International Journal of Econometrics and Financial Management, 2016, Vol. 4, No. 1, 11-16
Available online at http://pubs.sciepub.com/ijefm/4/1/2

DOI:10.12691/ijefm-4-1-2

Test for Autoregressive Conditional Heteroscedasticity in Naira/US Dollar Exchange Rate in Nigeria

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Abstract The objective of this paper is to analyse the behaviour of Naira/US$ exchange rates in Nigeria. Specifically, the paper examines the descriptive statistics of Naira/US$ exchange rates and whether the series follow autoregressive conditional heteroscedastic (ARCH) using monthly data sample covering January 2000 to December 2013. The estimates from descriptive statistics show that the official market exchange rate in Nigeria is negatively skewed with platykurtic distribution. The Jarque-Bera statistics support evidence of non-normality in the Naira/US$ exchange rate series. The results of the augmented Dickey-Fuller (ADF) unit root tests suggest that the series contain unit root at level but are stationary at first difference. Estimates from the ARCH tests show that official market exchange rates in Nigeria are heteroscedastic. This implies that ARCH family models are appropriate for modeling volatility exchange rate in Nigeria.

Keywords: *exchange rates, descriptive statistics, heteroscedasticity, ARCH model, Nigeria*

Cite This Article: Emenike Kalu O., and Peter Ifeanyichukwu Ali, "Test for Autoregressive Conditional Heteroscedasticity in Naira/US Dollar Exchange Rate in Nigeria." *International Journal of Econometrics and Financial Management*, vol. 4, no. 1 (2016): 11-16. doi: 10.12691/ijefm-4-1-2.

1. Introduction

Exchange rate, according to Jhingan [9], is the rate at which one currency is exchanged for another. It is the price of one currency in terms of another currency. In the opinion of Olusola and Opeyemi [12] exchange rate is simply the price of foreign currency which clears the foreign exchange market. Thus exchange rate of currency is the link between domestic and foreign prices of goods and services. Exchange rate can either appreciate or depreciate. Appreciation in the exchange rate occurs if less unit of domestic currency exchanges for a unit of foreign currency while depreciation in exchange rate occurs if more unit of domestic currency exchanges for a unit of foreign currency. Exchange rate can be measured in two ways: the nominal exchange rate and the real exchange rate. The nominal exchange rate is the number of unit of domestic currency that must be given up to get a unit of foreign currency, whereas real exchange rate is inflation adjusted exchange rate. Exchange rate volatility as the risk associated with the unexpected movement in the exchange rate. In other word, it is the risk associated with currency depreciation or appreciation.

The role of exchange rates and its volatility on macroeconomic performance has continued to generate interest among international finance scholars. Many of the scholars argue that exchange rate stability facilitates production activities and economic growth. Obadan [11], for example, posits that the exchange rate plays a role in connecting the price system in different countries thus enabling traders to compare price directly. Changes in exchange rate have a powerful effect on imports and exports of the countries concerned through effects on relative prices of goods. He further argue that some of the factors that led to the depreciation of the Nigerian exchange rate include weak production base, import-dependent production structure, fragile export base and weak non-oil export earnings, expansionary monetary and fiscal policies, inadequate foreign capital inflow, excess demand for foreign exchange relative to supply, fluctuations in crude oil earnings, unguided trade liberalization policy, speculative activities and sharp practices (round-tripping) of authorized dealers, over-reliance on imperfect foreign exchange market, heavy debt burden, weak balance of payments position, and capital flight. Mordi [10] argued that the exchange rate movements have effects on inflation, prices incentives, fiscal viability, and competitiveness of exports, efficiency in resource allocation, international confidence and balance of payments equilibrium.

The importance of appropriate exchange rate policy to stability of the economy need not be overemphasised. Opara, Emenike and Ani [14] observe that prior to the year 1986; Nigeria practiced a fixed exchange rate, when the Naira was pegged against the British pound and later on the American dollar. However, with the collapse of the Bretton Wood institutions, a flexible exchange rate policy was adopted, and the Nigerian exchange rate was allowed to float, with its value relative to the US dollar determined by market forces of demand and supply. Some of the policies employed to ensure exchange rate stability included among others: Second-Tier Foreign Exchange Market (SFEM), Autonomous Foreign Exchange Market

(AFEM), Inter-bank Foreign Exchange Market (IFEM), the enlarged Foreign Exchange Market (FEM), and the Dutch Auction System (DAS). It is pertinent to mention here that the inability and failure of individual policy to achieve stability in the exchange rate led to the adoption of another. Despite various efforts by government to maintain exchange rate stability in the last two decades, the Naira continued to depreciate against the American dollar. For example, the Naira appreciated against the US dollar from N0.7143 in 1970 to N0.6159 in 1975 and further to N0.5464 in 1980. However, the exchange rate depreciated throughout the 1980s. For instance, the naira depreciated from N0.6100 in 1981 to N2.0206 in 1986 and further to N8.0378 in 1990. Although the exchange rate became relatively stable in the mid-1990s, it depreciated further to N102.1052, N120.9702, and N133.5004 in 2002, 2002, 2004; respectively. Thereafter, the exchange rate appreciated to N132.147, N128.6516, and N117.968 in 2005, 2006, and 2007.

The most important themes that emerge in the discussion of exchange rates and their management in Nigeria include the high volatility, real exchange rate overvaluation albeit in the context of continuous nominal depreciation, and the search for mechanism for market-determined rate where government is the dominant supplier of foreign exchange. Exchange rate stability is one of the goals of monetary policy in Nigeria and over the years, exchange rate policy has been driven mostly by an obsession to keep the nominal exchange rate stable.

Emenike and Aleke [7] observe that one of the important assumptions of the classical linear regression model is that the variance of all squared errors is homoscedastic; that is they all have the same variance. However, many empirical studies have shown that asset price series exhibit heteroscedasticity, where the variances of the error term are not equal, and in which error terms may be expected to be larger for some observations or periods of the data than for others. The importance of the existence of heteroscedasticity in a series is that it is condition precedence for estimation of generalised autoregressive conditional heteroscedasticity (GARCH) model. Engle [8] introduced the autoregressive conditional heteroscedasticity (ARCH) model to model volatility by relating the conditional variance of the error term to the linear combination of the squared error terms in the recent past. Although there are many studies that model volatility of exchange rates using GARCH models, none of the studies examine the series for ARCH process before estimation. This pattern is misleading given that series that do not follow ARCH process will not require GARCH family models.

The objective of this study is to analyse the behaviour of Naira/US$ exchange rates in Nigeria by examining whether the series follow the ARCH process. The finding of this study will useful to future researchers who desire to model Naira/US$ exchange rate volatility in Nigeria because ARCH process is a preceding condition for modeling with ARCH family models. The remainder of the paper is organised as follows. Section 2 presents the causes of changes in exchange rate and empirical literature review. Section 3 provides the data and methodology. Section 4 presents the empirical results, and section 5 provides the summary and conclusions.

2. Causes of Changes in Exchange Rates and Empirical Literature Review

2.1. Causes of Changes in Exchange Rates

Jhingan ([9]:443) notes that the exchange rates between two countries changes due to changes in demand or supply in the foreign exchange market. The factors which cause changes in demand and supply include the following:

- **Changes in prices**. It is changes in the relative price levels that cause changes in the exchange rates. If, for example, USA price level rises relative to Nigeria price level, it will lead to the rises in price of USA goods in terms of Naira. Nigeria goods will become dearer in the USA. On the other hand, a reduction in USA price level relative to Nigeria price level will lead to a reduction in price of USA goods in terms of Naira.
- **Changes in Exports and Imports**. The demand and supply of foreign exchange is also influenced by changes in exports and imports. If exports of Nigeria to USA are more than imports, the demand for Naira increases so that the rate of exchange moves in her favour. If on the other hand, imports are more than exports, the demand for dollar increases and the rate of exchange will move against the Naira.
- **Capital Movements**. Short-term or long-term capital movements also influence the exchange rates. Capital-flows tend to appreciate the value of the currency of the capital-importing country and depreciate the value of the currency of the capital-exporting country. The exchange rate will move in favour of the capital-importing country and against the capital-exporting country.
- **Influence of Banks**. Banks also affect the exchange rates through their operation. They include the purchase of and sale of bank drafts, letters of credits, dealing in bills of exchange, arbitrage, etc. These banking operations influence the demand for and supply of foreign exchange. If the commercial banks issue a large number of drafts and letters of credit on foreign banks, the demand for foreign currency rises. The bank rate also influences the exchange rates. If the bank rate rises relative to other countries, more funds will into the country from abroad to earn high interest rates. It will tend to raise the demand for the domestic currency and exchange rate will move in favour of the country. Converse will be the case when the bank rate falls.
- **Influence of Speculation**. The growth of speculative activities also influence exchange rate. Speculation causes short-run fluctuations in the exchange rate. If the speculators expect a fall in the value of currency in the near future, they will sell that currency and start buying the other currency they expect to appreciate in value. Consequently, the supply of the former currency will increase and its exchange rate will fall, whereas the demand for the latter currency will increase and its exchange rate will go up.
- **Structural influences**. Structural changes are those changes which will bring changes in the consumer demand for commodities. They include technological changes, innovations, etc. which also affect the cost

structure along with the demand for products. Such structural changes tend to increase the foreign demand for domestic products. This implies increase in exports, greater demand for domestic currency, appreciation of its value and rise in the exchange rate.

- **Political Conditions**. Political conditions in the country have a significant influence on the exchange rate. If there is political stability and the government is strong and efficient, foreigners will have tendency to invest their funds into the country. With the inflow of capital, the demand for domestic currency will rise and exchange rate will move in favour of the country. On the contrary, if the government is weak, inefficient and dishonest and there is no safety to life and property, capital will flow out of the country and exchange rate will move against the country.

2.2. Literature Review

Many empirical studies have examined the exchange rates and their management in Nigeria. These studies concentrate on exchange rate stability and volatility. Bangaké [4], for example, examines the relationship between bilateral exchange rate volatility and the relevant variables of optimum currency areas (OCA), which include asymmetric disturbances to output, dissimilarity of the commodity composition of export, trade linkages, and size, for 21 selected African countries for the period 1990-2003 using a system of simultaneous equations and the GMM technique. The findings of the study provide evidence concerning the link between bilateral exchange rate volatility and variables such as: size, trade intensity, sector-specific shock and disturbance to output. Then, we derived an OCA index for African countries. He concludes that the results have important policy implications for proposed monetary unions in Africa (CEDEAO, COMESA and SADC). In the same vien, Bayoumi and Eichengreen (1998) point out that exchange rate volatility could be explained by the relevant OCA variables that have been used in the literature, such as the difference in economics shocks, the trade links, the dissimilarity of the composition of the exports and country size.

Aliyu [3] examine the impact of exchange rate volatility on nonoil export flows in Nigeria using quarterly observations of the naira exchange rate volatility, the US dollar volatility, Nigeria's terms of trade and index of openness. Empirical results of the study show the presence of unit root at level; however, the null hypothesis of nonstationarity was rejected at first difference. Cointegration results revealed that a stable long-run equilibrium relationship exists between nonoil exports and the fundamental variables. The results further reveal that the naira exchange rate volatility decreased nonoil exports by 3.65%, while the same estimate for the US dollar volatility increased export of nonoil in Nigeria by 5.2% in the year 2003. He recommends the measures that would promote greater openness of the economy and exchange rate stability in the economy.

Omojimite and Akpokodje [13] observe that exchange rates have been highly volatile in Africa especially since the move to a floating exchange rate system with negative repercussions for trade, investment and growth. As a result, they study the effect of exchange rate volatility on exports of a group of Communaute Financiere Africaine (CFA) countries and compared it with that of the non-CFA counterparts during the period 1986-2006. They generate the exchange rate volatility series using the GARCH model, and find that the exchange rate volatility to be negatively impinge on the exports of both groups of countries. They also report that exchange rate volatility has a larger effect on the group of non-CFA countries than on the CFA. They conclude that there is need to take appropriate monetary and fiscal policy actions to stem the rising exchange rate volatility.

Adelowokan [1] posits that there is no simple answer to what determines the equilibrium exchange rate, and that the degree of exchange rate misalignment remains one of the most challenging empirical problems in open economy macroeconomics. Consequently, he examines the precise channel of exchange rate pass-through in Nigeria using data ranging from 1970 to 2010. The empirical results of his study reveal that previous Naira/US$ exchange rate pass-through interest rate in Nigeria. He further reports that neither current nor previous Naira/US$ exchange rates pass-through inflation rate in Nigeria. He concludes that interest rate channel is the significant path of exchange rate pass-through in Nigeria.

Olusola and Opeyemi [12] observes that **e**xchange rate volatility has to do with the unusual movements of the exchange rate, and that the standard theoretical justification of the investigation of the volatility in exchange rate is that exchange rate volatility represents uncertainty and risk which will impose costs on risk-averse economic agents. Hence, they examine the trend and possible causes of exchange rate volatility in Nigeria using the Exponential Generalised Autoregressive Conditional Heteroskedasticity (E-GARCH) modelling technique on annual time series over the period 1986 to 2009. The results of the study reveal that exchange rate has been volatile in Nigeria given the fact that the standard deviation of exchange rate has been unusually high and unusually low during the period under investigation. The parametric measure of exchange rate further confirmed a high degree of volatility which portrays higher risk to a risk-averse economic agent. They recommend that the government should always take a cognizance look at the frequent movement in the exchange rate with a view to regulating it because higher risks attached to high degree of volatility may scare off both domestic and foreign investors.

Considering that the naira exchange rate depreciation and volatility is among the vast macroeconomic maladjustments which have unfolded in the Nigerian economy in the recent past, Ajao and Igbekoyi [2] investigates the determinants of real exchange rate volatility in Nigeria by applying the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) and Error Correction Models on annual data ranging from 1981 through 2008. They used the GARCH (1,1) model to obtain the volatility of exchange rate, and the ECM to examine the various determinants of exchange rate volatility in Nigeria. The results of their empirical analysis show among others that openness of the economy, government expenditures, interest rate movements as well as the lagged exchange rate are among the major significant variables that influence exchange rate volatility during this period. They recommends that the central

monetary authority should institute policies that will minimize the magnitude of exchange rate volatility while the federal government exercises control of viable macroeconomic variables which have direct influence on exchange rate fluctuation.

Taiwo and Adesola [15] investigate the impact of exchange rate on bank performance in Nigeria using two proxies for bank performance, namely loan loss to total advances ratio and capital deposit ratio. Government expenditure, interest rate, real gross domestic product were added to exchange rate as independent variables. The two models specified show that the impact of exchange rate on bank performance is sensitive to the type of proxy used for bank performance. Loan loss to total advance ratio shows that fluctuating exchange rate may affect the ability of lenders to manage loans resulting into high level of bad loans while capital deposit ratio does not have significant relationship with exchange rate. They recommended that a stable exchange rate is needed to improve the ability of the banking sector to channel credit to the economy.

Opara *et al* [14] examine behaviour of financial market indicators in Nigeria, which include stock market returns, interest rates, exchange rate, and inflation rates using Nigerian monthly time series data for the period of January 2000 to December 2013. The descriptive statistics of the stock returns shows a positive stock return for the NSE during the sample period. It also shows that the stock returns are negatively skewed, with peaked distribution. The monetary policy rate (MPR) average is 12.6% for the study period. It further shows that the MPR is not normally distributed. The analysis of the Naira/US$ exchange rate indicate that mean rate for the sample period is ₦133.6, with negative skewness and flat kurtosis coefficients. The analysis of the consumer price index (CPI) shows that the average monthly change in CPI is 0.9%, with a standard deviation of 1.76% for the sample period. It also shows positive skewness and peaked kurtosis coefficients. The study recommends that financial market researchers should start by describing their variables before delving into the inferential analysis.

The literature review shows clearly that while many empirical studies have evaluated exchange rate volatility, others have introduced exchange rate volatility as a variable in their model of analysis. Many of these studies did not conduct heteroscedasticity test to find out if the series under study are heteroscedastic, which is preceding condition for the application of GARCH model. There is need for such preliminary test before analysis of volatility.

3. Methodology and Data

3.1. Methodology

In order to determine whether or not an ARCH specification is necessary, there is need to test the residuals of the conditional mean equation for ARCH effect. Engle [8] proposed the Lagrange Multiplier (ARCH-LM) test for examining whether a series contain heteroscedastic variance. The ARCH-LM is estimated in accordance with Engle [8] as follows:

$$Rt = \theta + \varepsilon t \tag{1}$$

$$\varepsilon_t^2 = c_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + ... + \alpha_q \varepsilon_{t-q}^2 \tag{2}$$

Where R_t is return of the Naira/US$ exchange rate, ε_t is residual term, ε_t^2 is squared residuals from the regression model specified in equation (1), c_0 is constant, α_1 to α_q are coefficients of the lags of the squared residuals. If there are no heteroscedasticity (i.e., ARCH effects), the estimated values of α_1 through α_q should not be significantly different from zero. The decision rule, therefore, is to reject the null hypothesis of no heteroscedasticity if the *p*-value is less than the level of significance [6]. Evidence against ARCH effect is an indication that GARCH family models are not appropriate.

3.2. Description of Data

The monthly official Naira/US$ exchange rates data are used in this study. The series are obtained from Central Bank of Nigeria (CBN) statistical databank. The period under consideration for the variables ranges from January 2000 to December 2013.

4. Empirical Results

4.1. Graphic Presentation and Descriptive Statistics

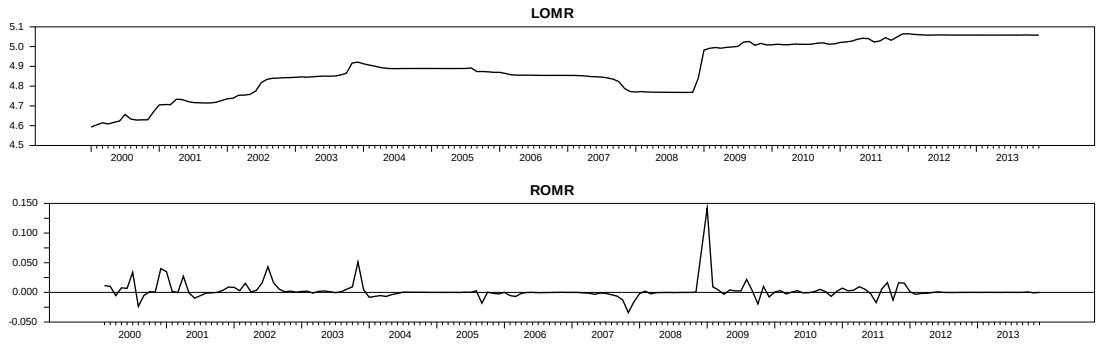

Figure 1. Time Graph of Level and Returns of Average Naira/US$ Exchange Rate (January 2000 to December 2013)

Figure 1 shows a time series graph of the log-level and return series of the Naira/US$ exchange rates in Nigeria for the January 2000 to December 2013 sample period. As can be seen in Figure 1, Naira/US$ was trending upward from the below ₦100 in the year 2000 to ₦130 in January 2004, before falling as a result of the global financial

crisis. From first quarter of 2009, the exchange rate started rising to ₦150. The figure also shows that the change in Naira/US$ exchange rate hovers around the mean except the spike in the first quarter of 2009. In addition, the first differenced series (ROMR) appear not have unit root. These indicate that the levels of the series (LOMR) are trending and appear non-stationary, whereas their logarithmic first differences are stationary.

Table 1 displays the descriptive statistics of the level and change series of the Naira/US$ official market exchange rate. Notice from Table 1 that the average Naira/US$ exchange rate for the sample period is ₦133.6, with a standard deviation of 17. Notice also, from Table 1, the negative skewness, which indicates that the Naira has depreciated more in value than appreciation. The negative skewness and flat distribution further suggest non-normality in the exchange rate series. The Jarque-Bera statistics also support that both the level and change series of the Naira/US$ are not normally distributed.

Table 1. Descriptive Statistics

	Mean	Std. Dev.	Skewness	Kurtosis	J-B Stat.	Observations
ExR	133.63	17.119	-0.088	-1.049	7.928	168
DExR	0.0027	0.0156	5.173	40.467	12140.01	167

Note: J-B Stat is the Jarque-Bera statistics. ExR is the level of the official market exchange rate and DExR is the rate of change of the official market exchange rate.

4.2. Stationarity Test

Table 2 presents the results of augmented Dickey-Fuller (ADF) unit root tests performed on log-level and first difference of the Naira/US$ official market exchange rate series. The Naira/US$ exchange rate series contain unit root at levels but do not contain unit roots at the first difference. This indicates that the Naira/US$ official market exchange rate series require first differencing to achieve stationarity, that is they are *I*(1) variables.

Table 2. ADF Unit Root Test Results

Log-level Series			**First Difference Series**	
Variables	Critical Value 5%	Computed Value	Critical Value 5%	Computed Value
ExR	-3.437	-2.534	-3.437	-8.712**

Table 3 displays the results of a regression model estimated to obtain the residuals required for estimating the ARCH test. Observe that the coefficient of lag of change in exchange rate is significant with *t*-statistic and *p*-value stood at 5.088 and 0.000 respectively. This indicates that history of exchange rate has predictive effect on current exchange rate. The Durbin-Watson coefficient shows that there is no first order serial correlation in the exchange rate series.

Table 3. Results of Regression Model

Variable	Coefficient	*t*-statistic	*p*-value
Constant	0.0016	1.477	0.141
DExR {1}	0.368	5.088	0.000
R^2 = 0.162,	F(1,164) = 25.892 [0.000],		DW= 1.899

Table 4 displays the univariate ARCH test results. Notice that the estimates of the ARCH coefficient, up to lags 8, show evidence against the null hypothesis of no ARCH effects at 99% confidence level. This implies that official market exchange rate is heteroscedastic and GARCH family models are adequate for modeling volatility exchange rate in Nigeria.

Table 4. ARCH Test of the Regression Residual

Lags	Coefficient	*p*-value
1	35.351	0.000
2	21.247	0.000
3	14.192	0.000
4	10.537	0.000
5	8.383	0.000
6	6.803	0.000
7	5.828	0.000
8	5.038	0.000

5. Summary and Conclusions

The objective of this paper is to investigate the behaviour of Naira/US$ exchange rates in Nigeria using descriptive analysis and the autoregressive conditional heteroscedastic (ARCH) test on monthly data ranging from January 2000 to December 2013. The estimates from descriptive statistics show negative skewness and platykurtic distribution thus suggest non-normality in the official market exchange rate series. The Jarque-Bera statistics support that both the level and change series of the Naira/US$ are not normally distributed. The results of the ADF unit root tests show that the variables are not stationary at level but are stationary at first difference. Estimates from the ARCH tests show evidence in support of ARCH effects, thus indicate that official market exchange rate in Nigeria is heteroscedastic. The conclusion therefore is that GARCH family models are adequate for modeling volatility of exchange rate in Nigeria. We recommend that scholars should examine their dataset for heteroscedasticity before estimating GARCH family models.

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