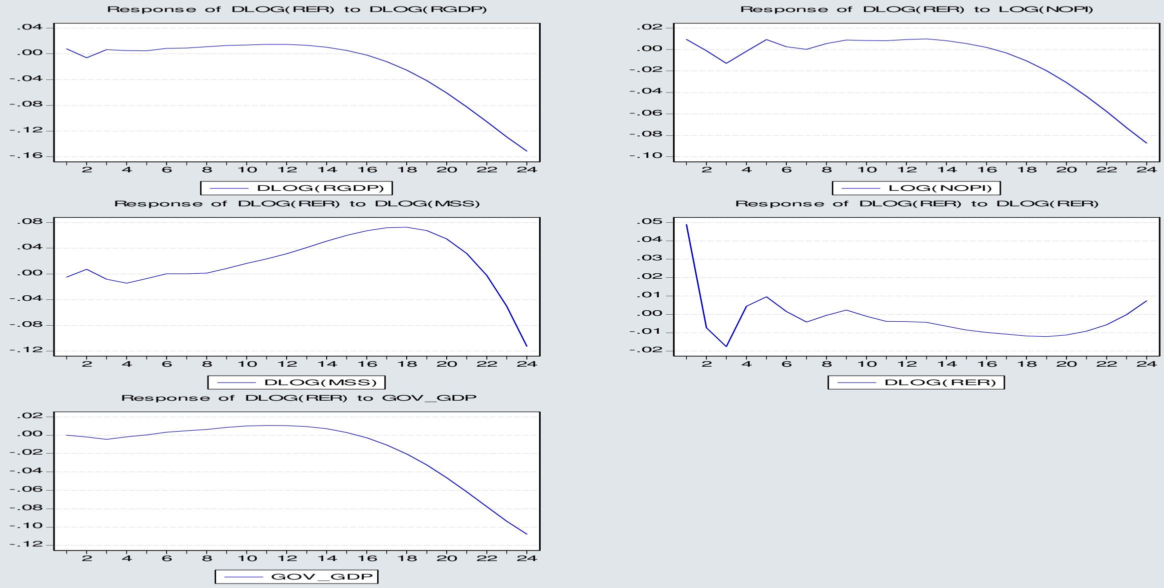


Table 10
Accumulated Response of the rate of change in rer to a 1% oil price shock (NOPI Specification)

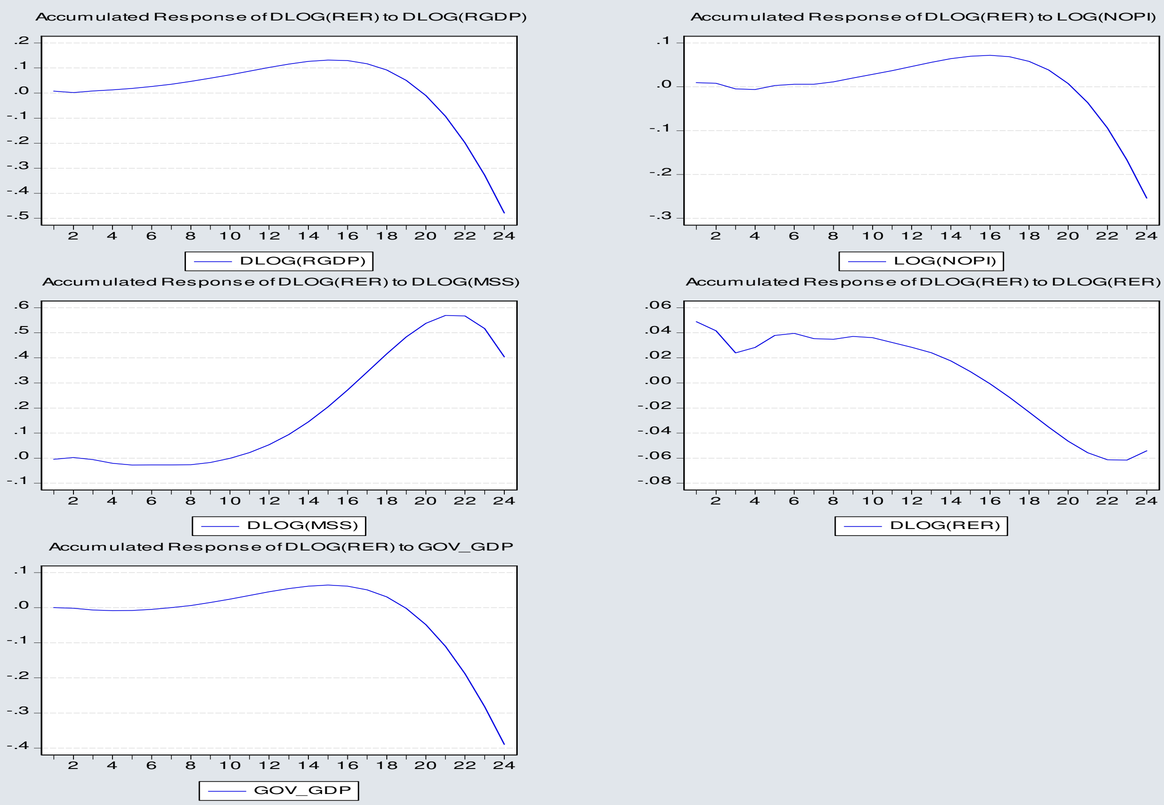


Figure 11
Orthogonalised impulse-response function of rer to a one-standard-deviation oil price innovation
(Asymmetric Specification)

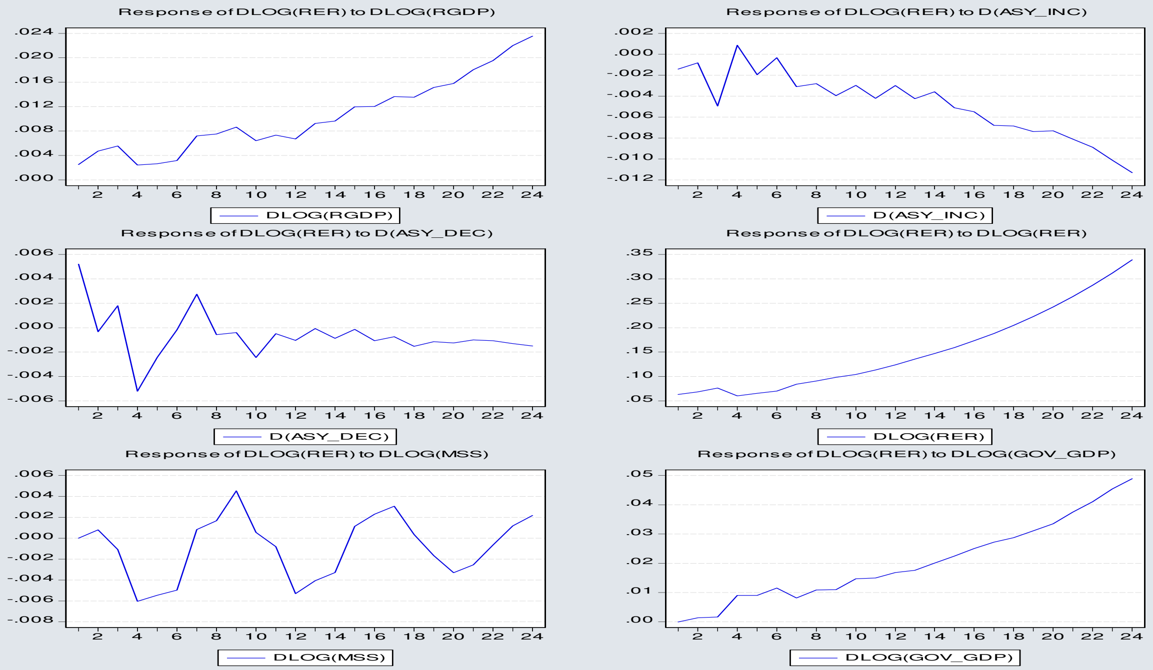


Table 12
Accumulated Response of the rate of change in rer to a 1% oil price shock
(Asymmetric Specification)

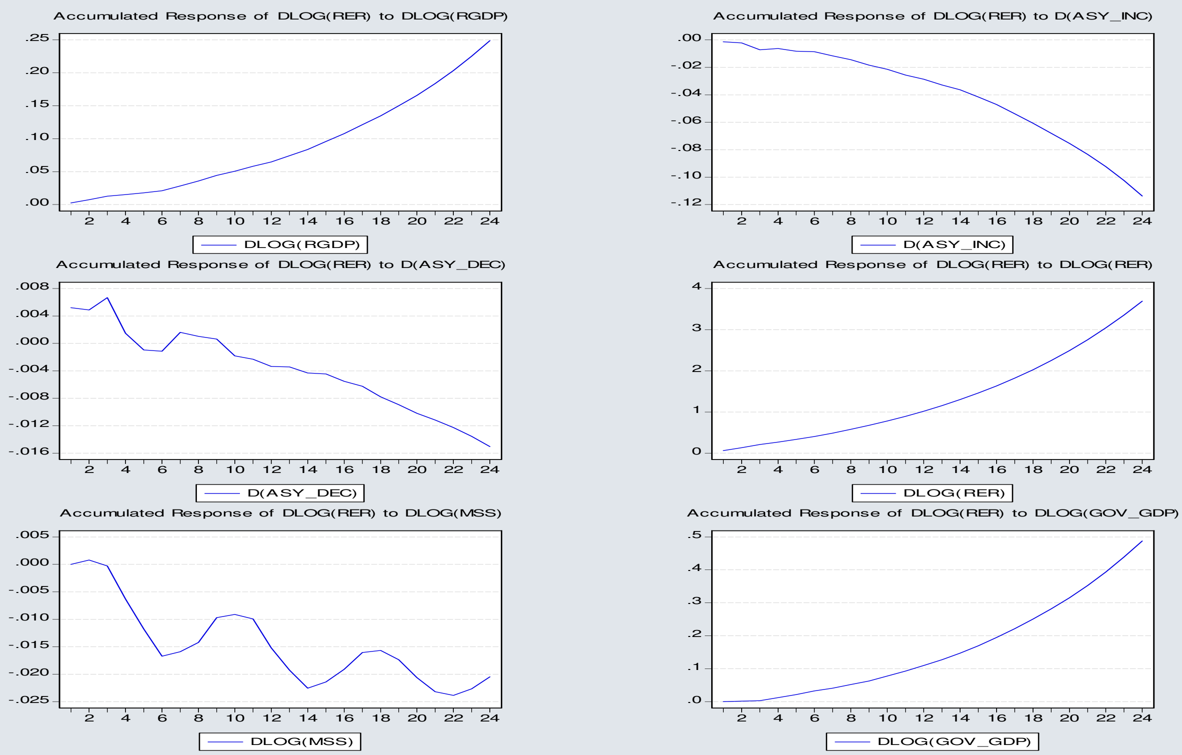


Figure 13
Variance Decomposition
(Linear Specification)

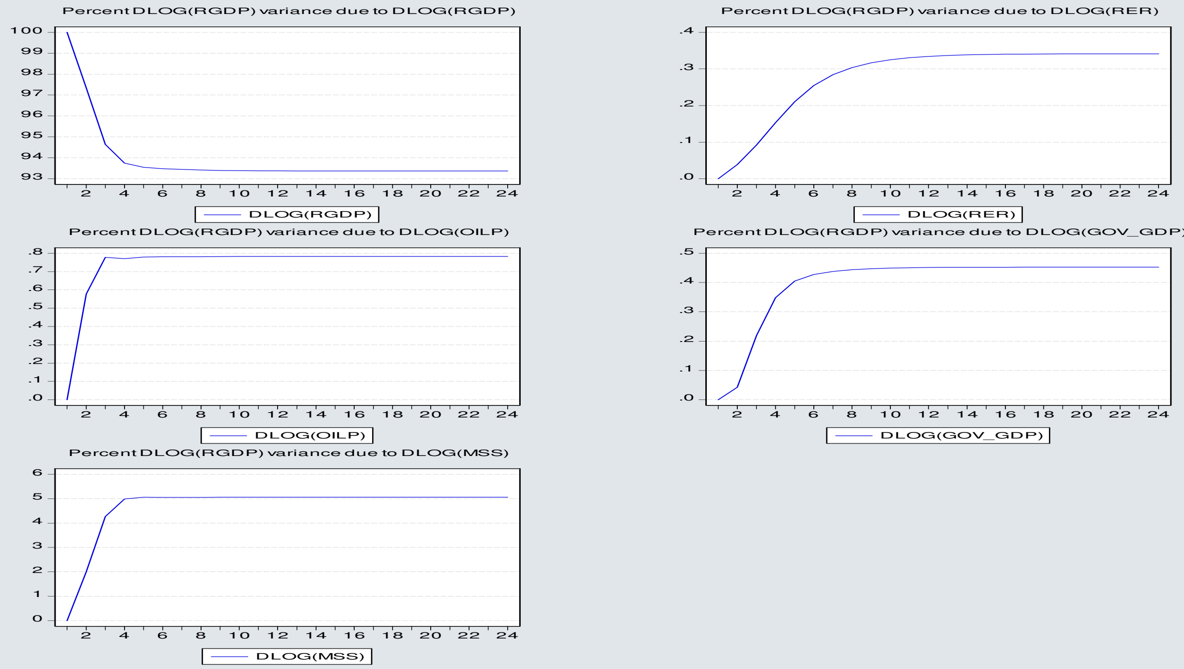


Figure 14
Variance Decomposition
(NOPI Specification)

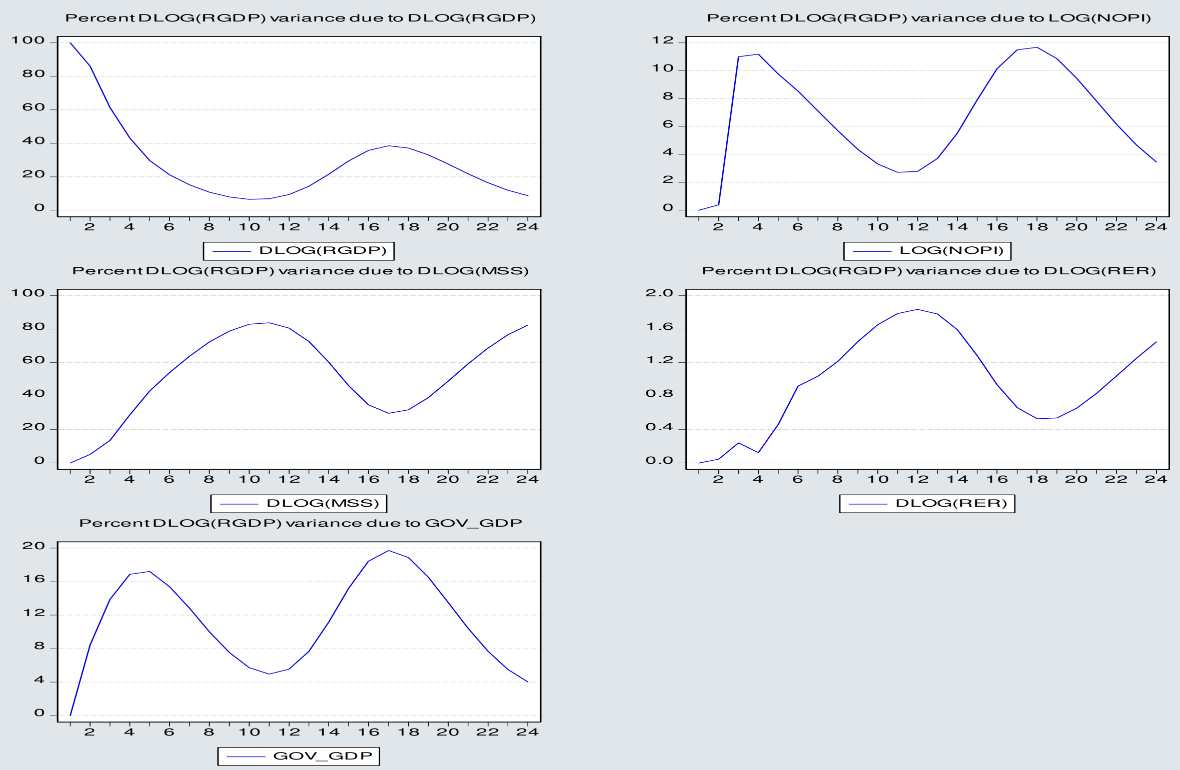


Figure 15
Variance Decomposition
(Asymmetric Specification)

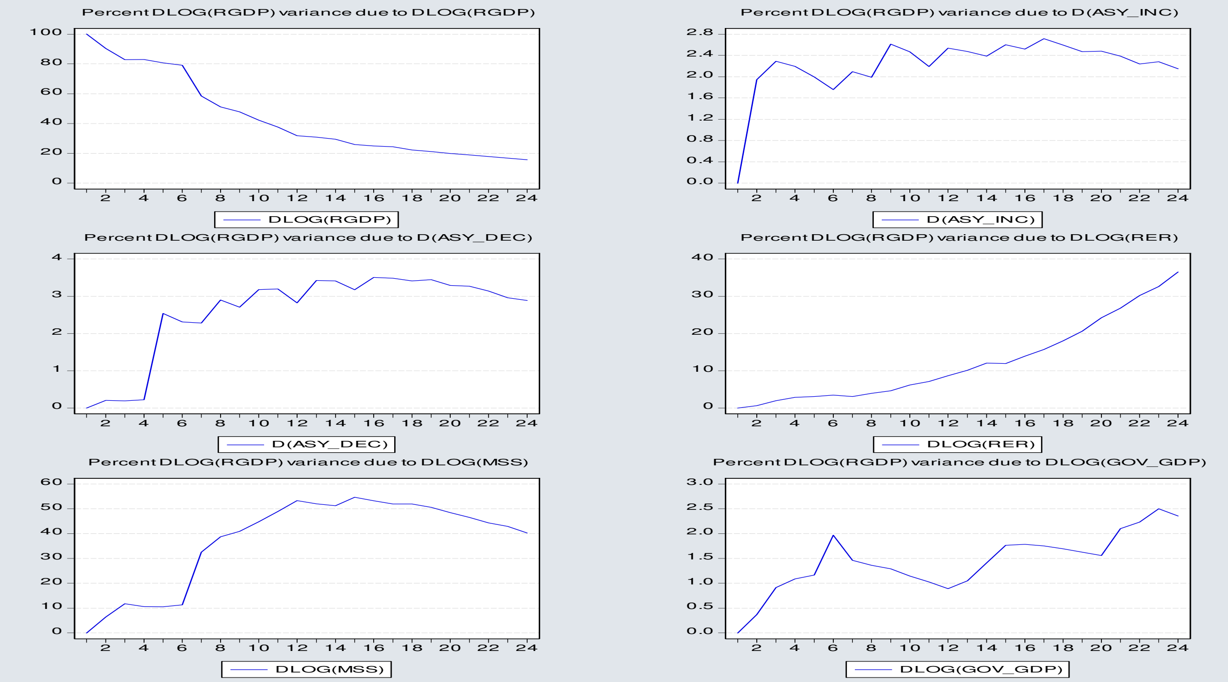
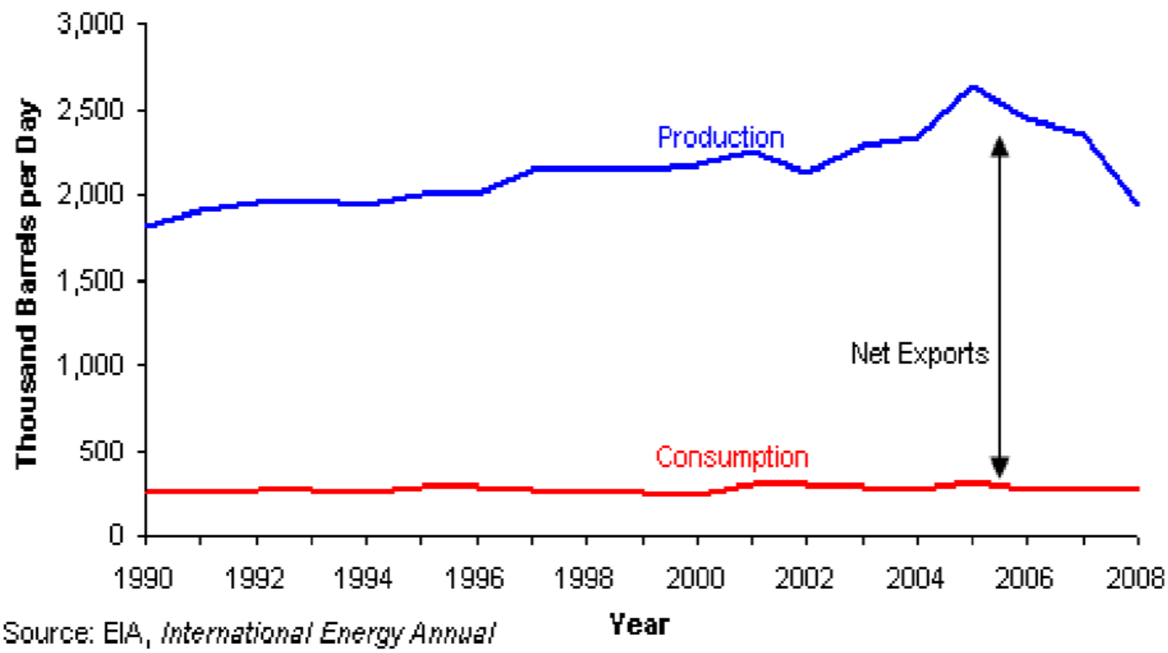


Figure 16
Nigeria's Oil Production and Consumption, 1990-2008



Source: EIA, *International Energy Annual*
Short Term Energy Outlook March 2009