Empirical Modeling of Nigerian Exchange Rate Volatility

Awogbemi Clement 1* Alagbe Samuel 2

1. National Mathematical Centre, Sheda - Kwali, Abuja, Nigeria
2. Mathematics Department, Bayelsa State College of Education, Okpoama, Nigeria

* E-mail of the corresponding author: Awogbemiadeyeye@yahoo.com

Abstract
In this study, we examined the volatility of Naira/US Dollar and Naira/UK Pound Sterling exchange rates in Nigeria using GARCH model. The data on the monthly exchange rates were collected from Central Bank of Nigeria which spanned through the period 2007-2010, and the analysis of the series was carried out using Econometric software (E-view 7.0) Investigation conducted on the exchange rates showed that volatility on the returns is persistent. The result of normality test indicated that the series residuals are asymmetric The plots on the original series and unit root test on the return series established the non-stationarity status of Nigerian foreign exchange series. The paper therefore recommends that the impact of policies of government on foreign exchange rates should be investigated.

Keywords: Exchange rates, GARCH model, Heteroscedasticity, Volatility, Uncertainty, Stability.

1. Introduction
Exchange rate volatility refers to the swings or fluctuations to the exchange rates over a period of time or the deviations from the benchmark or equilibrium exchange rate (Charles 2006). The vital role played by exchange rate has been traced to its volatility and the consequent impact on the standard of living of Nigerians and various sectors of the economy (Adetiloye 2010). Foreign exchange market is by far the largest financial market in the world, a continuous one with no opening or closing hours. Financial markets sometimes appear calm and at other time highly volatile.

Describing how this volatility changes over time is important for two reasons. Firstly, the risk of an asset is an important determinant of its price and secondly, the econometric inference about the conditional means of a variable requires the correct specification of its conditional variance. The role of Central Bank of Nigeria is not a passive one in the foreign exchange market as it continues to intervene to maintain an ‘orderly market’ through trading in the exchange market. This trading generally involves the use of US dollar. This is because of the depth and importance of the dollar currency in the market and associated lower transaction costs (Sengupta 2002). As a country, Nigeria depends heavily on imports from various countries with adverse effects on domestic production, balance of payments positions and external reserves level.

The foreign exchange market in the fixed exchange rate period was dominated by high demand for foreign exchange with inadequate supply of foreign exchange by the Central Bank of Nigeria (CBN). This has led to the promotion of parallel market for foreign exchange and creation of uncertainty in exchange rates. The fixed exchange rate period was also characterized by sharp practices perpetrated by dealers and end-users of foreign exchange rates (Sanusi 2004). Through its monetary policies in the money market, the Central Bank of Nigeria usually intervenes in the foreign exchange market to influence the exchange rate movement in the right direction.

The emergence of the managed floating rate regime increases the uncertainty in exchange rates and thus, increasing exchange rate volatility by the regime shifts (Olowe 2009). The understanding of the behaviour of exchange rate is crucial to monetary policy (Longmore & Robinson 2004). According to the duo, the policy makers concentrate on information content of short-term volatility in deciding intervention policy.

Once an exchange rate is not fixed, it is subject to variations, which implies that floating exchange rates tend to be more volatile. The degree of volatility and the extent of stability maintained are affected by economic fundamentals which are meant to produce favourable economic conditions and results. These in turn appreciate the currency and maintain relative stability in the market (Charles 2006).

1.1 Objective of the Study
The main objective of an exchange rate policy is to determine an appropriate exchange rate and ensure its stability. Over the year, efforts put in place by Nigerian governments to achieve this objective through
The application of various techniques and policies have not been able to yield positive result. This has prompted the need for this study. The purpose of this research work is to build a forecasting model that best captures the volatility of Nigerian exchange rate return series using GARCH model.

1.2 Significance of the Study
The outcome of this research work will go along way to achieve the following:
(i) Assist government to manage the exposure of the exchange rates volatility in the short run.
(ii) Inform the investors in the country on the future behaviour of exchange rates in earning assessments, and making financial and capital budgeting decisions.
(iii) Help end-users of volatility models of exchange rates such as importers, exporters, currency traders, banks and foreign exchange bureau to access their earnings or costs.

2. Review of Time-Varying Volatility Model
The traditional measure of volatility as represented by variance or standard deviation is unconditional and does not recognize that there are interesting patterns in asset volatility (time varying and clustering features).

ARCH model is a time-varying volatility model which has proven to be useful in capturing volatility clustering in financial time series. Autoregressive Conditional Heteroscedasticity (ARCH) model was introduced by Engle (1982) to explain the volatility of inflation rates and generalized (GARCH) by Bollerslev (1986). Engle in his work found evidence that for some data, the disturbance in time series models were less stable than usually assumed. He modeled the heteroscedasticity by relating the conditional variance of the disturbance term to the linear combination of the squared disturbances in the recent past.


2.1 Specification of the Model
In ordinary least square estimation, variance of the error term \( \mu \) is assumed to be constant as

\[
\text{Va}(\mu) = \delta^2
\]  
(1)

If the condition given above is violated, the variances of the error terms becomes

\[
\text{Var} (\mu) = \delta_i^2, \ i = 1,2,\ldots t
\]  
(2)

Thus, ARCH models introduced by Engle (1982) have conditional variances that fluctuate with time (Gujarati 2004).

Let \( r_t \) be the exchange rate return to be modeled, then

\[
r_t = w + \mu_t
\]  
(3)

where \( s_t \) is the exchange rate and \( w \) is a constant and \( \mu_t \sim N(0, \sigma_t) \)

Suppose \( \delta_i^2 = g_t \) denotes the conditional variance to be predicted, then

\[
g_t = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \alpha_2 \mu_{t-2}^2 \ldots + \alpha_p \mu_{t-p}^2
\]  
(4)

This is ARCH (q) process where \( q \) denotes the number of lags under consideration and \( \alpha_0 > 0, \alpha_i \geq 0 \) and \( i \geq 1 \). The conditional variance \( g_t \) depends on the past squared lags of the returns and when \( \alpha_i = 0 \) and \( g_t \) is equal to a constant, then heteroscedasticity is violated.

2.2 Problems with ARCH (q) Models
1. Violation of non-negativity constraints when estimating ARCH model. This may result in forecasting of negative variances. We require \( \alpha_i > 0 \), for all \( i = 1, 2, \ldots, q \).

2. The required number of lags (q) might be very large. This may produce final model that is cumbersome, large and infeasible to use.

3. Non stationarity may be generated due to long lag in the conditional variance equation. The generalized ARCH (GARCH) introduced by Bollerslev (1986) takes care of the shortcomings of slow decaying process of ARCH(q) models.

The GARCH model enables the conditional variance at time \( t \) to be dependent on a constant, previous shocks and past variances. In GARCH \((p, q)\), the previous shocks denotes the ARCH term while the previous variances \((p)\) represent GARCH component. Mathematically, GARCH \((p, q)\) is defined as

\[
\delta_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \mu_{t-i}^2 + \sum_{j=1}^{p} \beta_j \delta_{t-j}^2
\]

(5)

Where \( \delta_t^2 \) is the conditional variance of \( \mu_t \). \( \alpha_0 > 0, \alpha_i \geq 0, \beta_j \geq 0 \) for all \( i \geq 1, j \geq 1 \).

3. Material and Methodology:

3.1 The Data

The scope of the time series data for this study spans through 2006 – 2010, and the data were collected from the Statistical Bulletin of Central Bank of Nigeria.

We employed the rate of returns to investigate the currency exchange rate volatility of (NGN)/US Dollars and (NGN)/UK Sterling. The rate of return is defined as

\[
r_t = \frac{E_t - E_{t-1}}{E_{t-1}}
\]

(6)

where \( E_t \) denotes currency exchange rate at time \( t \) and \( E_{t-1} \) is the currency exchange rate at time \( t-1 \).

The exchange rates used in this study were chosen because US dollar and UK Sterling are major currencies traded in the foreign exchange markets among others.

3.2 Unit-Root Test on the Returns of the Series

The Augmented Dickey Fuller (ADF) and Philips Perron (PP) test statistics were applied to determine whether the exchange rate returns contain one or more unit roots (Dickey & Fuller 1986; Philips & Perrons 1988).

Let the return series \( r_t \) be defined as

\[
r_t = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 r_{t-1} + \mu_t
\]

(7)

The test hypothesis of unit root presence is formulated as

\( H_0: \alpha_1 = 1 \) vs \( H_1: \alpha_1 < 1 \)

The null hypothesis is rejected if the ADF and PP test statistics are less than the critical value at \( \alpha \) level of significance.

3.3 Estimation of the Model Parameters

The non-linear nature of the variants of ARCH model implies that the ordinary least squares estimation may not be optimal. Thus, parameter estimation is carried out in this study using Maximum Likelihood Estimation Method.

3.4 Normality Test

Jacques Bera (JB) statistic is computed from skewness and kurtosis statistics to determine whether the series is symmetrically (normally) distributed or not. The normality test using Jacques Bera statistic is \( \chi^2_{(2)} \) distributed and based on the null hypothesis of skewness = 0 and kurtosis = 3 (Jacques & Bera 1987).

A comparable smaller probability value leads to rejection of the hypothesis that the series is normally distributed. The JB test is an asymptotic test based on ordinary least squares residuals:
\[ JB = \frac{t-k}{6} \left[ S_k^2 + \left( \frac{K_u - 3}{4} \right)^2 \right] \]

where \( S_k \) is the skewness, \( K_u \) is the kurtosis and \( k \) represents the number of estimated coefficients used to create the series.

\[ S_k = \frac{1}{t} \sum_{i=1}^{t} \left( \frac{r_i - \mu}{\hat{\delta}} \right)^3, \quad K_u = \frac{1}{t} \sum_{i=1}^{t} \left( \frac{r_i - \mu}{\hat{\delta}} \right)^4 \]

And \( r \) is the exchange rate returns, \( \mu \) is the mean, \( t \) is the sample size and \( \hat{\delta} \) is an estimator for the standard deviation (Greene 2006).

### 3.5 Adequacy of the Models and ARCH Disturbances

The adequacy of the models was determined in this study using Schwarz Information Criterion [SIC] and Hannan-Quinone Criterion [HQC] (Gujarati 2004).

After fitting ARCH models to the data, ARCH disturbances were investigated using Lagrangean Multiplier test. Suppose \( \varepsilon_t^2 \) is the disturbance from the fitted regression model to return series. ARCH effect of order \( q \) is tested for by regressing the square of residuals at time \( t \) on its own lags:

\[ \varepsilon_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \mu_t \]

Where \( \mu_t \) is independently and identically distributed. Obtain the coefficient of determination \( R^2 \) from the estimation and define the test statistic as \( TR^2 \) where \( T \) is the number of observations and \( TR^2 \sim \chi^2 \)

The hypothesis is formulated as

\[ H_0: \alpha_0 = \alpha_1 = \ldots = \alpha_q = 0 \text{ vs } H_1: \text{ at least } \alpha_i \neq 0, i = 1, 2, \ldots q \]

Reject \( H_0 \) if \( TR^2 > \chi^2 \)

### 4. Results and Findings

#### 4.1 Plots of the Series

The return, logged and difference logged series of NGN/USD and NGN/UK P- Sterling exchange rates were plotted to have a depiction of the behavior of the series:

![Figure 1](2006 - 2010 MONTHLY)
Figure 2. (2006 – 2010) MONTHLY LOG RETURN OF NGN/USD EXCHANGE RATE

Figure 3. (2006 -2010) MONTHLY DIFFERENCE LOGGED RETURN OF NGN/USD EXCHANGE RATE

Figure 4. (2006 – 2010) MONTHLY RETURN OF NGN/UK P-STERLING EXCHANGE RATE

Figure 5. (2006 – 2010) MONTHLY LOG RETURN OF NGN/UK P-STERLING EXCHANGE RATE
From figures 1 – 6, the level and difference forms of the series are characterized with fluctuations. This shows that there was persistence in the volatility of the series within the period considered.

### 4.2 Summary Statistics of Exchange Rate Returns

<table>
<thead>
<tr>
<th>Statistic</th>
<th>NGN/USD Series</th>
<th>NGN/UK Sterling Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>231.68</td>
<td>134.3333</td>
</tr>
<tr>
<td>Median</td>
<td>234</td>
<td>128</td>
</tr>
<tr>
<td>Max.</td>
<td>256</td>
<td>155</td>
</tr>
<tr>
<td>Min.</td>
<td>179</td>
<td>116</td>
</tr>
<tr>
<td>Std.dev.</td>
<td>15.66</td>
<td>13.5492</td>
</tr>
<tr>
<td>Skewness</td>
<td>-1.06666</td>
<td>0.1460</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.2876</td>
<td>1.4128</td>
</tr>
<tr>
<td>Jarques Bera</td>
<td>15.5210</td>
<td>6.5109</td>
</tr>
<tr>
<td>Prob.</td>
<td>0.0000426</td>
<td></td>
</tr>
</tbody>
</table>

From table 1, NGN/USD is leptokurtic and negatively skewed with respect to normal distribution while NGN/UK P-Sterling is platykurtic and positively skewed.

The Jacques Bera statistics shows that the exchange rate returns series showed that the exchange rate returns series departed from normality.

Table 2. Unit Root Test for NGN/USD Series:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Statistic</th>
<th>Critical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey fuller (ADF)</td>
<td>9.5239</td>
<td>0.0085</td>
</tr>
<tr>
<td>Philip penning PP</td>
<td>7.1341</td>
<td>0.0282</td>
</tr>
</tbody>
</table>

The ADF and PP statistics exceeded the critical values at 5% level of significance. This implies that the return of the exchange rate series has unit root which confirms the fluctuations in figures (i) – (vi).

Table 3. Unit Root Test for NGN/UK P- Sterling Series:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Critical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ADF)</td>
<td>10.1429</td>
</tr>
<tr>
<td>PP</td>
<td>7.50084</td>
</tr>
</tbody>
</table>
In Table 3, ADF and PP statistics are greater than the critical values which establishes the presence of unit root (non-stationarity).

Table 4. Estimated Parameters of the Models for NGN/USD Returns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SIC</th>
<th>HQC</th>
<th>Sig Prob.</th>
<th>T*R^2</th>
<th>χ^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARIMA(1,2)</td>
<td>0 = 0.0025</td>
<td>-45.5755</td>
<td>-45.5700</td>
<td>0.0000</td>
<td>0.3000</td>
</tr>
<tr>
<td>GARCH(1,1)</td>
<td>α = 0.1500</td>
<td>β = 0.6000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The variance equation $\delta_t^2 = 0.0025\mu_{t-1}^2 + 0.6000\mu_{t-1}^2 + t$  

(11)

The return series in tables 4 and 5 have lower values for GARCH model than the ARIMA models. The ARCH-LM statistics in tables 4 and 5 shows that the standardized residuals are not characterized by additional ARCH effect. This implies that the variance equations are well specified in the GARCH model.

5. Conclusion

We have attempted to model volatility in Nigerian exchange rate by establishing the presence of persistent volatility in the return series. The persistence could be due to the import dependence of Nigerian, inadequate supply of foreign exchange by Central Bank of Nigeria and activities of foreign exchange dealers and parallel market.

Further work should be carried out using higher frequency data and other variants of volatility models. The impact of government intervention either through direct intervention or through official financing flows on the foreign exchange market should also be investigated.

References


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