Empirical Modeling of Nigerian Exchange Rate Volatility

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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 models, ARCH Effects, 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 and 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, thus, 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 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.

1. Review of Time-Varying Volatility Model (ARCH/GARCH)

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.

Bollerslev in his own case generalized the ARCH (GARCH) model by modeling the conditional variance to depend on its lagged values as well as squared lagged values of disturbances. Other researchers who have tremendously used GARCH model in modeling the behaviour of financial time series include: Oguntade (2008), Longmore and Robinson (2004), Awogbemi and Ajao (2011) Luu and Martens (2002), Shittu (2009), Takezawa (1995), Brooks (2008), Laopodis (1997), Lobo et al (1998), Mckenzie (1997) among others.

2.1 Specification of the Model

In ordinary least square estimation, variance of the error term μ is assumed to be constant as

$$Va(\mu_t) = \delta^2$$

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

$\text{Var}(\mu_t) = \delta_i^2$, $i = 1,2,\ldots t$

This is heteroscedasticity

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

$r_t = w + \mu_t$

$r_t = \Delta s_t$ where s_t is the exchange rate (in logarithm) and w is a constant and $\mu_t \sim N(0, g_t)$

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

$g_t = \alpha_o + \alpha_1\mu^2_{t-1} + \alpha_2\mu_t^2{}_{-2} \ldots + \alpha_p{}^2\mu_{t-p}$

This is ARCH (q) process where q denotes the number of lags under consideration and $\alpha_o > 0$, $\alpha i \geq 0$ and $i \geq 1$

The conditional variance g_t depends on the past squared residuals 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 $i = 1, 2, \ldots\ldots\ldots\ldots q$
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 he 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, pervious 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

$$\delta_t^2 = \alpha_o + \sum_{i=1}^{q} \alpha_i \, \mu_{t-i}^2 + \sum_{j=1}^{p} \beta_j \delta_{t-j}^2$$

Where δ_t^2 is the conditional variance of μ_t, $\alpha_o > 0$, $\alpha_i \geq 0$, $\beta_j \geq 0$ 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

$$r_t = \frac{E_t - E_{t-1}}{E_{t-1}}$$

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.
Let the return series r_t be defined as

$$r_t = \alpha_o + \alpha_1 r_{t-1} + \alpha_2 r_{t-1} + \mu_t$$

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 α level of significance. [Dickey and Fuller (1986) , Philips and Perrons (1988)]

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 carriedout 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 and 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.

$$S_k = \frac{1}{t}\sum_{i=1}^{t}\left(\frac{r_t - \mu}{\overset{n}{\delta}}\right)^3, \quad K_u = \frac{1}{t}\sum_{i=1}^{t}\left(\frac{r_t - \mu}{\overset{n}{\delta}}\right)^4$$

And r_t is the exchange rate returns, μ is the mean, t is the sample size and $\overset{\Lambda}{\delta}$ 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-Quinne Criterion [HQC] (Gujarati, 2004).

After fitting ARCH models to the data, ARCH disturbances were investigated using Lagrangean Multiplier test. Suppose ε_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:

$$\varepsilon_t^2 = \alpha_o + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \mu_t$$

Where μ_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 $TR^2 \sim \chi^2_{(q)}$

The hypothesis is formulated as

$H_0 : \alpha_o = \alpha_1 = \ldots \alpha_q = 0$ vs H_1 : at least $\alpha_i \neq 0$, $i = 1, 2, \ldots q$

Reject H_0 if $TR^2 > \chi^2_{(q)}$

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:

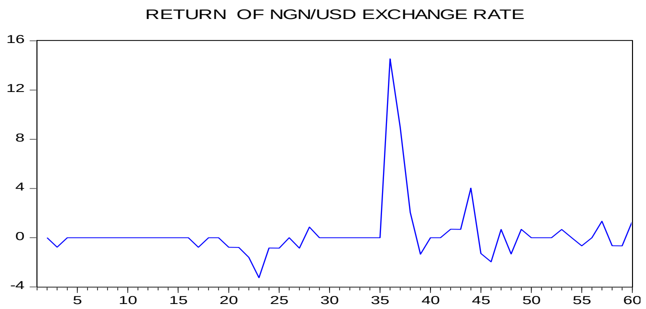

Fig. (i) **(2006 – 2010) MONTHLY**

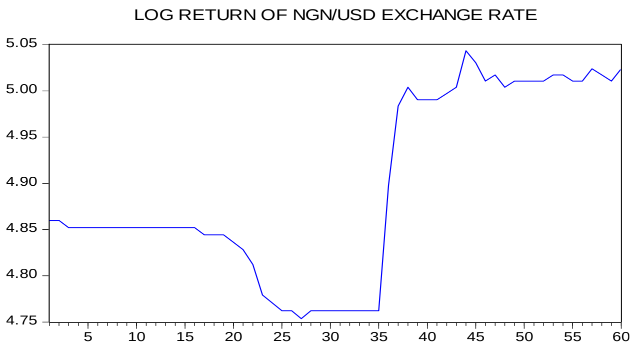

Fig. (ii) **(2006 – 2010) MONTHLY**

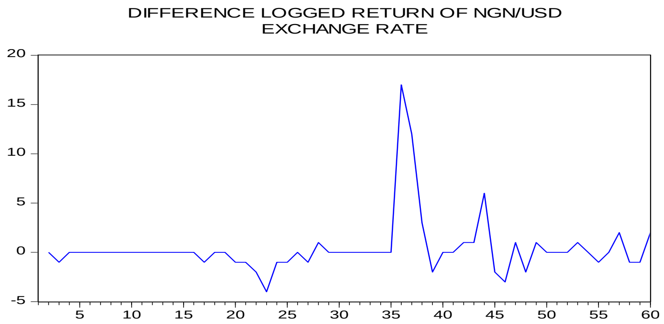

Fig. (iii) **(2006 -2010) MONTHLY**

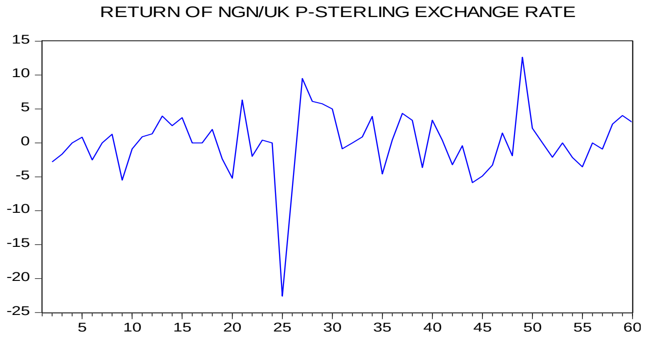

Fig. (iv) **(2006 – 2010) MONTHLY**

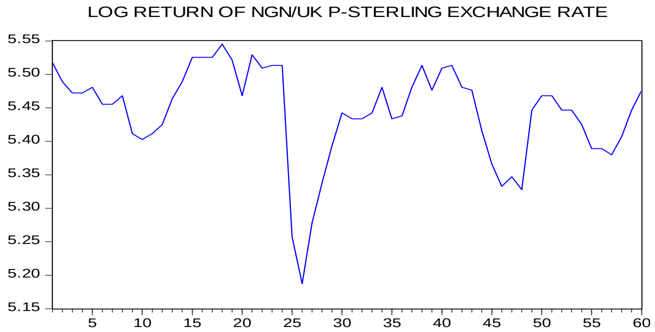

Fig. (v) **(2006 – 2010) MONTHLY**

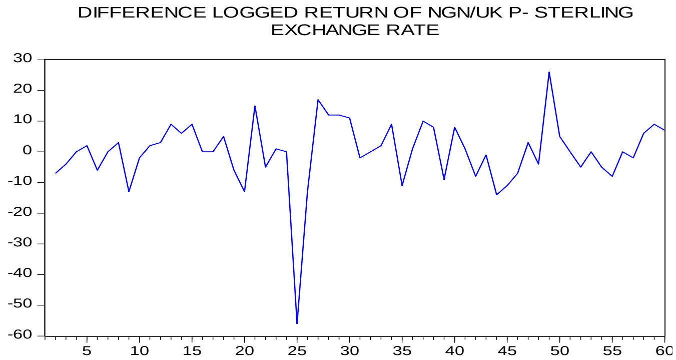

Fig. (vi) **(2006 – 2010) MONTHLY**

From figures (i) – (vi), the level and difference forms of the series are characterized with fluctuations. This shows that there was persistence in the volatility of the series with in the period considered.

4.2 Summary statistics of Exchange Rate Returns

Table 1: Summary of	NGN/USD Series	NGN/UK Sterling Series
Mean	231.68	134.3333
Median	234	128
Max.	256	155
Min.	179	116
Std.dev.	15.66	13.5492
Skewness	-1.06666	0.1460
Kurtosis	4.2876	1.4128
Jarques Bera	15.5210	6.5109
Prob.	0.0000426	

From table 1, NGN/USD is leptokurtic and negatively skewed with relative 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 he exchange rate returns series departed from normality.

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

	Statistic	**Critical value**
Augmented Dickey fuller (ADF)	9.5239	0.0085
Philip pennon PP	7.1341	0.0282

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:

	Statistic	**Critical value**
(ADF)	10.1429	0.00381
PP	7.50084	0.1117

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

	Parameter	SIC	HQC	Sig Prob.	T^*R^2	χ_2^2
ARIMA(1,2)	$\theta_1 = 0.0025$	-45.5575	-45.5700	0.0000		
GARCH (1,1)	$\alpha = 0.1500$				0.3000	0.1026

	β = 0.6000.					

Table 5: NGN/UK P-Sterling

	Parameter	SIC	HQC	Sig Prob.	T^*R^2	χ_2^2
ARIMA(1,2)	θ_1= 0.0025	-45.5529	-45.5789	0.0000		
GARCH(1,1)	α = 0.1500 β = 0.6000	-67.6168	-67.5971		0.3000	0.1026

The variance equation δ_t^2 = $0.0025\mu^2_{t-1} + 0.6000\mu^2_{t-1}$ + t

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 and Recommendation

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.

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