Modelling Volatility Persistence and Asymmetry of Naira-Dollar Exchange Rate

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This paper modelled the volatility persistence and asymmetry of naira-dollar exchange rate in interbank and Bureau de Change (BDC) using monthly data between January 2004 and November 2017. The study employed Generalized Autoregressive Conditional Heteroscedasticity [GARCH (1,1)], Threshold GARCH [TGARCH (1,1)] and Exponential GARCH [EGARCH (1,1)]. The results of Bai-Perron (2003) structural break identified two significant breaks in each market. Interestingly, the breaks, particularly for the interbank exchange rate(December, 2014 and January, 2015), seem to have coincided with the period of depreciation in the country's exchange rate which could be linked to the precipitous movement in the international crude oil prices. The findings showed that persistence is generally explosive in the BDC market as compared to interbank market where the persistence was high but not explosive especially under asymmetric models. Based on our model selection criteria, the symmetric GARCH model, appears to be better than the asymmetric ones in dealing with exchange rate volatility in the interbank market while asymmetric GARCH, especially TGARCH, seems to be better in the case of BDC market. By implication, it is important that the monetary authority considers the developments and reactions of the markets to news most especially the BDC, when designing appropriate exchange rate policies for the country.

Keywords: Bureau De Change (BDC); Exchange rate; Interbank Market; Volatility modelling.
JEL Classification: F0; F310; G150; G190.

1.0 Introduction

A key issue that has attracted considerable attention in international economics is modelling the dynamics of exchange rate in an economy. Inspite of the elaborate and detailed literature on volatility of financial series, divergent views still exist on the major causes of economic fluctuations in developing countries. Some studies in the literature have explained these fluctuations through the perspective of inflation and oil price volatility (See Fasanya and Adekoya 2017; Salisu and Fasanya, 2013); others have considered exchange

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volatility as the major cause of economic instability (See Bala and Asemota, 2013; Adeoye and Atanda, 2012). There are still some outstanding issues requiring further investigation. For instance, there is no consensus on the appropriate measure of exchange rate volatility in an economy. This lack of consensus is attributable to a number of factors. While theory provides some direction as to fundamental factors, the choice of measures of such factors are within the purview of the empiricists. In addition, the choice of measures is influenced to some extent by the constraint imposed by the scope of analysis. In other words, considerable attention should be paid to the period in which the variability will be captured; if the volatility is conditional, and the level of correlation between unexpected movement in the exchange rate and its predicted value.

The degree of exchange rate volatility in emerging markets such as Nigeria is largely driven by the United State dollar, a major trading currency. In the last two decades, the vacillations have been considerable and often unrelated to economic fundamentals. This prompted monetary authorities in most developing countries to intervene in the markets regularly with the objective of stabilizing the exchange rate. However, such interventions are often done without any clear sense of a sustainable equilibrium. In addition, the interventions operate with lags and sometimes too late to forestall severe exchange rate misalignment and volatility. The natural reactions to these imbalances include economic fluctuations, protectionist trade pressures, and inevitably sharp exchange rate policy reversals. Indeed, the exchange rate instability experienced in Nigeria especially between 2015 and 2017 exposed all these foregoing challenges.

It is incontrovertible that economic activities in Nigeria rely mostly on imported inputs. Coupled with this, the average consumer has excessive preference for foreign goods due to product quality disparity. On the exports side, Nigeria's main export commodity is oil that is subject to vagaries of international market challenges and quota allocations. This has had a moderating impact on the flows of foreign exchange and thus led to high exchange rate volatility over the years. In other words, exchange rate volatility in an import dependent economy may lead to huge losses or gains to government and domestic investors that engage frequently in foreign trade and hence are confronted with greater risk of uncertainty about the exchange rate. Thus, the extent of exchange rate volatility is of great importance to both the policy makers and investors.

A plethora of studies have extensively explored exchange rate volatility in Nigeria. Some of these studies including Olowe (2009), Clement and Samuel (2011), Adeoye and Atanda (2013), Bala and Asemota (2013), Emenike and Peter (2016), Ajao and Igbekoyi (2013), Clement and Samuel (2011), Musa and Abubakar (2014) and Isenah and Olubusoye (2016) focus more on the official exchange rate markets. A more recent study by Atoi and Nkwede (2017) accounted for asymmetry in exchange rate volatility for both official and unofficial markets. However, many areas still require significant attention which this study seeks to explore. Specifically, this paper contributes to the literature on exchange rate in Nigeria in two main ways.

First, the volatility persistence of exchange rate is critical to the understanding of exchange rate behaviour in Nigeria. A critical look at foreign exchange rate episodes in Nigeria from 2010 to late 2014 indicates that both official and unofficial markets experienced significant shocks in terms of excessive demand pressure and speculative aggression from foreign exchange market participants which promote volatility in these markets. Recently, the persistent exchange rate instability witnessed in Nigeria after the significant drop in oil price revealed the extent to which unofficial market is important to the economy. The huge activities in the foreign exchange markets which official market failed to handle prompted the booming of unofficial foreign exchange market. Accounting for these two markets in the study for better understanding of exchange rate volatility is necessary for efficient and effective policy formulation. In addition, the demand pressure was heightened in 2015 before the introduction of more liberalized new exchange rate regime. Thus, understanding and comparing the level of volatility persistence in these markets may shed more light on the challenges facing the foreign exchange markets as well as guide the investors in decision making especially in their portfolio diversification.

Second, the issue of asymmetry calls for concern in these two markets. The upward and downward movements of domestic currency against foreign currency (i.e. Naira/Dollar) in the foreign exchange markets over the years create more uncertainty for the players in the markets. More so, the policy of the Central Bank to rely heavily on external reserves contributed to the issue of asymmetry in the markets. Thus, we explore asymmetric conditional volatility model to sufficiently estimate the variations in exchange rate in these markets and compare the extent of the asymmetry. In addition, the study gives detailed information in both markets from persistence and asymmetric perspective for better understanding of the issues surrounding exchange rate and policy formulation. Therefore, this study is motivated to model and compare the extent of persistence and asymmetry for both markets.

The rest of this paper is organized as follows. Section two presents the stylized facts on development in the foreign exchange market, while section three presents the literature review. Section four provides the data and preliminary analysis while section five presents the empirical results as well as ensuing discussion. Section six concludes the study.

1.1 Developments in the Foreign Exchange Market and Exchange Rate Movements in Nigeria

The management of the foreign exchange (forex) rate market in Nigeria has witnessed series of reforms which first led to a shift from a controlled exchange rate to the Second-tier Exchange Market introduced in September 1986. As part of the reform, the Bureau de Change Foreign Exchange Market was introduced in 1989 purposely to deal with privately sourced foreign exchange. The introduction of this segment of the exchange rate market led to large volatility in the rates, thus prompting further reforms ranging from the formal pegging of the naira exchange rate to reaffirmation of the illegality of the parallel exchange rate market. By 1995, the Central Bank of Nigeria enhanced the sale of foreign exchange to end-users through the Autonomous Foreign Exchange Market. Central to the reforms is the handling of the Bureau de Change Market as authorized dealers. To further enhance accessibility of forex market, the interbank foreign exchange market was introduced in 1999. In 2002 and 2013 the exchange rate policy was managed between a Retail Dutch Auction System and Wholesale Dutch Auction System. Subsequently, the interbank foreign exchange market (with CBN interventions) operated from November 2013 till June 2016 when it was further enhanced to improve the exchange rate flexibility. Nonetheless, the Central Bank of Nigeria continued to intervene in the market to stabilize the exchange rate.

There was relative stability in the exchange rate market, as expected, under the control regime, with the official exchange rate at an average of N1.75 per US dollar (USD). The movement of the foreign exchange experienced mostly depreciation since the liberalization of the 1986 until 1993 when it was again, fixed at N22/USD. This fixed exchange rate could not be supported again leading to further depreciation to N92/USD by 1999. Meanwhile, at this same time, the AFEM intervention rate depreciated continuously from N81.98 in 1997 to N91.83 in 1999. Subsequent reforms led to unceasing depreciation between 1999 and 2004, when it reached N132/USD. A slight respite for the economy was achieved between 2004 and 2008 when it appreciated for the first time. The rate however, has been heading north since then, reaching N192/USD in 2015 and N253/USD on the average in 2016. It should be noted that the rate depreciated between June and September 2016, when it was officially maintained at N305/USD till date (July, 2018).

The movement in the bureau de change rate followed similar trend, but more volatile as expected. As at 1995, the rate was N83.69/USD and depreciated to N99.26/USD in 1999. The rate increased to N140/USD in 2004 and appreciated continuously till it reached N120/USD in 2008. By 2009, at the period of the fallout of the global financial crisis, it depreciated to average of

N161/USD, a rate that was maintained until 2014 and 2015, when it depreciated again to N171/USD and N222/USD, respectively. The period marked the new era of continuous and unwavering depreciation in the market due to the inability of the Central Bank of Nigeria to fully support the forex as a result of the dwindling fortune of the country which suffered immensely from the global oil price crash. The management of exchange rate was hampered by speculative activities at this period. The exchange rate reached the peak of N493.29/USD by January 2017, until it stabilized to about N360/USD by end of 2017 and till mid of 2018.

2.0 Literature Review

2.1 Theoretical Framework

This sub-section presents the Purchasing Power Parity (PPP) as the underlying theoretical framework for this study. Following the introduction of the concept by Cassel (1918), it has been explored by many studies, including Officer (1976) and Rogoff (1996). Empirical validation of the theory has been carried out by several studies such as Sollis (2005) and Oyinlola et al. (2011). The purchasing-power-parity (PPP) theory involves the ratio of two countries' price levels (absolute PPP) or price indices times a base period exchange rate (relative PPP) as the most important variable determining the exchange rate, but it allows both for other explanatory variables and for random influences. The basic rationale for PPP theory is that the value of a currency is determined fundamentally by the amount of goods and services that a unit of the currency can buy in the country of issue. To this end, PPP is regarded as one of the most important theories in explaining the behaviour of exchange rate. As documented in Atoi and Nkwede (2017), the theory explains that exchange rate between two currencies will adjust to reflect price level changes between two countries. More specifically, the theory proposes that the same goods (in terms of basket) should have the same costs in each country given that allowance between different currencies is taken into consideration. This theory relies on "law of one price" which argues that identical goods should sell at the same price irrespective of the country. Thus, the understanding of exchange rate behaviour is well captured through "real exchange rate". The real exchange rate is driven by some key factors that are subjected to volatility which in turn causes volatility in the real exchange rate and this leads to nominal exchange rate volatility.

However, the theory failed to explain this behaviour because of its assumption of identical goods in any two countries and there is little or no transport costs and trade barrier. In reality, this assumptions cannot hold due to differences in the quality of commodities produced in the two countries. In addition, PPP theory does not account for good and services whose prices are excluded in country's measure of price level and non-tradable goods across borders, this leads to evolution of interest rate parity condition (IRP). The interest rate parity theory explains the relationship among domestic interest rates, the interest parity and expected appreciation of the domestic currency. It also stipulates that domestic interest rate should equal the foreign interest rate less the expected appreciation of the domestic currency. The algebraic form of domestic interest in the IRP theory is presented below:

$$i^d = i^f - \frac{\varepsilon^e_{t+1} - \varepsilon_t}{\varepsilon_t} \tag{1}$$

where i^d represents domestic interest rate,i^d is the foreign interest rate, ε^e_{t+1} is the expected domestic currency at time and ε_t is the actual domestic currency at time t. on the other hand, IRP is presented as:

$$\varepsilon_t = \frac{\varepsilon^e_{t+1}}{i^f - i^d + 1} \tag{2}$$

2.2 Empirical Literature

The modelling of exchange rate volatility has increasingly gained prominence in the international economics literature in recent years. A number of factors have been attributed to this development. First is the availability of high frequency exchange rate series which provides robust evidence for the presence of statistically weighty correlations between series. Second, high frequency data on exchange rate creates the possibility of time varying volatility which is popularly known as conditional heteroscedasticity (see Harris and Sollis, 2004). Specifically, exchange rate fluctuations signify huge gains or losses arising from exchange rate misalignment in countries operating a mono-product economy and thereby leading to economic instability. Also, exchange rate volatility exposes investors to greater danger of uncertainty with either making huge losses or gains from their investment. Therefore, both the policy makers and investors are interested in the extent of exchange rate volatility to make informed decisions (Salisu and Fasanya, 2012).

Surveying economic literature revealed that modelling exchange rate volatility has followed different dimensions over the years (See Diebold and Nerlove, 1989; Sengupta and Sfeir, 1996; Usman and Adejare, 2010; Ojebiyi and Wilson, 2011; Adeoye and Atanda, 2012; Ajao and Igbekoyi, 2013; Bala and Asemota, 2013 among others). The Diebold and Nerlove (1989) appears to be the first study to model the exchange rate volatility using the Auto Regressive Conditional Hereteroskedasticity (ARCH) framework. The ARCH model only account for symmetric impacts in a shock. However, economic agents do not respond the same way to both positive and negative shocks. Thus, the study did not account for asymmetric shocks in the model. Estimating the likely presence of asymmetric shocks in exchange rate is of immense importance to individuals, firms and government who are concerned on managing the associated risk and uncertainties of the foreign exchange market.

Also, Sengupta and Sfeir (1996) attempted the modelling of exchange rate volatility in five countries (Japan, France, United Kingdom and West Germany) using the Autoregressive Conditional Hereteroskedasticity (ARCH) and Generalized Autoregressive Conditional Hereteroskedasticity (GARCH). The study revealed that exchange rate follows a random walk while the volatility follows a persistent nonlinear behaviour. Again, the study failed to capture for asymmetric impact that is often common with volatile series.

Examining Ghana Cedi-United States Dollar exchange rate volatility, Luguterah et al. (2015) applied monthly exchange rate returns between January 1990 and November 2013 on symmetric and asymmetric GARCH models. Their results show the volatility persistence and absence of leverage effects from the asymmetric models. Consequently, the results suggest that the investors who hedged against future exchange rate risk do not rely on information about asymmetry in the Ghana foreign exchange market. Similarly, Rofael and Hosni (2015) employed daily data between January 2003 and June 2013 in modelling exchange rate volatility in Egypt using ARCH type and the State Space models. Their results revealed that exchange rate returns display volatility clustering and there is existence of time-varying variance in the exchange rate which has to be considered when modelling nominal exchange rates. This further shows that financial returns series exhibit sustained period of relative calmness and high volatility in the Egyptian exchange rate market.

In Nigeria, a number of studies have attempted to model exchange rate volatility. A notable work in this regard is Adeoye and Atanda (2012). The study revealed the presence of overshooting volatility shocks. However, the study did not account for asymmetric impacts in the model. This is because the ARCH and GARCH framework only account for symmetric impacts and shocks in a model. Further, Bala and Asemota in their 2013 paper on modelling exchange rate volatility in Nigeria, argued that asymmetric impacts and shocks are important when dealing with high frequency data. Therefore, evaluating the presence of asymmetric shocks on exchange rate is very pertinent to investors and policy makers. In their paper, Atoi and Nkwede (2017)examined asymmetric analysis of exchange rates volatility in Nigeria using three segments of the Nigerian foreign exchange market, namely; (Interbank Foreign Exchange Market (IFEM), Bureau de Change and Wholesale Dutch Auction System (WDAS). The authors employed Asymmetric Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) and their results showed that there was persistence of exchange rate volatility in all markets. They found that interbank exchange rate volatility was persistent and explosive compared to the other two markets. Similarly, Yakubu and Abubakar (2014) employed different approaches such as GARCH, GJR-GARCH, TGARCH and TS-GARCH and found the persistence of exchange rate volatility and non-existence of leverage effect.

The study by Olowe (2009) investigated the volatility of Naira/Dollar exchange rates using first order symmetric and asymmetric models on monthly data from January 1970 to December 2007. The study addressed the volatility issue through the separation of volatility during fixed exchange regime from managed float regime and the findings indicate that volatility was persistent and there was presence of leverage effect for the two regimes. In addition, the examination of the consistency, persistency, and severity of volatility in exchange rates of Naira/Dollar by Adeoye and Atanda (2013) revealed that the nominal and real exchange rates of Naira/US Dollar is not consistent with the traditional long-run PPP model. They concluded that symmetric GARCH model does not fully account for the stylized facts in terms of leverage effect inherent in financial time series. Clement and Samuel (2011) employed symmetric GARCH model to study volatility of Naira/US Dollar and Naira/UK Pound Sterling exchange rates in Nigeria and their results showed that volatility on the returns was persistent. In addition, Olusola and Opeyemi (2013) examined exchange rate volatility in Nigeria using Parametric Measure. They found that exchange rate volatility represents uncertainty and risk, which impose costs on risk averse economic agents. The results from their Exponential Generalised Autoregressive Conditional Heteroscedasticity (E-GARCH) model indicated that exchange rate was volatile in Nigeria as a result of unusually high and low deviations.

This present study recognises that some studies have captured both the symmetric and asymmetric effects on exchange rate in Nigeria; these studies, however, did not consider a comparison of the levels of volatility persistence and asymmetry in the interbank and Bureau de Change exchange markets in Nigeria. Thus, to complement results from the previous studies, we examine this comparison to provide better insight to investors and policy makers since they also engage in buying and selling of currencies in both markets. In addition, this paper considered the plausible effects of the presence of multiple breaks of the series in the analysis. The study therefore, fills this gap by attempting to model exchange rate volatility persistence and asymmetry in both markets using the ARCH, GARCH, TGARCH and EGARCH frameworks.

3.0 Data and Methodology

3.1 Data sources and Construction

The monthly Naira/USD exchange rates data utilized in this study were collected on interbank market and Bureau de Change. The data which cover the period January 2004 to November 2017 were obtained from Central Bank of Nigeria (CBN) online database. Thus, as a standard precondition in the literature for dealing with volatile financial series, the pre-estimation analysis is done in three stages: the first provides descriptive statistics for the respective exchange rates considered; the second tests for the presence of structural breaks in the series; while the third tests for potential heteroscedasticity feature of the series using ARCH LM test.

A time series exhibiting conditional heteroscedasticity-or autocorrelation- in the squared series is said to have autoregressive conditional heteroscedastic (ARCH) effects. To test the probable existence of ARCH effects in the respective exchange rate series under consideration, we explore the ARCH Lagrangian Multiplier (LM) test procedure developed by Engle (1982) which begins with a univariate model as specified below:

$$r_t = \lambda + \sum_{i}^{k} \delta r_{t-i} + \varepsilon_i; i = 1, ..., k, t = 1, ..., T; \varepsilon_1 \sim iid(0, \sigma^2); \quad |\delta t| < 1 \tag{3}$$

where r_t denote exchange rate returns and is measure in this paper as:

$$R\_BDCEXR_t = 100 \times [\Delta \log(BDCEXR)] \tag{4a}$$

$$R\_IFEXR_t = 100 \times [\Delta \log(IFEXR)] \tag{4b}$$

$$r_t = \lambda + \sum_{i}^{k} \delta r_{t-i} + \varepsilon_i; i = 1, ..., k, t = 1, ..., T; \varepsilon_1 \sim iid(0, \sigma^2); \quad |\delta t| < 1$$

where BDCEXR in equation (4a) denotes Bureau de Change exchange rate, while IFEXR is interbank or official exchange rate and Δ is a first difference operator.

In this section, we consider different plausible symmetric and asymmetric GARCH modeling frameworks to capture volatility and persistence in both the interbank and BDC exchange rate markets. That said, another significant contribution of this paper, as far as modelling of exchange rate volatility is concerned, is the inclusion of two break dates as earlier established by the outcomes of the Bai-Perron (2003) structural break test. Starting with the symmetric GARCH model, our mean equation following the standard GARCH (1, 1) procedure is as follow:

$$r_t = \eta + \delta r_{t-1} + \alpha_1 D_{1,t} + \alpha_2 D_{2,t} + \varepsilon_t \tag{5}$$

where r_t represents the returns on Bureau de Change and interbank exchange rates, $D_{i,t} = 1 \text{if} t \geq BD_i \text{andzerootherwise}; BD_i (i = 1, 2)$ denote the selected break dates. Given that $\varepsilon_t = \sigma_t e_t$ and $e_t \sim (0, 1)$ However, while the mean equation (5) is applicable to all the models used in this paper, the variance for the GARCH(1,1) model can be expressed as below:

$$\sigma_t^2 = \alpha + \beta \varepsilon_{t-1}^2 + \gamma \sigma_{t-1}^2; \quad \alpha > 0, \quad \beta \geq 0, \quad \gamma \geq 0 \tag{6}$$

Equation (6) typically expresses the conditional variance dependent on information about volatility observed in the previous period (the ARCH term,ε_{t-1}^2) and forecasted variance from last period (the GARCH term,σ_{t-1}^2). The persistence of σ_{t^2} is captured by $\beta + \gamma$ and covariance stationarity requires that$\beta + \gamma < 1$.The model is consistent with volatility clustering where large changes in returns are likely to be followed by further large changes and small values of variance from last period will be followed by small values of conditional variance in current period (Mandelbrot, 1963). The pattern of the volatility clustering may vary if bad and good news are received. Zivot (2008) argued that the signs of the residuals or shocks have no effect on conditional volatility in the basic GARCH model because the observed volatility in the previous period enters in squared value. The study also noted the fact that bad news (negative shocks) tends to have a larger impact on volatility than good news (positive shocks) of the same magnitude. In other words, volatility tends to be higher with negative shocks than with positive shocks. Black (1976) inferred that this effect increases the leverage effect and causes more volatility. Based on this conjecture, the asymmetric news impact on volatility is commonly referred to as the leverage effect. This asymmetric effects is demonstrated in this study with the use of EGARCH(1,1) and TGARCH(1,1) in equations 8 and 9, respectively. The EGARCH model was developed by Nelson (1991) to specifically capture asymmetries in the volatility. It is typically represented as follows:

$$\ln(\sigma_t^2) = \phi + \psi \left| \sqrt{\varepsilon_{t-1}^2 / \sigma_{t-1}^2} \right| + \tau \sqrt{\varepsilon_{t-1}^2 / \sigma_{t-1}^2} + \gamma \ln(\sigma_{t-1}^2) \tag{7}$$

For the asymmetric effect to hold, then,$\tau < 0$ implying that negative shocks increases volatility more than positive shocks of the same magnitude. If the sign is positive and statistically significant, that suggests positive shocks lead to higher volatility than negative shocks of the same magnitude. However, if the parameter is not statistically significant then the model is symmetric. The TGARCH model is a modification of equation (6) by the inclusion of the dummy variable I_{t-1}.

$$\sigma_t^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\sigma_{t-1}^2 + \vartheta\varepsilon_{t-1}^2 I_{t-1} \tag{8}$$

where $I_{t-1} = 1$ if $\gamma_{t-1} > 0$ and 0 otherwise. Hence, there is evidence of asymmetric effect if $\vartheta < (>)0$ which implies that positive (negative) shocks reduce the volatility of r_t by more than negative (positive) shocks of the same magnitude.

4.0 Analysis and Discussion of Results

4.1 Descriptive statistics

Table 1 below presents the descriptive statistics for exchange rate returns in both markets covering the entire period under investigation. There appears to be an evidence of significant variations in exchange rate as shown by the large difference between the minimum and maximum values for both markets. On the statistical distribution of exchange rate, both official and BDC rates show evidence of positive skewness for all the sample period, suggesting that the right tail was predominant. In relation to kurtosis, the BDC exchange rate is leptokurtic while the official exchange rate is platykurtic. Lastly, the study discovered that exchange rate is not normally distributed in both markets judging by the Jarque Bera (JB) statistic.

Table 1: Descriptive Statistics of BDC and Interbank Market Exchange Rate Returns

	R_BDCEXR	R_IFEXR
Mean	0.0053	0.0048
Median	0.0000	0.0000
Maximum	0.1448	0.2398
Minimum	-0.1748	-0.0340
Std. Dev.	0.0374	0.0278
Skewness	0.2471	5.7986
Kurtosis	8.3545	41.6440
Jarque-Bera (prob.)	201.1984 (0.0000)	11327.1600 (0.0000)
Observations	166	166

Source: Author's computation

An analysis of the trend of the exchange rate in the BDC and interbank markets in Nigeria is presented in Figures 1 and 2. Figure 1 depicts the trends of returns in the Bureau de Change (BDC) market and the underlying data. The trajectory of Figure 1 presents an apt picture of instability of exchange rate. The Figure portends traits of volatility clustering; these are periods of high volatility shadowed by that of relatively low volatility. This reflection supports the evidence in Table 1 thus demonstrating that volatility is highest in 2008 and around 2016 which coincided with the global financial crises and the fall in global oil price that affected the Nigerian economy. Indeed, as a consequence of the structure of the economy that depends mainly on crude oil for foreign exchange, the economy fell into recession by second quarter of 2016.

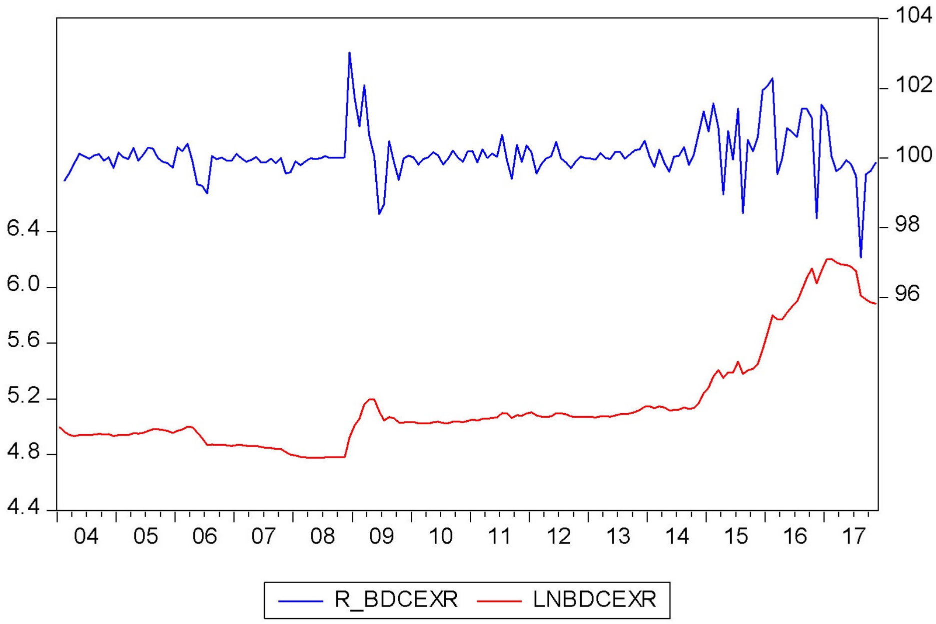

Figure 1: Graph of BDC Exchange Rate Returns

Figure 2 shows the dynamics of the returns in the interbank foreign exchange market and its underlying data. The behaviour of the interbank market exchange rate is also unsteady similar to the observed trend in Figure 1. As seen in the figure below, the volatility is highest in 2016.

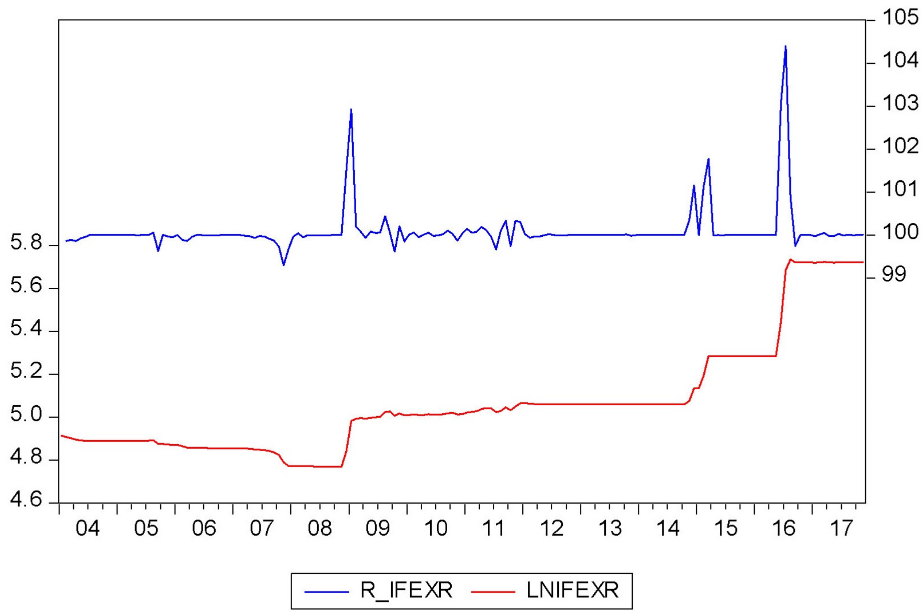

Figure 2: Graph of Interbank Exchange Rate Returns

4.2 Structural Break Test

Table 2: Bai-Perron Multiple Structural Breaks Test Results

Variable	T_1		T_2		NSB
	$\sup F_T(\ell+1\|\ell)$	Break Date(BD_1)	$\sup F_T(\ell+1\|\ell)$	Break Date(BD_2)	
R_BDCEXR	10.37	09/2016	14.07	11/2016	2
R_IFEXR	59.53	12/2014	93.60	01/2015	2

Note: NSB denotes number of significant structural breaks. The $\sup F_T(\ell+1|\ell)$ test statistic for the breaks are reported in Table 2 above. The critical values for $\sup F_T(\ell+1|\ell)$ at 10% level of significance as obtained from the Bai and Perron (2003) paper are 7.04 and 8.51 respectively for $\ell = 1, 2$.

Presented in Table 2 above are the results of the structural break test prompted by the notable indication of shifts in the historical movements of exchange rates in both the BDC and interbank exchange rate markets (see Figures 1 and 2). In essence, we follow the Bai and Perron multiple structural breaks test to determine significant structural shifts in the movement of the series. Our choice of Bia-Perron (2003) in determining the breaks is hinged on the fact that it allows for a maximum of five structural breaks in time series (see Narayan and Liu, 2015). The test also involves a sequential application of $\sup F_T\,(\ell+1|\,\ell)$test which is assumed to work best in selecting the number of breaks. The results of the structural break using Bai-Perron (2003) shows that the exchange rates (nonetheless the market under consideration) exhibit at least two significant structural breaks. Interestingly, the breaks particularly for the interbank exchange rate seem to have coincided with the period of depreciation in the country's exchange rate which may be linked to the recent precipitous movement in the international crude oil prices. Consequently, the identified break dates in the case of the BDC exchange rate may be traceable to the period of significant response of the market to shocks due to monetary policy intervention to mitigate the depreciation of the exchange rate which was due to fall in crude oil prices.

4.3 ARCH LM test

Essentially, Engle (1982) proposes three steps for the implementation of ARCH test: the first step is to estimate equation (3) by OLS and obtain the fitted residuals; the second step is to regress the square of the fitted residuals on constant and lags of the squared residuals, i.e., estimate equation (9) below:

$$\hat{\varepsilon}_t^2 = \rho_0 + \rho_1\hat{\varepsilon}_{t-1}^2 + \rho_2\hat{\varepsilon}_{t-2}^2 + \cdots + \rho_p\hat{\varepsilon}_{t-p}^2 + \mu_t; \tag{9}$$

and the third and final step is to use the LM test option to evaluate the validity or otherwise of the null hypothesis of no ARCH effects, $H_0 : \rho_1 = \rho_2 = \cdots = \rho_p = 0$

Table 3: ARCH LM test results

BDC Exchange Rate			
F-statistic	13.318	Prob. F(1,163)	0.000
Obs*R-squared	12.468	Prob. Chi-Square(1)	0.000
Interbank Exchange Rate			
F-statistic	26.288	Prob. F(1,163)	0.000
Obs*R-squared	22.933	Prob. Chi-Square(1)	0.000

Table 3 presents results of the ARCH effects for the BDC and interbank exchange rate. In the case of BDC exchange rate, the Obs*R-squared statistic which is Engle's LM test statistic shows a value of 12.468 and has a probability limit of 0.000. Similarly, obs*R-squared for interbank exchange rate is 22.933 and has a probability limit of 0.000. This clearly suggests that we reject the null hypothesis of homoscedasticity and confirm the presence of ARCH effects in the BDC exchange rate and the interbank market exchange rate series. We can conclude that exchange rates in both interbank and BDC exchange markets exhibit ARCH effects. Thus, this necessitates the modelling of exchange rate volatilities under symmetric and asymmetric scenarios in both markets for better understanding of exchange rate dynamics for meaningful policy formulation and investment decisions.

4.4 Discussion of Results

The discussion here focuses on the GARCH models. Given the evidence of ARCH effects in the series, the estimation proceeds with the implementation of the symmetric GARCH(1,1) model in equation (7) and subsequently considers the variants of asymmetric models specified in equations (8) and (9), respectively in each market. The subsequent discussion is twofold. First, the models with a better fit is determined. Model selection criteria such as the Schwartz Information Criterion (SIC), Akaike Information Criterion (AIC) and Hannan-Quinn Information Criterion (HQC) were used to decide the model with the best fit. Fitness of models is typically determined using the Rsquared and adjusted Rsquared but these are flawed with over-fitting and loss of degrees of freedom. Thus, in this study, we chose the SIC in the two markets for ease of interpretation. Within each market also, the extent of volatility persistence and asymmetry were also discussed.

4.4.1 Volatility persistence and asymmetry of BDC exchange rate

The discussion here focuses on results of different volatility models with structural breaks presented in Table 4 below. Volatility persistence measures the period of time required for volatility in the market to dissipate or decay and it is computed by the sum of the coefficients of ARCH and GARCH effects.

In the BDC exchange rate market, the sum of the coefficients in the GARCH and TGARCH models is greater than one (1.77, 1.20, respectively) while persistence in the EGARCH (1, 1) model (0.91) is also close to one. The results indicate that EGARCH model has high persistence while GARCH and TGARCH are both highly explosive. However, there is an indication of greater explosive level of persistence under GARCH model with structural breaks compared to the TGARCH model.

Following standard inferences from the literature, it suggests that there is greater indication of explosive level of persistence in the BDC market. This clearly lends support for the generalization of persistence by other studies such Bala and Asemota (2013), Emenike and Peter (2016) Clement and Samuel (2011), in the exchange rate market. In comparing the performance of the volatility models in the BDC market, the TGARCH(1,1) model appears to provide a better fit over the GARCH(1,1) and EGARCH (1,1) models as judged by the SIC value.

The answer to the question as to whether BDC exchange is more volatile after bad or good news (negative or positive shocks) is provided by the sign and significance of the coefficients of asymmetry in the TGARCH model. The coefficient of asymmetry for TGARCH (1,1) in Table 4 is negative and statistically significant, but only at the 10 percent level. This suggests that in the BDC market, negative shocks have the penchant of reducing volatility more than positive shocks of the same magnitude. In other words, bad news in the exchange rate markets has more propensity of increasing exchange rate volatility in the BDC market than good news.

Table 4: Estimation results of Volatility Models with two structural breaks for BDC

Variable	GARCH (1,1)	TGARCH (1,1)	EGARCH (1,1)
Mean equation			
η	-0.00048* (0.00012)	-0.00049 (0.00034)	3.68×10^{-6} (0.00023)
δ	0.02629* (0.00864)	0.08856** (0.03560)	0.2709* (0.0368)
α_1	0.08283 (1.35268)	0.0777* (0.00483)	0.0620 (0.1538)
α_2	-0.01064** (0.00457)	-0.01199* (0.00221)	-0.0102* (0.0018)
Variance equation			
α	0.000109** (4.64×10^{-5})	5×10^{-5}* (1.41×10^{-5})	-0.7648** (0.306)
β	1.46796 (0.91603)	0.5657 (0.351)	-
γ	0.31086*** (0.17631)	0.6412* (0.039)	0.9094* (0.035)
ϑ	-	-0.5894*** (0.3481)	-
ψ	- -	-	0.1055 (0.1345)
τ	-	-	0.3422** (0.1373)
Persistence	1.779	1.207	1.015
Observations	167	167	167
AIC	-4.965	-5.063	-4.906
SIC	-4.814	-4.894	-4.737
HQC	-4.904	-4.995	-4.837
ARCH LM F Stat.(prob.)	0.968	0.968	0.970

Note: *, **, *** indicate 1%, 5% and 10% levels of significance, respectively. Standard errors are reported in the parenthesis

4.4.2 Volatility persistence and asymmetry of interbank exchange rate

Persistence in the interbank exchange rate market as shown in Table 5 indicates moderate to high persistence especially in the TGARCH (0.74) and EGARCH (0.72) models. The GARCH model has a persistence of 1.49, which suggests an explosive persistence. However, on the whole, the results suggest that the BDC exchange rate market is more persistent than the interbank exchange rate market. In terms of the performance of the volatility models, the symmetric model, GARCH(1,1), proved to have a better fit based on the SIC value. This indicates that participants in the interbank foreign exchange market do not respond to news differently.

In summary, the TGARCH provides better insight into the impact of news on the exchange rate returns volatility in the BDC market while the interbank seems to be unresponsive (or less responsive) to news. The results may not be unsurprising based on the structure of these markets. These results further confirm the responses of the markets to news and indeed, to market forces as determined by the participants. The BDC market is adjudged to be more market driven, hence its ostensible asymmetric reaction to news.

As a follow up to the pre-estimation test that confirms the presence of ARCH effects in the foreign exchange markets, the study also provides post-estimation diagnostic test using the F-test. Adjudging by the probability values of the models in the two markets we could not reject the null hypothesis of no ARCH effects in the BDC and the interbank markets (with and without structural breaks). All the values were statistically insignificant at 5% and 1% levels of significance.

Table 5: Estimation results of Volatility Models with two structural Breaks for interbank

Variable	GARCH (1,1)	TGARCH (1,1)	EGARCH (1,1)
Mean equation			
η	$2.17\text{x}10^{-8}$	-0.00014^{*}	$3.41\text{x}10^{-5*}$
	$(2.88\text{x}10^{-8})$	$(5.13\text{x}10^{-6})$	$(4.83\text{x}10^{-7})$
δ	0.000287	0.479^{*}	0.3847^{*}
	(0.0004)	(0.0067)	(0.0167)
α_1	0.0588	0.0508	0.0522^{*}
	(283.477)	(0.0034)	(0.008)
α_2	$-7.16\text{x}10^{-9*}$	0.00014^{*}	$-5.36\text{x}10^{-5*}$
	$(1.53\text{x}10^{-9})$	$(1.83\text{x}10^{-5})$	$(1.6\text{x}10^{-5})$
Variance equation			
α	$3.82\text{x}10^{-5}$	0.0003	-2.9848^{*}
	$(3.09\text{x}10^{-5})$	(0.0005)	(1.0008)
β	0.8750	0.2571	-
	(0.830)	(0.3049)	
γ	0.6130	0.4864	0.7261^{*}
	(0.1500)	(0.6115)	(0.097)
ϑ	-	-0.4852	-
		(0.8312)	
ψ	-	-	1.7858^{*}
	-		(0.5862)
τ	-	-	-1.3495^{**}
			(0.5277)
Persistence	1.488	0.743	0.726
Observations	167	167	167
AIC	-9.405	-8.5149	-9.003
SIC	-9.255	-8.3455	-8.834
HQC	-9.344	-8.4461	-8.934
ARCH LM test(2)			
F-test(Prob)	0.997	0.5782	0.988

Note: *, ** indicate 1% and 5% levels of significance, respectively. Standard errors are reported in the parenthesis

5.0 Conclusion and Policy Implications

The specific objective of this study was to model volatility persistence and asymmetry of Naira-Dollar exchange rates in both BDC and Interbank markets using monthly data between January 2004 and November 2017. The essence of volatility in exchange rate is to provide useful information to participants in the market with respect to uncertainty or risk in the market. The investors are more interested in the stability of exchange rate before investing in the host country. The implication of fluctuation in the exchange rate suggests huge losses (gains) to the investors and thus, low return on investment may be detrimental to both investors and economy as a whole. For the profit maximizing and risk averse agents/investors, the occurrence of high volatility persistence may shape the investment decision in the area of portfolio diversification to less risky assets. Therefore, modelling volatility persistence and asymmetry is critical to policymakers and thus motivating the study. The contribution of this paper is twofold. First, we employed Bai-Perron Multiple Structural Breaks Test which gives opportunity for determining more than one structural break from BDC and Interbank markets. Second, we augmented for the latter in both symmetric and asymmetric models.

Based on our model selection criteria, the symmetric GARCH model, appeared to be better than the asymmetric ones in dealing with exchange rate volatility in interbank markets while asymmetric GARCH, especially TGARCH, appeared to be better in the case of BDC market whether structural breaks are accommodated in the models or not. These findings revealed evidence of asymmetric effects in both markets. In addition, the persistence in the BDC market was largely moderated after the shocks (i.e. structural breaks) compared to interbank market where the persistence was not explosive especially under asymmetric models. These results tend to suggest the need to account for market differences when designing appropriate exchange rate policies for the country as the market participants respond differently to developments in the markets. This will go a long way in aligning the exchange rate in the two markets for proper investment decision making and policy formulation. Finally, shocks to exchange rate need to be subdued through sufficient reserves accumulation to absorb any unforeseen shocks to the exchange rate structure.

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