Effect of Oil Price Shocks on Monetary Policy in Nigeria: A Vector Autoregressive Analysis

Ama Agyeiwaa Abrokwah, Ambassador Enterprises

Abstract

This paper examines the effects of oil price shocks on interest rate, real GDP and real effective exchange rate in Nigeria using a vector autoregressive (VAR) model. The results from the impulse response function suggests that positive oil price shocks have no effect on the interest rate (monetary policy), real exchange rate and real GDP. This result suggests that monetary policy in Nigeria does not respond to oil price shocks. Both the impulse response functions and variance decomposition analysis to a large extent confirmed that oil price shocks are only able to explain a small proportion of the forecast error variance of the variables under consideration.

Keywords: *oil price shocks, impulse response function, variance decomposition, JEL Classifications codes: C01, C51.*

Introduction

Nigeria is currently the largest oil producer in Africa, the 13th largest producer of crude oil in the world, the 6th largest crude oil exporter, has the 11th largest proven crude oil reserves in the world, and has an estimated 37.1 billion barrels of oil reserves, which places Nigeria as the second largest in terms of oil reserves on the African continent. Yet, due the economy's heavy reliance on crude oil and the instability in the Niger Delta region, Nigeria is vulnerable to shocks in world oil prices. The instability in the Niger Delta region has resulted in a significant drop in the amounts of crude oil production at onshore and shallow offshore fields. Crude oil production dropped from about 1.8 million barrels per day (bbl/d) in December 2015 to about 1.4 million barrels per day in 2017. The country's crude oil exports have also been fluctuating over the years. There was a decrease from 2.1 million bbl/d in December 2015 to 1.7 million bbl/d in December 2016 according to the Census and Economic Information Center (CEIC) data (2018). The Nigerian economy has consistently relied on the export of crude oil for foreign exchange earnings and revenues. The export of crude oil accounted for over 83 percent of export earnings, 77 percent of government revenues and 10 percent of the gross domestic product (GDP) in 2016. Nigeria has also been exposed to oil price shocks through massive importation of refined petroleum products since the collapse of local refineries in the late 1980s. Currently, Nigeria imports almost 85 percent of refined products for local consumption.

The continuous fluctuations in oil prices has posed many economic challenges for several oil exporting, developing economies that are heavily reliant on revenues from oil exports. There is therefore the need for extensive research to determine the effects of shocks to oil prices on

economic and monetary variables in order to provide policy recommendations to policy makers in these countries.

The impact of an oil price shock on any particular economy depends on several factors among which are: the magnitude of the shock; the duration of the shock (persistence); the dependency of the economy on oil (energy fuel mix and intensity); the immediate policy response to the shock; and the state of the economy before the shock (absorptive capacity or vulnerability). A number of recent theoretical and empirical studies have provided insights into the macroeconomic implications of oil price shocks. However, very limited work has been done on the association between oil price shocks and monetary policy. Most studies have examined the oil price - monetary policy linkage for industrial economies, especially the United States and the Organization for Economic Cooperation and Development (OECD) countries (Balke, Brown, & Yucel, 2002; Bernanke, Gentler and Watson, 1997). The role of oil price shocks in net oil-exporting developing countries has not been sufficiently covered in the literature. This paper studies the impact of oil price shocks on monetary policy and some macroeconomic variables.

Studying the role of monetary policy distinguishes this study from earlier research studies that have dealt with oil price-output relationships in the context of developing countries, notably Nigeria. This study uses a vector autoregressive (VAR) model to examine the impact of oil price shocks on interest rate, real gross domestic product (GDP) and the real effective exchange rate in Nigeria. Hamilton's (1996) Net Oil Price Increase (NOPI) was used as the oil price shock measure.

Literature Review

According to Barsky and Kilian (2004), increases in oil prices have been held responsible for recessions, periods of excessive inflation, reduced productivity and lower economic growth. However, they conclude in their paper that disturbances in the oil market are likely to matter less for U.S. macroeconomic performance than has commonly been thought.

With regard to the response of monetary authority to oil price changes, Bohi (1989) asserted that, if a classic supply shock explains the principal effects of an oil price shock, energy intensive industries should be the most affected after an increase in energy prices. However, since he found no relationship between these industries and their level of energy-intensity as well as no statistically significant effects of oil price shock on the business cycle of four countries, he concluded that the restrictive monetary policy carried out by the central banks of these countries accounts for much of the decline in aggregate economic activity in the years that follow oil price increases.

Similarly, results by Bernanke et al. (1997) clearly support this view and demonstrate that if following an oil price shock, the Federal Reserve had not increased interest rates, the economic downturns that hit the U.S. might have been largely avoided. In particular, they show that the U.S. economy responds differently to an oil price shock when the federal fund rate is constrained to be constant than in the case in which monetary policy is unconstrained. In the unconstrained case, a positive oil price shock leads to an increase in the federal fund rate and a decline in the real GDP. With the federal funds rate held constant, Bernanke et al. (1997) find that a positive oil price shock

results in an increase of the real GDP and of the inflation rate. According to their findings, these results show the important role of the real effects of oil price shocks due to the monetary policy response.

Herrera and Hamilton (2001) challenged the conclusions of Bernanke et al. (1997) on two grounds. First, they found that both the nature and magnitude of the actions suggested by the U.S. central bank are sufficiently inconsistent with the historical correlations as to call into question the feasibility of such a policy. Second, they demonstrated that if a longer lag length is considered even when the federal fund rate is kept constant, an oil price shock still yields a sizable reduction in output, which implies that monetary policy has little effect in easing the real consequences of an oil price shock. The analysis of Herrera and Hamilton is consistent with those of other authors who show that counter-inflationary monetary policy was only partly responsible for the real effects of oil price shocks that hit the U.S. during the last thirty years.

As outlined so far, the literature on an oil price monetary policy relationship has focused mainly on developed countries. In the case of developing economies, Adusei and Pastuszyn (2007) examined the relationship between the world oil price and the aggregate demand in Ghana, via the interest rate channel by means of a cointegration analysis. They found that monetary policy is initially eased in response to a surge in the price of oil in order to lessen any growth consequences but at the cost of higher inflation. The ensuing higher inflation, however, prompts a subsequent tightening of the monetary policy.

Mahmud (2009) used structural VAR to study the impact of innovations to oil prices on inflation, money supply, interest rate, government expenditure, GDP per capita growth rate, exchange rate and manufacturing output in Nigeria. He concluded that oil price shocks have distortionary effects on macroeconomic aggregates. The study, therefore suggests that in order to curtail the macroeconomic distortions associated with oil price increases, monetary authorities should have a closed cap on inflationary pressure. However, only the balance of payment ratio and the exchange rate are found to be significant, but the author explains his results as though all variables are significant.

This paper seeks to add to the literature focusing on the developing economy, oil producing countries, particularly African countries, where the literature seems almost non-existent. Specifically, this paper evaluates how the monetary policy in Nigeria, the largest crude oil producer in Africa, responds to oil price shocks.

Empirical Analysis

Data description

This paper studies the impact of oil price shocks on monetary policy and some macroeconomic variables. Quarterly data from 1981Q1 to 2013Q4, a total of 132 observations for each variable, is used for this study. The variables used are interest rate, real gross domestic product (RGDP), the real effective exchange rate (Naira/Dollar rate) and the price of oil (a measure of oil price shocks). Interest rate was used, particularly the discount rate as a measure of monetary

policy, since it is used by the Central Bank of Nigeria as a monetary policy measure. The macroeconomic variables used are the real gross domestic product (RGDP) and the real effective exchange rate. The real GDP serves as a measure of economic activity, while the real effective exchange rate captures changes in revenue as a result of relative changes in the exchange rate (Naira per dollar). Also, the real GDP and exchange rate are widely used in the literature as measures of macroeconomic activity. All of the variables with the exception of the real GDP were obtained from the International Monetary Fund (IMF) International Financial Statistics data-base. The data for real GDP was obtained from the Central Bank of Nigeria statistics database. With the exception of the interest rate and oil price shocks, all the variables are seasonally adjusted and in logarithm format.

Methodology

First I performed an Augmented Dickey Fuller (ADF) test to determine if the variables have unit roots. The variables would be differenced to induce stationarity following the results of the ADF test. In addition, the Johansen cointegration test was used to test for cointegration among the variables. If there is no cointegration, an estimate of a three variable vector autoregressive (VAR) model was used to capture the short-run relationships among the variables. If the variables are cointegrated, a vector error correction model (VECM) was estimated to capture the long-run relationships among the variables.

A vector autoregressive (VAR) model was estimated with a Choleski decomposition to create impulse response functions (IRFs) as well as variance decompositions (VDCs) for my estimation. The Cholesky decomposition examines the contemporaneous relationships among the variables in the model based on the Cholesky ordering. The impulse response functions examine the response of a particular variable in the system relative to a shock in another variable in the dynamic system, whereas the variance decomposition analysis helps to explain how much the forecast error variance of a particular variable in the system is explained by variations in the other variables and the variable itself.

Each IRF and VDC is based on a four-variable VAR model in this order: (1) an indicator of the oil price shocks; (2) the interest rate; (3) the log of real effective exchange rate; and (4) the log of real GDP. The ordering of the oil price indicator was first in the ordering because the world crude oil price (international variable) is used to generate the oil price shock measures. This ordering imposes the reasonable assumption that oil price shocks have a contemporaneous effect on monetary policy and economic variables within the quarter.

The most challenging feature identifiable from the oil macroeconomy literature is the measure of oil price shocks to be used for analysis. The traditional, also linear, measure of oil price shocks in the literature as popularized by Hamilton (1983) is the quarterly changes in real oil prices, which is constructed as the first log differences of the oil price variable and expressed as:

$$\Delta O_t = lnO_t - lnO_{t-1}$$

However, in this paper, the Hamilton (1996) approach was followed, which is the most commonly used approach in the literature. Hamilton (1996) proposed a net oil price increase

(NOPI) measure on the basis that not all oil price increases impact the behavior of rational agents. Hamilton argues further that a measure of how an oil increase alters household and firm spending decisions would be a comparison of the current oil price to its historical path. He specifies NOPI as:

$$NOPI = max[0, (\ln(OP_t)) - \ln(\max(OP_{t-1}, \dots, OP_{t-4}))]$$

The above specification is used to compare the oil price for the current quarter with the previous four quarters' prices. The amount by which the log real oil price in the current quarter exceeds its maximum over the previous last four quarters is used, while oil price increases less than this benchmark is assumed to be zero.

Empirical Results

The first part of the analysis is the Augmented Dickey-Fuller (ADF) test for unit roots. From the results in Table 1, and using a five percent level of significance, there is the presence of unit roots in all the variables with the exception of net oil price increase (NOPI). Three variables are non-stationary and hence standard regression analysis if applied is likely to produce spurious results. The non-stationary variables to induce stationarity was differenced, and the results show that the first difference of the variables is stationary.

Table 1
Augmented Dickey Fuller Test

Variables	t-statistic	p-value
Interest Rate (IR)	-2.61	0.09
Log Real Effective Exchange Rate (LREER)	-2.32	0.17
Log Real GDP (LGDP)	-0.73	0.83
Net Oil Price Increase (NOPI)	-6.75***	0.00
Diff Interest Rate (DIR)	-10.62***	0.00
Diff Log Real Effective Exchange Rate (DLREER)	-5.76***	0.00
Diff Log Real GDP (DLGDP)	-11.62***	0.00

Note. *** Imply statistical significance at 1%, ** Imply statistical significance at 5%.

Table 2 shows the results from the Johansen Cointegration Test. The results indicate that there is no cointegrating equation at the 5 percent level of significance. Since the variables are not cointegrated, I proceeded with a vector autoregressive (VAR) model estimation which captures the short-run relationships among these variables.

Table 2

Johansen Cointegration Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.09	22.75	29.79	0.08
At most 1	0.07	11.37	15.49	0.12
At most 2	0.02	2.19	3.84	0.13

Note. Series: Interest Rate, Log Real Exchange Rate, Log GDP
Trace test indicates no cointegrating eqn(s) at the 0.05 level,
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values.

Impulse Response Functions. Figure 1 shows the impulse response functions (IRFs) of the response of interest rate, real GDP and real exchange rate to oil price shocks. With regard to the response of monetary policy to an oil price shock, from the IRF, it can be observed that a positive shock to oil prices does not have a significant effect on the interest rate (monetary policy). This suggests that the Central Bank of Nigeria does not respond to positive oil price shocks by changing the level of the interest rate. This implies that oil price shocks affect macroeconomic variables directly but not through monetary policy.

For the real effective exchange rate, there is a positive response up until the 7th quarter after which there is a negative response for the rest of the entire period to a positive oil price shock. This response is however insignificant over the entire horizon.

From the IRF, it can be observed that a positive shock to oil prices has an initial positive and then negative but insignificant effect on the real GDP. This result shows that positive oil price shocks have no effect on economic activity in Nigeria.

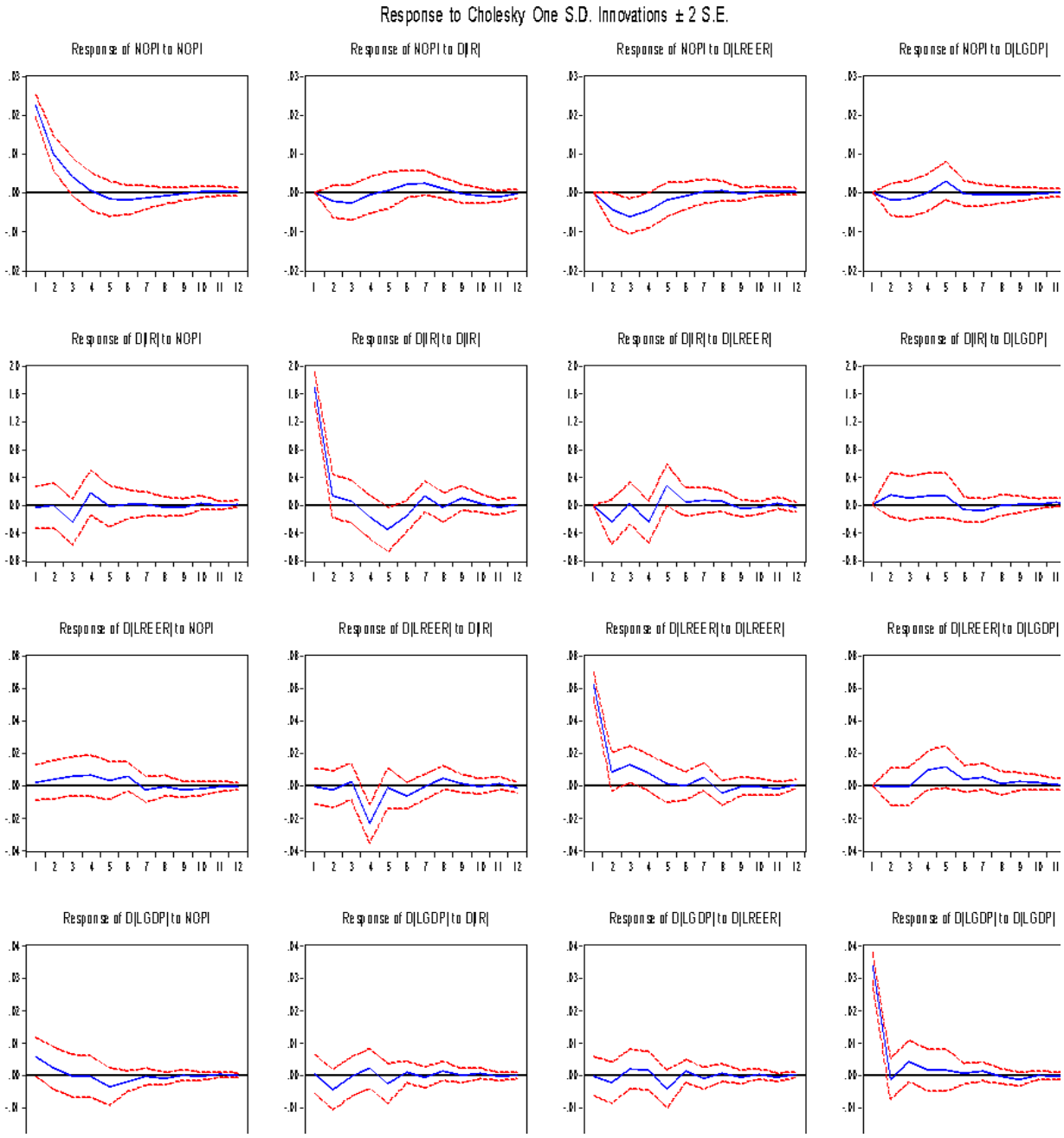

Figure 1. Impulse Response Function.

Variance Decomposition. The variance decomposition helps in explaining how much the forecast error variance of a particular variable is explained by variations in the other variables and the variable itself. Table 3 presents the VDCs. The results show that the real GDP, real effective exchange rate and interest rate solely and strongly account for their own fluctuation through the period when oil price shocks have a 0 - 1.46 percent, 0 - 1.36 percent and 0 - 3.5 percent influence on all three variables respectively from the 1st - 12th quarters.

Table 3
Variance Decomposition

Period	DLGDP	DLREER	DIR	NOPI
Variance decomposition of DLGDP:				
1	100.00	0.00	0.00	0.00
4	96.05	0.21	2.40	1.35
8	95.22	0.30	3.05	1.43
12	94.94	0.31	3.29	1.46
Variance decomposition of DLREER:				
1	0.03	99.97	0.00	0.00
4	2.18	83.03	14.29	0.50
8	2.50	78.94	17.33	1.23
12	2.74	77.20	18.70	1.36
Variance decomposition of DIR:				
1	0.48	0.61	98.92	0.00
4	9.01	7.82	79.47	3.70
8	14.45	12.55	69.56	3.44
12	18.21	15.75	62.54	3.50
Variance decomposition of NOPI:				
1	3.10	0.10	0.01	96.79
4	2.08	1.57	1.43	94.93
8	1.56	1.32	0.98	96.14
12	1.43	1.25	0.87	96.45

Interest Rate (IR), Log Real Effective Exchange Rate (LREER), Log Real GDP (LGDP), Net Oil Price Increase (NOPI), Diff Interest Rate (DIR), Diff Log Real Effective Exchange Rate (DLREER), Diff Log Real GDP (DLGD).

Conclusion and Policy Implications

This paper examines the effects of oil price shocks on interest rate, real GDP and real effective exchange rate in Nigeria using a vector autoregressive (VAR) model. The results from the impulse response function suggest that positive oil price shocks have no effect on the interest rate (monetary policy), real exchange rate and real GDP. This result suggests that the monetary

policy in Nigeria does not response to oil price shocks. Both the impulse response functions and variance decomposition analysis to a large extent confirmed that oil price shocks are only able to explain a small proportion of the forecast error variance of the variables under consideration. Oil price shocks, as revealed by variance decomposition, accounted for less than 4 percent of the variations in the GDP, real effective exchange rate and interest rate. Hence, I find evidence of a muted effect of oil price shocks on the Nigerian economy. Although a policy of diversification is usually recommended for economies that depend solely on oil revenue, the applicability of such an option appears unclear from what has been found in the case of Nigeria.

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