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Macroeconomic Impact of Oil Price Levels and Volatility in Nigeria

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Abstract

This study investigates the time-series relationship on the impact of oil price volatility on macroeconomic activity in Nigeria using exponential generalized autoregressive conditional heteroskedasticity (EGARCH), impulse response function and lag-augmented VAR (LA-VAR) models. We found evidence that there is a unidirectional relationship exists between the interest rate, exchange rate and oil prices, with the direction from oil prices to both exchange rate and the interest rate. However, a significant relationship between oil prices and real GDP was not found.

Our results suggest a potentially important role for energy prices in future research on exchange rate modelling.

Keywords: Oil Price Volatility, Egarch Model, La-Var Model, Granger Causality

Introduction

The price of oil attracts a considerable degree of attention for many decades. Various attempts have been undertaken to explain the behaviour of the oil price as well as to assess the macroeconomic consequences of oil price shocks. The price oil oscillating between $17 and $26 at different times in 2002 hovered around $53 per barrel by October 2004 and moved further to $55 in 2005. By July 2008, the price of oil rocketed to a record $147 per barrel and thereafter, a sharp drop to US $46 a barrel. In fact, the price of oil has witnessed profound fluctuations since 1974. Persistent oil shocks could have severe macroeconomic implications, thus inducing challenges for policy making - fiscal or monetary in both the oil exporting and oil importing countries over the past three decades (Kim and Loughani, 1992; Taton, 1988; Mork, 1994; Hooker, 1996; Caruth, Hooker and Oswald, 1996; Daniel, 1997; Hamilton, 1996; and Cashin et al 2000).

Policymakers are therefore concerned with oil price levels and large movements in oil prices. Nigeria despite being the 6th largest producer of oil in the world, is highly vulnerable to fluctuations in the international oil market. This is given the fragile nature of the Nigerian macro economy and the heavy dependence on crude oil proceeds.

Theoretically, an oil-price increase leads to a transfer of income from importing to exporting countries through a shift in the terms of trade. The magnitude of the direct effect of a given price increase depends on the share of the cost of oil in national income, the degree of dependence on imported oil and the ability of end-users to reduce their consumption and switch away from oil. It also depends on the extent to which gas prices rise in response to an oil-price increase, the gas-intensity of the economy and the impact of higher prices on other forms of energy that compete with or, in the case of electricity, are generated from oil and gas. Naturally, the bigger the oil-price increase and the longer higher prices are sustained, the bigger the macroeconomic impact (Majidi, 2006).

Literature Review

In this section of the study we shall consider the research work which was carried out by the different researchers. Hamilton, Bruno and Sachs (1982 and 1983) had the study that the effects of oil prices volatility on economic growth, development and inflation in case United Kingdom. The result has shown that there is significant relationship among the variables. They used the quarterly data between the periods of 1950 to 1979.

The volatility of oil prices was examined in comparison with volatility of other commodities by a number of authors (Pindyck, 1999, Regnier, 2007). In particular, Pindyck (1999) examined oil, coal, and natural gas over a long horizon and found that oil presented the highest degree of volatility. More generally, it has been proven by Regnier (2007) that oil price volatility is relatively high compared to volatility of other commodities. Another area of research is dealing with the relationship between oil price volatility and stock prices. Huang et al. (1996) finds that daily changes in oil price volatility do impact the daily stock prices of oil companies, but there is little impact on the broad stock market. Sadorsky (1999, 2003) estimates vector autoregressions with monthly data on industrial production, interest rates, oil prices, and stock prices and finds that oil price volatility does have a significant impact on stock price volatility. Oberndorfer (2009) focuses on effects of energy market developments on the energy stock market of Eurozone.

Duffie and Gray (1995) construct in-sample and out-of-sample forecasts for volatility in the crude oil, heating oil, and natural gas markets over the period May 1988 to July 1992. Forecasts from GARCH(1,1), EGARCH(1,1), bi-variate GARCH, regime switching18, implied volatility, and historical volatility predictors are compared with the realized volatility to compute the criterion RMSE for forecast accuracy. They find that implied volatility yields the best forecasts in both the in-sample and out-of-sample cases, and in the more relevant out-of-sample case, historical volatility forecasts are superior to GARCH forecasts.

Burbidge and Harrison (1984) examine the impact of oil price shocks on some macroeconomic variables in the U.S.A., Canada, U.K., Japan and Germany. Using VAR models they show that the 1973-74 oil embargo explains a substantial part of the behavior of industrial production in each of the countries examined. They reach the same conclusions as in Hamilton’s work. However, for the oil changes in 1979-80 they find little evidence that the changes in oil prices have an effect on industrial production. The existence of an asymmetric relationship between oil price changes and economic output was studied by various researchers. Mork (1989) extends Hamilton’s analysis, by including the oil price collapse of 1986. He confirms

Hamilton's (1983) results by finding that a strong, negative correlation between oil price increases and the growth of GNP for the United States persists when the sample is extended beyond the 1985-86 the decline of oil price. Moreover, the coefficients on oil price increases and oil price decreases were significantly different from each other indicating that the effects if oil price increases and decreases were asymmetric.

Cunado and de Gracia (2005) study how oil price shocks affect the growth rate of output of a number of developed countries employing alternative regime switching models. The findings of their analysis show that positive oil price changes, net oil price increases and oil price volatility have an affect on output growth.

Cologni and Manera (2009) using a Markov-switching analysis for the G-7 countries show that positive oil price changes, net oil price increases and oil price volatility tend to have a greater impact on output growth. Moreover, their analysis suggests that the role of oil shocks in explaining recessionary episodes have decreased over time. Finally, they conclude that oil shocks tend to be asymmetric.

Morana (2001) uses the semiparametric approach that exploits the GARCH properties of the oil price volatility of Brent market. Narayan and Narayan (2007) apply exponential generalized conditional heteroskedasticity (EGARCH) model, which allows estimating two features of crude oil price volatility, namely asymmetry and persistence of shocks. Moreover, volatility iS examined over the full DATA sample and across the various sub-samples in order to analyze the robustness of results. The results state that the behavior of oil prices tends to change over short periods of time. Vo (2009) works with a concept of regime-switching stochastic volatility and explains the behavior of crude oil prices of WTI market in order to forecast their volatility. More specifically, it models the volatility of oil return as a stochastic volatility process whose mean is subject to shifts in regime. Kang et al. (2009) investigates the efficiency of a volatility model with regard to its ability to forecast for three crude oil markets (Brent, Dubai, andWTI). It was shown that the CGARCH and FIGARCH models are better equipped to capture persistence than are the GARCH and IGARCH models.

In summary, the relationships between oil price and macroeconomic variables have been examined in several developed and developing countries. In this study, we focus on whether these causal relationships exist in Nigeria. We analyze the relationships between oil price volatility and macroeconomic variable volatility based on the data of Nigeria from 1970 to 2009. Furthermore, we use an EGARCH model to estimate the volatility of the oil price and of macroeconomic variables. Moreover, the lag-augmented VAR (LA-VAR) approach is applied to investigate the causal relationships between oil price volatility and macroeconomic variable volatility.

This paper is organized as follows. Section 3 provides a description of the data used. Section 4 outlines the methodology of the EGARCH model and reveals the results of the estimation of the oil price volatility and macroeconomic variable volatility of Nigeria. In Section 5, we analyze the causal relationship between oil price volatility and macroeconomic variables volatility using LAVAR model. Finally, in Section 6, we present the conclusions.

Data

In this section of this study we analyze the variables as well as the nature and sources of the data which is used in this study. To represent the oil price (Nominal oil price), we chose the price index in US dollars of Bonny Light crude oil (*rop)*. The choice of the macroeconomic variables was difficult but important. Based on Fama’s (1981) hypothesis, the measure of economic activity and inflation is important for the analysis of oil price activity. So we selected the inflation rate (*inf*) as measured by the percentage changes of consumer price index; real effective exchange rate (*rexr*); real GDP (*rgdp*) defined as the nominal GDP deflated by the CPI; interest rate (intr) and government expenditure (*gex)*. The trend of the data is analyzed by DF, (Dickey Fuller), ADF (Augmented Dicky Fuller) and PP (Philip-Perron) unit root test and analysis the long run association among the variables with the help of Johansen co integration test. The oil price data which is used in this study is taken from International Monetary Fund and International Energy Agency websites. Data of key macroeconomic variables will be obtained from the central Bank of Nigeria (CBN) publications, National Bureau of statistics (NRS) and the World Bank publications. The annual data generated from 1970 to 2009 will be interpolated in order to capture real effect.

Methodology

In empirical analysis, heterosecdasticity is often associated with cross-sectional data, whereas time series are usually studied in the context of homoscedastic processes. However, in the analyses of macroeconomic data, Engle (1982) found evidence that for some kinds of data, the disturbance variances in time-series models were less stable than usually assumed. For instance, the uncertainty of stock market returns, which are measured using variance and covariance, changes over time. Thus, we should pay more attention to the heteroskedasticity when performing the time series analysis. For this problem, it is necessary to specify the variance dynamics (volatility).

Engle (1982) suggested the ARCH (autoregressive conditional heteroskedasticity) model as an alternative to the standard time series treatments. It is well known that a period of high volatility continues for a while after a period of increased volatility, a phenomenon called volatility clustering. The ARCH model takes the high persistence of volatility into consideration and so has become one of the most common tools for characterizing changing variance and volatility. This observation led Bollerslev (1986) to extend the ARCH model into the generalized ARCH (GARCH) model. The virtue of this approach is that a GARCH model with a small number of terms appears to perform as well as or better than an ARCH model with many terms. It is commonly thought that volatility is likely to rise during periods of falling growth and likely to fall during periods of increasing growth. However, neither the ARCH nor the GARCH model can capture this asymmetry. The exponential GARCH (EGARCH) model developed by Nelson (1991) can demonstrate the existence of asymmetry in volatility with respect to the direction of real growth. The EGARCH (p, q) model is given by

$$\log \sigma_t^2 = \omega + \sum_{i=1}^{p} \left(\alpha_i z_{t-i} + \gamma \left| z_{t-i} \right|\right) + \sum_{i=1}^{q} \beta_i \log \sigma_{t-i}^2 \qquad (1)$$

where $z_t = \varepsilon_t / \sigma_t$ and ε_t is an error term. Note that the left-hand side of equation (1) is the logarithm of the conditional variance. The logarithmic form of the EGARCH (p, q) model ensures the non-negativity of the conditional variance without the need to constrain the model's coefficients. The asymmetric effect of positive and negative shocks is represented by inclusion of the term z_{t-i}. If $\alpha_i > 0 (< 0)$ volatility tends to rise (fall) when the lagged standardized shock, $z_{t-i} = \varepsilon_{t-i} / \sigma_{t-i}$ is positive (negative).

The persistence of shocks to the conditional variance is given by $\sum_{i=1}^{q} \beta_i$. As a special case, the EGARCH (1, 1) model is given as follows

$$\log \sigma^2_t = \omega + \alpha_1 |z_{t-1}| + \gamma z_{t-1} + \beta_1 \log \sigma^2_{t-1} \quad (2)$$

For a positive shock ($z_{t-1} > 0$), equation (2) becomes

$$\log \sigma^2_t = \omega + z_{t-1}(\alpha + \gamma) + \beta_1 \log \sigma^2_{t-1} \quad (3)$$

whereas for a negative shock ($z_{t-1} < 0$), equation (2) becomes

$$\log \sigma^2_t = \omega - z_{t-1}(\alpha - \gamma) + \beta_1 \log \sigma^2_{t-1} \quad (4)$$

Thus, the presence of a leverage effect can be tested by the hypothesis that $\gamma_i < 0$. The impact is asymmetric if $\gamma_i \neq 0$. Furthermore, the parameter β governs the persistence of volatility shocks for the EGARCH (1, 1) model. There are several benefits to using the EGARCH model. First, since the log value of volatility is used as an explained variable, there is no need to impose nonnegative constraint on the parameters of variance dynamics. Second, the EGARCH model can take into consideration the asymmetric effect of the volatility. Third, only the coefficients of the GARCH term govern the persistence of volatility shocks. Considering its benefits, it is useful to estimate the volatility of the oil price and of macroeconomic variables by applying the EGARCH approach. It is hoped that this analysis can provide empirical evidence regarding the relationships between the volatility in the oil price and macroeconomic variables.

Empirical Result 5.1 The Unit Root

Macroeconomic data usually exhibit stochastic trend that can be removed through only differencing. We employed the Dickey-Fuller (DF), Augmented Dickey Fuller (ADF) and PhillipPerron- z test (PP), to test the order of integration of the variables. 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. The results of the DF, ADF and PP test are presented in Table 1 below.

Table 1:
The Unit Root Test

Variables	DF		ADF		Phillips -Perron	
	Level	1st Diff	Level	1st Diff	Level	1st Diff
ROP	-2.48	-5.67***	-2.48	7.11***	2.47	-7.15***
GDP	-1.07	-11.94***	-1.07	-11.78***	-5.93	-32.02***
EXR	-0.87	-9.52***	-0.	-9.41***	-1.63	-9.52***
INF	-3.18***	-6.15***	-1.84	-6.08***	-3.10**	-10.04***
INTR	0.85	-5.86***	0.60	-5.77***	0.60	-5.76***
GEX	-0.85	-1.99**	-2.88	2.98**	0.67	2.98**

Note :, **, *** statistically significant at 10%, 5% and 1% significant level*

The unit root result above shows that ROILP, BOP and INF are stationary at levels. But at first difference, all the variables were found to be integrated of order 1. That is, they are 1 (1) variables. The result from the stationarity test therefore calls for long-term relationship.

Cointegration

We now turn to determine the existence of long run equilibrium relationship among our 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, were utilized to determine the number of cointegrating vectors. The cointegration tests were performed allowing for both the presence and absence of linear trends. The results of the maximal eigenvalues and trace test statistics for the two models were presented in Table 2 below. The procedure followed to determine the number of cointegrating vectors began at the top of the table with the hypothesis that there are no cointegrating vectors and with trends. A rejection of the hypothesis would lead to testing the alternative hypothesis of no cointegrating vectors, and no trend. The testing procedure continues until the hypothesis cannot be rejected.

Table 2:
Johanson Cointegration test under the assumption of deterministic trend.

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
None *	0.923600	228.5933	95.75366	0.0000
At most 1 *	0.820427	148.8682	69.81889	0.0000
At most 2 *	0.694413	95.63585	47.85613	0.0000
At most 3 *	0.586098	58.88465	29.79707	0.0000
At most 4 *	0.488348	31.53871	15.49471	0.0001
At most 5 *	0.293384	10.76531	3.841466	0.0010

The test statistics indicate that the hypothesis of no cointegration among the variables can be rejected for Nigeria. The result indicates six cointegrating equations at 5% level of significance. That is, all the variables included in the model have a long term relationship.

The GARCH model

The Experiential GARCH models were estimated after interpolation.

The empirical results of the GARCH model offer important insights into the behavior of oil price in relation to the macroeconomic uncertainties. In general, the study finds that the GARCH model is a good measure of the persistent volatility present in oil prices. Additionally, past volatilities and errors are significant determinants of the variance of the futures price and past prices are a significant determinant of the expected price. However, a more nuanced analysis shows how monetary policy influences prices levels and volatilities. The residual of the prediction error on the fed funds futures contract is not significant in the mean equation but is significant at the five percent level in the variance equation. This suggests that uncertainties surrounding monetary policy contribute significantly to the volatility of the oil price, but do not necessarily help predict the current futures' price of oil. Higher uncertainty regarding monetary policy does not bid up the price of oil future but increases the arc of the price swing.

The parameter estimation for the EGARCH (1, 1) model is presented in Table 3. According to the results we can find that the leverage effects ⍰ are almost positive that significant at 5% significant level which means that good news generates more volatility than bad news for Nigerian oil price market. It is interesting to observe that the coefficient of exchange rate (EXR) is negative as the exception. This indicates that a negative change in the Nigerian naira has a larger impact on its volatility, which mainly indicates that during an appreciation (*negative change*) the currency tends to be more volatile. Given the insignificance of the exchange rate in the model, *negative* changes in naira, may be indirectly associated to *positive* changes in the oil price; and this is because the relationship between the two series is a negative one. Thus, when the oil price increases its volatility increases as well, as consistent with the theory of storage; subsequently, the price increase determines an appreciation of the currency, while the increase in price volatility is passed on to the volatility of the currency. It is reliable to declare that the selected macroeconomic variables (except for EXR) are more sensitive for good news.

The symmetric effect ⍰ for GDP and EXR are relatively large and positive, i.e. above 0.1 which is a little bit different than it in the previous period in EGARCH model, however it is relatively large than 0.1 too, so it means that the volatility is sensitive to market events in the whole period. On the other hand, during the crisis a is the largest, implying that volatility was very sensitive in the bad time.

The parameter ⍰ measures the persistence in conditional volatility irrespective of anything happening in the market. All the coefficient of ⍰ are positive and significant at 5% level except for EXR which appeared to be insignificant. Since the coefficient of INTR is relatively large, e.g. above 0.9, then volatility takes long time to die out following a fluctuation in oil price. This implies that volatility in oil price has permanent effect in the selected macroeconomic variables, except for EXR.

Table 3:
Result of EGARCH Model

	GDP	GEX	INF	INTR	EXR
Mean equation					
C	3301.35**	662.9035	2.2370	0.2103	2.2795
D(ROP)	-44.8704	-41.1801	-0.0931	-0.0885**	-0.1465**
Variance equation					
⍰	5.8959**	3.0248**	1.1670**	0.6252**	1.4463
⍰	1.7223**	-1.2046**	-0.6609**	-0.93329**	2.7551**
⍰	1.4637**	2.2719**	0.7226**	1.1721**	-0.9471
⍰	0.5527**	0.8366**	0.8672**	0.95887**	0.6863

Causality Test

Here, we investigate the causal relationship between oil price volatility and macroeconomic variable volatility using the lag-augmented VAR (LA-VAR) model developed by Toda and Yamamoto (1995). The LA-VAR approach is applicable to the Granger-causality test in the VAR framework. The most significant benefit to using LA-VAR model is as avoiding biases by paying little attention to the integration and cointegration properties of the data-generating process. The standard VAR or VECM (vector error correction model) relied on the prior test of integration or cointegration order, which subjects coefficient restrictions test based on the VAR or VECM to pretest biases if there were flaws in these conclusions. The LA-VAR method avoids these biases by elaborating the Granger causality test and other tests of coefficient restriction. Therefore, using the LA-VAR technique, we can cope with pretest biases that give rise to problems in statistical inference and execute the Granger-causality test in a level VAR model when the variables are of unknown integration or cointegration order.

Table 4 presents the results of the Granger causality test from the LA-VAR procedure . The null hypothesis is that there is no causality among the variables, and the Wald test statistic and the corresponding *p*-value are presented the second and third columns. pairwise Granger causality between the oil price shock and exchange rate volatility. The results show that the null hypotheses that oil price shock do not Granger cause interest rate could be safely rejected at 5 percent level – a unidirectional causality also emanates from oil prices volatoility to exchange rate volatility. This is consistent with the expectation and with the realities in the Nigerian economy, that is, any fluctuation in oil price would reflect on the macroeconomic variables (i.e. INTR & EXR,).

Table 4:
Causality results of LA-VAR model

Null Hypothesis	**Wald Statistics**	**p-value**
INF Volatility does not Granger Cause Oil price Volatility.	1.14262	0.33138
Oil price Volatility does not Granger Cause INF Volatility	0.22518	0.79959
INTR Volatility does not Granger Cause Oil price Volatility.	1.48662	0.24089
Oil price Volatility does not Granger Cause INTR Volatility	4.07997	0.02332
GDP Volatility does not Granger Cause Oil price Volatility.	1.20869	0.25329
Oil price Volatility does not Granger Cause GDP Volatility	1.41288	0.47296
EXR Volatility does not Granger Cause Oil price Volatility.	2.08763	0.14005
Oil price Volatility does not Granger Cause EXR Volatility	3.50259	0.04513
GEX Volatility does not Granger Cause Oil price Volatility.	0.05126	0.95011
Oil price Volatility does not Granger Cause GEX Volatility	0.07258	0.9304

Conclusion

The econometric findings presented in this study demonstrate that oil price volatility do not have substantial effects on government spending , output and inflation rate in Nigeria over the period covered by the study. However, the findings demonstrated that fluctuations in oil prices do substantially affect the real exchange rates and interest rate in Nigeria. Also, it was found out that it is not the oil price itself but rather its manifestation in real exchange rates and interest that affects the fluctuations of aggregate economic activity proxy, the GDP. Thus, we conclude that oil price shock is an important determinant of real exchange rates and in the long run interest rate, while exchange rate rather than oil price shocks that affects output growth in Nigeria.

These findings cements the fact that international oil prices is a key variable that influence economic growth in Nigeria within the sample period. A number of empirical studies earlier cited in the paper have reported similar findings, namely, Mork (1989), Hamilton (1996 and 1997), Balke *et al.,* (2002) and Jin (2008).

Our results make several useful contributions. They show that real oil prices can account for innovations in another important Nigerian macroeconomic variable and thereby add to the literature that documents the influence of oil price shocks on the Nigerian economy. They also provide support for McCallum's (1989) conjecture that oil price shocks should be incorporated into models of real business cycles and present another interesting stylized fact that models of international business cycles will need to capture. In addition, they advance the research on the failure of real interest rate parity by identifying a real factor that can account for the nonstationarity in real exchange rates.

The results finally suggest a potentially important role for energy prices in future research on exchange rate modelling.

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