The Interrelationship between Crude Oil Price Volatility and Money Market Rate Volatility in a Developing, Oil-Producing Economy

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Abstract
This study evaluates the interrelationship between crude oil price volatility and money market rate volatility in a developing, crude oil producing economy using monthly time series observations from January 2002 to December 2014. The results obtained from a BEKK specification of a multivariate GARCH (1,1) model indicate that shocks and increased volatility from crude oil prices and money market rates influence their current volatilities. The result also show evidence of volatility persistence in crude oil prices and money market rates in Nigeria. The results further provide evidence of significant unidirectional volatility spillovers from crude oil prices to the money market in Nigeria. These findings are important because they provide a strong indication that crude oil price volatility is a very strong variable in determining the money market rates volatility in Nigeria.

Keywords: Money market rate, crude oil price, volatility interrelationship, multivariate BEKK-GARCH model, oil producing economy, developing country

JEL Classification: E40, C32, G21, Q43

Introduction
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 it plays in economic activity. Crude oil is used in various areas such as transportation, heating, electricity generation, and industry. Based on its wide array of use, the market for crude oil is significantly larger than that of any other commodity. Crude oil is the mainstay of the Nigerian economy and plays a vital role in shaping the economic and political destiny of the country. CBN (2012) reports, for example, that crude oil revenue accounted for 75.3% of the federally collected revenue and that crude oil export accounted for 96.8% of total export. This underscores the magnitude of reliance of the Nigerian economy on crude oil. The money market, on the other hand, plays an increasingly important role in the mobilisation of financial resources for short-term investment through financial intermediation. The existence of a money market facilitates trading in short-term debt instruments to meet the short-term needs of large users.
of funds such as governments, banks and similar institutions. Government treasury bills, and company commercial bills are examples of instruments traded in the money market. A wide range of financial institutions, including merchant banks, commercial banks, the central bank, and other dealers operate in the money market. Public as well as private sector operators make use of various financial instruments to raise and invest short-term funds at the prevailing money market rates. The stability of crude oil prices and money market rates is a major concern to the monetary authorities of oil producing countries such as Nigeria because of their tendency to experience high volatility resulting from demand and supply pressures.

Despite the ever growing importance of crude oil as major source of revenue to crude oil producing economies and the vital role of money market in the mobilisation of financial resources for short-term investments, little is known about their volatility interrelationship, especially in countries with developing money markets such as Nigeria. Understanding the interrelationship between shocks and the volatility of crude oil prices and money market rates is necessary to prevent potential systemic risk or market-specific instability that may arise from such shock and/or volatility transmission. More so, monetary authorities’ ability to control money market short-term rates with high precision is necessary for credible monetary policy implementation.

Numerous empirical studies have been conducted to examine volatility of money market short-term rates (see for example, Ayuso et al., 1997; Sarkar and Ariff, 2002; Shahiduzzaman and Naser, 2007; and Neupane, 2011). Shahiduzzaman and Naser (2007) for example, find strong evidence that volatility shocks are quite persistent in the Bangladesh call money rate. A similar study by Neupane (2011) documents evidence of clustering of large and small variances as well as high volatility persistence in the interbank rate of Nepal. Empirical studies have also been conducted on the volatility interrelationship, but most of the studies concentrated on volatility interdependence between crude oil and stock markets as well as among financial markets. The majority of these studies have, however, been conducted for developed and emerging economies (see for example, Badrinath and Apte, 2005; Demiralay and Gencer, 2014; Hamma et al., 2014; and Harathi and Almohaimeed, 2015). Badrinath and Apte (2005) for example, document the existence of symmetric volatility spillovers from the call money market to stock market and asymmetric volatility spillovers from the
stock market to the call money market in India. Demiralay and Gencer (2014) report a negative and unidirectional shock transmission from oil market to financial and energy indices, while negative and bi-directional shock transmissions exist between the oil market and the industrials index. Hamma et al. (2014) find unidirectional volatility transmission from the crude oil market to the Tunisian stock market using a bivariate GARCH-BEKK model. Harathi and Almohameed (2015), using the BEEK specification of a multivariate GARCH model, report that oil prices and stock markets are more affected by their own shocks and volatility. They also reported that oil price volatility affects all Gulf Coast (GCC) stock markets except those of Bahrain and Kuwait. There is no empirical evidence, to the author’s knowledge, on dynamic linkage between the volatility of crude oil market and the money market in Nigeria. There is therefore a need for empirical evidence-based knowledge on the nature of interrelationship between crude oil price volatility and money market rate volatility in Nigeria.

This paper contributes to closing the gap in empirical literature by evaluating the interrelationship between crude oil price volatility and money market volatility in Nigeria. The findings of this study are important to money market authorities and participants. The money market authorities, for example could anticipate the destabilizing effects of a shock in the crude oil price on the money market and devise proactive policy measures to guide against systemic risk or market-specific instability that may arise from such. Money market participants could also build optimal hedging strategies against volatility shocks from the crude oil market. In addition, this study contributes to the empirical literature on the volatility interrelationship between crude oil and money markets in developing countries and points the way for further inquiry into the subject for future studies. Section 2 presents an overview of the crude oil and money markets in Nigeria. Section 3 describes the data and methodology. Section 4 contains empirical results and discussion, and section 5 provides the conclusions.

**Overview of Crude Oil Industry and Money Market in Nigeria**

The Nigerian money market was established and nurtured by the Central Bank of Nigeria (CBN), primarily for mobilising domestic savings for productive investment and providing government with funds to enable it to implement its economic programmes as well as to serve as a channel
for monetary policy transmission. Before the establishment of the CBN in 1959, there was no formal or organized market money market in Nigeria. The banking space was dominated by foreign-owned commercial banks, and their main activities centered on the financing of foreign trade in favour of expatriate merchants. The operations of these expatriate banks were directly linked to the London money market, where surplus funds could be invested (Nnanna et al. 2004). With the establishment of the CBN in 1959, and the subsequent attainment of political independence in 1960, the CBN became actively involved in the development of the Nigerian money market. Specifically, in line with the Treasury Bills Ordinance of 1959, the CBN designed and issued, on behalf of the federal government, the first Nigerian Treasury Bills in April 1960. In 1968, Treasury Certificates were issued for the first time as short-to-medium term government securities maturing in either one or two years and was designed to bridge the gap in government fiscal operations. Certificates of Deposit, Bankers Unit Fund and Special Deposits with the CBN were subsequently introduced between 1974 and 1976 (Ibeabuchi et al. 2004). Other forms of money market instruments that evolved with the development of the Nigerian money market include Commercial Papers, Repurchase Agreements, Inter-bank Placements, Money Market Funds, and so on (Onoh, 2002). The operators in the Nigerian money markets are the financial institutions operating in the country, who are actively engaged in the financial intermediation process. They include Commercial Banks, Merchant Banks, Discount Houses, Finance Companies, Bureaux de Change, Individuals/Households, Specialised Banks, etc. Another major operator in the Nigerian money market is Nigeria Inter-Bank Settlement System (NIBSS) Plc. The NIBSS provides the infrastructure for automated processing, settlement of payments and fund transfer instructions between Banks, Discount Houses and Card Companies in Nigeria. The regulatory authorities of the Nigerian money market include the CBN, Nigeria Deposit Insurance Commission, Federal Ministry of Finance, and the Bankers’ Committee which represents the key stakeholders. The indicators of the Nigerian money market include the Inter-Bank Call Rate, the Minimum Policy Rate, the Treasury Bill Rate, the Savings Deposit Rate, and Lending Rates (both Prime and Maximum).

Oil was discovered in Nigeria, according to NNPC (undated), in 1956 at Oloibiri in the Niger Delta after half a century of exploration. The discovery was made by Shell-BP, at the time the sole concessionaire.
Nigeria joined the ranks of oil producers in 1958 when its first oil field came online, producing 5,100 bpd. After 1960, exploration rights in onshore and offshore areas adjoining the Niger Delta were extended to other foreign companies. In 1970, the end of the Biafran war coincided with the rise in the world oil price, and Nigeria was able to reap instant riches from its oil production. Nigeria joined the Organisation of Petroleum Exporting Countries in 1971 and established the Nigerian National Petroleum Company in 1977; a state-owned and -controlled company which is a major player in both the upstream and downstream sectors. By the late sixties and early seventies, Nigeria had attained a production level of over 2 million barrels of crude oil a day. Although production figures dropped in the eighties due to an economic slump, 2004 saw a total rejuvenation of oil production to a record level of 2.5 million barrels per day. Petroleum production and export play a dominant role in Nigeria's economy and account for about 90% of the country’s gross earnings. This dominant role has pushed agriculture, the traditional mainstay of the economy from the early fifties and sixties, to the background. The Nigerian oil sector can be categorized into three main sub-sectors, namely, upstream, midstream, and downstream ventures. The operators of the petroleum industry include the Department of Petroleum Resources, the Nigerian National Petroleum Corporation, Independent Petroleum markets operating in the downstream sector, and Joint venture operations involving foreign owned companies.

Data and Methodology

Methodology

Rachev et al. (2007) observe that considering a generalized autoregressive conditional heteroscedasticity (GARCH) model independently for every asset is not sufficient, because volatilities of asset returns or market indexes move together in time. This study therefore estimates a BEKK representation of a multivariate GARCH model outlined in Baba et al. (1990), and Engle and Kroner (1995) to examine the nature of volatility spillover between crude oil and money markets in Nigeria. The BEKK model, named after its authors of the paper, presents a natural way to estimate the interaction within conditional mean and conditional variance of two or more series because of its capability to detect returns comovement and volatility transmission.
between the series, as well as persistence of volatility within each series (Bauwens et al., 2006).

The first step in estimating the multivariate GARCH parameters is to specify the mean equation. Hence, the mean equation for the markets return series was specified, in accordance with Engle and Kroner (1995), and Bauwens et al. (2006), as follows:

\[ R_t = \mu + \theta R_{t-1} + \varepsilon_t \]
\[ \varepsilon_t = H_t^{1/2} \eta_t \]  

(1)

where \( R_t = (R_{t}^{co}, R_{t}^{mm})' \) is a vector of returns of the crude oil market and money market respectively, \( \theta \) refers to a 2x2 matrix of coefficients, \( \varepsilon_t = (\varepsilon_t^{co}, \varepsilon_t^{mm})' \) is the vector of error terms of the conditional mean equation for crude oil and money market returns respectively, \( R_{t-1} \) is the autoregressive term in the mean equation in order to account for any autocorrelation in the market returns. \( \eta_t = (\eta_t^{co}, \eta_t^{mm}) \) is a sequence of independently and identically distributed (i.i.d) random errors; \( H_t = \begin{pmatrix} h_t^{co} & h_t^{co,mm} \\ h_t^{co,mm} & h_t^{mm} \end{pmatrix} \) is the conditional variance-covariance matrix of crude oil and money markets returns.

The next step is to specify the conditional variance-covariance equation. For this reason, the conditional variance-covariance equation of the BEKK representation of a multivariate GARCH(1,1) model was specified according to Engle and Kroner (1995), and Tsay (2005), as follows:

\[ H_t = CC' + A \varepsilon_t \cdot 1 \varepsilon_t' \cdot 1 A' + BH_t \cdot 1 B' \]

(2)

where \( H_t \) is the conditional variance matrix. \( C, A, \) and \( B \) are parameter matrices. \( C \) is a 2x2 lower triangular matrix with three parameters, \( A \) is a 2x2 square matrix that shows how conditional variances correlate with past squared errors, and \( B \) is 2x2 square matrix that measures the effect of past conditional variances on the current conditional variances and the degree of persistence in the volatility of the markets. The parameter matrices from (Eq. 2) can be represented as follows:
where \( h_{\text{co},t} \) denotes the conditional variance of the crude oil market, \( h_{\text{comm},t} \) the covariance of crude oil and money markets, and \( h_{\text{mm},t} \) the conditional variance of the money market. Statistical significance of the diagonal coefficients \( a_{\text{co},t} \) \( (a_{\text{mm},t}) \) would suggest that the current conditional variance of \( h_{\text{co},t} \) \( (h_{\text{mm},t}) \) is correlated with its own past squared errors, while the statistical significance of the lagged variance \( b_{\text{co},t} \) \( (b_{\text{mm},t}) \) indicate that the current conditional variance of \( h_{\text{co},t} \) \( (h_{\text{mm},t}) \) is affected by its own past conditional variance. Similarly, the statistical significance of the off-diagonal coefficients \( a_{\text{comm},t} \) and \( b_{\text{comm},t} \) will indicate evidence of shock and volatility spillover effects from the crude oil market to the money market, whereas the statistical significance of the off-diagonal coefficients \( a_{\text{mmco},t} \) and \( b_{\text{mmco},t} \) will show evidence of volatility spillover effects from the money market to the crude oil market (Steeley, 2006; Joshi, 2011; Kim, 2013).

The matrix multiplication leads to equations (4) and (5) where \( h_{\text{co},t+1} \) and \( h_{\text{mm},t+1} \) are conditional volatilities of crude oil market and money market respectively, \( h_{\text{comm},t} \) is the conditional covariance, \( \varepsilon_{\text{co},t}^2 \), \( \varepsilon_{\text{mm},t}^2 \) and \( \varepsilon_{\text{co},t} \varepsilon_{\text{fm},t} \) are the lagged own squared and cross-market random shocks.

\[
\begin{align*}
\begin{bmatrix} h_{\text{co},t} & h_{\text{comm},t} \\ h_{\text{mm},t} & 0 \end{bmatrix} &= \begin{bmatrix} c_{\text{co}}^0 & c_{\text{comm}}^0 \\ 0 & c_{\text{mm}}^0 \end{bmatrix} \begin{bmatrix} c_{\text{comm}}^0 & c_{\text{mm}}^0 \\ 0 & c_{\text{mm}}^0 \end{bmatrix} + \\
&+ \begin{bmatrix} a_{\text{co}}^* & a_{\text{comm}}^* \\ a_{\text{mmco}}^* & a_{\text{mm}}^* \end{bmatrix} \begin{bmatrix} \varepsilon_{\text{co},t-1}^2 & \varepsilon_{\text{co},t-1} \varepsilon_{\text{mm},t-1} \\ \varepsilon_{\text{co},t-1} \varepsilon_{\text{mm},t-1} & \varepsilon_{\text{mm},t-1}^2 \end{bmatrix} \begin{bmatrix} a_{\text{co}}^* & a_{\text{comm}}^* \\ a_{\text{mmco}}^* & a_{\text{mm}}^* \end{bmatrix} + \\
&+ \begin{bmatrix} b_{\text{co}}^* & b_{\text{comm}}^* \\ b_{\text{mmco}}^* & b_{\text{mm}}^* \end{bmatrix} \begin{bmatrix} h_{\text{co},t-1} & h_{\text{comm},t-1} \\ h_{\text{mmco},t-1}^* & h_{\text{mm},t-1}^* \end{bmatrix} \begin{bmatrix} b_{\text{co}}^* & b_{\text{comm}}^* \\ b_{\text{mmco}}^* & b_{\text{mm}}^* \end{bmatrix} \quad (3),
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix} h_{\text{co},t+1} \\ h_{\text{mm},t+1} \end{bmatrix} &= \begin{bmatrix} c_{\text{co}}^2 + a_{\text{co}}^2 c_{\text{co},t}^2 + 2a_{\text{co}} a_{\text{comm}} \varepsilon_{\text{co},t} \varepsilon_{\text{mm},t} + a_{\text{mmco}}^2 \varepsilon_{\text{mm},t}^2 + b_{\text{co}}^2 h_{\text{co},t}^2 + \\
&+ 2b_{\text{co}} b_{\text{comm}} h_{\text{comm},t} + b_{\text{mmco}}^2 h_{\text{mm},t} 
\end{align*}
\]
Maximum likelihood estimates of the parameters in equations (4) and (5) were obtained using the Broyden, Fletcher, Goldfarb, and Shanno (BFGS) algorithm. The likelihood element for an \( n \)-vector at time \( t \) is estimated in accordance Joshi (2011), and Kim (2013), and Emenike (2015) as follows:

\[
h_{mn,t+1} = c_{comm}^2 + c_{mm}^2 + a_{comm}^2 e_{co,t}^2 + 2a_{comm} a_{mm} e_{co,t} e_{mm,t} + a_{mm}^2 e_{mm,t}^2 + b_{comm}^2 h_{co,t}^2 + 2b_{comm} b_{mm} h_{comm,t} + b_{mm}^2 h_{mn,t}
\]

(5)

where \( \theta \) is the parameter vector to be estimated.

The adequacy of the multivariate GARCH model fitted to the crude oil and money markets returns series were evaluated by testing the standardised residuals for independence and heteroscedasticity (Tsay, 2005). If the mean model is adequately specified, the standardised residuals would be uncorrelated. Likewise, a good variance model would display uncorrelated squared standardized residuals and absence of heteroscedasticity. The autocorrelation function (ACF), Ljung and Box (1978) \( Q \) test statistic, and Engle (1982) Lagrange multiplier (LM) test were adopted to diagnose the BEKK model. The ACF and L-BQ test statistics were used to test the null hypothesis of no autocorrelation in the estimated residuals and squared standardised residuals up to a specific lag.

**Data**

Monthly observations on the crude oil prices (COP) and Interbank Call Rate (MMr), which proxy the money market, were obtained from the Central Bank of Nigeria (CBN) statistics databank for the period ranging from January 2002 to December 2014, totaling 156 observations for each series. The choice of the interbank call rate as a proxy for the money market is due to its ability to capture borrowing and lending movements in the money market as well as its close link with other interest rates in the financial market. Earlier studies that adopted the interbank call rate as a proxy for money market include: Cocco *et al.* (2009), Freixas and Jorge (2008), and Hamim (2012). The crude oil price, on the other hand, is the only valid proxy for the crude oil and gas industry considering the
nature of the study. The crude oil price is determined in the international oil market and mirrors the demand and supply behaviour of oil and gas products. Any shock in the world oil and gas market is transmitted to the world economy through crude oil price volatility. The Nigerian economy, being an oil-dependent economy, feels the impact of oil price shocks – both positive and negative. Any other domestic proxy will be inappropriate because of the influence of regulation of crude oil byproducts prices through subsidy in Nigeria. The COP and MMr series were transformed to returns series by taking their first log difference thus:

\[ R_t = \ln (P_t - P_{t-1}) \times 100 \]  

(7)

where \( R_t \) is the vector of monthly returns of the COP and MMr, \( P_t \) is closing value of the COP and MMr in month \( t \), \( P_{t-1} \) is the previous month closing value, and \( \ln \) natural logarithm.

**Empirical Results and Discussions**

**Descriptive Statistics**

Figure 1 presents a time-series graph of the log-level series of crude oil and money markets for the study period. Notice from Figure 1 that the crude oil market exhibited a strong upward trend from January 2002 which attained its peak in the second half of 2008, before moving downward, as a result of the Global Financial Crisis (GFC). The market price of crude oil rebounded from the third quarter of 2009 and remained fairly stable until June 2014, when it started to decline. Notice also that the series appears to be trending. The money market series graph, on the other hand, shows wide fluctuations. In January 2002, for example, the money market rate was 23.91%, but fell to 1.13% in March 2006, before rising to 24.30% in December 2014. The series does not also appear to be stationary.
The time series graph of the return series of the crude oil and money markets are presented in Figure 2. Observe that the crude oil return series was above its average value at the beginning of the study period. This was followed by wide fluctuations in the return series with many noticeable spikes. Observe also that the most negative change in the crude oil return series was recorded during the period of the GFC. However, the series shows a tendency toward mean reversion. This is easily seen in its ability to return to the mean after a deviation. Another noticeable feature of Figure 2 is that the money market return series are above their average for the study period. Notice also that the money market return series exhibits mean reversion, as can be seen in the ability of the series to return to the mean after a deviation. This is so because stationary series will always return to their mean irrespective of how far they deviate; that is one of the desirable attributes of stationary series and the reason for their choice in econometric estimation.
Panel A of Table 1 presents results of descriptive statistics for the crude oil and money market level series. The average crude oil price for the study period is $74 per barrel, with minimum and maximum prices of $19 and $138 respectively. The mean money market rate for the study period is 11.7%, with minimum and maximum rates of 1.3% and 27%. The wide variation between the minimum and maximum markets values are indications of their volatile movements.

Panel B of Table 2 provides some summary statistics for the crude oil and money markets returns series. Notice that the mean monthly returns of 0.75% and 0.01% for the two markets are statistically not different from zero. This is evidenced in p-value of 0.28 and 0.99 for crude oil and money markets respectively, used to examine whether the mean=0 at the 5% significance level. A p-value greater than the significance level (i.e.0.05) indicates that the mean returns for crude oil and money markets are zero. The monthly standard deviation for the crude oil and money markets return are 8.78% and 47.86% respectively. Notice that the money market, which has the lowest average monthly return, has the highest monthly standard deviation. This may be as a result of the short-term nature of the money market rate and its role of engendering a balance between deficits and surpluses in the settlements accounts of deposit money banks with the CBN.

The returns distribution of crude oil is negatively skewed, whereas that of the money market is not skewed. Skewness plays an important role in asset pricing. Negative skewness suggests that there are more negative observations in the return distributions of crude oil and zero skewness, in the case of the money market, shows a balance between the positive and negative returns. Liu, Zhang, and Wen (2014) posit that a negatively skewed return distribution will increase the loss probability, while the positively skewed one will increase the possibility of gaining. Negative skewness in the return distribution of crude oil may not surprise us given global decline in oil prices in recent past. Zero skewness of the money market returns may be an indication of efficiency in the market's price discovery process.

For symmetric unimodal distributions, positive excess kurtosis coefficient indicates heavy tails and peakedness relative to the normal, whereas negative excess kurtosis coefficient indicates light tails and flatness (DeCarlo, 1997). Panel B of Table 1, shows that the market returns have heavy tails and are peaked. The excess kurtoses are 1.7 and 6.5 for crude oil and money markets respectively. The heavy tail implies
that uncertainty is coming from outlier events and extreme observations are much more likely to occur. Therefore, investors can earn very high returns and as well lose large amounts of their investments (see, Wilcox and Keselman, 2003; Hung, Lee and Liu, 2008).

The Jarque-Bera test results are significant at conventional levels, suggesting that normality assumptions for all the market series are doubtful.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (Std. Dev.)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. Dev.</th>
<th>Skewness (Std. Dev.)</th>
<th>E. Kurt. (Std. Dev.)</th>
<th>J-B Stat. (Std. Dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Level series</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude oil</td>
<td>74.81 (0.00)</td>
<td>19.65</td>
<td>138.74</td>
<td>32.5</td>
<td>-0.024 (0.90)</td>
<td>-1.23 (0.00)</td>
<td>9.98 (0.00)</td>
</tr>
<tr>
<td>Money market</td>
<td>11.70 (0.00)</td>
<td>1.13</td>
<td>27.06</td>
<td>5.65</td>
<td>0.57 (0.00)</td>
<td>0.42 (0.28)</td>
<td>9.80 (0.00)</td>
</tr>
</tbody>
</table>

Note: P-values are displayed as (.). Std.Dev. and E. kurt. are the standard deviation and excess kurtosis of the market returns. J-B stat. is the Jarque-Bera statistics for the market returns.

Preliminary Analysis
This section aims at examining the crude oil and money market returns in Nigeria for signs of unit roots, autocorrelation and heteroscedasticity.

Results of tests for unit roots
Table 2 presents the results of unit root tests on log level and return series of crude oil and money markets. The testing methodologies are the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) tests. The critical values of the tests were taken at the 5% level of significance. The critical value of both the ADF and PP tests is -3.439 for the study period. Notice from Panel A of Table 2 that the calculated values of the ADF test statistics is more than the ADF critical tau value at 5% significance level. This indicates that the crude oil and money market level series contain unit roots at the 5% significance level. In other words, the crude oil and money markets series are not stationary in levels. The PP estimates uphold the results of the ADF tests except for the money market.
In the case of the market returns series, however, both the ADF and PP computed critical tau values are all less than the 5% critical tau value. These suggest that the crude oil and money markets returns series do not contain unit root at the 5% significance level. In other words, the market returns series are stationary at the 5% significance level. These results suggest that the crude oil and money markets returns series are stationary.

<table>
<thead>
<tr>
<th>Augmented Dickey Fuller results</th>
<th>Phillip-Perron results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Level series</strong></td>
<td></td>
</tr>
<tr>
<td>COP</td>
<td>-3.4394</td>
</tr>
<tr>
<td>MMr</td>
<td>-3.4394</td>
</tr>
<tr>
<td><strong>Panel B: Return series</strong></td>
<td></td>
</tr>
<tr>
<td>COP</td>
<td>-3.4394</td>
</tr>
<tr>
<td>MMr</td>
<td>-3.4394</td>
</tr>
</tbody>
</table>

**Note:** ** refers to 1% statistical significance levels.

Results of tests for serial correlation, lag selection, and heteroscedasticity

Table 3 displays the autocorrelation functions (ACF) and Ljung-Box Q significance level, Bayesian Information Criterion (BIC) lag selection, and ARCH-LM heteroscedasticity tests results for the crude oil and money markets returns series. The ACF test is conducted to ascertain whether the return series are independent of each other or are serially correlated. The nature of autocorrelation of the market returns series is necessary to define the appropriate conditional mean equation (Emenike, 2016). The results of independence tests conducted using the Ljung-Box Q-statistic indicate that the crude oil and money markets returns series exhibit serial correlation at the 5% significance level. Evidence of serial correlation in the markets returns series give an impetus to estimation of autoregressive (AR) specification.

To select an appropriate AR specification, 12 lags of the Bayesian Information Criterion (BIC), and from Table 3 the market returns require autoregressive lag one ($AR_1$) model.

The results of the test for heteroscedasticity estimated using the ARCH-LM test for the squared residuals of the crude oil and money markets returns series show that there is heteroscedasticity (i.e., ARCH

The presence of heteroscedasticity in the series is a justification for the estimation of a GARCH model.

### Table 3.

**Ljung-Box Q Statistics, Bayesian information criterion (BIC) lag selection, and Test for Heteroscedasticity**

<table>
<thead>
<tr>
<th>Lags</th>
<th>L-B Q statistics</th>
<th>BIC lag selection</th>
<th>Heteroscedasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COP COP</td>
<td>MMr MMr</td>
<td>COP COP</td>
</tr>
<tr>
<td>0</td>
<td>0.24 -0.42(0.00)</td>
<td>-4.839 -1.448</td>
<td>10.66 5.52</td>
</tr>
<tr>
<td>1</td>
<td>0.13 0.06(0.00)</td>
<td>-4.866* -1.61*</td>
<td>5.62 18.88(0.02)</td>
</tr>
<tr>
<td>2</td>
<td>0.00 -0.02(0.00)</td>
<td>-4.839 -1.596</td>
<td>4.00 12.95</td>
</tr>
<tr>
<td>3</td>
<td>-0.01 -0.09(0.00)</td>
<td>-4.778 -1.557</td>
<td>3.21 9.73</td>
</tr>
<tr>
<td>4</td>
<td>0.07 0.08(0.00)</td>
<td>-4.752 -1.525</td>
<td>2.53 11.19</td>
</tr>
<tr>
<td>5</td>
<td>-0.18 0.03(0.00)</td>
<td>-4.773 -1.497</td>
<td>2.24 9.39</td>
</tr>
<tr>
<td>6</td>
<td>-0.12 -0.08(0.00)</td>
<td>-4.743 -1.467</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-0.22 0.12(0.00)</td>
<td>-4.728 -1.441</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-0.08 -0.27(0.00)</td>
<td>-4.696 -1.456</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.03 0.20(0.00)</td>
<td>-4.669 -1.424</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.04 -0.10(0.00)</td>
<td>-4.640 -1.394</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>-0.00 0.08(0.00)</td>
<td>-4.612 -1.364</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.00 0.08(0.00)</td>
<td>-4.612 -1.364</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** *is the lag length selected by BIC.

**BEKK-GARCH (1,1) Result of Volatility Spillover between Crude Oil and Money Markets in Nigeria**

The results of the bivariate BEKK-GARCH(1,1) model employed to investigate the nature of volatility spillover between crude oil and the money market in Nigeria are shown in Table 4. Notice from the estimates in Table 4 that the diagonal parameters, $A_{co,co}$, $A_{mm,mm}$, $B_{co,co}$ and $B_{mm,mm}$ are all statistically significant at the 5% significance level. These indicate that shocks and volatilities from the respective markets influence their current volatilities. In other words, there is volatility clustering in crude oil and money market returns in Nigeria. The result of volatility clustering in money market rates agree with the findings of Shahiduzzaman and Naser (2007), Neupane (2011) who document
Evidence of volatility clustering in money market rates; and Harathi and Almohaimeed (2015) who report that the oil price and the stock market are more affected by their own shocks and volatility.

The off-diagonal elements of matrix A do not show any significant evidence of shock spillover between crude oil market and money market returns in Nigeria. This suggests that information flows in the markets do not significantly increase their respective volatility.

The results of the off-diagonal elements of matrix B, however, show evidence of unidirectional volatility spillovers from the crude oil market to the money market, as only the off-diagonal parameter $B_{co,mm}$ is significant at the 5% significance level. The calculated $t$-statistic (5.270) of the off-diagonal parameter $B_{co,mm}$ is greater than the critical $t$-statistic at 5% significance level (1.960). Similarly, the $p$-value (0.000) of the off-diagonal parameter $B_{co,mm}$ is less than the significance level (0.05). These show that there is significant unidirectional volatility spillover from crude oil market to money market in Nigeria. Evidence of significant volatility spillover from the crude oil market to the money market provides support for partial integration between the markets. It also implies that the money market is a receptor of crude oil market’s volatility and not otherwise. This finding of unidirectional volatility spillover, which supports partial integration between the crude oil and money markets, is not puzzling. Oil is the mainstay of the Nigerian economy and plays a vital role in the economy of Nigeria. CBN (2012) reports, for example, that crude oil revenue accounted for 75.3% of the federally collected revenue, and crude oil exports accounted for 96.8% of total exports. This implies that 97% of export earnings are outside the control of Nigeria. Given that the government is the major contributor of Nigerian money market and crude oil is major driver of government revenue, it is not puzzling therefore that crude oil market volatility spillover to the money market.

The major economic implications of the partial integration between the crude oil and money markets in Nigeria are for money market investment management and money market regulation. Given the partial integration between the markets, money market investment managers can reduce the risk of their investment in the money market by consistently monitoring developments in the crude oil market and by hedging their positions in the money market using crude oil derivative securities since volatility from the money market do not spillover to the crude oil market. More so, given that crude oil pricing is determined at
the international commodities market, regulatory authorities of the money market should formulate stabilization policies to absorb any unexpected impacts of negative shocks from the oil and gas market to the money market.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coefficient</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(co,co)</td>
<td>0.0662</td>
<td>8.4359</td>
<td>0.0000</td>
</tr>
<tr>
<td>C(mm,co)</td>
<td>0.0061</td>
<td>0.2277</td>
<td>0.8198</td>
</tr>
<tr>
<td>C(mm,mm)</td>
<td>-0.6190</td>
<td>-0.3238</td>
<td>0.7460</td>
</tr>
<tr>
<td>A(co,co)</td>
<td>0.5193</td>
<td>4.7848</td>
<td>0.0000</td>
</tr>
<tr>
<td>A(mm,mm)</td>
<td>0.0269</td>
<td>1.1273</td>
<td>0.2595</td>
</tr>
<tr>
<td>A(mm,co)</td>
<td>0.0269</td>
<td>1.1273</td>
<td>0.2595</td>
</tr>
<tr>
<td>A(mm,mm)</td>
<td>0.9782</td>
<td>7.1755</td>
<td>0.0000</td>
</tr>
<tr>
<td>B(co,co)</td>
<td>0.4260</td>
<td>2.5202</td>
<td>0.0117</td>
</tr>
<tr>
<td>B(co,mm)</td>
<td>0.5998</td>
<td>5.2708</td>
<td>0.0000</td>
</tr>
<tr>
<td>B(mm,co)</td>
<td>-0.0183</td>
<td>-1.0689</td>
<td>0.2851</td>
</tr>
<tr>
<td>B(mm,mm)</td>
<td>0.5765</td>
<td>6.9020</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: Author’s computation

The adequacy of bivariate BEKK-GARCH (1,1) model fitted to the oil and gas and money market returns series was evaluated using both the univariate and multivariate model adequacy tests. Serial correlation tests conducted on the standardized residuals (Q_{co} and Q_{mm}) and squared standardized residuals (Q_{co}^2 and Q_{mm}^2), at up to 6 lags using Ljung-Box Q statistic and presented in Table 5, indicate that both the mean and variance models are adequate. The univariate Ljung-Box statistics give Q(6) = 8.87 and Q^2 (6) = 7.61, which correspond to p-values of 0.18 and 0.26 respectively for the residuals and squared residuals of the crude oil returns model. For the money market returns model, we have Q (6) = 5.03 and Q^2 (6) = 1.89 with p-values of 0.53 and 0.92 respectively for the residuals and squared residuals. The multivariate ARCH (0.81 with p-values of 0.99) and serial correlation (6.34 with p-values of 0.38) estimates also show an absence of heteroscedasticity and autocorrelation in the standardized residuals and squared standardized residuals of the bivariate BEKK-GARCH model. These diagnostic tests results thus confirm adequacy of the BEKK-GARCH (1,1) model for analysis of the nature of volatility spillover between the crude oil and money markets in Nigeria.
Table 5.
Diagnostic tests results for GARCH-BEKK model of volatility spillovers between crude oil and the money market in Nigeria

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>p-value</th>
<th>p-value ($\chi^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{co}(6)$</td>
<td>8.876</td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td>$Q_{co}^2(6)$</td>
<td>7.618</td>
<td>0.267</td>
<td></td>
</tr>
<tr>
<td>$Q_{mm}(6)$</td>
<td>5.035</td>
<td>0.539</td>
<td></td>
</tr>
<tr>
<td>$Q_{mm}^2(6)$</td>
<td>1.893</td>
<td>0.929</td>
<td></td>
</tr>
<tr>
<td>MV LM {6}</td>
<td>0.810</td>
<td>0.991</td>
<td></td>
</tr>
<tr>
<td>MV Q (6)</td>
<td>6.346</td>
<td>0.385</td>
<td></td>
</tr>
</tbody>
</table>

Note: MV LM and MV Q are the multivariate autoregressive conditional heteroscedasticity Lagrange multiplier test and multivariate Ljung-Box Q statistic respectively.

Conclusions

This paper analysed volatility interrelationship between crude oil prices and money market rates in Nigeria by estimating a multivariate BEKK-GARCH(1,1) model using monthly data ranging from January 2002 to December 2014. The estimates obtained from a BEKK-GARCH(1,1) model indicate that shocks and volatilities from respective markets influence their current volatilities. In other words, there is volatility clustering in crude oil and money market returns in Nigeria. The estimates also provide evidence to show that there are significant unidirectional volatility spillovers from crude oil market to the money market in Nigeria. Hence, crude oil price changes are a very strong variable in determining the money market return volatility in Nigeria. This conclusion has economic implications for money market investment management and money market regulation. Given the unidirectional volatility spillover from crude oil market to money market, money market investment managers can reduce the risk of their investment in the money market by consistently monitoring developments in the crude oil market and by hedging their positions in the money market using crude oil derivative securities since volatility from the money market do not spillover to the crude oil market. More so, given that crude oil pricing is determined in the international commodities market, Nigeria money market regulatory authorities should be proactive in formulating stabilization policies to absorb any unexpected impacts of negative shocks from the crude oil market to the money market.
References


