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Oil price shock and macroecomomic aggregates: Empirical evidence from Nigeria using the structural vector autogregressive (SVAR) approach

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Abstract. The continual fluctuation in oil price has continued to be a source of concern for economists and policymakers, both in Nigeria and abroad, given its sudden implications on existing and future policy plans as well as on some macroeconomic indicators. The Nigerian economy is an oil-dependent one and has about 90% of its export earnings come from oil and so is highly vulnerable to the sudden changes in oil prices either positive or negative. This paper evaluates the relationship between this unanticipated changes in oil price and some selected macroeconomic aggregates in Nigeria using the structural vector autoregressive (SVAR) methodology while employing its impulse response functions, to further explore the impact of oil price shock on the Nigerian economy over different time period. The SVAR result shows that oil price shock has a negative impact on all of the selected macroeconomic indicators such as economic growth, import, investment, inflation, and the exchange rate except export in the long term. Furthermore, the impulse response functions shows that the response of all selected macroeconomic indicators in this study to oil price shock were mixed but mostly negative over a time period of 12 months. The ADF unit root test confirmed that all series were stationary at I(1) only except inflation rate which was I(0) and I(1). The autocorrelation LM and White heteroscedasticity test confirms the non-rejection of the null hypothesis concluding that the residuals from the SVAR model were not serially correlated and homoscedastic. Based on the findings the study recommended the diversification of the economy to other key sectors such as agriculture and mining to help reduce the over-reliance on crude oil earnings also, measures should be taken to lower the cost of production for crude oil per barrel to minimize the impact of oil price shock on macroeconomic indicators.
Keywords. Oil price shock, Macroeconomic indicators, SVAR Models, GDP, Impulse Response, Exchange rate, Inflation.
JEL. C32, E30, F41.

1. Introduction

Oil price shock can be defined as the unplanned and sudden fluctuation in price which might be a result of changes to the supply or demand side of the global oil market. Oil price has witnessed large fluctuations over the years, studies from the past decade

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show that crude oil price increased on average from $25 per barrel in 2002 to $55 per barrel in 2004 Awe (2002), in recent time this upward steep in price have been recorded to achieve a nominal high of US $147 in 2005 and declined sharply to $87 in 2012, and $46 per barrel since 2014 to $41.95 in 2016 (Ben, Abayomi, & David 2016).

Over the past years, the economic relevance of this changes in oil prices has been analyzed by many researchers and studies have shown that continuous oil shock has a significant impact on macroeconomic indicators and also influences policymaking decisions in both oil-exporting and oil-importing countries over the past years (Kim & Loughani, 1992; Taton, 1998; Mork, 1994; Hooker, 1996; Hamilton, 1996; Olomola, 2006). In more recent times, crude oil price has declined rapidly in response to the coronavirus pandemic and in addition to the lack of consensus between the OPEC and its allies production cut which led to a sharp drop in the demand for oil with the price reaching below $30 per barrel. Meanwhile, oil prices have started to rebound owing to the gradual easing of lockdown globally and recent OPEC production-cuts.

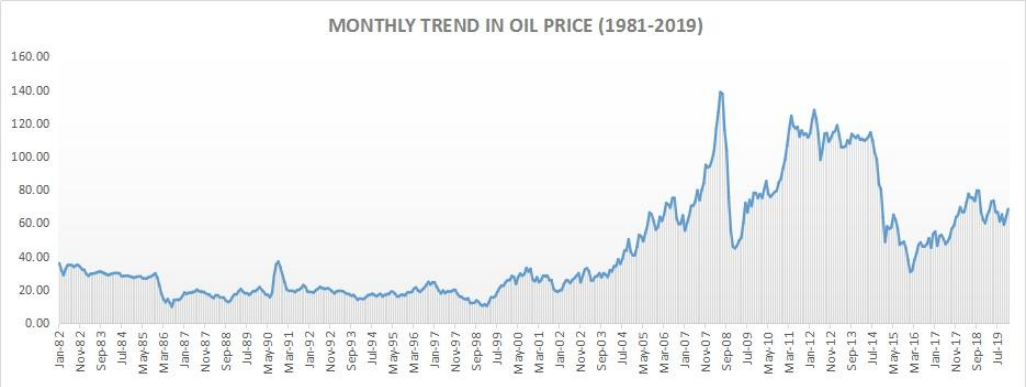


Figure 1. *Monthly trend in oil price (1981-2019).*

Nigeria has the 6th largest producer of crude oil, and a major exporter as well is highly in peril to the sudden changes in oil price given the nature of the economic structure and the fact that Nigeria relies heavily on crude oil export earnings. Nigeria depending on returns from oil indirectly means, banking on the agreement and decisions of other countries to run its economy as the behavior in oil is highly determined by the Organization of the Petroleum Exporting Countries (OPEC) which constitutes of members of major oil-exporting countries and other exogenous factors; global demand and supply, lack of spare refining capacity, lack of sufficient spare production capacity as well as the nonlinear relationship between oil price and supply (Dees, *et al.*, 2008), this sudden changes in oil price do not only affect the economic performances but also leads to uncertainty in economic decision making (Lee *et al.*, 2017). To prepare for this uncertainty several measures need to be taken to understand the behavior of oil shock on certain macroeconomic variables to be able to reduce the negative effect of the sudden changes.

Studies have shown that while an increase in oil price has a negative impact on oil-importing countries, the effect on exporting countries have shown to be positive, while the difference is eventually even out by the law of demand. That is an increase in crude oil prices will lead to an increase in oil revenue for exporting countries but the increase in price will have a counter-effect on oil-importing countries as it will lead to a decrease in demand of crude oil from the importing countries thereby reducing the revenue earned from crude oil by exporting countries. Empirical findings have also shown over time how Nigeria's GDP fluctuates positively to changes in oil prices (Aliyu, 2009; Chuku & Sam, 2010; Umar & Abdulhakeem, 2010).

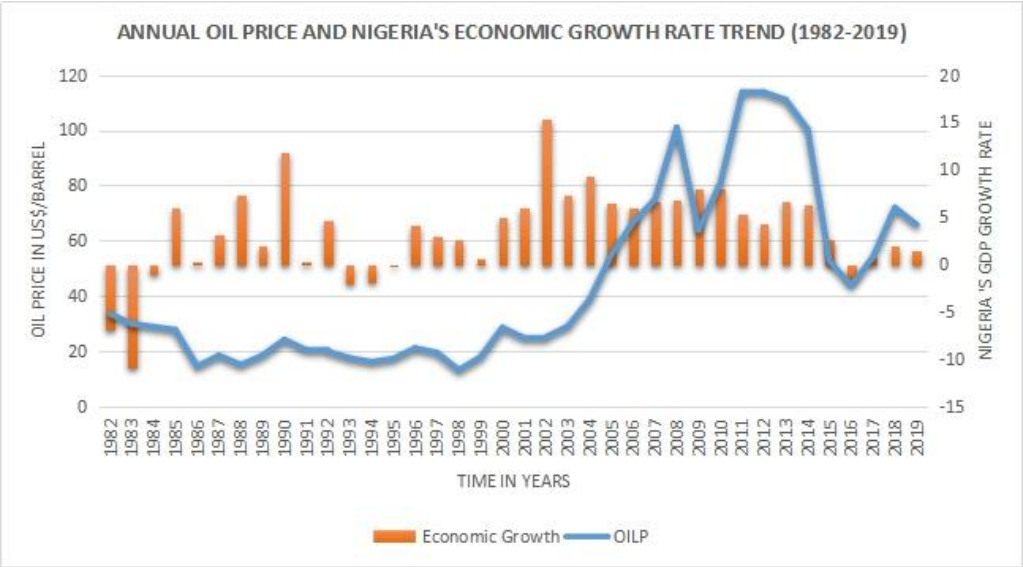


Figure 2. *Annual oil price and Nigeria's economic growth rate trend (1982-2019)*

Plunging the Nigeria economy into recessions at various time over the past years while leaving the country with a huge budget deficit problems since Nigeria is an oil dependence country (Babajide & Soile 2015).

This study is motivated as a result of Nigeria's vulnerability to changes in oil price, with returns from oil exports covering on average about 70 percent of government revenue in annual budgets which has several implications for the Nigerian economy. Therefore, it becomes imperative to consider the implication of sudden reaction in oil prices on some selected macroeconomic aggregates. Thus, the primary objective of this paper is to investigate the impact of unanticipated changes in oil prices on Nigeria's economic growth, exchange rate, inflation rate, investment expenditure, import, and export.

2. Literature review

Over the past years, several scholars have explored the relationship between oil shock price and macroeconomic variables performance on economic growth. Different methods of analysis have been used and each

have yielded different results. Most of the earliest studies on the relationship between oil price shocks on macroeconomic variables concentrated on the developed economy. Hamilton (1983) cited in Ozturk (2015) found that there is a negative relationship between oil price fluctuation and economic growth of the United States economy. Hooker (1994) found that between the period 1948 and 1972 variation in oil prices reflected negatively on GDP growth for the United States, he analyzed that a 10% increase in oil price led to a reduction in GDP growth estimation of 0.6% during the third and fourth quarter succeeding the shock. Cavalla & Wu (2006) also carried out research using a VAR methodology containing three main macroeconomic variables; oil price, GDP, and inflation rate to determine the effect of oil price shock on the output of the United States economy, the model showed a positive relationship indicating that output declined and prices escalated after an oil price shock. Rodriquez & Sanchez (2004) also applied linear and nonlinear methods to the effect of oil price shock on main industrialized countries US, Germany, France, Italy, Norway, Canada and the UK and found positive evidence of price increase effects of oil price shocks on GDP growth than that of price decrease. Recently there has been a growing concern over the effects of oil price shock on less developed economies given their dependence on oil export, some empirical findings have claimed that oil price shock is associated with varying impacts on these countries. Ayadi *et al.*, (2000) carried out a research using a VAR model on some macroeconomic variables; oil production, real exchange rates, inflation, interest rates, output for 1975-1992 in Nigeria, the impulse response of the research showed that positive oil production was followed by a rise in output depreciation of domestic currency and reduction in inflation. Mehrara (2006) found that oil price shock have a significant impact on the economies of Iran and Saudi Arabia but found no significant impact between oil shock prices and the economies of Indonesia and Kuwait. Wakeford (2006) evaluated the impact of oil price shock on South Africa macroeconomic variables and found that while commodity exports- specifically gold provided an initial support, in the long run, the economy is still highly vulnerable to oil shock prices. Olomola (2006) examined the impact of oil price shocks on macroeconomic variables; output, inflation, real exchange rate and money supply in Nigeria with VAR framework using quarterly data from 1970 to 2003 and found that oil price shocks do not affect output and inflation. However, money supply and exchange rates were found to be significantly affected by oil price shocks. Also, for Nigeria Akpan (2009) studied the asymmetric effects of oil price shocks on the Nigerian economy and found that a positive and significant relationship exists between positive oil price changes and real government expenditure. She also showed that the impact of oil price on industrial output growth was found to be marginal with the significant appreciation of the real exchange rate. Aliyu (2009) used a nonlinear approach to investigate the relationship between oil price shock and macroeconomic variables and macroeconomic activity for the Nigerian

economy he used both linear (asymmetric and net specifications) and non-linear specifications of oil price shocks as well as various test (Wald tests, granger causality and VAR) the research finds evidence for both shocks on real GDP. Adeniyi *et al.,* (2011) study the relationship that exists between oil price shocks and economic growth using threshold autoregressive model with a quarterly data from 1985-2008 through the non-linear model. The result shows that oil price shocks account for a minimal proportion of the movement in macroeconomic variables. Ben *et al.,* (2016) estimated the effects of oil price shock on macroeconomic performance using yearly data spanning 1979-2014 with various test (Johansen co-integration technique, variance decomposition test, granger casualty test, and Vector Autoregressive (VAR) technique to examine the speed of adjustment of the variables (oil price changes, inflation rate, GDP, and real exchange rate) from short-run dynamics to long run. The result that a proportionate change in oil price leads to a more than proportionate change in real exchange rate, interest rate, and GDP in Nigeria.

3. Theoretical framework, data and methodology

3.1. Theoretical framework

The impact of shock to oil price on macroeconomic aggregates can be explained using the basic demand and supply channels. From basic economic theory, the effect of changes in price on economic activity can be shown using the demand and supply channels. This further reinstate the importance of the demand and supply theory to explaining the impact of crude oil price changes. The theory of production will be used to explore the supply side while the theory of consumer demand will be used to analyse the demand side. Oil can typically be taken as an important input in production in an economy. From the demand side, there are different factors that can influence the demand for crude oil which includes crude oil price, population and consumer income. If there is an increase in the price of oil, the demand for oil is expected to increase. On the other hand, this will raise the cost of production of firms thereby negatively impacting firms productivity, revenue and profitability. Increased crude oil price can also result in inflationary pressures on the economy thereby reducing aggregate demand for commodities. This can be further analysed with a neoclassical production function. The standard way to present this argument (Hamilton, 2005) is a simple Cobb-Douglas model of a representative form with the following production function:

$$Y = F(L, K, E)$$

Where L is labor, K is capital, and E is energy input with output Price 'P', wage 'W', capital rent 'r', and the nominal Price of energy 'PE'.

$$\pi = R\text{-}C \text{ (Profit= revenue – cost)}$$

Revenue (R) = P . X

Cost (C) = wL + rK + PE

π=P.X - wL - rK - PE (Profit= price of product. Quantity minus wage of labor minus rent of capital minus price/cost of energy or power supply)

Supply side channel

Since oil is an important element of factor of production of most industries, changes in oil prices will significantly impact these firms production costs. Furthermore, a rise in crude oil price will directly result in an increase in cost of production which could translate to contraction of the firms output and a rise in the price of final output. Also, according to Patti & Ratti (2007), increase in input costs can drive down non-oil potential output supplied in the short run given existing capital stock and sticky wages. In addition, increasing oil price will lead to decline in real wages, raise labour cost of industries and reduce profit margin. Meanwhile, to an oil exporting country, increase in oil price in the global market will raise export revenue from oil, positively impact external reserves, balance of payment and may also be favourable for exchange rate stability.

Demand Channel

The effect of oil price changes on aggregate demand will be through its effect on commodity prices. From the supply side analysis, a rise in oil price is expected to drive up cost of production which will be transmitted to the commodity prices by producers. Commodity prices will also trend higher thereby decreasing the demand for basic non-oil items. Consumer expenditure will decrease which will in turn negatively impact aggregate demand. In summary, an increase in oil prices causes a leftward shift in both the demand and supply curve, resulting in higher prices and lower output. Moreover, Many researchers such Aliyu (2009), Hamilton (2005) etc have argued that the dangerous economic effects of oil-price hikes may be substantially stronger than the favorable economic effects of oil-price declines.

3.2. Methodology

This paper uses the structural vector autoregressive (SVAR) methodology using the data that ranges between 1981M01 and 2019M12 which contains 468 monthly observations. We use the Gross Domestic Product, Official Exchange Rate, Inflation Rate, Import, Export and Investment Expenditure series for our analysis. Some variables were annual time-series data, however they were disaggregated using quadratic low to high frequency method. The description and source of data are presented in Table 1 below:

Table 1. *Description and source of data*

Variable	Full Name	Description	Source
OILP	Brent Oil Price	UK Brent Oil Price in US dollar per barrel	CBN Statistical Database
GDP	Nominal GDP	Nigeria GDP in billion Naira	WDI
INV	Investment Expenditure	INV proxied with gross fixed capital formation in billion naira.	WDI
EXPORT	Value of Nigeria's Export	Value of Nigeria's Export in local currency units.	WDI
IMPORT	Value of Nigeria's Import	Value of Nigeria's Import in local currency units.	WDI
INFR	Annual Inflation rate	Year-on-year inflation rate for Nigeria in Percentage	CBN Statistical Database
EXR	Official Exchange rate	CBN Official Exchange rate in N/$	

In order to determine the effect of shock in oil price on these variables, we use the SVAR model which includes oil price and some other macroeconomic variables such as gross domestic product (GDP), investment expenditure (INV), EXPORT, IMPORT, inflation rate (INFR) and exchange rate (EXR). The SVAR model can be specified thus:

$$Bx_t = \Pi_0 + \sum_{i=1}^{n} \Pi_i x_{t-i} + \varepsilon_t$$

x_t = (OILP, GDP, INV, EXPORT, IMPORT, INFR, EXR) is a 7 X 1 vector of endogenous variables.

B = represents the 7 X 7 contemporaneous matrix

Π_0 = vector of constant terms

Π_i = 7 X 7 autoregressive coefficient matrices

ε_t = 7 X 1 vector of serially and mutually uncorrelated structural innovations.

$$x_t = \Pi_0 B^{-1} + \left(\sum_{i=1}^{n} \Pi_i x_{t-i} \right) B^{-1} + \varepsilon_t B^{-1}$$

Let $e_t = \varepsilon_t B^{-1}$

We can however estimate vector of structural shocks ε_t as well as responses to these shocks x_t when elements of B^{-1} are estimated (Ahmadi, *et al.*, 2016, Zerrin & Yasemin, 2017). Following Kilian (2009), Kilian & Park (2009), and Zerrin & Yasemin (2017), we decompose the error terms implied by reduced-form VAR using the representation $e_t = \varepsilon_t B^{-1}$;

$$e_t = \begin{bmatrix} e_t^{oilp} \\ e_t^{exr} \\ e_t^{infr} \\ e_t^{import} \\ e_t^{export} \\ e_t^{inv} \\ e_t^{gdp} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{12} & a_{22} & 0 & 0 & 0 & 0 & 0 \\ a_{13} & a_{23} & a_{33} & 0 & 0 & 0 & 0 \\ a_{14} & a_{24} & a_{34} & a_{44} & 0 & 0 & 0 \\ a_{15} & a_{25} & a_{35} & a_{45} & a_{55} & 0 & 0 \\ a_{16} & a_{26} & a_{36} & a_{46} & a_{56} & a_{66} & 0 \\ a_{17} & a_{27} & a_{37} & a_{47} & a_{57} & a_{67} & a_{77} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{oilp} \\ \varepsilon_t^{exr} \\ \varepsilon_t^{infr} \\ \varepsilon_t^{import} \\ \varepsilon_t^{export} \\ \varepsilon_t^{inv} \\ \varepsilon_t^{gdp} \end{bmatrix}$$

4. Empirical results

4.1. Unit root test

Most macroeconomic series are often non-stationary at level which necessitates the need to conduct a unit-root test on the series used for this study. The ADF unit root test was adopted.

Table 2. *ADF Unit Root Test Result*

VARIABLES	ADF Unit Root Test		Order of Integration
	Level	First Difference	
OILP	0.4829	0.0000	I(1)
GDP	0.8631	0.0063	I(1)
INV	0.5775	0.0212	I(1)
EXPORT	0.8459	0.0000	I(1)
IMPORT	0.8355	0.0000	I(1)
INFR	0.0479	0.0000	I(0) and I(1)
EXR	0.9908	0.0004	I(1)

The ADF unit root test result reveals that all the variables used by this paper were stationary at first difference only except inflation rate (INFR) which was stationary at level and first difference. This is because their probability values are less than the chosen level of significance (5%) thereby rejecting the null hypothesis of non-stationarity.

4.2. VAR model

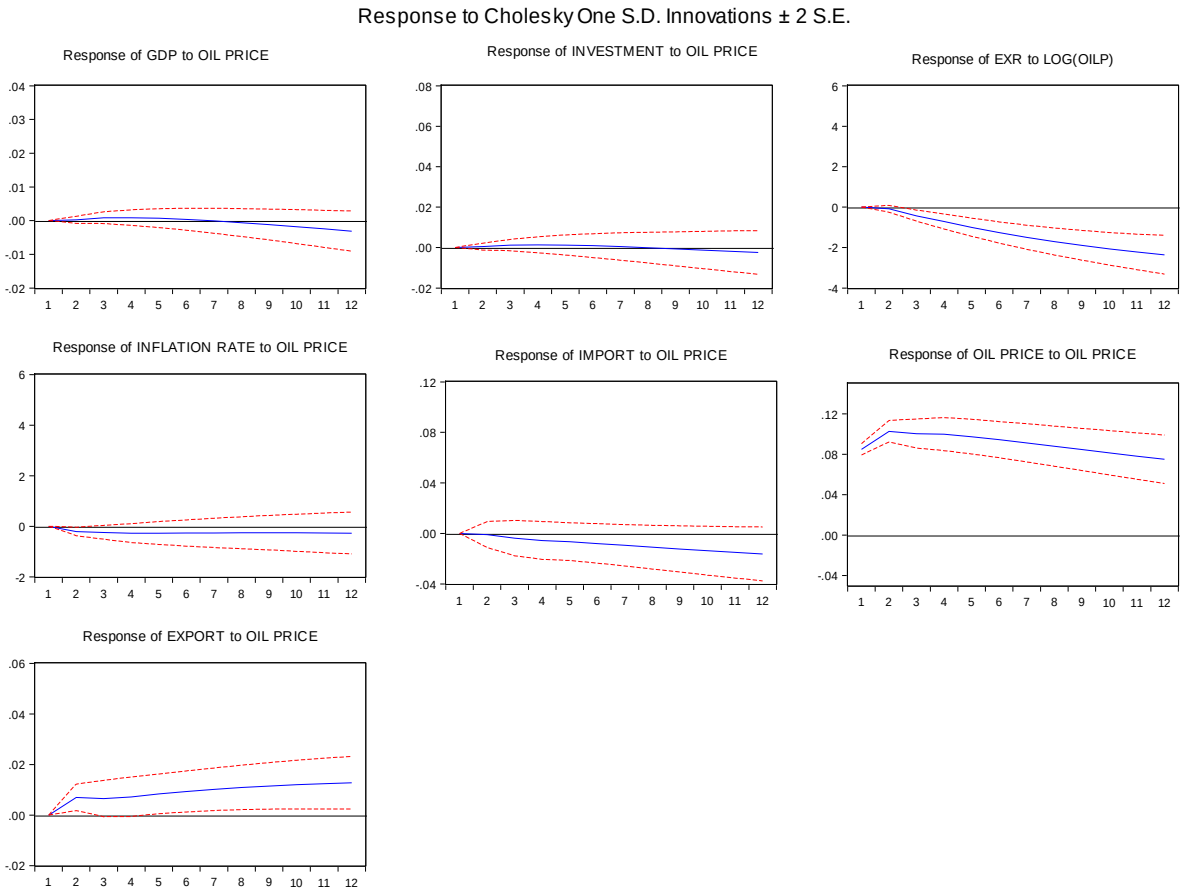
The coefficients in this matrix table was obtained from the impulse response functions tables for each endogenous variables. These sign and significance of these coefficients are indicative of the effect of oil price shocks on the macroeconomic aggregates employed for this study. The row values are independent variables, and column values indicate the effects of shocks on variables.

Table 3. *Long-term coefficients matrix from the impulse response functions*

	OILP	GDP	INV	EXPORT	IMPORT	INFR	EXR
OILP	0.081337*						
	(0.01095)						
GDP	-0.001811*	0.025425					
	(0.00251)	(0.00281)					
INV	-0.001254*	0.006079*	0.017234*				
	(0.00461)	(0.00541)	(0.00057)				
EXPORT	0.011995*	0.003008*	0.003469*	0.030165*			
	(0.00482)	(0.00479)	(0.00734)	(0.00490)			
IMPORT	-0.013779*	0.026271*	0.027520*	-0.00659*	0.058328*		
	(0.00967)	(0.00986)	(0.01464)	(0.00996)	(0.01098)		
INFR	-0.261602	1.355869	-0.252729	0.189645	0.403300	2.588019	
	(0.36604)	(0.41148)	(0.54763)	(0.36340)	(0.40032)	(0.28832)	
EXR	-2.063221	-1.092578	-0.133241	1.281365	-0.791061	0.209183	3.372851
	(0.40360)	(0.46349)	(0.59353)	(0.40889)	(0.38628)	(0.45092)	(0.45052)

According to the result in Table 3, the response of all the macroeconomic variables except inflation rate (INFR) and exchange rate (EXR) used in this paper are statistically significant. They were significant because the probability values were less than the chosen level of significance (5%). Meanwhile, the effect of oil price shock on all these variables is negative. This means that gross domestic product (GDP), investment expenditure (INV), value of export (EXPORT), value of import (IMPORT), inflation rate (INFR) and exchange rate (EXR) would respond negatively in Nigeria to any shock (increase or decrease) in oil prices. Specifically, this paper found out that oil price shock has a negative significant impact on the Nigerian economy. In other words, fluctuation in oil prices would have a negative and significant impact on the Nigerian economy and other macroeconomic indicators such as investment expenditure (INV) and international trade activities.

We are going to use the graphical representation of the impulse response functions to show the specific impact of oil price shock on the selected macroeconomic aggregates over time.



Graph 1. *Graphical representation of the impulse response functions*

Figure 1 reports the impulse responses of the oil price itself, economic growth (GDP), inflation (INFR), investment(INV), import (IMPORT), export (EXPORT) and official exchange rate (EXR) for one standard deviation (S.D.) innovations to oil prices based on the SVARs as the

endogenous variables for a time period of 12 months in Nigeria. The SVAR model does not only determine the effect of oil price shock on other variables but also on oil price itself. Crude oil price response to its own shock in Nigeria is positive over the 12 months period. The response of GDP to oil price shocks was negative initially and after fluctuating for a while turned negative after the 6th month period. Therefore, the impact of an oil shock on GDP appears was significant over the 12 months period. Like GDP, the response of investment also fluctuated between positive and negative for the 12 months' time period. More so, response of investment to shocks of oil price was positive till the 7th period and afterwards turned negative. Similarly, the response of oil price shock to export is positive and significant throughout the 12 months' time period. In contrast, the response of exchange rate and inflation rate to the shock in the price of oil is negative and significant up to the second period while its effect damped after the 2nd period to the 12th period. Also, import responded negatively to a shock in oil price in Nigeria over a period of 12 months.

4.3. Diagnostic test results

Table 4 shows the Autocorrelation LM and White heteroscedasticity test results for the SVAR residuals. Autocorrelation LM Test results suggest non-rejection of the null hypothesis of non-autocorrelation in the 3rd lag, that is, there is no serial correlation among the residual. According to White Heteroskedasticity Test, we do not reject null hypothesis in this model.

Table 4. *Serial correlation and heteroscedasticity test result*

Autocorrelation LM Test			White Heteroscedasticity Test	
Lags	LM-Stat	Prob	Chisq	1109.993
1	67.78668	0.0389	Df	1176
2	100.8054	0.0000	Prob	0.9152
3	23.55737	0.9992		

The null hypothesis is the absence of heteroskedasticity among the residuals of the VAR model. In summary, the results of the post-estimation tests suggest that residuals of the VAR model are not serially correlated and are homoscedastic. The lag lengths are determined based on SIC criteria and it is chosen to be 3.

5. Conclusion and recommendations

Nigeria relies heavily on energy for a huge chunk of its revenue as about 90% of Nigeria export earning comes from crude oil. This indicates how vulnerable Nigeria's macroeconomic indicators are to fluctuation in oil prices. Furthermore, oil prices are mostly determined by the demand from oil importing countries and supply of oil from oil exporting countries. This indicates how oil price changes is to Nigeria's economic performance. In addition, it is important to note that oil price fluctuations will negatively impact external reserves, exchange rate stability, economic growth, general

price level, export revenue and budget size of oil exporting countries. Recently Nigerian government initially revised its budget size downwards to N10.52 trillion from N10.59 trillion as a result of the drop in oil price. However the budget size has been revised again upwards to N10.81 trillion while oil benchmark now stands at $28pb owing to recent rebound in oil prices. This shows the significance of fluctuation in oil prices to the Nigerian economy. This paper empirically examines the effect of oil price shock on some selected macroeconomic indicators such as inflation rate, economic growth, exchange rate, import, export and investment expenditure. The empirical result from the SVAR analysis shows that oil price shock have a negative effect across macroeconomic aggregates used in this paper. Specifically, shock to oil prices have a negative impact on inflation rate, exchange rate and a significant negative impact on Nigeria's economy.

Based on the empirical findings, this paper recommends;

(1) In order to reduce the detrimental effect of oil prices fluctuation on macroeconomic variables, it is important to reduce the dependency on export earnings from oil by developing a medium and long term plan to diversify the economy to other key sectors such as agriculture and mining.

(2) Nigeria should also seek measures to lower its cost of production for crude oil per barrel to minimise the impact of fall in price of oil on macroeconomic indicators.

(3) The government should also heighten development in the power sector to decrease the dependency on crude oil products by households and businesses which forms the major proportion of demand for crude oil. This will result in the influx of more private investors and foreign capital inflows as well as improve economic welfare. This will make the country less vulnerable to any changes in the global oil market.

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