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Dynamic Correlation between Stock Market Returns and Crude Oil Prices: Evidence from a Developing Economy

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Modeling the correlation of assets returns volatilities across different markets or segments of a market has practical value for portfolio selection and diversification, market regulation, and risk management. This paper therefore evaluates the nature of time-varying correlation between volatilities of stock market and crude oil returns in Nigeria using Dynamic Conditional Correlation-Generalised Autoregressive Conditional Heteroscedasticity (DCC-GARCH) model. Results from DCC-GARCH (1,1) model show evidence of volatility clustering and persistence in Nigeria stock market and crude oil returns. The results also show that there is no dynamic conditional correlation in ARCH effects between stock market returns and crude oil prices in Nigeria. The results further show that there is strong evidence of time-varying volatility correlation between stock market and crude oil returns volatility. The findings will help shape policy-making in risk management and market regulation in Nigeria.

Keywords: *stock market; crude oil prices; volatility interdependence; multivariate GARCH; dynamic conditional correlation model; developing economy*

Introduction

The nature of correlation between assets returns and their volatilities across different markets or segments of a market has practical value. The principle of portfolio selection and diversification provides motivation for studying correlation among assets returns and volatility. It describes the optimal combination of portfolio returns and risks required to maintain expected portfolio return. Markowitz (1952), for instance, stresses the importance of selecting portfolio components that have low correlation in their returns as well as low covariance. Cappiello, Engle, and Sheppard (2006) emphasise, among others, that portfolio diversification is achieved using two main strategies: investing in different classes of assets that have little or negative correlation or investing in similar classes of assets in multiple markets through international diversification. The extent to which investors can reduce their risk by diversifying their portfolio depends on the correlation between asset returns and/or volatilities. The lower the correlation between two assets returns and/or volatilities, the greater the potential benefit to be obtained from combining the assets in a portfolio. From regulatory perspective, the extent to which the markets return volatility correlate is of great concern to regulators and financial policy-makers. In a correlated markets for example, it may be possible for a shock in one market to have destabilising effects on other markets thereby negatively affecting financial stability (Emenike, 2014).

Understanding the dynamic correlation between stock market and crude oil returns volatility in a developing country such as Nigeria is

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important for several reasons. First, Nigeria is a major supplier of crude oil in the world energy market and thus her stock market may be susceptible to changes in crude oil prices. Second, a shock in one of the market may lead to shock in other markets as apparently illustrated by the recent global financial crises which started in the United States and spread to almost all other world economies. Third, financial markets volatility correlation has important implications for portfolio selection and diversification, optimal hedging strategy, risk management and markets regulation. Finally, the Nigerian stock market represents very promising areas for regional and world portfolio diversification. Hence, evidenced-based knowledge of the nature of volatility correlation between crude oil prices and stock market returns is important for financial market investors to make good investment decisions and for policy-makers to regulate markets more proactively.

More so, the crude oil market is one of the most important markets in Nigeria as well as in the world economy due to the crucial role of oil within economic activity. Oil is used in various areas such as transportation, heating, electricity generation, and industry. Based on its wide array of use, oil market is significantly larger than that for any other commodity. Oil is also the mainstay of the Nigerian economy and plays a vital role in shaping the economic and political destiny of the country. Central Bank of Nigeria (CBN) (2012) reports, for example, that crude oil revenue accounted for 75.3% of the federally collected revenue and crude oil export accounted for 96.8% of total export. This implies that 97% of export earnings are partially outside the control of Nigeria. The CBN (2014) observes that the developments in the international oil market have intensified the risks and vulnerabilities faced by oil exporting countries in the wake of a new episode of falling oil prices. Similarly, the Nigeria stock market provides platform for mobilising long-term finance for incubating and sustaining industrial development as well as financing infrastructural facilities which are needed to catalyse economic growth.

Given the important role of crude oil in generating majority of the revenue required to finance Nigeria government's budget, the recent sharp and continual decline in crude oil prices, and the importance of stock market in providing avenue for mobilising long-term fund, it is important to understand the time-varying volatility correlation with stock and crude oil market in Nigeria. Such understanding will provide basis for investors to manage the risks emanating from crude oil price shocks. It will also assist financial market regulatory authorities in contemplating proactive policy measures against destabilising effects of crude oil price shock on investment returns and investors' confidence in the stock market.

While, a large literature exists on the time-varying nature of correlations between stock market returns and crude oil prices in both developed and developing countries using the framework of multivariate generalised autoregressive conditional heteroscedasticity time series models (see, for example, Filis, Degiannakis & Floros, 2011; Guesmi, Fattoum & Ftiti, 2014; Jouini & Harathi, 2014; Mishra & Yadav, 2014; Teulon & Guesmi, 2014;), such evidence is not available in the case of Nigeria. The few available empirical studies using Nigerian data concentrated on the impact oil price changes on the economy and exchange rate (see, for instance, Iwayemi & Fowowe, 2011; Salisu & Mobolaji, 2013). Given the continental position of Nigeria as the 'Giant of Africa', there is a need for an empirical study on the time-varying correlation between stock market and crude oil returns.

The objective of this study therefore is to complement extant evidence on nature of time-varying correlation in asset prices in both developed, emerging and developing countries by evaluating the dynamic conditional correlation between stock market returns and changes in crude oil prices in Nigeria. Findings of this study will enhance stock portfolio risk management and stock market regulation in Nigeria, as well as contribute to grow the existing literature on volatility dynamics between stock market and crude oil returns in developing countries. The rest of the paper is organised as follows: the next section presents brief review of empiri-

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cal literature. Section three contains description of data and methodology, while section four provides empirical results and discussion of findings. Finally, section five provides the concluding remarks.

Literature Review

Following the development of dynamic conditional correlation multivariate GARCH model by Engle (2002) and Engle and Sheppard (2001), there has been a large literature on the time-varying correlations of assets prices across countries as well as within domestic markets in different economies. Empirical studies that concentrate on the dynamic correlation between volatilities of stock market returns and crude oil prices are growing. A study by Nandha and Hammoudeh (2007) analysed the impact of the OPEC oil price on stock markets of fifteen Asia-Pacific region countries, observed weekly, covering a period from May 4, 1994 to June 30, 2004. The estimates from regression model suggest that oil exporting and importing countries respond differently to a change in oil price. The positive change in the oil price has a positive effect on oil exporters but negatively affects oil importers and vice versa for a negative change in the oil price. They also report that the oil price increase is negative and insignificant for the stock markets of India and China.

Filis, Degiannakis and Floros (2011) investigated the time-varying correlation between stock market prices and oil prices for oil-importing and oil-exporting countries using DCC-GARCH-GJR approach on data from six countries; oil-exporting: Canada, Mexico, Brazil and oil-importing: USA, Germany, Netherlands. The results show among others that although time-varying correlation does not differ for oil-importing and oil-exporting economies, the correlation increases positively (negatively) in respond to important aggregate demand-side oil price shocks. The results also show that supply-side oil price shocks do not influence the relationship of the two markets. The results of lagged correlation further show that oil prices exercise a negative effect in all stock markets, regardless the origin of the oil price shock. The only exception is the 2008 global financial crisis where the lagged oil prices exhibit a positive correlation with stock markets. They conclude that in periods of significant economic turmoil the oil market is not a safe haven for offering protection against stock market losses.

Dhaoui and Khraief (2014) examined whether oil price shocks impact stock market returns using monthly data for eight developed countries namely, US, Swiss, France, Canada, UK, Australia, Japan and Singapore, from January 1991 to September 2013. The results indicate evidence of strong negative connections between oil price and stock market returns all the selected countries except Singapore. Oil price changes are without significant effect on the stock market of Singapore. On the volatility of returns, the changes in oil prices are statistically significantly sensitive to the oil price variation for all selected countries with the exception of the cases of France and UK, without much effect on the others.

Guesmi, Fattoum, and Ftiti (2014) investigated crude oil and stock market interdependence in oil exporting countries of the United Arab Emirates, Kuwait, Saudi Arabia and Venezuela by measuring the interaction between oil price and stock market indices using the asymmetric DCC-GARCH approach. Their results show, apart from the Venezuelan stock market, that high oil prices driven by demand-related shocks move in line with stock prices for the case of exporting countries. They also show that supply shocks cause higher correlation in the case of exporting countries. They conclude therefore that, in terms of potential diversification, oil is not always countercyclical with respect to stock markets, as generally predicted by the previous literature. On the other hand, if the shock originates from demand, oil prices and stock markets tend to move together with varying degrees of strength in exporting countries, depending on the origin of the shock. In a related study, Teulon and Guesmi (2014) evaluate the time-varying correlations between stock market returns and oil prices in oil-exporting countries using DCC-GARCH framework on monthly data from Venezuela, the United Arab Emirates, Saudi Arabia and Kuwait, over the period August 31, 2000 to June 31, 2010. The results show that there are time-varying correlations between the oil and stock markets in emerging, oil-producing countries. They also report that the relationship between oil prices and stock returns is influenced by the origin of shocks to oil prices, with stock market responses being stronger in demand-side shocks caused by political turmoil or fluctuations in the global business cycle than to supply-side shocks caused by cuts in oil production. The results further provide evidence of volatility spillovers between the oil and stock markets.

Research Methods

Methodology

The dynamic conditional correlation multivariate generalized autoregressive conditional heteroscedasticity (DCC-MGARCH) model, which was introduced in Engle (2002) and Engle and Sheppard (2001), was adopted to evaluate the time varying relationship between stock market returns and changes in crude oil prices in Nigeria. The major advantage of DCC-MGARCH model is that it enables estimation of conditional covariance matrices for large number of assets in a two-step procedure with smaller number of parameters than most of the MGARCH specifications such as VECH representation (see, Bollerslev, Engle & Wooldridge, 1988), BEEK representation (see, Engle & Kroner, 1995), and so on. The variance covariance matrix equations depend on the squares and cross products of εt which is derived from the following mean equation:

$$r_{it}=\varphi+\delta r_{it-i}+\varepsilon_{it} \quad (1)$$

$$\varepsilon_t|\Omega_{t-1}\sim N(0,H_t)$$

$$H_t= D_t R_t D_t \quad (2)$$

Where r_{it} is return of market i at time t; φ is the conditional expectation of market i return given the information set Ω_{t-1}, δ is the autoregressive (AR) parameter to account for serial correlation in market i return, ε_t is the residuals of market i returns at time t; Ω_{t-1} is the matrix of conditional previous information set, H_t is the variance-covariance matrix, D_t is the n x n diagonal matrix of time varying conditional variances from univariate GARCH models with $\sqrt{h_{it}}$ on the ith diagonal, and R_t is the time-varying correlation matrix.

The AR order of p for both the stock market and crude oil returns were selected on the basis of Bayesian information criterion (BIC). The BIC was computed thus:

$$BIC=(-2\log L)/T+log(T)K/T \quad (3)$$

where K is the number of variables in the AR model, T is a number of observations. The lag length of AR term was selected by minimising the function over different choices for the lag length.

The time varying conditional variances (elements of D_t in equation 2) are obtainable from univariate GARCH model specified thus:

$$h_{it}=\omega_i+\alpha_i\varepsilon^2_{it}\beta_i h_{it-1} \quad (4)$$

Where h_{it} is the conditional variance of asset i (eg stock market returns) at time t, ω_i is the constant variance that correspond to the long run average, α_i refers to a first order ARCH term which transmits news about volatility from the previous period and β_i, the first order GARCH term, is the new information that was not available when the previous forecast was made (Engle, 2003).

The time varying correlation matrix t R, according Engle (2002) and Engle & Sheppard (2001), was estimated as follows:

$$R_t=(diag(Q_t))^{-\frac{1}{2}}Q_t(diag(Q_t))^{-\frac{1}{2}} \quad (5)$$

$$Q_t=(1-\omega_1-\omega_2)\bar{Q}+\omega_1 z_{t-1}z'_{t-1}+\omega_2 Q_{t-1} \quad (6)$$

$$\bar{Q}=\frac{1}{T}\sum_{t=1}^{T}z_t z'_t \quad (7)$$

Where Q_t is a variance-covariance matrix of standardized residuals ($z_t=\frac{\varepsilon_t}{\sigma_t}$), $\bar{Q}$ is an unconditional covariance of the standardized residuals resulting from the first stage estimation, z_t is a standardized residual at time t.

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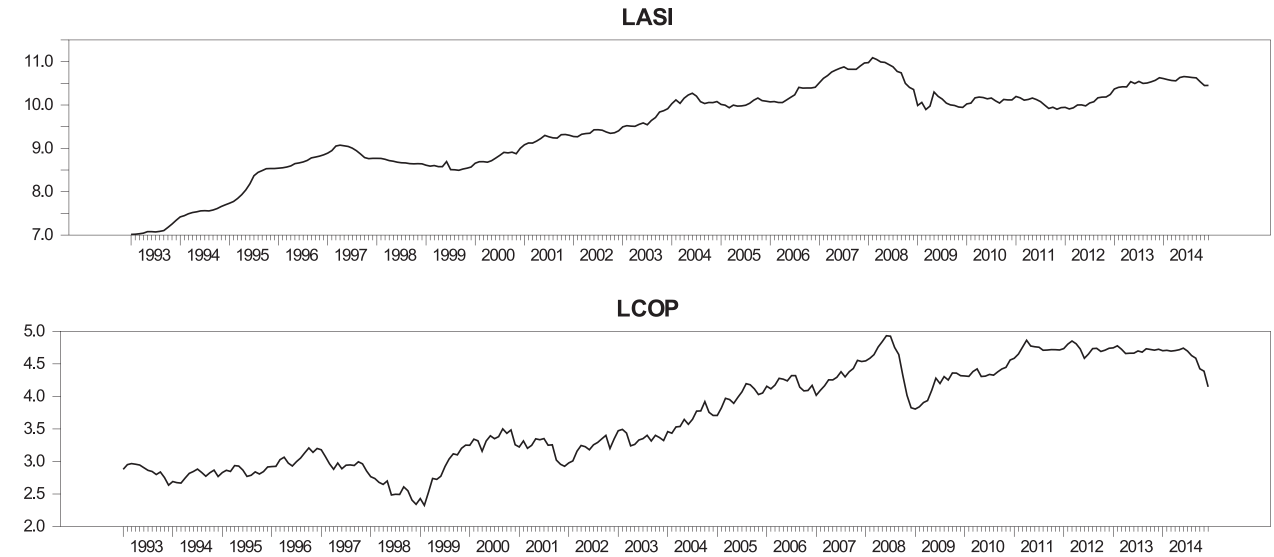

Figure 1. Time Series Plot of Log-Levels of Stock Index and Crude Oil Prices January 1993 to December 2014

The following non-negativity and stationarity constraints were imposed:

$\omega_1+\omega_2<1$, $\omega_1\omega_2>0$

The DCC model was designed to allow for a two stage estimation procedure. In the first stage, the conditional variances are estimated using a univariate GARCH specification. In the second stage, the standardized residuals are used to estimate the parameters of the dynamic correlations. The parameters are estimated using the maximum likelihood estimation method optimized with the Berndt, Hall, Hall and Hausman (BHHH) algorithm. The log likelihood function of the model is given by:

$$
\begin{aligned}
L(Q) &= -\frac{n}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln|D_tR_tD_t| + \varepsilon_t'(D_tR_tD_t)^{-1}\varepsilon_t \\
&= \left(-\frac{1}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln|D_t^2| + \varepsilon_t' D_t^{-2}\varepsilon_t\right) \\
&+ \left(-\frac{1}{2}\sum_{t=1}^{T}\left(\ln|R_t| + z_t'R_t^{-1}z_t - \frac{1}{2}z_t'z_t\right)\right) \\
&= L(\theta_1) + L\left(\frac{\theta_2}{\theta_1}\right) \qquad (8)
\end{aligned}
$$

Where T is a number of observations, n is a number of variables, θ is a vector of unknown parameters, θ_1 is a vector of unknown parameters of volatility component, θ_2 is a vector of unknown parameters of the correlation component.

Data

Monthly observations on the All-share index (ASI) of the Nigerian Stock Exchange (NSE) crude oil prices (COP) were obtained from the Central Bank of Nigeria statistics databank for the period ranging from January 1993 to December 2014, totaling 264 observations for each series. This time period was chosen to capture the effect of deregulation of the Nigerian capital market in 1993 and subsequent relaxation of all the restrictions that constrained foreign portfolio investments. The selected study period is therefore devoid of regulatory bottleneck associated with regulated markets. The COP and ASI series were transformed to returns series by taking their first log difference thus:

$$r_t=Ln(p_t-p_{t-1})*100 \qquad (9)$$

Where r_t is the vector of monthly returns of the COP and ASI specified in equation (1), p_t is closing value of the COP and ASI in month t, p_{t-1} is the previous month closing value, and *Ln* is natural logarithm.

Results and Discussions

Descriptive Statistics

Figure 1 and 2, show the time plots of log-levels and returns series of the Nigerian stock

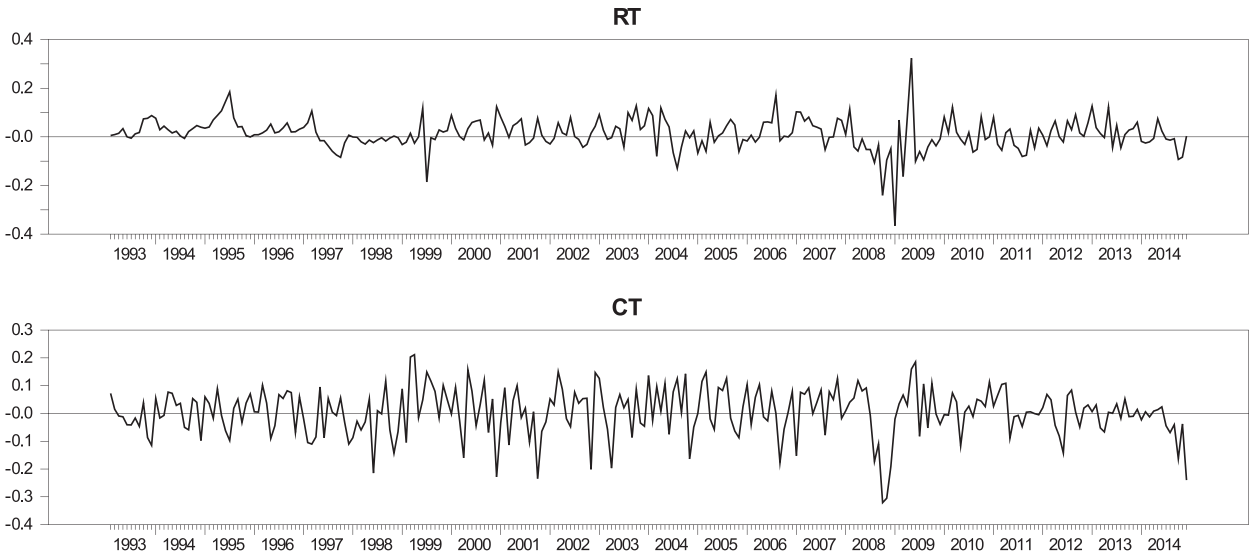

Figure 2. Time Series Plot of Return Series of Stock Index and Crude Oil Prices January 1993 to December 2014

Table 1. Univariate Statistics for Stock Market and Crude Oil Returns

Variable	Mean	Std. Dev.	Skewness	Kurtosis	J-B Stat.
Stock	0.013	0.064	-0.600	6.915	539.9
			(0.000)	(0.000)	(0.000)
Oil	0.004	0.085	-0.707	1.180	37.203
			(0.000)	(0.000)	(0.000)

Note: *P*-values are displayed as (.). S.D and E. kurt are the standard deviation and excess kurtosis of the market returns. Skew and JB stat are the skewness and Jarque-Bera statistics for the market returns.

market index and crude oil prices for the January 1993 to December 2014 period. The level of both stock market index and crude oil price series exhibit upward movements with visible fluctuations. The downward movement during the 2008 global financial crisis is very noticeable in both series. The return series, on the other hand, do not appear smooth, they rather appear volatile. The stock returns have fewer spikes than the crude oil returns. In addition, the two return series appear to return to their mean after deviations.

Univariate statistics for each of the return series are presented in Table 1. The average rate of return in the Nigeria stock market over the study period is positive and represents 15.6% annualised return, with a standard deviation of 76.8%; whereas the mean return for oil is 4.8%, with 102% standard deviation. This shows that the average return of crude oil prices is less than stock market return but with more variability from expectation. Excess kurtosis of the stock market and crude oil returns series are 6.9 and 1.8 respectively. Since all excess kurtosis are greater than 0, the distribution of the stock market and the crude oil returns has heavy tails but the tail of stock market return is heavier than that of crude oil return. Heavy tail implies that uncertainty is coming from outlier events and extreme observations are much more likely to occur. Therefore, investors can make very high returns and as well lose large amount of their investments (Hung, Lee, & Liu, 2008). Notice also that both return series are negatively skewed. Liu, Zhang, and Wen (2014) observe that negatively skewed return distribution will increase the loss probability, whereas positively skewed one will increase the possibility of gaining. The Jarque-Bera statistics suggest that the null hypothesis of normality does not hold for the two series.

Results of Autocorrelation and Lag Selection in Stock and Oil Returns Series

Table 2 displays the autocorrelation functions (ACF) of the stock market and crude oil returns series and the Ljung-Box Q-statistic

Table 2. Autocorrelation and Lag Selection for Stock Market and Crude Oil Returns

Panel A: Autocorrelation analysis for stock market and crude oil returns							
Lags	1	2	4	6	8	10	12
Stock	15.97	29.26	38.82	48.42	51.86	58.92	58.95
	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}
Oil	7.62	9.15	10.43	13.58	18.67	21.29	22.99
	{0.00}	{0.01}	{0.03}	{0.03}	{0.01}	{0.01}	{0.01}
Panel B: BIC lag analysis for stock and crude oil return series							
Lags	0	1	2	3	4	5	6
Stock	-5.480	-5.521	-5.530*	-5.520	-5.513	-5.520	-5.499
Oil	-4.892	-4.899*	-4.880	-4.861	-4.842	-4.821	-4.811

Note: The p-values of Ljung-Box Q statistic for the autocorrelation functions are displayed as {.}.

Table 3. ARCH-LM Test for Heteroscedasticity in Squared Return Series

Lags	1	2	3	4	5	6
Stock	14.49	7.28	9.85	15.40	12.27	10.37
	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}
Oil	11.83	6.10	4.00	2.98	2.66	2.35
	{0.00}	{0.00}	{0.00}	{0.01}	{0.02}	{0.03}

Note: The p-values of ARCH-LM test for heteroscedasticity are displayed as {.}.

Table 4. Unit Root and Stationarity Tests Results

ADF Unit Root Test Results				
	Log-level series		Return series	
Variables	critical value 5%	computed value	critical value 5%	computed value
Stock	-3.428	-2.095	-3.428	-5.393 **
Oil	-3.428	-2.665	-3.447	-13.331**
KPSS Stationarity Test Results				
Variables	critical value 5%	computed value	critical value 5%	computed value
Stock	0.463	4.472**	0.463	0.383
Oil	0.463	4.938*	0.463	0.079

Note: ADF and KPSS lag lengths are selected using Akaike information criterion (AIC). ** indicates significant at 99% confidence level.

used for testing significance of the ACF up to lags 12. The ACF test is conducted to ascertain whether the return series are serially correlated. The nature of autocorrelation of the returns series is necessary to define appropriate conditional mean equation (Strydom & Charteris, 2011). Rachev, Mittnik, Fabozzi, Focardi & Jasic (2007: 293) state that if the conditional mean is not specified adequately, then the construction of consistent estimates of the true conditional variance would not be possible and statistical inference and empirical analysis might be wrong. The ACF and Ljung-Box Q-statistic indicate that the stock market and crude oil returns series are serially correlated at the 5% significance level. The existence of serial correlation in the stock market and crude oil returns series give impetus to estimate an autoregressive (AR) specification in the their mean model to account for time dependence in the residuals. Hence, Schwarz/Bayesian information criterion (BIC) lag analysis was conducted to select the appropriate autoregressive lag length, and the results are displayed in *Panel B* of *Table 2*. Notice from *Table 3* that the BIC suggests autoregressive lag one (*AR*1) and two (*AR2*) for the crude oil and stock market returns respectively.

Results of Tests for Heteroscedasticity in Stock and Oil Returns Series

Table 3 presents results of the test for heteroscedasticity in the squared residuals of the crude oil and stock market returns series estimated using autoregressive conditional heteroscedasticity Lagrange multiplier (ARCH-LM) test. It is glaring from *Table 3* that stock market and crude oil squared residuals are heteroscedastic (i.e., exhibit ARCH effects). This is evident at the 1% significance level for the coefficients of squared residuals up to lags 6. The presence of heteroscedasticity in the squared residual series is a justification for the estimation of GARCH family models.

Unit Root Tests Results for Stock Market and Crude Oil Returns

Table 4 contains the results of the augmented Dickey-Fuller (ADF) unit root tests and Kwiatkowski (KPSS) stationarity tests for the stock and crude oil log-level and return series. The null hypothesis of the ADF test is that a time series contains a unit root, whereas the null hypothesis of the KPSS test is that a time series is stationary. As shown in *Table* 4, the computed values of the ADF test statistics indicate that the level series contain a unit root at the 1% significance level, implying that the level series are non-stationary. However, in the case of the return series, the statistics reject the null hypothesis of a unit root at the 1% significance level, implying that the returns are stationary for the two series. The results of the KPSS tests, on the other hand, show that the level series are non-stationary, whereas, their first differences are stationary. Therefore, both the ADF and KPS show that the stock and crude oil series require first difference to become stationary.

Results of AR(*p*)-DCC-GARCH (1,1) Model of Stock and Crude Oil Returns

Table 5 shows the results of DCC-GARCH (1.1) model estimated to evaluate whether there is time-varying conditional correlation between the Nigerian stock market and crude oil returns volatility. From the estimates in *Table 5*, it is apparent that coefficients of the ARCH parameters in both the stock market (0.33) and crude oil (0.15) are significant at the 5% level. These indicate that the news about volatility from the previous periods has explanatory power on returns in both stock market and crude oil. Given the magnitude of the coefficients, it appears that volatility shocks in stock market have more explanatory power on current volatility than that of crude oil returns. Similarly, volatility clustering parameters are statistically significant, at the 5% level, for both the stock market (0.63) and crude oil (0.78). These indicate evidence of volatility clustering in the monthly returns of the Nigerian stock market and crude oil returns. But the magnitude of the GARCH coefficients suggests that there is more clustering in crude oil price volatility than in the stock market return volatility. Notice also from *Panel B* of *Table 5* that volatility clustering is persistent in both stock market and crude oil return series. However, volatility clustering is more persistent in stock market returns (0.96) than in crude oil prices (0.94). High Volatility persistence implies that average variance will remain high since increases in conditional variance due to shocks will decay slowly (Rachev *et al*., 2007: 296).

Panel C of *Table 5* presents estimates obtained from the DCC-GARCH (1,1) parameters. These estimates were used to examine the existence of time-varying correlation in assets prices. Notice, from *Panel C*, that the DCC ARCH parameter is not significant. This result suggests that there is no dynamic conditional correlation in ARCH effect between stock market and crude oil prices in Nigeria. In other words, there is no comovement in the manner volatility shock from the previous period affects current volatility in the stock market and crude oil prices. The estimate of DCC GARCH parameter, on the other hand, is highly statistically significant at the 1% level. The DCC GARCH coefficient (0.97) with *t*-statistic (57.00) and *p*-value (0.00) indicates that there is strong evidence of dynamic conditional correlation in GARCH effect between stock market returns volatility and crude oil price volatility. In other words, volatility clustering in the Nigerian stock market and crude oil returns are dynamically correlated. Evidence of conditional correlation is consistent with some of the earlier findings (see for example, Filis, Degiannakis & Floros, 2011; Jouini & Harathi, 2014; Teulon & Guesmi, 2014). Teulon & Guesmi (2014), for example, find among others, that there are time-varying correlations between the oil and stock markets in emerging, oil-producing countries. Jouini and Harathi (2014), using the BEKK-GARCH (1,1), provide evidence of bidirectional volatility transmission between GCC stock and oil markets returns.

Evidence of time varying conditional correlation provides support for volatility interdependence between the stock market and

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Table 5. Estimate of DCC-GARCH (1,1) Model parameters

Parameters	Coefficients	*t*-statistic	*P*-value
	Panel A: Conditional mean estimates		
Constant $_{(stock)}$	0.0066	2.1785	0.0293
Stock return$_{t-1}$	0.6604	4.8133	0.0000
Stock return$_{t-2}$	0.3765	2.1155	0.0343
Constant $_{(oil)}$	0.0023	0.4938	0.6213
Oil return$_{t-1}$	0.1051	1.5010	0.1333
	Panel B: Conditional variance estimates		
$C_{(stock)}$	0.0003	2.4130	0.0158
$C_{(oil)}$	0.0005	1.3706	0.1704
$A_{(stock)}$	0.3330	4.0736	0.0000
$A_{(oil)}$	0.1563	2.1775	0.0294
$B_{(stock)}$	0.6282	9.7415	0.0000
$B_{(oil)}$	0.7874	9.3532	0.0000
	Panel C: Dynamic conditional correlation estimates		
$DCC_{(A)}$	0.0149	1.2664	0.2053
$DCC_{(B)}$	0.9733	57.033	0.0000
	Panel D: Standardized residuals diagnostics		
	Statistic	*p*-value	*p*-value ($\chi 2$)
Q stock model residuals [6]	2.514	0.8669	
Q stock model residuals^2 [6]	8.751	0.1880	
Q oil model residual [6]	2.812	0.8320	
Q oil model residual2 [6]	5.910	0.4333	
MV ARCH {6}	5.760		0.4506
MV Q [6]	8.434		0.2079

Note: Qstock and Qoil are the Ljung-Box Q-statistic for the stock market and oil returns respectively. MV LM and Q are multivariate ARCH-LM and Ljung-Box Q-statistic for null hypotheses of no heteroscedasticity and no serial correlation in the multivariate DCC-GARCH model. Lag length is displayed as [.] and degrees of freedom is shown as {.}. Decision is taken at the 5% significance level.

crude oil markets in Nigeria. Interdependence between the stock market and crude oil markets has implications for portfolio selection and diversification, risk management and stock market regulation. Investors interested in the Nigerian market may not achieve significant risk reduction by combining assets from the two markets in a portfolio. However, investors could manage their portfolio risk by constantly monitoring volatility behaviour of the crude oil market, and adjust their portfolio accordingly. In addition, time varying correlation between the stock market and crude oil markets in Nigeria presupposes that stock market regulators should monitor developments in the crude oil market so as to formulate proactive policy measures to contain the effect of any expected volatility shock from the crude oil market.

Panel *D* of *Table* 5 displays the results of diagnostic tests conducted to examine adequacy of the fitted DCC-GARCH (1,1) model. As shown in *Panel D*, the univariate Ljung-Box statistics give Q(6) = 2.51 and Q2 (6) = 8.75, which correspond to p-values of 0.86 and 0.16 respectively for the residuals and squared residuals of the stock returns model. For crude oil returns model, we have Q (6) = 2.81 and Q2 (6) = 5.91 with *p*-values of 0.83 and 0.43 respectively for the residuals and squared residuals. These imply that the Q-statistics for the residual series and squared residual series of stock market and crude oil returns are insignificant, suggesting that there are no serial correlations in their residuals and squared residuals. Similarly, the multivariate ARCH-LM and multivariate Ljung-Box Q statistic results provide evidence, at the 99% confidence level, in support of the null hypotheses of no conditional heteroscedasticities and no serial correlations, respectively, in the bivariate standardized residuals of the DCC-GARCH model. Hence, the DCC-GARCH (1,1) model appears to be well specified in both mean and variance.

Conclusions

This paper evaluated the nature of relationship between the volatilities of Nigerian stock market and crude oil return series using multivariate DCC-GARCH (1,1). The data for the study ranges from January 1993 to December 2014. The results obtained from univariate GARCH (1,1) model show evidence of volatility clustering and volatility persistence in Nigeria stock market and crude oil returns. The results provide evidence to show that there is strong evidence of time-varying volatility correlation between stock market returns volatility and crude oil price volatility. Overall results from this study suggest that there is persistent time-varying conditional correlation between the volatilities of Nigerian stock market and crude oil returns. The DCC-GARCH (1,1) model, therefore, provides a simple and parsimonious model as it successfully accounts for time-varying correlated schedastic processes, which allows examination of the nature of time varying correlation between stock and crude oil markets returns in Nigeria. In addition, evidence of time varying correlation between stock and oil markets returns suggests that investors may not achieve significant risk reduction by combining assets from the two markets in a portfolio.

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