Archives of Current Research International

15(2): 1-12, 2018; Article no.ACRI.39862
ISSN: 2454-7077

The Relationship between Crude Oil Prices, Exchange Rate and Agricultural Commodity Price Returns Volatility in Nigeria: A Time Series Approach

David Adugh Kuhe[1*] and Tersoo Uba[1]

[1]Department of Mathematics/Statistics/Computer Science, Federal University of Agriculture, Makurdi, Benue State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author DAK designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript and managed the analyses of the study. Author TU managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACRI/2018/39862
Editor(s):
(1) Dr. Gongxian Xu, Associate Professor, Department of Mathematics, Bohai University, Jinzhou, China.
Reviewers:
(1) Oscar Chiwira, BA ISAGO University, Botswana.
(2) Senibi. K. Victoria, Covenant University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/27272

Original Research Article

Received 05 December 2017
Accepted 25 February 2018
Published 17 November 2018

ABSTRACT

This paper examines the causal relationship between crude oil prices, Naira/US Dollar exchange rate and Agricultural commodity price return volatility in Nigeria using time series econometric models. The study utilizes monthly time series data on the study variables from January 2006 to April 2017 and employs the popular Augmented Dickey-Fuller unit root test and KPSS stationarity test to investigate the stationarity characteristics of the series. Simple linear regression model, Johansen Cointegration, Vector Error Correction Model (VECM), Vector Autoregressive (VAR) Granger Causality test based on Toda-Yamamoto as well as Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model were employed as methods of analysis. Results showed that all the study variables are integrated of order one, I(1), crude oil prices and exchange rate are found to have a positive, significant but temporal impact on Agricultural commodity prices and there is a long-run stable relationship existing among the study variables. Crude oil prices and exchange rate are also found to Granger caused Agricultural commodity prices in Nigeria and exchange rate is found to be Granger-caused by crude oil prices. The results of the estimated

**Corresponding author: Email: davidkuhe@gmail.com;*

GARCH (1,1) models showed that the conditional variances of Agricultural commodity prices and exchange rate log returns are stable with volatility half-lives of 1 month and 7 months respectively. While the conditional variance of crude oil prices log return series is unstable and explodes to infinity indicating that future crude oil prices cannot be predicted from the past and current prices. The study provides some policy recommendations.

Keywords: Commodity prices; crude oil; exchange rate; time series; volatility shock; Nigeria.

1. INTRODUCTION

Food price volatility is not new in agricultural markets; the degree of food price volatility and the number of countries affected have been very high since 2007. Food price volatility over the last four years has hurt millions of people, undermining nutritional status and food security. By definition, volatility is the rate of price variation over a successive period of time; it is determined by the speed, magnitude, and change in direction of the variation in prices [1]. Volatility in the prices of agricultural products and raw materials can have serious consequences for countries such as losses in economic efficiency, increased food insecurity, more malnutrition, negative impacts on the balance of trade and possible social unrest among others [1]. It is also feared to have a ravaging impact on the poor as a greater percentage of their family budget is spent on food. This is why the issue of price volatility should be addressed to ameliorate the food insecurity situation in Nigeria.

Nigeria as one of the countries that exports and imports crude oil and its products as well as agricultural commodities, farm equipment and machineries also depends on foreign exchange rates for international transactions. Crude oil is one of the most important driving forces of the Nigerian economy and as such changes in the price of crude oil would have significant effects on economic growth and welfare in Nigeria. Oil is used to power agricultural machines, processing machines, and to transport inputs such as fertilizer, pesticides, and final agricultural products to the ultimate consumer. Increases in the price of oil, therefore, add serious pressure on the cost of these operations. Higher prices of oil may trigger inflation in the economy, increase the cost of input, transport cost and subsequently reduce investment.

Persistent increases in agricultural commodity prices and food prices in recent times have raised concerns among policymakers about a global food shortage. These rising prices for agricultural products are causing food riots in many developing countries including Nigeria. It is becoming obvious that millions of people would be driven into poverty by higher food prices in the absence of policy changes. Many academics and policymakers are now relating higher food prices to the persistent increase in the price of crude oil. This is because oil products are required to run agricultural equipment, thereby raising the costs of producing food commodities and that higher oil prices may raise the price of processing, storing, and distributing food to retail customers. The increased reliance on biofuels by industrialized economies has even worsened the situation.

The dynamic relationship between crude oil price, exchange rates and agricultural products prices has become topical in recent times among scholars. Rezitis [2] examined the link between crude oil prices, US dollar exchange rates, 30 selected international agricultural prices and five international fertilizer prices using panel data for the period of June 1983 to June 2013. The study employed panel VAR models with Granger causality tests. Results showed that crude oil prices and US dollar exchange rates affect international agricultural commodity and fertilizer prices. Bidirectional panel causality was observed between crude oil prices and international agricultural prices as well as between US exchange rates and international agricultural prices. Ardian et al. [3] examined the price relationship of the primary agricultural commodities, exchange rates and oil prices using cointegration relationship between prices to determine changes in the strength of the linkage between markets through time. They found that commodity prices are linked to oil for corn, cotton, and soybeans and that exchange rate play a role in the linkage of prices over time. Other studies which investigate the effects of changing crude oil prices on exchange rates and agricultural commodity prices with similar results include [4,5,6,7] among others. However, a comprehensive evaluation of the relationship between crude oil prices, foreign exchange rates and agricultural commodity prices still unfolds. Changes in these relationships have implications for risk management strategies which affects long-term policy implementations for agriculture.

On the link between crude oil price and agricultural commodity prices, Wei & Chen [8] investigated the relationships between crude oil futures and agricultural grain commodities prices using daily data for soybeans, wheat and corn in Chicago Board of Trade and crude oil from New York Mercantile Exchange from January 3, 2006 to February 22, 2012. They employed vector autoregressive (VAR) model and found that the change in each of agriculture grain commodities was significantly influenced by the change in the crude oil and other agriculture grain commodities. Saghaian [9] examined the causal link between oil, ethanol, corn, soybeans and wheat prices using contemporary time-series analysis and Granger causality supplemented by a directed graph theory modeling approach. The results showed a strong correlation between oil and commodity prices and mixed causality results between oil and commodity prices. Alvalos [10] investigated the link between crude oil price, corn and soybeans prices in a VAR model framework using monthly prices from January 1986 to April 2006. Results showed that oil price shocks exhibited no predictive causality over corn and soybeans prices. Oil prices had negative impact both in the long-run and short-run price dynamics on the two food commodities.

Gogoi [11] examined the long-run stable relationship between crude oil and world food commodity prices such as maize, rice, soybean, and wheat for the period between 1980 and 2011 using time series econometric techniques. The co-integration test indicated a long-run stable equilibrium relationship between crude oil prices and the prices of maize, soybean, and wheat with the exception of rice prices. He also found unidirectional causalities between crude oil prices “Granger causing” each of the four food commodity prices. However, crude oil prices were not found to be influenced by prices of food commodities. Campiche [12] investigated the relationship between crude oil prices and Agricultural commodity prices from 2003 to 2007 using cointegration and vector error correction model. They found a long-run stable relationship among the study variables. Further results from the same study indicate that crude oil prices do not adjust to changes in the corn and soybean market. Yu et al. [13] also examined the cointegration and causality relationship between crude oil prices and the price and demand for vegetable oils. They found that the influence of shocks in crude oil prices on the variation in vegetable oil prices was relatively small, which agrees with the findings of [14].

From the reviewed literature, it is reasonable to conceptualize the linkages between crude oil price, exchange rates, and agricultural commodity prices as can be seen in Figs. 1 and 2. Here, one expects the *trickledown* effect of crude oil price on agricultural commodity prices through foreign exchange rates. The poser is whether foreign exchange rates affect crude oil price. It is, however, reasonable to expect that a dollar-denominated asset like crude oil is affected by dollar exchange rates. Direct empirical evidence of this hypothesis is one of the objectives this study seeks to achieve. Finally, crude oil prices affect agricultural commodity production through input prices. Increasingly, crude oil prices potentially affect at least some agricultural products through competition in output markets (bio-fuels). Thus, one can anticipate a direct linkage between crude oil price and agricultural commodity prices in addition to the indirect effect through exchange rates.

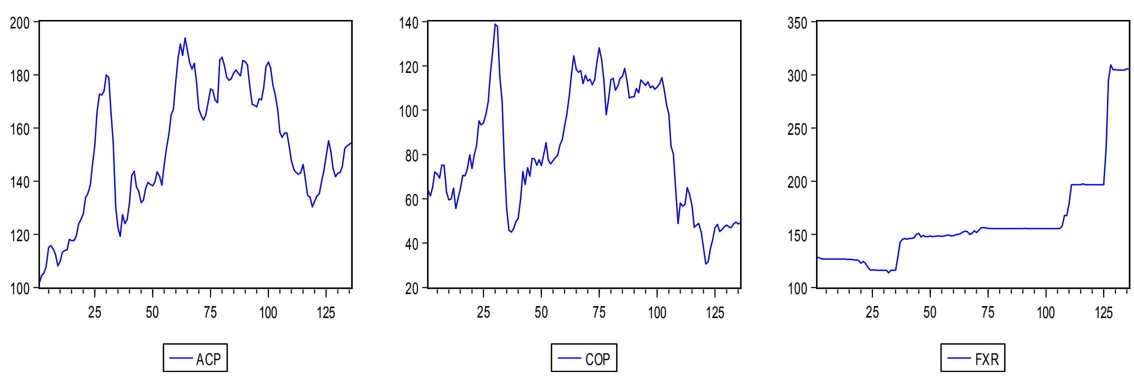

Fig. 1. Time series plots of agricultural commodity prices, crude oil prices and foreign exchange rate

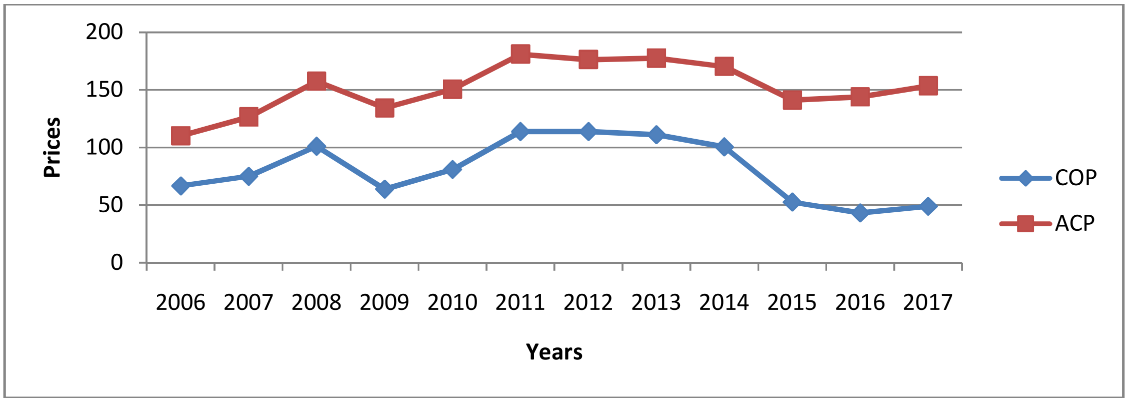

Fig. 2. Time plot of commodity prices and crude oil prices in Nigeria from 2006-2017

2. MATERIALS AND METHODS

2.1 Data Source and Integration

The data used in this study are monthly time series data on crude oil prices, Naira/US Dollar exchange rate and Agricultural Commodity prices covering the period from January 2006 to April 2017. These secondary data on crude oil price and exchange rate are obtained from Central Bank of Nigeria's website while the data on Agricultural commodity prices are obtained from http://www.indexmundi.com/commodities/?commodity=food-price-index&months=360. The monthly log returns of these data are computed from the following formula:

$$r_t = 100 \times \ln\left[\frac{P_t}{P_{t-1}}\right] \quad (2.1)$$

where P_t is the monthly closing price index or exchange rate at time t for $t = 1, 2, 3, \ldots, T$ where T is the total number of observations and the variance of return is referred as the volatility of r_t.

2.2 Methods of Data Analysis

The following statistical tools are employed for analysis in this work using Eviews version 8.0.

2.2.1 Unit root test

Unit root test is conducted to check the stationarity and order of integration of the study variables. Before proceeding to the estimation procedure of cointegration test, it is necessary that the series under consideration be integrated of the same order [15]. In this study, we employ the popular Augmented Dickey-Fuller unit root test (see [16]). The ADF test regressions with drift are given as:

$$\Delta ACP_t = \alpha_0 + \alpha_1 ACP_{t-1} + \sum_{j=1}^{k} a_j \Delta ACP_{t-1} + \varepsilon_t \quad (2.2)$$

$$\Delta COP_t = \beta_0 + \beta_1 COP_{t-1} + \sum_{j=1}^{k} b_j \Delta COP_{t-1} + \varepsilon_t \quad (2.3)$$

$$\Delta FXR_t = \psi_0 + \psi_1 FXR_{t-1} + \sum_{j=1}^{k} c_j \Delta FXR_{t-1} + \varepsilon_t \quad (2.4)$$

where Δ is the first difference operator, ε_t is the random error term which is iid. k is the number of lagged differences. The ADF equations test the following pairs of hypotheses:

$H_0: \alpha_1 = \beta_1 = \psi_1 = 1$ (the series contains a unit root) against $H_1: \alpha_1 \neq \beta_1 \neq \psi_1 < 1$ (the series is stationary). We reject H_0 if the ADF test statistic is less than the appropriate test critical value.

Since the ADF parametric unit root test suffers from severe size distortions and low power property depending on the sample size, we employ the non-parametric KPSS stationarity test to cross-check the result given by the ADF unit root test.

2.2.2 The KPSS test

In the KPSS [17] stationarity test, the null hypothesis is that the series (Y_t) is stationary against the alternative that the series (Y_t) is I(1).

The logic behind this test is that if Y_t can be written as $Y_t = u + u_t$ where u_t is some zero-mean stationary process, then not only does the sample average of the $Y_t s$ provide a consistent estimator of u but the long-run variance of u_t is a well-defined finite number. Neither of these properties holds under the alternative hypothesis. The KPSS test is based on the following statistic:

$$\eta = \sum_{i=1}^{T} S_t^2 \Big/ T^2\hat{\sigma}^2 \qquad (2.5)$$

where $S_t = \sum_{s=1}^{t} e_s$ and $\hat{\sigma}^2$ is an estimate of the long-run variance of $e_t = (\hat{Y}_t - \bar{Y})$. We reject H_0 if η is bigger than the appropriate critical values.

2.2.3 Johansen cointegration test

Johansen cointegration test which is only applied to variables that are integrated of the same order is employed in this study to investigate the long-run stable equilibrium relationship among the study variables. Johansen [18,19] developed a Vector Autoregressive based cointegration test methodology as follows: Let a VAR (p) model can be defined as:

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + BX_t + \varepsilon_t \qquad (2.6)$$

Where Y_t is the $k-$vector of non-stationary I(1) variables, X_t is the $d-$vector of deterministic variables and ε_t is a vector of innovations. We may rewrite this VAR as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + BX_t + \varepsilon_t \qquad (2.7)$$

$$\text{where } \Pi = \sum_{i=1}^{p} A_i - \boldsymbol{I}, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j \qquad (2.8)$$

Granger's representation theorem assumes that if the coefficient matrix Π has reduced rank $r < k$, then there exist $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' Y_t$ is I(0). r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. Johansen cointegration test computes two statistics: trace statistic and maximum eigenvalue statistic. The trace statistic for the null hypothesis of r cointegrating relations is computed as:

$$LR_{tr}(r|k) = -T \sum_{i=r+1}^{k} \log(1 - \lambda_i) \qquad (2.9)$$

The maximum eigenvalue test statistic is computed as:

$$LR_{max}(r|r+1) = -Tlog(1 - \lambda_{r+1}) = LR_{tr}(r|k) - LR_{tr}(r+1|k) \qquad (2.10)$$

where λ_i is the i-th largest eigenvalue of the Π matrix in (2.8), $r = 0, 1, 2, \ldots, k-1$.

2.2.4 Multiple regression model specification

To investigate the impact of crude oil price and foreign exchange rate on Agricultural commodity prices in Nigeria, we employ a multiple cointegrating regression model which is specified as follows:

$$ACP = f[COP, FXR] \qquad (2.11)$$

and our multiple regression model then becomes

$$ACP_t = \beta_0 + \beta_1 COP_t + \beta_2 FXR_t + \varepsilon_t \qquad (2.12)$$

where ACP_t represents Agricultural commodity prices at time t, COP_t represents crude oil price at time t, FXR_t represents foreign exchange rate at time t, ε_t is the error term, β_0 is the intercept of the regression model while β_1, β_2 are the slope coefficients of COP_t and FXR_t respectively.

2.2.5 Vector error correction model (VECM)

According to economic theory, the existence of cointegration between two or more variables implies a long-run stable equilibrium relationship between them and we apply VECM to evaluate the short-run and long-run dynamics of the cointegrated series. In case of the variables not being cointegrated, VECM is no longer required and we directly proceed to Granger causality test to establish causal links between the study variables.

The regression equation form of VECM is expressed as follows:

$$\Delta ACP_t = c_1 + \sum_{j=1}^{m-1} \alpha_j \Delta ACP_{t-j} + \sum_{j=1}^{m-1} \beta_j \Delta COP_{t-j} + \sum_{j=1}^{m-1} \omega_j \Delta FXR_{t-j} + \lambda_1 EC_{t-1} + \varepsilon_{1t} \qquad (2.13)$$

$$\Delta COP_t = c_2 + \sum_{j=1}^{m-1} \gamma_j \Delta\, COP_{t-j} + \sum_{j=1}^{m-1} \delta_j\, \Delta ACP_{t-j} + \sum_{j=1}^{m-1} \phi_j \Delta FXR_{t-j} + \lambda_2 EC_{t-1} + \varepsilon_{2t} \tag{2.14}$$

$$\Delta FXR_t = c_3 + \sum_{j=1}^{m-1} \psi_j \Delta\, FXR_{t-j} + \sum_{j=1}^{m-1} \pi_j\, \Delta ACP_{t-j} + \sum_{j=1}^{m-1} \varphi_j \Delta COP_{t-j} + \lambda_3 EC_{t-1} + \varepsilon_{3t} \tag{2.15}$$

where EC_{t-1} is the error correction term which provides feedback and speed of adjustment that indicates how much of the disequilibrium that is being corrected in the system, $c_1, c_2,\ c_3$ are intercepts. The symbol Δ represents the first-differenced form of the variables in the model. The coefficient of the various explanatory variables $\alpha_j, \beta_j, \omega_j, \gamma_j, \delta_j, \phi_j, \psi_j, \pi_j$ and φ_j are the impact multipliers which measure the immediate impact that a change in the explanatory variable has on a change in the dependent variable. λ represents the speed of adjustment parameter. The value of λ must lie in the range $-1 \leq \lambda \leq 0$ and must be statistically significant.

2.2.6 VAR Granger causality test based on Toda-Yamamoto procedure

We employ Toda & Yamamoto Granger causality test procedure due to Toda and Yamamoto [20] to determine the direction of causality among the study variables. Toda and Yamamoto procedure uses a Modified Wald (MWALD) test for restrictions on the parameters of the VAR (k) model. The model is specified as follows:

$$ACP_t = \alpha_1 + \sum_{i=1}^{k+d} \beta_{1i} ACP_{t-i} + \sum_{t-i}^{k+d} \beta_{2i} COP_{t-i} + \sum_{t-i}^{k+d} \beta_{3i}\, FXR_{t-i} + \varepsilon_{xt} \tag{2.16}$$

$$COP_t = \alpha_2 + \sum_{i=1}^{k+d} \phi_{1i} COP_{t-i} + \sum_{t-i}^{k+d} \phi_{2i} ACP_{t-i} + \sum_{t-i}^{k+d} \phi_{3i} FXR_{t-i} + \varepsilon_{yt} \tag{2.17}$$

$$FXR_t = \alpha_3 + \sum_{i=1}^{k+d} \psi_{1i} FXR_{t-i} + \sum_{t-i}^{k+d} \psi_{2i} ACP_{t-i} + \sum_{t-i}^{k+d} \psi_{3i} COP_{t-i} + \varepsilon_{zt} \tag{2.18}$$

where k is the optimal lag order; d is the maximal order of integration of the series in the system; ε_{xt} , ε_{yt} and ε_{zt} are error terms which are assumed to be white noise. The usual Wald test is then applied to the first k coefficient matrices using the standard χ^2-statistics. The test checks the following pairs of hypotheses: ACP_t "Granger causes" COP_t if $\beta_{2i} \neq 0$ in equation (2.16) against COP_t "Granger causes" ACP_t if $\phi_{1i} \neq 0$ in equation (2.17) and similarly in equation (2.18).

2.3 GARCH (p, q) Model with Gaussian Error

To further investigate the predictability, volatility shock persistence and volatility half-lives of crude oil price, exchange rate and agricultural commodity price log returns, we employ the basic GARCH (1,1) model proposed by Engle [21] and Bollerslev [22]. The time series ε_t following a GARCH (p,q) model is defined as:

$$\varepsilon_t = \eta_t \sqrt{h_t} \tag{2.19}$$

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \tag{2.20}$$

where ω, α_i and β_j are non-negative constraints with $\sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} < 1$ in order to ensure that the conditional variance (h_t) is positive and stationary. The GARCH (1,1) is the most popular and simplest model for volatility forecasting. The standard GARCH (1,1) model is expressed as:

$$\varepsilon_t = \eta_t \sqrt{h_t} \tag{2.21}$$

$$h_t = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{2.22}$$

where ε_t is the underlying process, $\{\eta_t\}$ are iid random variables with mean zero and variance 1 and are assumed to be standard normally distributed. For a standard GARCH (1,1) model to be stationary the sum of ARCH term (α_1) and GARCH term (β_1) must be less than one. If $\alpha_1 + \beta_1 > 1$, the conditional variance becomes unstable, non-stationary and therefore explodes.

2.3.1 Volatility half-life

The half-life of a volatility shock is given by the formula:

$$\boldsymbol{L}_{half} = 1 - \left\{\frac{\log(2)}{\log(\alpha_1 + \beta_1)}\right\} \quad (2.23)$$

where $\boldsymbol{L}_{half}$ stands for half-life shock to volatility. The half-life measures the average time it takes for $|\varepsilon_t^2 - \hat{\sigma}^2|$ to decrease by one half. The closer $(\alpha_1 + \beta_1)$ is to one the longer the half-life of a volatility stock. If $(\alpha_1 + \beta_1) > 1$, the GARCH model is non-stationary and the volatility explodes to infinity.

3. RESULTS AND DISCUSSION

3.1 Summary Statistics of Study Variables

The summary statistics of the study variables such as mean, standard deviations, skewness, kurtosis, Jarque-Bera normality test are presented in Table 1. For the period under review, crude oil price, foreign exchange rate and agricultural commodity price had mean values of 82.81$/barrel, 161.40Naira/dollar and 151.71 naira with standard deviations of 27.48$/barrel, 46.40naira/dollar and 23.95 naira respectively. The skewness coefficient is negative for agricultural commodity price indicating that the series has a long left tail while the skewness coefficients for crude oil price and foreign exchange rate are positive suggesting that the two series have long right tails. The kurtosis value of foreign exchange rate is very high while that of the other variables are small indicating that the distributions are leptokurtic. The Jarque-Bera test rejects normality at the 5% significance levels for all series.

3.2 Unit Root and Stationarity Tests Results

Augmented Dickey-Fuller (ADF) unit root test and KPSS stationarity test have been applied in this study to investigate the stationarity characteristics as well as the order of integration of the series. The results of the tests are presented in Table 2. From Table 2, the ADF unit root test result fails to reject the null hypothesis of unit root in the levels of the series whereas the null hypothesis of unit root is rejected in the first differences of the ADF test statistics. This shows that all the study variables are non-stationary in levels but stationary after the first difference. We cross-check the result given by ADF unit root test using KPSS stationarity test. The KPSS test rejects the null hypothesis of stationarity in the levels of the series but accepts the null hypothesis of stationarity after the first difference has been taken thereby confirming the result given by the ADF unit root test. From the ADF and KPSS test results, we can conclude that all the study variables are integrated of order one, I(1). This is a necessary but not a sufficient condition for conducting Johansen cointegration analysis on the study variables.

Table 1. Summary statistics of the study variables

Statistic	COP	FXR	ACP
Mean	82.8078	161.402	151.711
Median	78.4600	152.625	151.795
Maximum	138.740	309.230	193.770
Minimum	30.6600	113.700	101.610
Standard Deviation	27.4784	46.402	23.9523
CV	0.331833	0.287029	0.151011
Skewness	0.0239598	2.08061	-0.151011
Kurtosis	1.729958	6.968803	1.951851
Jarque-Bera	9.15339	187.38	6.9523
P-value	0.0102889	0.0000	0.034385
No. of Observations	136	136	136

3.3 Johansen Cointegration Test Results

To investigate the long-run stable equilibrium relationship among the study variables, we apply Johansen cointegration test and the results of the test are presented in Table 3.

The Johansen cointegration test presented in Table 3 rejects the null hypothesis of no cointegration at $r = 0$ and $r \leq 1$ for both trace and maximum eigenvalue tests. The test shows two cointegrating equations in both trace and maximum eigenvalue tests. This means the existence of stable long-run equilibrium relationship among the study variables. The implication is that the variables are cointegrated and hence share a common stochastic drift. The variables are therefore bound to vary in sympathy with one another in the long-run.

3.4 Multiple Cointegrating Regression Result

To investigate the impact of crude oil price and foreign exchange rate on Agricultural commodity prices, Johansen multiple cointegrating regression equations using Fully Modified Ordinary Least Squares is employed. The result is presented in Table 4.

From the result of Johansen cointegrating regression equation presented in Table 4, we observe that the intercept and all the slope coefficients are positively related to Agricultural commodity prices and statistically significant at 1% marginal significance levels. This means that a one percent increase in crude oil price and the foreign exchange rate will lead to 85.59% and 25.90% increase in Agricultural

Table 2. ADF unit root and KPSS stationarity test results

Variable	Option	ADF test statistic	P-value	KPSS Test statistics	5% critical value
COP	Intercept only	-1.8271	0.3677	0.4817	0.465
	Intercept & trend	-1.9318	0.6377	0.4232	0.148
ΔCOP	Intercept only	-5.3316*	0.0000	0.0212*	0.465
	Intercept & trend	-5.3853*	0.0000	0.0385*	0.148
FXR	Intercept only	2.0405	0.9999	1.7848	0.465
	Intercept & trend	-0.1084	0.9948	0.3428	0.148
ΔFXR	Intercept only	-5.7485*	0.0000	0.0366*	0.465
	Intercept & trend	-5.1866*	0.0000	0.0777*	0.148
ACP	Intercept only	-2.6366	0.0856	0.9176	0.465
	Intercept & trend	-2.5569	0.3005	0.4412	0.148
ΔACP	Intercept only	-6.7894*	0.0000	0.0141*	0.465
	Intercept & trend	-6.9104*	0.0000	0.0380*	0.148

*Note: * denotes the significance of the ADF and KPSS test statistics; Δ denotes first difference of the variable*

Table 3. Johansen cointegration test results

Rank	H_0	Eigenvalue	Trace test	P-value	Max eigenvalue	P-value
0	$r = 0$	0.16066	39.380	0.0025*	21.717	0.0394*
1	$r \leq 1$	0.12155	17.663	0.0216*	16.070	0.0236*
2	$r \leq 2$	0.012766	1.5932	0.2069	1.5932	0.2069

*Note: * denotes rejection of the null hypothesis at 5% significance level.*

Table 4. FMOLS parameter estimates of the study variables

Dependent variable: ACP				
Variable	**Coefficient**	**Std. error**	**t-ratio**	**p-value**
Const	39.0331	6.26921	6.2262	0.0000
COP	0.85594	0.0406443	21.0593	0.0000
FXR	0.25898	0.0241077	10.7426	0.0000
R-squared	0.770035	F-statistic	222.4702	Durbin Watson
Adj. R-squared	0.766576	F-stat (P-value)	0.000000	2.240145

commodity prices respectively. This shows that although both crude oil price and foreign exchange rate are both driving forces of Agricultural commodity prices in the market, the impact of crude oil price is much higher when compared to the foreign exchange rate. The coefficient of variation has shown that about 77% of the total variability in the model has been explained.

The Durbin Watson statistic value of 2.240145 indicates that the estimated model is non-spurious. This also shows the absence of positive serial correlation in the model. The overall goodness-of-fit of the model is also adequate as the F-statistic p-value is highly statistically significant.

3.5 Vector Error Correction Model (VECM) Result

As the study variables are cointegrated, they are indeed in a state of stable equilibrium. We, therefore, use the residuals obtained from the cointegrating regression equation in Table 4 and estimate a vector error correction model (VECM) which adjusts the speed of disequilibrium in the system. The VECM result is presented in Table 5.

From the VECM result presented in Table 5, the slope coefficients of ΔACP(-1), ΔACP(-2) ΔCOP(-1), ΔCOP(-2), ΔFXR(-1) and ΔFXR(-2) are the short-run equilibrium coefficients while the slope coefficient of EC(-1) is the long-run equilibrium coefficient called the error correction coefficient. Theory expects the coefficient of EC(-1) to be negative and significant.

The short-run equilibrium coefficients tell us the rates at which the previous period's disequilibrium in the system is being corrected. In the estimated VECM model the system corrects its previous period's disequilibrium at the speed of 54.05% and 5.39% between Agricultural commodity prices and Agricultural commodity prices lag one month and two months respectively, 51.51% and 7.24% between Agricultural commodity prices and crude oil price lag one month and lag two months respectively and 21.84% and 6.82% between Agricultural commodity prices and foreign exchange rate lag one month and lag two months respectively. The slope coefficients of ΔACP(-1), ΔCOP(-1) and ΔFXR(-1) are all statistically significant at lag one month whereas the slope coefficients of ΔACP(-2), ΔCOP(-2) and ΔFXR(-2) are not statistically significant at lag two months. This indicates that the impacts of crude oil price and foreign exchange rate on Agricultural commodity prices are temporal and not long lasting.

The one lagged period error correction term is represented by EC(-1). This guides the independent variables in the system to restore back to equilibrium when it is negative and statistically significant. In the estimated VECM the EC(-1) coefficient is -0.622027. This value is negative and statistically significant as desired indicating that the system corrects its previous period's disequilibrium at a speed of 62.20% monthly. This means that the VECM model has identified a sizeable speed of adjustment by 62.20% for monthly correction of disequilibrium for achieving long-run equilibrium steady-state position.

3.6 VAR Granger Causality Test Result Based on Toda-Yamamoto Procedure

To determine the direction of causality among the study variable, we employ vector autoregressive Granger causality test based on Toda-Yamamoto procedure, the result is reported in Table 6.

Table 5. OLS parameter estimates of vector error correction model

Dependent variable: ΔACP				
Variable	**Coefficient**	**Std. error**	**t-statistic**	**Prob.**
C	0.253694	0.273630	0.927143	0.3556
ΔACP(-1)	0.540493	0.097702	5.532037	0.0000
ΔACP(-2)	-0.053932	0.100134	-0.538596	0.5911
ΔCOP(-1)	-0.515139	0.036073	-0.419670	0.0054
ΔCOP(-2)	0.072439	0.035452	0.209835	0.8341
ΔFXR(-1)	-0.218397	0.101678	-2.147918	0.0336
ΔFXR(-2)	0.068235	0.102408	0.666312	0.5064
EC(-1)	-0.622027	0.025615	-0.859920	0.0015
R-squared	0.675285	F-statistic	6.783102	Durbin Watson
Adjusted R-squared	0.534701	Prob(F-statistic)	0.000001	2.006512

Table 6. VAR granger causality test based on Toda-Yamamoto

	ACP	COP	FXR
ACP	------	9.5107 [0.0079]*	10.6851 [0.0074]*
COP	1.1276 [0.2883]	-----	1.2190 [0.2696]
FXR	3.4448 [0.0635]	12.5254 [0.0020]*	-----

*Note: * denotes significance of the test while values in [ ] are p-values*

Table 7. Parameter estimates of GARCH (1,1) models and volatility half-lives

	ω	α_1	β_1	$\alpha_1 + \beta_1$	Volatility Half-life	Remark
ACP	5.4661	0.3769	0.1595	0.5364	1 month	Stable
COP	2.3901	0.6310	0.4992	1.1302	∞	Unstable
FXR	4.0786	0.4846	0.4227	0.9073	7 months	Stable

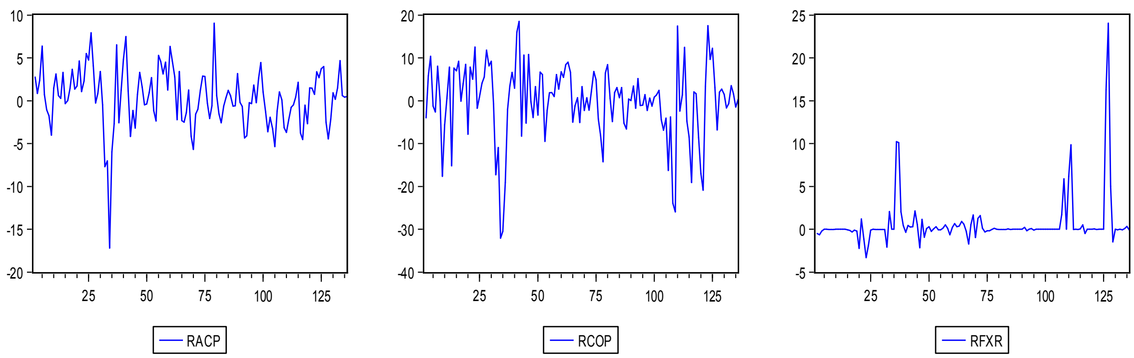

Fig. 3. Time plots of log return series of the study variables

From the VAR Granger causality test result reported in Table 6, there is a unidirectional causality running from crude oil price to Agricultural commodity prices, from foreign exchange rate to Agricultural commodity prices and from crude oil price to foreign exchange rate. This means that crude oil price and foreign exchange rate Granger causes Agricultural commodity prices. Also, crude oil price Granger causes foreign exchange rate. The implication is that crude oil price and the foreign exchange rate has been the driven force of Agricultural commodity prices in the Nigerian market. Crude oil price has also been one of the determinants of the foreign exchange rate in Nigeria.

3.7 Result of GARCH Model and Volatility Half-Life

To investigate the shock persistence to volatility of the Agriculture commodity price, crude oil price and foreign exchange rate log return series as well as their volatility half-lives, we employ GARCH (1,1) model and the result is presented in Table 7.

The results of the GARCH (1,1) models presented in Table 7 indicate that the conditional variances of Agricultural commodity price and foreign exchange rate log returns are stable as their sum of ARCH (α_1) and GARCH (β_1) terms are less than unity. This shows that prices of Agricultural commodities and exchange rate can be predicted from their past histories. However, the conditional variance of crude oil price is unstable as the sum of ARCH and GARCH term is greater than one ($\alpha_1 + \beta_1 = 1.1302 > 1$). This shows a very high level of shock persistence which explodes to infinity indicating that crude oil prices cannot be predicted from its past history. The time series plots of Agricultural commodity prices, crude oil price and foreign exchange rate log return series are reported in Fig. 3.

4. CONCLUSION

In this study, we examined the dynamic relationship between crude oil prices, Naira/US Dollar exchange rate and Agricultural commodity price return volatility in Nigeria using time series econometric models. The study utilized monthly time series data on the study variables from

January 2006 to April 2017 and employed Augmented Dickey-Fuller unit root test and KPSS stationarity test to investigate the stationarity characteristics of the series. Simple linear regression model was used to investigate the impact of crude oil price and exchange rate on agricultural commodity prices. Johansen Cointegration test was applied to determine the long-run stable relationship among the study variables. Vector Error Correction Model (VECM) was employed to integrate the short-run and long-run dynamics while Vector Autoregressive (VAR) Granger Causality test based on Toda-Yamamoto was applied to test for the direction of causality between study variables. The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model was employed to investigate volatility shock persistence, mean reversion and volatility half-lives.

Results showed that all the study variables were integrated of order one, I(1), crude oil prices and exchange rate was found to have positive, significant but temporal impact on Agricultural commodity prices and long-run stable relationship was found to exists among the study variables. Crude oil prices and exchange rate were also found to Granger caused Agricultural commodity prices in Nigeria and crude oil price was found to Granger cause exchange rate. The results of the estimated GARCH (1,1) models showed that the conditional variances of Agricultural commodity prices and exchange rate log returns were stable and mean reverting with volatility half-lives of 1 month and 7 months respectively while the conditional variance of crude oil prices log return series was unstable and explodes to infinity indicating that future crude oil prices cannot be predicted from the past and current prices.

These findings have some important policy implications. From the economic policy perspective, results of this study have shown that changes in crude oil price and exchange rate can cause significant changes in the agricultural commodity market. Therefore any changes in policy actions with respect to crude oil production and exchange rate need to consider the effect of these on agricultural commodity prices. There is need for both the government and private partners to develop policy options and interventions that will encourage cost-effective agricultural production, processing and production efficiencies. There is also need to increase the market depth for crude oil and allow aggressive trading on a wide range so as to make it less volatile.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO, Price volatility in agricultural markets (2000–2010): Implication for Latin America for policy options. The outlook for agricultural and rural development in the Americas: A perspective on Latin American and the Caribbean. Santiago; 2011.
2. Rezitis AN. The relationship between agricultural commodity prices, crude oil prices and US dollar exchange rates: A panel VAR approach and causality analysis. Inter. Rev. Appl. Econs. 2015; 29(3):12-21.
3. Ardian H, Lanier N, Darren H. The relationship between oil, exchange rates and commodity prices. J. Agric. Appl. Econs. 2009;41(2):501–510.
4. Hanson K, Robinson S, Schluter G. Sectoral effects of a world oil price shock: Economy wide linkages to the agricultural sector. J. Agric. Res. Econs. 1993;18(1): 96–116.
5. Trostle R. Global agricultural supply and demand: Factors contributing to the recent increase in food commodity prices. Economic Research Service. United States Department of Agriculture; 2008.
6. Schnept R. High agricultural commodity prices: What are the issues? Congressional Research Service; 2008.
7. Abbott P, Hurt C, Tyner W. What is driving food prices? Farm foundation issue report July 2008.
8. Wei CC, Chen SM. Examining the relationship of crude oil future price return and agricultural future price return in US. Inter. J. Ener. Econs. Pol. 2016;6(1):58-64.
9. Saghaian SH. The impact of the oil sector on commodity prices: Correlation or causation? J. Agric. Appl. Econs. 2010; 42(3):477–485.
10. Alvalos F. Do oil prices drive food prices. In a natural experiment; Proceeding of the 6th international conference on economic studies, July 22, 2013.
11. Gogoi A. Investigating the long run relationship between crude oil and food commodity prices (MSc thesis).

Department of Economics, University of Nottingham, Nottingham; 2014.
12. Campiche J, Bryant H, Richardson J, Outlaw J. Examining the evolving correspondence between petroleum prices and agricultural commodity prices. Paper presented at the American Agricultural Economics Association Annual Meeting, Portland, July 29–August 1, 2007.
13. Yu TH, Bessler DA, Fuller S. Cointegration and causality analysis of world vegetable oil and crude oil prices. Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 23–26, 2006.
14. Zhang Q, Reed M. Examining the impact of the world crude oil price on China's agricultural commodity prices: The case of corn, soybean and pork. Paper presented at the South Agricultural Economics Association Annual Meeting, Dallas, TX, February 2–5, 2008.
15. Engle RF, Granger CWJ. Cointegration and error correction representation, estimation and testing. Economet. 1987;55(2):251-276.
16. Dickey DA, Fuller W. Distribution of the estimators for autoregressive time series with a unit root. J. Amer. Stat. Ass. 1979;74(366):427-431.
17. Kwiatkowski D, Phillips PCB, Schmidt P, Shin Y. Testing the null hypothesis of stationarity against the alternative of a unit root. J. Econs. 1992;54:159-178.
18. Johansen S. Estimation and hypothesis testing for cointegration vectors in gausian vector autoregressive model. Economet. 1991;59:1551-1580.
19. Johansen S. Likelihood-based inference in cointegrated vector autoregressive models. Oxford University Press, Oxford. 1995;194-209.
20. Toda HY, Yamamoto T. Statistical inference in vector autoregressions with possibly integrated processes. J. Economet. 1995;66(2):225-250.
21. Engle RF. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom Inflation, Economet. 1982;50(4):987-1008.
22. Bollerslev T. Generalized autoregressive conditional heteroscedasticity. J. Economet. 1986;31:307-327.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27272