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A Vector Error Correction Modeling of Energy Price Volatility of an Oil Dependent Economy: The Case of Nigeria

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Abstract: This study examines the short run impact dynamics of energy price volatility on the macroeconomic performance in Nigeria. We employ six fiscal and monetary variables, which are: Gross domestic product, energy price (proxied by oil price), government expenditure, oil revenue, Money Supply (MS) consumer price index. All variables are expressed in their real form. The study scope ranges from 1970-2006. Having verified the stationarity status of the variables under consideration where, all are integrated after first difference, the study reveals that there exist at least three long run relationships among the variables. Consequently, the study employs the Vector Error Correction modeling, which focuses more on the short run behavior or responses of the variables to energy price volatility in Nigeria. Evidences from the result of VEC equations show that in the short run, oil revenue responds positively to a change in the energy (oil) price. It shows that 10% increase in the energy price brought about 79% increase in oil revenue, 45% increase in government expenditure, 17% increase in money supply, 11% decrease in CPI and 31% increase in GDP in the short run. Thus, the empirical results show how vulnerable the Nigerian economy is to the international energy price volatility.

Key words: Energy price, macroeconomic performance, vector error correction modeling, CPI, GDP

INTRODUCTION

Energy, which is seen as a critical input in many productive processes and thus, a very important causal factor of economic growth and development may be difficult to substitute for in the short run. It is not surprising, therefore, that the demand, supply and price of energy create a center of attention not only for the policy makers and various business firms but also the energy economists. Empirical investigation of energy price volatility and the macroeconomic adjustment in Nigeria is very crucial given the country's dependence on energy (oil) resource. Energy price volatility for instance has various implications on the macroeconomic activities through both demand and supply channels known as transmission mechanisms. The demand side effects are related to consumption and investment. Consumption is directly affected through its positive relation with disposable income. Given a substantial variability in energy price, both consumers' purchasing power and firm's incentive to invest may be influenced. On the other hand, the supply side effects relate to the fact that energy is a basic and vital input to production and consequently an upward trend in the price of energy leads to a rise in production costs, which eventually induces firms to lower output.

By simple economic theory we can easily trace the energy price volatility transmission mechanism in the economy (i.e., how unpredictable movements in energy price can affect the macroeconomic activities). Higher energy prices resulting can cause a temporary shift in the production function, thus, leading to decrease in real output. The decrease in real output, therefore, results in an excess demand for goods and an increase in the interest rate. Following this trend, the demand for real cash balances also reduces and with a given nominal quantity of money, the price level rises (Olomola and Adejumo, 2006).

Energy price volatility has a potential of affecting Nigeria's domestic economy, especially the fiscal and monetary sectors as the economy is oil dominant; therefore, proper examination of different channels of transmission between the external sector shock and the domestic economic performance becomes a very important issue for economic policy formulation and implementation in Nigeria. Although, Nigeria is trying hard to lessen its dependence on oil through the development of non-oil sector, its success, has so far been, at the best, very minimal following a significant and major role still being played by the oil sector. Although, different methods of analysis by various studies have yielded different results, the economic a priori expectation is that fluctuations in energy do significantly affect the aggregate economic activities.

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Nigeria, as one of the oil exporting developing economies whose economy is highly dominated by oil sector is susceptible to fluctuations in the international price of energy. In this trend of instability in the face of energy price fluctuations, evaluating the short run transmission mechanisms through, which international energy prices impact on real economic activities and analyzing the dynamic interrelationships among the selected macroeconomic variables become necessary as it helps in policy making for both private and government sectors.

This study is not only intended to fill this gap but also motivated by the findings that it was not the energy price volatility themselves but the monetary and fiscal policies responses to them that cause fluctuations in aggregate economic activities. While, different empirical studies have been able to investigate the long run relationship between energy (or oil) price volatility and macroeconomic response, it is of special interest to this study to examine the short run dynamics of energy price-economy interaction especially in an oil dependent open developing country-Nigeria.

Given that identifying the effects of systematic monetary and fiscal policies is central to understanding the dynamic response of the economy to energy price volatility, this study, though overlaps with and draws on the relevant aspects of the foregoing empirical studies, defines its scope differently. This study, by employing the Vector Autoregression (VAR) methodology investigates the short run dynamics between energy price volatility and other macroeconomic variables under consideration through the use of Error Correction Model.

Related empirical evidences: With the aim of examining the short run dynamics of energy price volatility and macroeconomic performance in Nigeria, this study briefly reviews some selected relevant literature from both the developed and developing countries.

For instance, Papapetrou (2001), examining the case of Greece and using a Vector Autoregressive (VAR) model, reports a negative effect of real oil price changes on the industrial production and employment.

Bellamy (2006) attempted modeling the macroeconomic impact of oil price shocks in South Africa using a VAR framework. He finds that the economy was fairly resilient in the face of shocks. Other studies are Bellamy (2006) and Jeremy (2006).

However, most of the studies carried out on the impact of energy (oil) price volatility on macroeconomic performance heavily concentrate on the oil importing countries mostly the developed ones with a very few ones on the oil exporting countries. But most recently, attention has now been shifted to evaluating energy price impacts in the oil exporting economies that are mostly developing.

To this end, Ayadi *et al*. (2000) study the effects of oil production shocks for Nigeria, as a net exporter of oil over the 1975-1992 periods. The study revealed the positive response of output after a positive oil production shock. Their results reveal that the impact response of output is <1/5th of that of oil production, but the response of output after a year is slightly larger than that of oil production. However, they notice that the response of inflation is negative after a positive oil production shock, to the extent that an oil price increase leads to an oil production increase. Therefore, the responses suggest that output increases; inflation decreases and the national currency depreciate following a positive oil-price shock.

Olomola and Adejumo (2006) examined the effect of oil price shock on the Nigerian macroeconomic activities using quarterly data from 1970-2003. The VAR method was employed to analyze the data. The findings were contrary to previous empirical findings in other countries. According to them oil price shock does not affect output and inflation in Nigeria. However, oil price shocks do significantly influence the real exchange rates. The study concluded with the implication that a high real oil price may give rise to wealth effect that appreciates the real exchange rate and may squeeze the tradable sector, giving rise to the Dutch Disease.

Rautava (2002) also, studied the effects of oil prices and exchange rates on the Russian economy using VAR methodology and co-integration techniques. He finds that in the long run a 10% permanent increase (decrease) in international oil prices is associated with a 2.2% growth (fall) in the level of Russian GDP. Respectively, a 10% real appreciation (depreciation) of the rouble is associated with a 2.4% decline (increase) in the level of output with significant short-run effects due to error-correction mechanism. He then concludes that international energy (oil) price volatility impacts on both the Russian domestic currency (rouble) and economic activities.

MATERIALS AND METHODS

Data definition and sources: With the aim of examining the short run dynamics of energy price volatility impact on the Nigerian economy, we employ the following variables: Gross Domestic Product (GDP), energy price (proxied by international oil price), government expenditure, oil revenue, Money Supply (MS) and Comsumer Price Index (CPI). All variables are expressed in the real forms. The data are sourced from the Central Bank of Nigeria (CBN) (2006) Statistical Bulletin and World Development Indicator (2007).

Econometric analytical procedure: In estimating the impacts of energy price volatility on the Nigerian macroeconomic performance, the following steps shall be followed:

Test for stationarity: That is, to investigate the existence of unit roots in the statistical series used in this study. The Augmented Dickey-Fuller and the Philip Perron Tests will be employed.

Test for cointegration among the variables: A vector of variables integrated of order one is cointegrated if there exists linear combination of the variables, which are stationary. Following the approach of Johansen and Juselius (1990) two likelihood ratio test statistics, the maximal eigenvalue and the trace statistic, would be utilized to determine the number of cointegrating vectors.

Estimation of vector error correction model: Having established a long run relationship among the variables, Vector Error Correction estimation helps to capture the short run dynamics of the model, therefore, a VECM will be formulated and estimated based on the earlier identified long run relationships.

Nigerian economy in the face of international energy price volatility: Nigeria is the 10th largest proven crude oil reserves country and also the 7th largest proven natural gas reserves country in the world. Its crude oil proven reserves as of Jan., 2007 amounted to 36.2 billion barrels, while that of proven natural gas reserves total 182 trillion cubic feet in the same period (World Energy Outlook, 2007).

Figure 1 and 2 reveal, the comparative natural resource endowment of Nigeria. With this, Nigeria has been playing a dominant and of course, prominent role in the world energy market. With the development of its oil sector in the 1960s and as a result of the increase in the global energy demand, Nigeria's energy export has been on the rise. Thus, Nigeria has greatly benefited both from exporting more energy commodities (oil and gas) in volume terms and from the improvement of its terms of trade due to the rise in prices of these commodities in the 2000's.

The trend in the international energy prices at least from 1970 till date has been one that is highly volatile. This volatility is mainly due to the global political and economic factors. Recently this volatility has been as a result of an increased oil and energy demand mainly by the "Asian tiger"-China.

Figure 3 shows, the crude oil price differential among the Nigerian Bonny Light (BL), United States West Texas Intermediate (WTI), Saudi Arabian Light (AL) and the

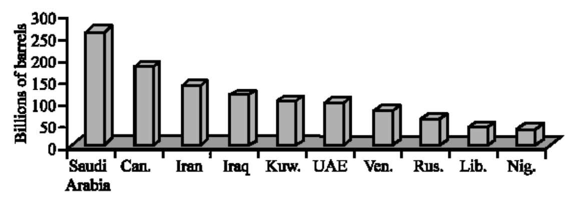

Fig. 1: Proven reserves of crude oil: nigeria and selected countries, Jan. 2007 (Billions of barrels)

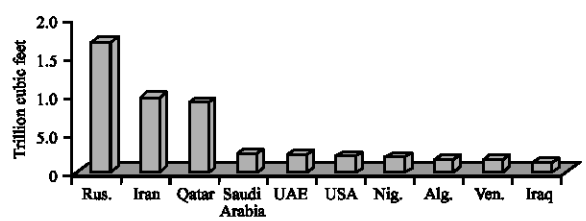

Fig. 2: Proven reserves of natural gas: Nigeria and selected countries, Jan. 2007 (Trillion cubic feet)

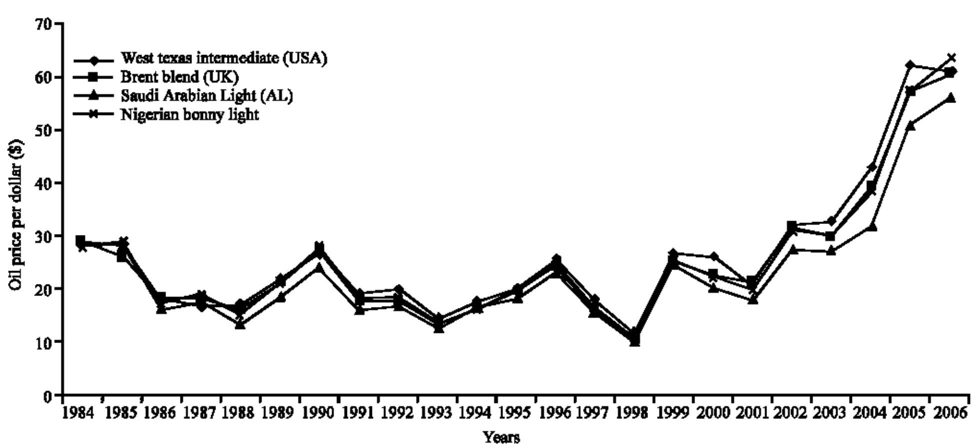

Fig. 3: Selected international crude oil prices (1984-2006)

U.K Brent Blend (B.B) between 1984 and 2006. The differential arises from different technical properties of crude oil in these selected countries. From Figure 3, it can be seen that the Nigerian crude oil price competes highly favourably when compared with other selected international oil prices. This therefore, signals the position, which reveals the relevance of the Nigerian crude oil in the international energy market.

RESULTS AND DISCUSSION

Measuring energy price volatility impacts for Nigeria: Energy price volatility is usually defined in terms of sharp and sudden rise or fall in the international price of oil. These may in turn emanate from changes in either the supply of or the demand for oil. In an attempt to examine the impacts of energy price variability on the macroeconomic performance in Nigeria, the diagram below (Fig. 4) depicts the major oil price shocks, among the various ones earlier mentioned, that impact significantly on the Nigerian economy. It is obvious from the diagram that the major oil price shock periods that impact significantly on the Nigerian economy are all positive, which are: 1979-1981, 1990, 2000 and 2003-2005 periods, respectively. These periods obviously are captured as being the most significant oil price shock periods as they both exceed or rise above the upper boundary.

Looking at the diagram below, the 1973-1974 oil price shock period, which though falls below the lower boundary, can still be identified as being a positive oil price shock period. Though, this shock cannot be compared with 1979-1983, 1990, 2000 and 2003-2005 periods in terms of magnitude, but can still be recognized as one of the significant oil price shock periods. The oil price trend shows the movement of oil price over time, while the mean of oil price equation equals 20.6. Given the standard deviation, which equals 7.2, the upper and lower boundary lines are calculated thus:

Upper boundary = Mean + 1(SD) = 20.6 + (7.2) = 27.8
Lower boundary = Mean - 1(SD) = 20.6 – (7.2) = 13.4

Unit root test: The aim here is to determine the underlying properties of the process that generate the time series variables employed in this research, that is whether, the variables in the model were stationary or non-stationary. The Augmented Dickey Fuller (ADF) and Phillip-Perron (PP) tests are used to test the order of integration of the variables. The results of the ADF and PP tests are presented in Table 1. Examination of test results in Table 1 shows that all the time series data employed in this work are stationary at first difference. The null hypothesis of two unit roots is rejected for all variables at the 5% significance level. Thus, the evidence suggests that first differencing is sufficient for modeling the time series considered in this study.

Cointegration result: The results of the trace and maximal eigenvalue test statistics are shown in Table 2. The test statistics indicate that the hypothesis of no cointegration, Ho, among the variables can be rejected. The results reveal that at least four cointegrating vectors exist among the variables of interest. Since, the variables are cointegrated, there is therefore, a long run relationship among the variables. It also means that the study can proceed to estimating the Vector Error Correction Model.

Vector error correction model specification: According to Granger's representation theorem, if there is cointegration there must exist Granger causality in at least one direction and therefore, one can reformulate the VAR into a VECM, in which error correction terms are included. Having found evidence supporting the existence of a cointegrating long run relationship among the variables under consideration, a Vector Error Correction (VEC) Model is estimated. A VEC Model is a restricted VAR, which has cointegration relations built into the

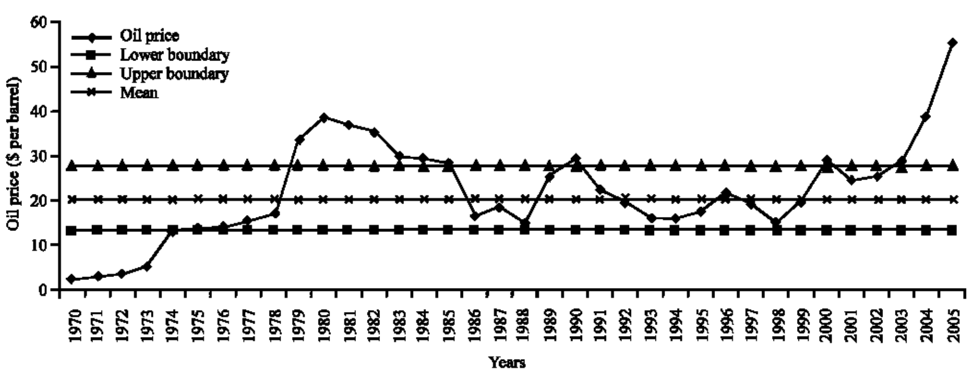

Fig. 4: Oil shocks and boundary limits

Table 1: Unit root test

	ADF				PP			
	Without trend		With trend		Without trend		With trend	
Variables	Level	FD	Level	FD	Level	FD	Level	FD
Oilp	-0.003	-4.616	-2.379	-4.587	-0.214	-4.616	-2.385	-4.593
MS	-0.995	-5.019	-3.111	-5.958	-1.244	-5.815	-2.091	-5.746
Oilr	-2.331	-6.148	-3.601	-6.015	-1.330	-6.23	-3.615	-6.077
Gexp	-0.110	-6.574	-2.516	-3.747	-0.271	-3.122	-1.910	-3.759
Cpi	-0.525	-3.297	-1.137	-6.446	-0.525	-6.188	-1.137	-6.446
Gdp	-2.852	-5.814	-2.849	-6.472	-2.766	-6.574	-4.593	-6.472

ADF: Augmented Dikey Fuller, PP: Phillip-Perron; FD: signifies First Difference

Table 2: Johansen cointegration test

Trace test (k = 2)					Maximum eigenvalues test (k = 2)				
			Critical values (%)					Critical values (%)	
H_O	H_A	(λ-trace)	5	1	Ho	H_A	(λ-max)	5	1
r≤0	r > 0	180.3**	124.2	133.6	r = 0	r = 1	63.8**	45.3	51.6
r≤1	r > 1	116.5**	94.2	103.2	r = 1	r = 2	46.2**	39.5	45.1
r≤2	r > 2	80.3**	68.5	76.1	r = 2	r = 3	37.6*	33.5	38.8
r≤3	r > 3	49.6*	47.2	54.5	r = 3	r = 4	30.8*	27.1	32.2

r-represents number of cointegrating vectors and k represents the number of lags in the unrestricted VAR model. *(**) denotes rejection of the null hypothesis at the 5 (1%) level

Table 3: Over parameterized short run vector error correction model

Variables	Equation 1 D(OILR)	Equation 2 D(GEXP)	Equation 3 D(MS)	Equation 4 D(CPI)	Equation 5 D(GDP)
CONSTANT	0.29 (2.53)	-0.71 (-0.05)	-0.12 (-3.01)	-0.08 (-2.04)	0.36 (0.25)
D(OILP(-1))	0.79 (2.56)	0.45 (1.99)	-0.02 (-0.12)	-0.16 (-1.34)	0.20 (1.28)
D(OILP(-2))	0.43 (1.96)	0.81 (0.17)	0.17 (1.98)	-0.11 (-3.56)	0.31 (3.17)
D(OILR(-1))	0.56 (2.11)	0.38 (2.56)	0.15 (2.01)	4.21 (3.12)	-0.19 (-1.99)
D(OILR(-2))	0.28 (1.08)	0.03 (2.67)	0.36 (2.13)	-0.17 (-2.22)	0.07 (0.09)
D(GEXP(-1))	0.45 (0.06)	-1.97 (-3.10)	-0.68 (-1.04)	0.16 (2.01)	2.48 (0.05)
D(GEXP(-2))	0.34 (2.57)	-0.29 (-1.65)	-0.04 (-2.19)	0.08 (0.01)	3.28 (3.00)
D(MS(-1))	1.84 (0.93)	-1.48 (-2.56)	0.33 (2.49)	0.38 (2.01)	0.35 (1.19)
D(MS(-2))	0.18 (1.56)	-0.09 (-1.23)	0.18 (1.96)	-1.72 (-4.32)	-1.66 (-2.10)
D(CPI(-1))	-0.03 (-1.99)	0.32 (2.78)	0.83 (1.09)	0.18 (2.05)	0.91 (1.32)
D(CPI(-2))	-0.80 (-0.05)	0.12 (1.73)	0.42 (3.26)	0.44 (3.89)	0.08 (4.21)
D(GDP(-1))	0.93 (0.77)	0.57 (2.44)	1.20 (0.64)	-4.12 -(2.16)	1.90 (2.48)
D(GDP(-2))	-0.09 (-4.28)	0.16 (1.01)	0.26 (3.12)	0.67 (0.78)	0.31 (2.04)
ECT(-1)	-0.19 (-1.99)	-0.37 (-4.45)	-0.25(-2.83)	-0.15 (-2.29)	-0.38 (-1.97)
R^2	0.77	0.95	0.87	0.91	0.81
Adj. R^2	0.72	0.92	0.86	0.89	0.78
F-stat.	261.08	174.45	118.63	56.39	371.10

Diagnostic tests: No. of observations = 33; Log-Likelihood = 223.8048; Vector Normality (LM) = Chi^2(8) = 11.890 (0.1562); Vector Heteroscedasticity (LM) = F(210,29) = 0.4383 (1.0000)

specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while, allowing for short-run adjustment dynamics. The cointegration term is known as the correction term since, the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. To capture, the short run dynamics of the model, a VECM is formulated based on the earlier identified long run relationships.

In this study, we specify the VECM as follow:

$$\Delta X_t = \mu + \alpha\beta' X_{t=1} + \sum_{j=1}^{k} \Pi_j \Delta X_{t-j} + \varepsilon_t$$

Let, X_t be a (p×1) vector of economic time series where, each contains a permanent shock component. Also, let Π jrepresents a (pxp) coefficient matrices (j = 1, …, k) and μ a (p×1) vector of constants including any deterministic components in the system, while α and β are (p×r) matrices. The error correction terms, $\alpha\beta' X_{t-1}$, are the mean reverting weighted sums of cointegrating vectors and data dated t-1. The matrix α is the matrix of error correction coefficients.

To capture the short run dynamics of the model, a VECM is estimated based on the earlier identified long run relationships. Error Correction Term, ECT(-1), from each cointegrating relation is included to capture the speed of

Table 4: Parsimonious short run vector error correction model

Variables	Equation 1 D(OILR)	Equation 2 D(GEXP)	Equation 4 D(MS)	Equation 5 D(CPI)	Equation 6 D(GDP)
CONSTANT	0.29 (2.53)	-0.71 (-0.05)	-0.12 (-3.01)	-0.08 (-2.04)	0.36 (0.25)
D(OILP(-1))	0.79 (2.56)	0.45 (1.99)	-	-	-
D(OILP(-2))	0.43 (1.96)	-	0.17 (1.98)	-0.11 (-3.56)	0.31 (3.17)
D(OILR(-1))	0.56 (2.11)	0.38 (2.56)	0.15 (2.01)	4.21 (3.12)	-0.19(-1.99)
D(OILR(-2))	-	0.03 (2.67)	0.36 (2.13)	-0.17 (-2.22)	-
D(GEXP(-1))	-	-1.97 (-3.10)	-	0.16 (2.01)	-
D(GEXP(-2))	0.34 (2.57)	-	-0.04 (-2.19)	-	3.28 (3.00)
D(MS(-1))	-	-	-	0.33 (2.49)	0.38 (2.01)
D(MS(-2))	-	-	0.18 (1.96)	-1.72 (-4.32)	1.66 (2.10)
D(CPI(-1))	-0.03 (-1.99)	0.32 (2.78)	-	0.18 (2.05)	-
D(CPI(-2))	-	-	0.42 (3.26)	0.44 (3.89)	0.08 (4.21)
D(GDP(-1))	-	0.57 (2.44)	-	-4.12 (-2.16)	1.90 (2.48)
D(GDP(-2))	-0.09 (-4.28)	-	0.26 (3.12)	-	0.31 (2.04)
ECT(-1)	-0.19 (-1.99)	-0.37 (-4.45)	-0.25 (-2.83)	-0.15 (-2.29)	-0.38(-1.97)
R^2	0.77	0.95	0.87	0.91	0.81
Adj. R^2	0.72	0.92	0.86	0.89	0.78
F-Stat.	261.08	174.45	118.63	56.39	371.1

adjustment to a disturbance in the long run equilibrium in the respective vectors. The results of the over-parameterised short run model are given in Table 3, while those of the parsimonious short run model are summarised in Table 4.

Here, the short-run dynamics for Nigeria are estimated using the error correction representation of the model that includes two lags for each of the first differences for the seven variables and the equilibrium error correction terms. Error correction coefficient can be treated as a mechanism, which ties the short-run behaviour to its long-run value. It simply shows the speed with which, the system converges to equilibrium. If it is statistically significant it shows what proportion of the disequilibrium in dependent variables in one period is corrected in the next period.

For instance, the oil revenue equation (Eq. 1) posits changes in real oil revenue, D(OILR), as a function of changes in its lag, the lags of oil price, price level (CPI), real output (GDP) together with one lag of Error Correction Term, ((ECT)-1). The Estimated Error Correction Term (ECT) in this equation has a right sign and is statistically significant, which is -0.19. This means that 19% of the discrepancy between the actual and the long-run, or equilibrium, value of real oil revenue is eliminated or corrected annually.

In the government expenditure equation (Eq. 2), apart from its own lagged value, only oil price, oil revenue, real output (GDP) and price level (CPI) appear to matter for short run growth of government expenditure. The estimated Error Correction Terms (ECT) in government expenditure follows the expected signs being significant. This shows that the speed of adjustment to the long run relationship in the equation is 37%. Moreover, the remaining equations, which are price level (CPI), Money Supply (MS) and real income (GDP) show the significance of oil price, oil revenue, government expenditure, Money Supply (MS), price level (CPI) and real income (GDP) in explaining changes in their respective equations in the short run. The result shows that the error correction terms (ECT) of these equations are significance and also rightly signed. They are -0.25, -0.15 and -0.38, respectively.

The main interest in this study is to look at how oil price shock impacts on other variables in the short run. Therefore, looking at the equations in the model, it can be seen that oil revenue responds positively to a change in the price of oil. It shows that 10% increase in the energy (oil) price brought about 79% increase in oil revenue, 45% increase in government expenditure, 17% increase in money supply, 11% decrease in CPI and 31% increase in GDP in the short run.

CONCLUSION

Energy price volatility whether, upward or downward is a development in the global economy that is posing a great challenge to different policy makers and researchers studying the stochastic nature of macroeconomic dynamics. And as one of the energy exporters, Nigeria has benefited both from exporting more crude oil in terms of volume and also from its improvement in its terms of trade due to the rise in oil price evidenced in a dramatic upward surge of government revenue from oil sector. This persistent oil price shocks could have severe macroeconomic implications and therefore, inducing several challenges for both fiscal and monetary policy making in the oil exporting as well as importing countries.

More specifically, energy price volatility is likely to affect Nigeria's domestic economy (more significantly in the short run) especially the fiscal and monetary sectors as the economy is oil dominant; therefore, proper examination of different short run channels of transmission between the external sector shock (energy price volatility) and the domestic economic performance becomes a very important issue for economic policy formulation and implementation in Nigeria. This study, though builds on various empirical studies concentrated on examining energy (oil) price volatility, however aims at investigating the short run dynamic impacts of energy price volatility on the Nigerian economy. Both fiscal and monetary variables are employed. The result of unit root test suggests that the variables are I(0) series. Again, the variables exhibit long run relationship as evident in the cointegration test result.

Since, our aim is to investigate the short run dynamics of the economy in the face of energy price volatility, this study specify a Vector Error Correction (VEC) model, which includes the following variables: Gross Domestic Product (GDP), energy price (proxied by oil price), Money Supply (MS), government expenditure and Consumer Price Index (CPI). Short run dynamic evidences from the result of VEC equations show that oil revenue responds positively to a change in the energy (oil) price. It shows that 10% increase in the energy price brought about 79% increase in oil revenue, 45% increase in government expenditure, 17% increase in money supply, 11% decrease in CPI and 31% increase in GDP in the short run. Thus, the empirical results show how vulnerable the Nigerian economy is to international energy price volatility.

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