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Strictly as per the compliance and regulations of:

Non-Linear Causal Link between Central Bank Intervention and Exchange Rate Volatility in Nigeria

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Abstract- The continued volatility of the Naira / USD exchange rate has attracted the attention of Nigeria's Central Bank (CBN) to engage in the foreign exchange market. This study aims to examine the long-run relationship between interventions on the foreign exchange market and the Naira / USD exchange rate. Regarding four variables, the analysis uses annual data, namely the: Naira / USD exchange rate, money supply, net foreign assets, and interest rates from 1980-2018. This research also used non-linear unit root, cointegration and causality testing approach. The non-linear unit root tests for stationarity by KSS and Breitung showed that the variables employed were stationary at the first difference. Besides, nonlinear Breitung cointegration tests showed the existence of the long-term relationship between foreign market interventions and the Naira / USD exchange rate. Similarly, non-parametric Diks and Panchenko causality tests verified the existence of a causal relation between net foreign assets and money supply and the Naira / USD currency exchange rate respectively. Hence, foreign market interference by the CBN is non-sterilized. As a result, Nigeria's central bank will ensure that it sterilizes all the amounts of currency used during intervention operations. This will avoid the impact of non-sterilized foreign-currency interventions on the Naira / USD exchange rate.

Keywords: breitung cointegration test; central bank interventions, diks, and panchenko causality test, exchange rate volatility.

I. Introduction

In most of the emerging markets and advanced economies, Central Banks intervene in the foreign exchange market to correct misalignment in their exchange rate, stabilize the volatility in their currency, accumulate a reasonable amount of foreign reserves and ensure the efficiency of the foreign exchange market by supplying foreign currencies. (Guimaraes and Karadacag, 2004). Furthermore, the issue on the effectiveness of the Central Bank interventions have remained a matter of debate in the previous literature-some believed that the action of the Central Banks in the foreign exchange market is effective (Pattanaik and Saho, 2003; Schmidt and Wollmerschauser, 2004; Dominguez, 2006; Fatum and Hutchison, 2006; Behera et al. 2008; Fatum 2009; Newman et al. 2011; Reitz and Taylor, 2012; McKibbin and Wanaguru, 2012; Mijiyama and Montoro, 2013; De Roure et al. 2013), some emphasized that the Central Bank intervention is ineffective (Beine et al. 2002; Simatele, 2003; Fatum and Hutchison, 2004; Simwaka and Mkandawire, 2012; Mehdi et al. 2012) while some have found mixed results in their empirical works (Guimaraes and Karadacag, 2004; Domac and Mendoza, 2004; Disyaatat and Galati, 2007; Mwansa, 2009). Over two decades ago, the Central Bank of Nigeria had been intervening in the foreign exchange market frequently to support and stabilize the value of Naira/US Dollar exchange rate, although the effectiveness of the intervention is temporary and short-lived (Sanusi, 2004; Adebiyi, 2007; Omojolaibi and Gbadebo, 2014). Even though the CBN provides timely intervention in the foreign exchange market, the previous empirical works on Nigeria are limited. This is due to the absence of publicly available data on CBN interventions (Adebiyi, 2007: Omojolaibi and Gbadebo, 2014). As a result, most of the empirical works on Central bank interventions were conducted in advanced economies (Guimaraes and Karadacag, 2004). In line with this, this study aims at examining the long-run relationship between foreign exchange market interventions and the Naira/USD exchange rate in Nigeria. The remaining parts of the paper are structured as follows. Section two is an overview of Nigerian Foreign Exchange Management in Nigeria. In Section three, theoretical and empirical evidence is presented and evaluated. In section four, the analytical method of data analysis is presented. Results and discussions of empirical findings follow in Section Five, the summary of the findings, and the conclusion of the entire work are presented. Lastly, the study provides some significant recommendations based on the findings.

II. Literature Review

a) Overview of Exchange Rate Management in Nigeria

In the 1970s, Nigeria had experienced a windfall that was followed by years of the budget deficit. This led to the emergence and implementation in 1986 of the Structural Adjustment Program (SAP), as recommended by the International Monetary Fund (IMF) and the World

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Bank as a means to restore and boost the growth and development of a given economy (Oyinbo and Rekwot, 2014). Among SAP's conditions was that naira must be devalued and allowed to float freely on the (deregulated) foreign exchange market; its value was to be decided by market forces. Since then, the Central Bank of Nigeria (CBN) has engaged in foreign exchange transactions, as Adebiyi (2007) opined. While Naira's value was fairly stable before 1986, the introduction of the Second-Tier Foreign Exchange Market (SFEM) as one of the International Monetary Fund (IMF) conditions in July 1986 continued to depreciate naira: naira, for example, was traded at 0.99=$1 in 1985. Nevertheless, with the implementation of SFEM in 1986, the merger of First and Second Tier Foreign Exchange Management policy in 1987 and the implementation of Interbank Rate in 1988 caused Nigerian Naira's value to depreciate to just $1.75=$1.00, sometimes $1.00, and sometimes $7.36=$1.00 (CBN, 2014). In its efforts to stabilize the Naira exchange rate, the Nigerian government established Guided Deregulation Policy, which in 1994 connected Naira to the US dollar at around 21,886. In 1999, the re-introduction of the interbank foreign exchange (AFEM) market-led Naira to further depreciate to $1.00 = $1.00. Another scheme, Whole Dutch Auction System, was implemented in 2006; as a result, in December 2007, Naira further depreciated $117.97=$1.00. Around the same time, there was a worldwide financial crisis in 2008, popularly known as the "Global Economic Meltdown." The result revealed that the value of Naira was further depreciated to $131.5=$1.00. Naira / dollar exchange rates stood at $1142.00 = $1.00 by February 2009 (Aliyu, 2009). In 2013, policymakers in Nigeria came up with Retail Dutch Auction in another attempt to achieve a stable value for the Naira. The strategy also caused Naira, sadly, to further depreciate to $157.31=$1.00 (CBN, 2014). The continuous weakening of the Naira / US dollar exchange rate has a close connection with the domestic goods and services rates. This relationship between the depreciation of the exchange rate and inflation was discussed in detail in the literature (see Leflache, 1996; Adebiyi, 2007; Mohamed, 2009; Aliyu et al., 2009). As such, any work aiming to stabilize Nigeria's domestic exchange rate is of paramount importance given the impact of the exchange rate on the domestic price of goods and services. Figure 1 below shows how the exchange rate expressed in Naira / US dollars has been gradually increasing (depreciation) at a higher and sustained rate since the implementation of the Structural Adjustment Program up to 2018.

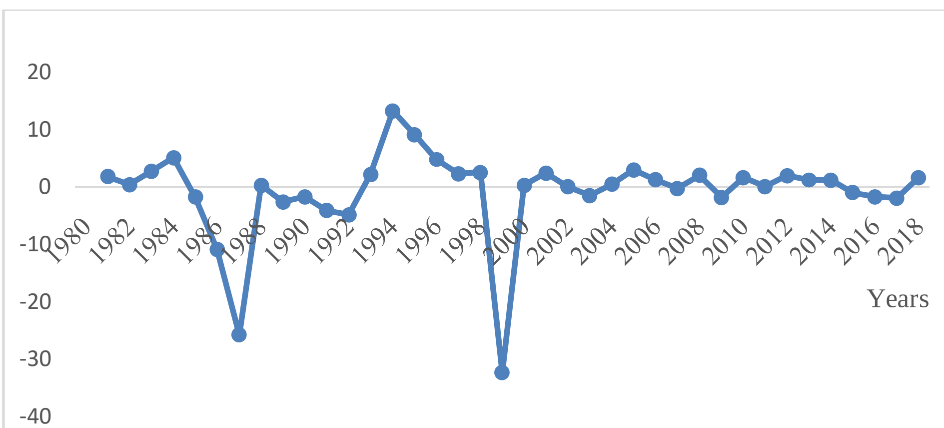

Figure 1: Percentage Change of Naira Exchange Rate from 1980-2018

b) Empirical Evidences

The methods use, and the usefulness of official foreign-exchange intervention as a policy framework for achieving price and exchange-rate convergence is a topic of divisive disputes (Schmidt and Wollmerschauser 2004). This is because of the inconclusive results of the previous studies (Edison, 1993; Sarno and Taylor, 2001; Dominguez, 2003). Dominguez (1998) employing the GARCH (1, 1) Model observed that the Federal Reserve of America's hidden foreign market intervention raised the volatility of the US dollar while the broadcasted intervention resulted in confusion and disorder on the foreign exchange market. This finding did not substantiate the Bonser-Neal et al. (1998) analysis, although the later used different approaches. Furthermore, Bonser-Neal et al. (1998) introduced the Event-Study Model and reported that intervention on the foreign exchange market by the Federal Reserve is necessary and successful in stabilizing the value of the US Dollar. In Japan, Kurihara (2011), Reitz and Taylor (2012), Seerattan (2012), and Hillebrand and Schnabl (2008) claimed that the Bank of Japan's (BoJ) foreign market intervention was successful and its role in stabilizing Japanese Yen's value. Their report, however, did not support that of Frenkel et al., (2004). From another research conducted with the support of GARCH (1, 1), Simwaka (2006) discovered that Reserve Bank of Malawi's (RBM) official participation in the forex market influenced Kwacha, very insignificant and yet significant in decreasing the unwanted volatility of their exchange rate. He inferred that RBM's net sales of dollars devalued the value of Kwacha rather than appreciated.

Adebiyi (2007) method using Autoregressive Distributed Lag (ARDL) hypothesized that the correlation between intervention variables and exchange rates was not reliable. Consequently, the role of the Nigerian central bank in the currency market is sterilized. This is attributed to insufficient intervention financing due to reduced economic reserve generation, the incoherence of intervention policies with macroeconomic strategies as well as regular involvement by politicians in the policymaking process. Looking objectively at the studies of Dominguez (1998), Hillebrand and Schnabl (2008), Guimaraes and Karadacag (2004), Domac and Mendoza (2004), Simwaka and Mkwandawire (2006), Kurihara (2011) and Reitz and Taylor (2012), they all use the GARCH (1, 1) model in their investigations. However, for the model to be statistically relevant, it takes many years of regular data. Nevertheless, their results from the GARCH (1, 1) model are less accurate, due to the insufficient data of interventions in the country's understudies coupled with the lack of real intervention data in some countries. Another drawback of GARCH (1, 1) is that its results are focused on the scale of the motions between the variables being examined and not on the direction of causality.

Lahura and Vega (2013) examined the correlation between undisclosed intra-daily data, the inter-bank exchange rate, and the dollar amount bought and sold using the Structural Vector Autoregressive (VAR) model. They noticed that foreign exchange intervention in Peru affected the exchange rate in the right direction, but marketing interventions were noticed to be more successful than simply purchase interventions. Omojolaibi and Gbadebo (2014) analyze the impact of foreign exchange market intervention on naira exchange rate stability. They employed the strategy of autoregressive distributed lag (ARDL) on four annual time series data from 1970 until 2006. The data include the money supply, total foreign net assets, accumulated foreign private inflow, actual gross domestic product (GDP) and structural breakdown. The findings indicated that the central bank has a long-term equilibrium relationship between the intervention of central banks in the foreign exchange market and the factors in the money supply.

Consequently, the process of CBN interference is considered non-sterilized. Even though this study is among Nigeria's earliest empirical work (second to Adebiyi, 2007), the researchers also refused to provide the exchange rate parameter that is the key focus of foreign exchange intervention. However, the approach they used (i.e., ARDL) was criticized for having a low degree of freedom while evaluating an equation with amassive number of regressors. This means that ARDL could not display more than one balance link in a model (Mehdi et al., 2012). Based on the above-mentioned empirical data, there is no consensus on the efficacy of foreign exchange interventions in foreign exchange markets. However, earlier studies have argued that the most regular, prevalent, and overlapping interventions appear to be more successful than broad one-off interventions (Seerattan, 2012); sales intervention is more successful than interventions bought (Lahura and Vega, 2013); Political meddling and monetary competition tend to influence the efficiency of intervention measures (Adebiyi, 2007; Hillebrand and Schnabl, 2008) and most of the literature that found the effectiveness of foreign-exchange interventions in curbing exchange rate volatility and chaotic market use of SVAR and VAR Markov-Switching Models (Seerattan, 2012).

III. Methodology

The study employed non-linear cointegration and causality test approaches to investigate the long-term relationship and causal link among foreign exchange market intervention and the exchange rate of Naira / US Dollar.

a) Data

The research employed data from 1980-2018 on an annual secondary time sequence. The data were mainly collected from the Statistical Bulletin of the United Nations and the Statistical Bulletin of the Central Bank of Nigeria (CBN). For this research, the non-parametric cointegration and causality tests of Breitung (2001) and Diks and Panchenko are used to examine the non-linear long-run and causal relationship between the CBN interventions in foreign exchange market interventions and the Naira / US dollar exchange rate. The study used four variables that set the Naira / US Dollar exchange rate as a function of net foreign assets, money supply and interest rate as written in the following equation:

$$EXR_t = f(\overset{+}{NFA_t}, \overset{+}{M2_t}, \overset{-}{IR_t}) \quad (1)$$

Where EXR represents the Naira exchange rate per US Dollar, NFA stands for net foreign assets (the proxy of foreign exchange market intervention variable), M2 represents the money in the Nigerian economy (proxy as the money supply variable), IR representing the interest rate variable. The t-sign denotes the time trend. The variables are converted into natural logarithms and composed in an econometric form in equation (2) below. Thus, the variables are separated from heteroskedasticity and their values can be presented as elasticity.

$$lnEXR_t = \alpha_0 + \varphi_1 lnNFA_{t-1} + \varphi_2 lnM2_{t-1} + \varphi_3 lnIR_{t-1} + \mu_t \quad (2)$$

From equation (2) above, α_0 is the constant term, φ_1, φ_2 and φ_3 are the slope coefficients and μ_t is the error term respectively.

b) Econometrics Procedures

i. *BDS Independence Test*

BDS test was first invented by W.A. Brock, W. Dechert, and J. Scheinkman in 1987 (Brock, Dechert & Scheinkman, 1987). BDS is one of the powerful tools for identifying serial dependence in time series. The BDS test is employed to test for the presence of the non-linear dependency in the continuing series measured after establishing the fitness of the ARIMA model (the Chu, 2001). The test statistic follows the normal distribution asymptotically. The null hypothesis of the BDS test assumes that the residuals are independently and identically distributed against the alternative hypothesis that the increments assume several deviations that make their level of dependency non-linear. The basic concept of the BDS test is built based on the integral correlation that estimates the frequency within which the spatial patterns are repeated in the series. The BDS test relies only on the signs of the successful return, without interest in their dimensions and does not need any assumptions about the distribution of the returns. A sequence of too many or too few runs suggests that the sample is not random (the Chu, 2001). The BDS test is initially developed by Brock, Dechert, Scheinkman and LeBaron (1996) and extensively applied in the Brock, Hsiech, and LeBraron (1991). Intuitively the correlation integral estimates the probability that any two m-dimensional points are within a distance of each other. The underlying assumption of the BDS test is that, let x_t be a random series data such that $x_t = x_1, x_2 \ldots\ldots\ldots\ldots x_3$ Also x_t is assumed to be a univariate series which is assumed to be iid. The BDS test is based on the following assumption:

$$H_0 : p_m = p_1^m$$

$$H_1 : p_m \neq p_1^m$$

The null hypothesis of iid is usually rejected at the 5% significance whenever the $p_m > 1.96$

$$I_t = 1 \; if \; |x - y| < \in \; \ldots\ldots.. \quad (3)$$

Likewise, the BDS test also relies on the value of the correlation integral as follows:

$$C(m, \in, T) = \frac{I[(t,s) : \|X_t^m - X_s^m\| < \in]}{T^2} \quad (4)$$

Where $X_t^m = (x(t) \ldots\ldots\ldots, x(t - m + 1)), \|.\|$ Is the l_∞ norm on R^m, and $I[.]$ indicates the number of elements subject to only modest regularity conditions as $T \to \infty, C(m, \in, T)$ has limit $C(m, \in)$ such that if $\{x(t)\}$ is iid, it then follows:

$$C(m, \in) = C(1 \;\; \in)^m \quad (5)$$

The reasoning motivates for the BDS test statistics are:

$$W(m, \in, T) = \sqrt{N} \frac{[C(m, \in, T) - C(1, \in, T)^m]}{\check{\sigma}(m, \in, T)} \quad (6)$$

Where $C(m, \in, T)$ stand as the correlation function that measures the probability between the dimensions of the series, $\check{\sigma}(m, \in, T)$ is the estimate of the non-parametric standard deviation of the $C(m, \in, T) - C(1, \in, T)^m$ The BDS test shows convergence in the distribution that $T(0,1) \; as \; T \to \infty$, respectively. In general, the BDS test statistic is the known asymptotic distribution under the null hypothesis of whiteness. The test provides a direct statistical test for randomness against general dependence, which comprises both the non-white linear and the non-white non-linear dependence.

ii. *Advanced Unit Root Test with a Nonlinearity*

Like the Augmented Dickey-Fuller and Phillips-Perron, several economists have questioned the use and implementation of conventional unit root stationarity test This is due to their failure to 'differentiate around unit-root and close unit root' tests (Campbell and Perron, 1991; DeJong et al., 1992; Tang and Chua, 2009). For this purpose, this research applied the unit root test widely known as stationary unit root test Breitung (2002) and newly developed unit-root ESTAR worked out by Kapetanios et al. (2003). Breitung (2002) developed a system for performing the unit root test commonly known as the Breitung unit root stationarity test. The method can be defined below by using equation (7):

$$\hat{\rho}N = \frac{N^{-4}\sum_{t=1}^{N}\hat{\mu}_t^2}{N^{-2}\sum_{t=1}^{N}\hat{\varepsilon}_t^2} \qquad \dots\dots\dots(7)$$

where $\hat{\varepsilon}_t$ is the ordinary Least Squares (OLS) residuals from equation (4) below:

$$y_t = x_t - \hat{\gamma}' d_t + x_t \qquad \dots\dots\dots(8)$$

Where d_t stands for the deterministic function of the constant and trend, x_t are the stochastic terms respectively.

$\hat{\mu}_t$ is the partial sum such that $\hat{\mu}_t = \hat{\varepsilon}_1 + \dots + \hat{\varepsilon}_t$. In the event, if x_t is integrated at the level I(0), the test statistic $\hat{\rho}N$ converges to zero (0). Meanwhile, Breitung presented simulation proof that the non-parametric test of unit root outperforms the traditional parametric tests. The Breitung non-parametric unit-root test is constructed based on the null hypothesis that the sequence is stationary. Recently, the increasing consensus between researchers on the nonlinear method, which may describe money supply, interest, net foreign asset rate and exchange rate, has led to the development of nonlinear stationary tests. This research used the newly evolved unit-root tests of the ESTAR, developed by Kapetanios et al. (2003) to examine if money supply, interest, net foreign asset rate and exchange rate are stationary or not. The nonlinear unit root test of KSS is centered on a unit root's null hypothesis against such an alternative hypothesis of the nonlinear yet internationally stationary phase of exponential STAR (ESTAR). Suggest the following sequence: ESTAR:

$$\Delta f_t = \rho f_{t-1} + \sigma f_{t-1}\{1 - \exp\{-\varphi(\sigma f_{t-1} - r)^2\} + \omega_t \qquad (9)$$

Where f_t is the series of examined variables, $\omega_t \sim iid$ (zero mean, constant variance), r location parameter is set to zero, and $\theta \geq 0$ is the smoothness parameter that governs the speed of transition. The null hypothesis here will be $Ho: \theta = 0$ versus the alternative of $\theta > 0$.

$$\Delta f_t = \pi + \delta f_{t-1}^3 + \sum_{i=1}^{k} a\Delta f_{t-1} + \omega_t, \qquad t = 1,2,\dots\dots\dots.T \qquad (10)$$

In Equation (10) if $Ho: \delta = 0$, then f_t contains a unit root and hence is non-stationary, while if $Ho: \delta < 0, f_t$ is non-linear stationery with the ESTAR process.

iii. *Cointegration Test*

The concept of cointegration refers to the econometrics term used to show the probability of the non-stationary variables to have a long-run relationship. Thus, there is the possibility that these non-stationary variables can walk together in the long-run (Balke and Fomby, 1997; Engle and Granger, 1987; Stigler, 2010). Time series analysts have developed and used different methods in the estimation of the long-run relationships and nature of their interactions.

a. *Breitung Rank Tests for Cointegration*

Breitung (2001) suggests a time series conversion co-integration test as an option to linear residual-based long-run tests that are incompatible with non-linear processes. The justification for using the non-linear rank test of Breitung (2001) is a result of the high rate of Naira / USD exchange rate volatility and CBN's continued attempts to protect Naira against further depreciation to the US Dollar, leading in non-linear occurrences.

Specifically, Breitung (2001) establishes the following test statistics to test for (nonlinear) cointegration among two-time series yt and xt:

$$\hat{\varepsilon}_t = \hat{g}(\hat{y}_t) - \hat{f}(\hat{x}_t) \qquad (11)$$

Where $\hat{g}(\hat{y}_t) \sim I(1), \hat{f}(\hat{x}_t) \sim I(1)$, and $\hat{\varepsilon}_t \sim I(1)$.

The cointegration tests implemented in the previous studies were generally built based on the premise that $\hat{f}(\hat{x}_t)$ is a linear function of $\hat{x}_t$. For some groups of non-linear functions, Breitung (2001) has already illustrated that residual-based linear co-integration tests are contradictory. To overwhelm this problem, Breitung proposed a cointegration test based on the time series rank transition. Such a transformation of rank helps one to avoid the fundamental functional aspects of the co-integrating association. Su (2011) claimed that the Breitung (2001) rank tests' significant attribute is that it helps scholars to get out of the essential functional nature of the cointegration correlation. Furthermore, there is no precondition for being clear about the precise functional structure of the non-linear cointegrating association. The Breitung rank test (2001) is based on a calculation of the modified gap between the graded sequence.

The accompanying test statistics were developed by Breitung (2001), in which $\hat{y}_t$ and $\hat{x}_t$ are assumed to be random walks connected in series:

$$\hat{\rho}N = \frac{N^{-4}\sum_{t=1}^{N}\hat{\mu}_t^2}{N^{-2}\sum_{t=1}^{N}\hat{\varepsilon}_t^2} \tag{12}$$

Where $\hat{u}_t =$ R($\hat{y}_t$)-R($\hat{x}_t$), for R($\hat{w}_t$)=Rank of $\hat{w}_t$ among $\hat{w}_1, \hat{w}_2, \ldots, \hat{w}_T$), and $\hat{w}=\{\hat{y},\hat{x}\}$.Breitung (2001) articulates the cointegration rating test hypothesis as:

H_0: Such series are not cointegrated

H_1: Such series are cointegrated

Other than that, the null hypothesis of no co-integration across exogenous and indigenous factors is rejected once the test statistics assume a value lower than the acceptable critical value, thus providing proof against the null hypothesis of no co-integration and in favor of the alternative hypothesis of co-integration, mainly because,throughout this scenario, over time, the variables shift closely together, and not that much break off. Such a test decides whether the graded series shift over time into a long-run co-integrating equilibrium, which can either be linear or non-linear.

b. *Causality Test*

The Diks and Panchenko non-parametric Granger causality test can be explained thus: Let assume the two-stationary series X_t and Y_t to represent the CBN's foreign market interventions and the Naira/US Dollar exchange rate, respectively. In the non-parametric causality tests, the null hypothesis is the same as the conditional independence of the Y_t on the $X_{t-1}, \ldots, X_{t-\ell_x}$, given the$Y_{t-1} \ldots,\ Y_{t-\ell_y}$; that is to say.

$$\mathrm{H}_0: Y_{t+1}\big|(X_t^{\ell_x}; Y_t^{\ell_x}) \sim Y_{t+1}\big|Y_t^{\ell_x}, \tag{13}$$

For each vector (x,y,z) in support of (X,Y,Z) Diks and Panchenko further show that the null hypothesis implies $X_{t-1}^{\ell_x} = (X_{t-\ell_x}, \ldots, X_{t-1})$ and $Y_{t-1}^{\ell_y} = (Y_{t-\ell_y}, \ldots, Y_{t-1})$ so the null hypothesis is the tentative statement about the invariant distribution of the $(\ell_x + \ell_y + 1)$-dimensional vector $W_t = (X_{t-1}^{\ell_x}, Y_{t-1}^{\ell_y}, Z_t)$, where $Z_t = Y_t$. For notation, assume that $\ell_x = \ell_y = 1$ and the drop time index. Then under the null hypothesis, the conditional distribution of Z given $(X,Y) = (x,y)$ is the same as that of Z given $Y = y$, and the joint probability density function $f_{X,Y,Z}(x,y,z)$Moreover, it's marginal must be consistent with:

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)} = \frac{f_{X,Y,Z}(x,y)}{f_Y(y)} \cdot \frac{f_{Y,Z}(y,z)}{f_Y(y)} \tag{14}$$

For each vector (x,y,z) in support of (X,Y,Z) Diks and Panchenko further show that the null hypothesis implies:

$$q \equiv E\big[f_{X,Y,Z}(X,Y,Z)f_Y(Y) - f_{X,Y}(X,Y)f_{Y,Z}(Y,Z)\big] = 0 \tag{15}$$

If $\acute{f}_W(W_i)$ is a local density estimator of a d_W-variate random vector W at W_{is} defined by $\acute{f}_W(W_i) = \frac{(2\epsilon_n)^{-d_W}}{n-1}\sum_{j,j\neq i} I_{ij}^W$ where $I_{ij}^W = I(\|W_i - W_j\| < \epsilon_n)$, with $I(.)$ is an indicator function, and ϵ_n is the bandwidth, the estimator of q simplifies to

$$T_n(\epsilon_n) = \frac{n-1}{n(n-2)}\sum_i (\acute{f}_{X,Y,Z}(X_i,Y_i,Z_i)\acute{f}_Y(Y_i) - \acute{f}_{X,Y}(X_i,Y_i)\acute{f}_{Y,Z}(Y_i,Z_i)) \tag{16}$$

For $\ell_x = \ell_y = 1$, if $\epsilon_n = cn^{-\delta}$ with $c > 0$ and $\delta\ \epsilon \left(\frac{1}{4}, \frac{1}{3}\right)$, this test statistics satisfy

$$\sqrt{n}\frac{T_n(\epsilon_n)^{-q}}{S_n} \xrightarrow{D} N\ (0,1) \tag{17}$$

Where$\xrightarrow{D}$ indicates convergence in the distribution and S_n is the asymptotic variance of $T_n(\epsilon_n)$.

IV. Results and Discussions

a) Descriptive Statistics

The majority of data from the economic time series are highly classified as distorted (non-normal). The primary explanation for this is the presence of many outliers along with the trend. To test the normality of the sequence, the Jarque-Bera test is applied from table 1 below. The analysis uses skewness and kurtosis coefficients based on the mean to test the normality of variables within our model. Skewness refers to the tilt in the distribution, and for the sequence to be normally distributed, it should be within the range between 0 and + 3. On the other hand, for the series to be normally distributed, Kurtosis refers to the peakedness of the distribution and is therefore supposed to lie within the range 0 and + 3. The null hypothesis employed in the normality test suggests that the sequence is usually distributed against the alternative non-normality hypothesis. If the likelihood value is below the 5 percent significance point of the Jarque-Bera normality test, then the series is not normally distributed. It is seen from Table 1 below that the series are far from being regular. Jarque-Bera's mean coefficients indicate that the sequence is not normally distributed. The standard deviation in the frequency distributions, on the other hand, insisted that the variables are far from natural. The standard deviation values in Table 1 below indicate that net foreign assets (a variable intervention proxy), money supply, exchange rates, and imports are highly volatile compared with interest rates. Also, the effects of the Pearson correlation matrix for the sequence are further represented in table 1.

Table 1: Descriptive Statistics and Correlation Matrices

	InEXR	InNFA	InM2	InIR
Mean	3.880	6.044	6.552	2.927
Median	4.602	6.577	6.469	2.924
Maximum	5.098	11.473	9.659	3.551
Minimum	0.001	0.095	3.261	2.202
Std. Dev.	1.380	2.650	2.005	0.241
Skewness	-1.082	-0.424	-0.041	-0.689
Kurtosis	2.909	2.214	1.776	4.884
		Correlation Matrices		
InEXR	1.000			
InNFA	0.888* (0.000)	1.000		
InM2	0.879* (0.000)	0.233* (0.000)	1.000	
InIR	0.149 (0.127)	-0.017 (0.855)	-0.011 (0.901)	1.000

b) *BDS Linearity Test based on VAR Estimates*

The BDS test is used to detect the non-linearity in the time series data. Correctly, the test is applied to the residuals data series made from the ARIMA models (Dorina and Simina, 2007). The test was named after the famous econometricians; Brock, Dechert and Schneinkman. The test is built on the hypothesis that the series exhibit randomness or whiteness among the series within the model against the alternative hypothesis that the series is asymmetric. The result of the BDS test is shown in table 2 below. From the table, it is shown that the null hypothesis in all dimensions is rejected at a 1% level of significance. This confirms that the model is non-parametric.

Table 2: BDS Linearity Test based on VAR Estimates

Embedded Dimension	Statistics	Standard error	z-statistics
2	0.092*	0.007	11.469
3	0.169*	0.013	13.210
4	0.214*	0.013	13.964
5	0.235*	0.016	14.646
6	0.249*	0.016	16.036

Note: the asterisks (*), (**), and (***) denotes the 1%, 5% and 10% level of significance respectively

c) *Results of Unit root Test*

The nature of the time series data used in the research necessitates the use of the non-linear unit root test. Meanwhile, the research uses the Breitung unit root test to prove that the series is non-linear. From column 3 of Table 3 below, the Breitung test and ESTAR test of stationarity failed to reject the null hypothesis of linearity of the series at a level and rejected the alternative hypothesis at the first difference. This indicated that all the variables were stationary at first difference.

Table 3: Nonlinear Unit Root Test

VARIABLES	KSS	Breitung
InEXR	2.534	0.077
InNFA	3.152	0.095
InM2	2.487	0.091
InIR	3.182	0.012
∆InEXR	-4.623*	0.000*
∆InNFA	-3.671**	0.000*
∆InM2	-3.840**	0.003*
∆InIR	-3.614**	0.004*

*Note: the asterisks *, **, and *** denotes the 1%, 5%, and 10% level of significance respectively. The ∆represented the variables in the first difference.*

d) Results of Cointegration Test

The majority of linear cointegration tests are built based on many unattainable and questionable assumptions that are hard to meet when it comes to the empirical application (Onour, 2008). This is due to the use of logarithmically transformed data in performing such tests. Onour (2008) further argued that it is only the non-linear cointegration test that can estimate the accurate long-run co-movements between the time series data. For over three decades, many studies have shown that the adjustment mechanism, as well as long run co-movements between the time series data, are more of non-linear (asymmetry) than linear (symmetry) approach (Enders and Siklos, 2001). For this reason, the study applies the Breitung (2002) non-linear cointegration test. The result of the Breitung non-linear cointegration test is presented in Tables 5 and 6. While table 5 reported the Breitung non-parametric test without the presence of drift; on the other hand, table 6 presented the Breitung non-linear cointegration test with the presence of drift respectively. The Breitung non-linear cointegration testis built based on the null hypothesis that the series are not cointegrated. The decision on whether to accept or reject the null hypothesis requires the study to compare the test statistics in column 3 with the critical values in columns 4 and 5 in table 5 and table 6 respectively. Frequently, the null hypothesis is rejected if the test statistics are more significant than the critical values at 5% and, or 10% level of significance.

Based on the above hypothesis, the study rejected the null hypothesis of no cointegration in both tables 5 and 6 at a 5% level of significance. The result is in line with studies ofAdebiyi (2007), Kohlscheen (2013), Omojolaibi and Gbadebo (2014) and De Roure et al. (2015). The justification here is that, by looking critically at the pattern of CBN intervention operations in the foreign exchange market in recent years, its primary aim is to defend Naira from further depreciation against foreign currencies (Alawiye, 2013; Nweze, 2015; Komolafe, 2015). As a result, the CBN's intervention is lopsided on the purchase rather than sales interventions. In its efforts to stabilize the Naira/US Dollar exchange rate, Nigerian monetary authority (the CBN) has been employing various exchange rates management policies such as AFEM, RDAS, WDAS, and IFEM. Probably, this is the reason for having cointegration in the presence of drift.

Table 5: Breitung cointegration test without Drift

H_0	H_1	Test statistics	10% critical value	5% critical value	Simulate p-values
r = 0	r > 1	17665.400*	1200.000	1360.000	0.000
r = 1	r > 2	5895.410*	627.800	741.100	0.000
r = 2	r > 3	705.800*	261.000	329.900	0.001

Note: r indicates the number of cointegration vector—asterisk (*) denotes rejection of the null hypothesis at the 1% level of significance respectively.

Table 6: Breitung Cointegration Test with Drift

H_0	H_1	Test statistics	10% critical value	5% critical value	Simulate p-values
r = 0	r > 0	24573.380*	1972.000	2184.000	0.000
r = 1	r > 1	11876.910*	1158.000	1330.000	0.000
r = 2	r > 2	2265.530*	596.200	713.300	0.000
r = 3	r > 3	471.620*	222.400	281.100	0.007

Note: r indicates the number of cointegration vector—asterisk (*) denotes rejection of the null hypothesis at the 1% level of significance respectively.

e) Diks and PanchenkoNon-Parametric Causality Test

The study employed the Diks and Panchenko (2006) non-parametric causality test to examine the nature of the causal link between the variables within the model. Table 7 shows the Diks and Panchenko non-parametric causality test. The tests were conducted using the lag values of $\ell x = \ell y$ selected to be two based on the Akaike Information Criterion. The bandwidths (ε-value) are adjusted to be 0.5 for the entire period of the series. For example, considering the 0.5 bandwidths (or ε-values) from table 7 below, a non-linear unidirectional causal relationship is found running from the net foreign asset (i.e., the intervention variable) to the Naira exchange rate at 1% level of significance. This means that the CBN's intervention operation in the foreign exchange market is capable of altering the volatility of the Naira/US Dollar exchange rate at a 1% significance level. This result is consistent with the studies of Holub (2004); Akinci et al. (2005). On the other hand, the result is also contrary to the findings of Sahadevan (2002) in India.

Moreover, the money supply and exchange rate are found to have a non-linear causal link with the money supply having unidirectional causality with the exchange rate at a 1% level of significance. The result is inconsistent with the findings of Sahadevan (2002) in India. Also, non-linear unidirectional causality running from the net foreign asset to the money supply is found at a 1% level of significance. Both unidirectional causalities from the net foreign asset (i.e., intervention variable) to the money supply and from the money supply to the Naira/US Dollar exchange rate confirmed that the CBN's intervention in the foreign exchange market increase (decrease) the volume of Naira in the foreign exchange market. Meanwhile, an increase (decrease) in the intervention funds increases (decrease) the volume of money in circulation. As a result, this leads to the depreciation (appreciation) of the Naira/US Dollar exchange rate in the world currency market. As a result, the central bank intervention in Nigeria is, therefore, non-sterilized. This result confirms the central idea of the monetary theory of exchange rate determination, as argued by (Frenkel, 1984; Dominguez, 1998). Also, the result is inconsistent with the findings of Adebiyi (2007).

Additionally, unidirectional causality is found running from the lending rate (i.e., the proxy for intervention) to the net foreign asset at a 10% level of significance. Lastly, based on the non-parametric Diks and Panchenko (2006) causality test presented in Table 7 below, no causal link is found to exist from the money supply to the interest rate. In contrast, the money supply is found to granger cause interest rate also at a 1% level of significance. The implication here is because of the high rate of the Naira volatility which makes the foreign investors lose confidence in the local currency. The high rates of Naira misalignment violate one of the significant characteristics of the money. Meanwhile, money must be a durable item such that one Naira today is one Naira tomorrow and any other day. As a result, the volatility in the value of the Naira/USD exchange rate could make foreign investors incur even if no single transaction takes place.

Table 7: Diks and Panchenko Non-linear Causality Test

lnEXR –/→ lnNFA	lnNFA–/→ lnEXR	Direction
1.054 (0.146)	3.400* (0.000)	Unidirectional
lnEXR –/→ lnM2	lnM2–/→ lnEXR	
1.130 (0.158)	4.372* (0.000)	Unidirectional
lnEXR –/→ lnIR	lnIR–/→ lnEXR	
0.939 (0.173)	0.914 (0.180)	No causality
lnNFA –/→ lnM2	lnM2–/→ lnNFA	
2.391* (0.008)	0.832 (0.202)	Unidirectional
lnNFA –/→ lnIR	lnIR–/→ lnNFA	
1.222 (0.110)	1.081 (0.139)	No causality
lnM2 –/→ lnIR	lnIR–/→ lnM2	
0.598 (0.274)	0.650 (0.257)	No causality

Note: the asterisks,**, and *** denotes the 1%, 5% and 10% level of significance the test was conducted bases on Akaike lag length criterion which suggested two lags (i.e. $\ell_x = \ell_y$=2) respectively. The "**ε**-value" band-with of the sequence is 0.5. The values in the parenthesis are the p-values.*

V. Conclusions and Recommendations

KSS and Breitung unit root tests of stationarity were employed to test for the degree of stationarity of the variables. Interestingly, the results of the unit root test showed that the variables are not stationary at level. Interestingly, they become stationary after converting them to the first difference. To test whether the model can be considered as a non-linear model, the BDS test is employed. The result of the BDS test of linearity confirmed the non-linearity of the model. The study used non-linear unit root tests of stationarity cointegration test to test for the long-run equilibrium relationship to avoid the misleading conclusion of linear models. Meanwhile, Breitung non-parametric cointegration approach was used to detect the presence of a non-linear long-run equilibrium relationship between the series in the model. Interestingly, the non-linear test of cointegration confirmed the presence of a long-run relationship between the foreign exchange market interventions and the Naira/USD exchange rate.

Disks and Panchenko non-parametric causality tests have also detected the unidirectional causality running from lnM2 to lnEXR, from lnLR (Interest rate variable) to lnEXR and from lnNFA to lnM2 respectively. Furthermore, Diks and Panchenko causality test established the existence of unidirectional causal link running from foreign market intervention to exchange rate. This emphasizes that the CBN's intervention operation is correct, non-sterilized. Besides, the monetary approach to exchange rate determination highlighted that non-sterilized foreign market interventions affect the value of the domestic currency through its effect on the money supply. Nigeria's Central Bank (CBN) has been involved in the foreign exchange market since 1986 (Sanusi, 2004; Adebiyi, 2007), but Naira has also been dreadfully losing its value on the foreign exchange market (Nweze, 2015; Komolafe, 2015). Therefore, the CBN has little or no impact on stabilizing Naira's value. The primary explanation for this is the CBN's incapacity to sterilize the amount of money used during the operation. These have resulted in a gradual rise in the price of domestic goods and services through the pass-through exchange rate (Aliyu, 2009; Zubair et al. 2015). However, CBN needs to accumulate and retain a sufficient amount of foreign reserves for intervention operations to be efficient and profitable. Foreign reserves are used to intervene in the foreign exchange market in most countries. Moreover, countries with high foreign reserve rates continue to draw international investors than they would otherwise.

For this reason, the Central Bank Management Board's policy formulation should be free of any political influences. This will require the board of directors to have skilled staff who will formulate and enforce effective policies to restore and sustain a competitive and stable Naira. Central Bank of Nigeria will ensure sterilization of all the amounts of currency used during intervention operations. It is well known that non-sterilized measures are related to the increase in the circulating volume of money. This contributes to inflation, and it also negatively impacts economic growth. The monetary and fiscal policies and intervention policies should be harmonized. This will improve the efficiency of all initiatives as they seek and aim to accomplish the same purpose. This will guarantee a stable and reasonably affordable Naira. Central Bank of Nigeria should establish a parity band of exchange rates above which Naira is not permitted to depreciate or appreciate as the case may be. The exchange office and the parallel markets should be appropriately monitored and regulated. The primary explanation for this is the vast difference between the official Naira / USD exchange rate and the Bureau de Change's Naira / USD exchange rate and the black marketers. The foreign exchange market deregulation should be tracked carefully and with utmost caution. That can be achieved by embarking on operations of strategic measures (such as handling pegging) that will stabilize and restore the Naira value. Besides, Nigeria's central bank will cease providing foreign exchange to importers of inessential commodities. This will reduce the volume of importation and will also act as a protectionist policy for local industries. Furthermore, domestic Commercial Banks should stop accepting deposits in all sorts of foreign currencies. Lastly, the policymakers should implement strategies for diversifying the Nigerian economy. This will discourage the massive importation of inessential goods and services into the economy.

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