Nonlinear Adjustments between Exchange Rates and External Reserves in Nigeria: A Threshold Cointegration Analysis

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This study investigates the long run relationship between exchange rate and external reserves in Nigeria during 1990Q1 – 2012Q4. We confirm the existence of threshold cointegration between the variables in Nigeria, as against linear cointegration. Consequently, a two-regime threshold vector error correction model (TVECM) is estimated via maximum likelihood procedure. Model results indicate that cointegration between the variables occurs only when the equilibrium error exceeds an estimated threshold parameter of 0.52. Having partitioned the TVECM into two regimes based on the obtained threshold, we find that the error correction coefficients of the exchange rate in the two regimes are not significant, implying that exchange rates do not respond to equilibrium error during the estimation period. On the other hand, external reserves adjust to correct past divergence, albeit only when the equilibrium error exceeds the threshold parameter. Overall, external reserves adjust to maintain long run equilibrium while exchange rates do not, which seems to align with the monetary authority's action of deploying external reserves to maintain exchange rate stability in the country.

Keywords: Exchange rates, External reserves, Threshold cointegration, Threshold error correction

JEL Classification: C22, F31

1.0 Introduction

Central banks all over the world use foreign exchange interventions to correct exchange rates misalignments, ensure exchange rate stability as well as increase their stock of foreign reserves. The type and frequency of such interventions depend on the prevailing exchange rate regime. After the collapse of the Bretton Woods system of fixed exchange rates in March 1973, many developed countries adopted the flexible exchange rate system and their exchange rates were allowed to float, implying zero intervention. However, the policy of free float led to significant real and nominal exchange rate volatility, with its attendant effects on investments, output and social welfare. As noted by Ahmad and Pentecost (2009) and Sarno and Taylor (2001), policy makers have responded to such instabilities in exchange rate by

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embracing policy strategies that favour intervention. Such interventions are non-trivial, that in some cases lead to substantial external reserves depletion.

In Nigeria, for instance, the events of the 2008/09 global financial crisis mounted substantial pressure on the Foreign Exchange Market (FEM), causing significant depreciation pressures on the Naira. The Central Bank of Nigeria was proactive in defending the value of the naira during the period, in line with its mandate. Fortunately, the country was buoyant at the onset of the crisis, with her gross external reserves amounting to about US$54.2 billion in January 2008 and reaching a peak US$62.08 billion in October. Thus, as depreciation pressures mounted on the Naira, the Bank continued to intervene in the FEM, defending the value of the domestic currency. These interventions were, however, not without substantial costs to the nation's external reserves, which declined steadily as the crisis worsened, from its level in October 2008 to about US$42.38 billion at end December, 2009 (Chart 1).

Historically, exchange rate policies in Nigeria have evolved from an era of fixed regime prior to the adoption of the structural adjustment Programme (SAP) in 1985 to different forms of managed float afterwards. The Wholesale Dutch Auction System (WDAS) was introduced on the 20th of February, 2006 to further liberalize the foreign exchange market, reduce the dependence of authorized dealers on CBN for foreign exchange and achieve convergence in exchange rates. Ultimately, the policy was aimed at achieving a realistic value for the Naira while ensuring stability in the FEM. It is also important to emphasize that the main source of external reserves in the country is the production and sales of crude oil, which are susceptible to the vagaries of world oil shocks and allocation of OPEC[2] quota. In recognition of this fact, numerous policy initiatives and measures have been taken in the management of the external reserves to ensure the achievement of the main objectives of exchange rate policy. These objectives are to preserve the value of the domestic currency, maintain a favourable external reserves position and ensure external balance without compromising the need for internal balance and the overall goal of macroeconomic stability.

The explanation of the relationship between exchange rate and external reserves is well documented in literature as the latter is used to determine and

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stabilize the former. It is in this regards that many works have used reserves volatility as a crucial determinant of exchange rate and these include Bordo *et al.* (2001), Berg *et al.* (2004). In fact, studies have also shown that adequate external reserves holding reduce the probability of a currency crisis. This derives from the improved confidence associated with external reserves build up. Thus, a country with high external reserves may experience less exchange rate volatility and vice versa. However, the relationship between the two variables may be non-linear, due probably to the presence of threshold effects. Extant literature investigating this phenomenon is till sparse in Nigeria.

To the best of our knowledge, no empirical work has been done on the possible nonlinear relationship between exchange rates and foreign reserves in Nigeria, except that of Ahmad and Pentecost (2009) who established a threshold parameter of 0.97 for the country in their two-regimes threshold error correction model. However, since their study predated the period of the 2008/09 financial crisis, it failed to capture recent developments in the domestic and global economy. Such developments may have led to a change in the threshold parameter found by Ahmad and Pentecost (2009). Besides, the debate as to the exact relationship between external reserves and exchange rate in Nigeria is still inconclusive. For instance, while Ahmad and Pentecost (2009) found a non-linear relationship, the works of Abdullateef and Waheed (2010) and Olayungba and Akinbobola (2011) revealed linear relationship and Nwude (2012) failed to establish any relationship, both in the short run and the long run. The intention of this study is to contribute to this debate and bridge the existing gap by using recent data set.

Thus, the broad objective of this study is to examine the exact relationship between external reserves and exchange rate in Nigeria and extend the work of Ahmad and Pentecost (2009) by investigating the non-linear relationship between exchange rates and external reserves using more recent data. The threshold parameter that governs the cointegrating relationship between exchange rate and external reserves as well as the adjustment coefficient are estimated based on the techniques of threshold cointegration and threshold vector error correction model proposed by Balke and Fomby (1997).

For ease of exposition, this study is structured into six sections. Following this introduction, section two presents stylised facts on exchange rate and external reserves management in Nigeria. A review of relevant extant literature is done

in section three. Section four explains the study methodology while section five presents the results. The last section concludes the paper.

2.0 Stylized Facts on Exchange Rate and External Reserves Management in Nigeria

This section presents some stylised facts on exchange rate and external reserves management in Nigeria between 1990 and 2013. The Inter-bank Foreign Exchange Market (IFEM) was introduced in January 1989 in order to douse the demand pressure that ensued at the Autonomous Foreign Exchange Market (AFEM) introduced in 1988. Under IFEM, authorized dealers were to be responsible for funding the market with foreign exchange while the CBN intervened only when necessary. The objective was to further deepen the foreign exchange market (FEM) by enlarging the supply base of foreign exchange to the market. However, this objective was not realised as the CBN remained the principal supplier of foreign exchange to the market during the period of the policy. The IFEM period was characterised by unbridled demand pressure for foreign exchange, a flourishing parallel market and widening of the arbitrage premium between the official and parallel rates.

Table 1: Exchange Rate Regimes/Policy in Nigeria, 1990 – 2013

Exchange Rate Regime/Method of Exchange Rate Determination	Date	Average Exchange Rate
Creation of Interbank Foreign Exchange Market (IFEM)	January 1989	12.9377
Pegged exchange rate system	1994	21.8861
Autonomous Foreign Exchange Market (AFEM)	1995	21.8861
Reintroduction of IFEM	October 1999	108.0000
Retail Dutch Auction System (rDAS) of foreign exchange management	July 2002	130.8500
Wholesale Dutch Auction System (wDAS)	February 2006	141.7600
Retail Dutch Auction System (rDAS) of foreign exchange management	October 2 2013	157.4166

In order to correct these anomalies and evolve a stable and realistic value for the Naira, the Dutch Auction System and a fully deregulated system were introduced in 1990 and 1992, respectively. Again, these policies could not resolve the crises in the FEM, thus necessitating a drastic policy shift. A policy reversal was undertaken in 1994 when the naira exchange rate was pegged to about N21.9/US$ (Chart 1, Table 1). The principal motive for this

policy was the stabilization of the value of the Naira. The reintroduction of the Autonomous Foreign Exchange Market (AFEM) in 1995 marked another era of liberalization as the CBN sold foreign exchange to end-users through selected authorized dealers at market-determined exchange rate. This led to another round of depreciation in exchange rate, which stood at N82.3 per dollar at the end of 1995 (Chart 1). Two exchange rates prevailed in the country during this era with the fixed exchange rate applied to official transactions on debt service payments and national priority projects while the market determined AFEM rates was used for other transactions. However, there were incidences of round tripping and this made the central bank to abolish the fixed exchange rate system at the official segment of the market in 1999 and the AFEM rate remained the only recognized exchange rate, explaining the sudden jump in the exchange rate in 1999.

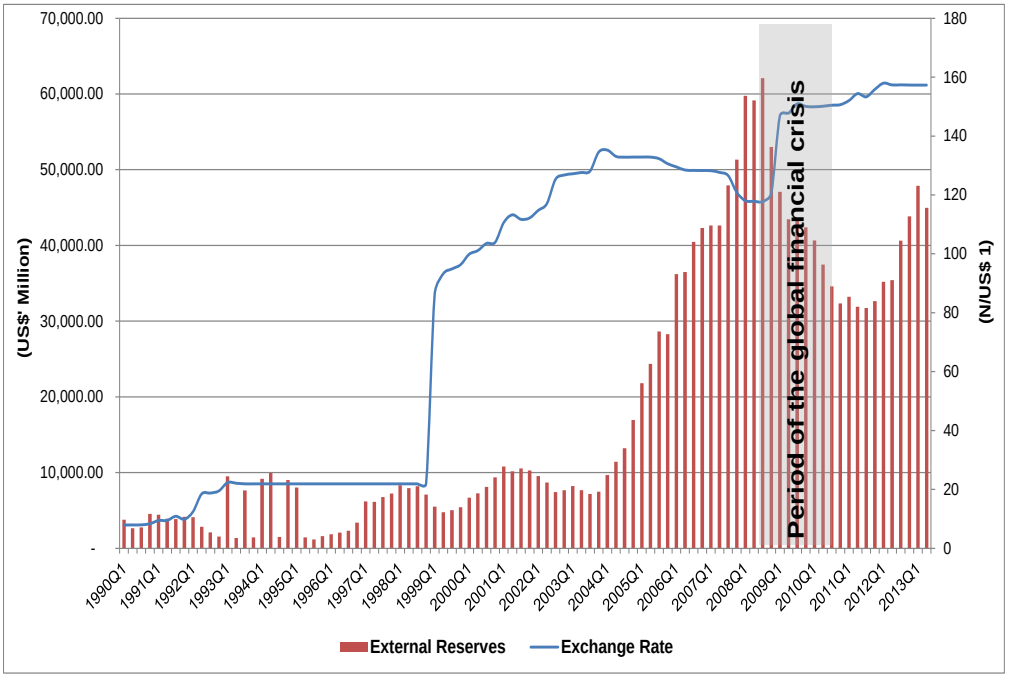


Chart 1: Movement in Exchange Rate and External Reserves in Nigeria, 1990 - 2013

The Inter-bank Foreign Exchange Market (IFEM) was introduced in 1999 to broaden and deepen the foreign exchange market. Contrary to the expectations of the policy, the demand for foreign exchange consistently outstripped its supply as the CBN remained the principal supplier of foreign exchange at the IFEM. Thus, the Dutch Auction System of foreign exchange management was introduced as a system that took cognizance of the scarcity of foreign

exchange and the need to discourage implicit or explicit subsidy on the commodity. Though the operation under the RDAS helped to engender some level of discipline among the operators, there was need for a further liberalization of the FEM as well as a system that would reduce the over reliance of the market on CBN for foreign exchange supply. The Wholesale Dutch Auction System (WDAS) was therefore introduced on the 20th of February, 2006. However, the need to engender some orderliness in the market led to the reintroduction of the RDAS on October 2, 2013.

As in exchange rate policies, the management of Nigeria's external reserves is the responsibility of the CBN. The CBN Act of 1958, the amendment of 1999 and 2007 CBN Act vest the custody and management of the country's external reserves in the CBN as they mandate the CBN to "maintain external reserves to safeguard the international value of the legal tender currency". Nigeria's external reserves, which stood at US$44,957.00 million at Q2 2013, are sourced majorly from sale of Nigeria's crude oil, royalties, petroleum profit tax, receipt from gas sales as well as penalty for gas flaring, rentals and signature bonuses (Aluko, 2007).

Over the years, reserves management strategy in Nigeria has focused on investment in secure, short term liquid assets in order to ensure prompt availability of funds when required. Also, a few correspondent banks are selected to operate documentary credits on an unconfirmed basis in order to ensure that payments are made only when shipments are made" (Aluko, 2007). This strategy was modified in 2006 with the appointment of global custodians for the management of the CBN portion of the external reserves. This was to enhance returns on the reserve portfolio through investments in high-yielding assets (Olawoyin, 2007).

From its level of US$3, 770.03 million at end Q1 1990, the stock of external reserves rose to about US$6, 682.80 million about a decade later and US$21, 807.98 at end-2005. It peaked at US$62, 081.86 million in Q3 2008 before declining steadily to US$31, 740.23 in Q3 2011, following the effects of the global financial crisis of 2008/09 (Chart 3). As can be noticed from Chart 1, the depreciation pressures resulting from the financial crisis began to manifest in the exchange rate in Q4 2008 as the naira depreciated from its level of N117.745US$ in Q3 2008 to N120.65/US$ and N146.88/US$ in Q4 2008 and

Q1 2009, respectively. These periods also recorded substantial reserves depletion, indicative of the fact that the monetary authority deployed its external reserves to defend the value of the Naira during the crisis, in line with its mandate. However, the stock of external reserves grew steadily from its level of US$ 31, 740.23 million in Q3 2011 to US$47,884.12 million in Q1 2013. This may not be unconnected with the gains recorded in the international price of crude oil during the period.

3.0 Literature Review

Countries are becoming more concerned about the stability of their exchange rates following the collapse of the Bretton Woods system of fixed exchange rates in the early 1970s and the incidences of global economic/financial crises. This was underscored by Ahmad and Pentecost (2009) who noted that the introduction of flexible exchange rates in the 1970s has made most countries to focus on the appropriate external reserves levels they should hold in order to protect themselves from currency crises. Fisher (2001) also pointed out that, reserves are among the determinants of a country's capability of preventing economic and financial crises. He further elaborated that reserves are important to countries, but are more pertinent to the emerging and developing countries that generally experience volatile international capital flows. In view of these arguments, many researchers have attempted to investigate the relationship between exchange rate and external reserves in both country-specific and cross-country studies. For instance, Calvo and Reinhart (2002) argued that developing countries seem to always seek to maintain exchange rate instability as the expense of external reserves fluctuations. In other words, policy makers in those countries intervene to maintain stability in the foreign exchange market using their stock of external reserves. This explains why several empirical works have used reserve volatility as a determinant of exchange rate. Some of these works include Klingebiel and Soledad-Martinez (2001), Bordo, *et al.* (2003), Berg *et al.* (2004) and the IMF (2006),

Ahmad and Pentecost (2009) investigated the long run relationship between exchange rates and external reserves in a sample of eight African countries, including Nigeria, during 1980Q1- 2004Q4. They used the threshold cointegration method and found evidence of non-linear cointegration between the variables. The results of their estimated threshold vector error correction model (TVECM) showed that the threshold cointegration parameter varied

from country to country, depending on the prevailing exchange rate regime in the countries. They concluded that countries with more flexible exchange rate regimes have higher threshold than those operating fixed exchange rate regimes. For Nigeria, a threshold parameter of 0.97 was found and adjustment in the second regime of the TVECM was principally due to external reserves.

In studying the relationship between external reserves and exchange rates in a group of 28 emerging countries, Hviding *et al.* (2004) found strong non-linear effects of high reserves on exchange rate volatility. They concluded that a country with high reserves stock would experience less exchange rate volatility. Similar conclusions were reached by Flood *et al.* (1998) as they found significant relationship between reserves loss, balance of payment crises and subsequent devaluations in the Latin American countries in the 1990s.

Choi and Baek (2007) used pooled data for 127 countries for the period 1980-2000 to investigate whether increased exchange rate flexibility impacts on external reserves holdings negatively. They found that the degree of exchange-rate flexibility has an inverted-U relationship with the countries' reserve holdings. They also showed that exchange rate regimes with intermediate flexibility need more reserves than hard pegs and freely floating regimes. In terms of reserves holding under different exchange regimes, they also discovered that reserve holdings are smaller under countries with hard pegs than countries under freely floating.

In his study on China and India, Romero (2005) used ordinary least squares (OLS) regression to empirically examine the dynamics of foreign currency reserves. He modelled reserves holding as a function of current account balance, average propensity to import and exchange rate and found that exchange rate was statistically significant in determining external reserves in India while the same was not found for China.

In their effort to further understand the impact of India's unprecedented accumulation of reserves on the Rupee/US dollar exchange rate, Gokhale and Raju (2013) investigated causality and cointegration between the two variables using time series data for the period 1980 – 2010. Based on the results of their Johansen cointegration test and the vector Autoregression, they concluded that there is neither short nor long run relationship between the

variables, contrary to the findings of Romero (2005). However, it is important to note that Gokhale and Raju (2013) failed to explore the possibility of non-linear relationship between the two variables.

Aizenman and Marion (2002) modelled the demand for external reserves in a group of 125 developing countries during 1980-1996 based on panel regression. Variables such as population, real GDP per capita, volatility of real export receipts, ratio of total imports to GDP as well as the nominal effective exchange rate were included in their model. In line with theoretical expectation, they found that the scale variables (i.e. population and real GDP per capita) impacted positively on demand for reserves while increased exchange rate volatility significantly reduced reserves holding.

Batten (1982) determined the demand for foreign reserves under fixed and floating exchange rates using an intervention model of the central bank which incorporates variables such as total imports, external reserves volatility, opportunity cost of holding external reserves as well as the country's propensity to import. They however found that irrespective of exchange rate regimes, central banks hold external reserves for purposes other than intervention motive.

In Nigeria, some studies have also been carried out on the relationship between exchange rate and external reserves. For instance, Abdullateef and Waheed (2010) used a combination of OLS and Vector Error Correction (VEC) methods to examine the impact of change in external reserve positions of Nigeria on domestic investment, inflation rate and exchange rate. The study revealed that, change in external reserves in Nigeria has no influence on domestic investment and inflation, but only influences foreign direct investment (FDI) and exchange rates. They recommended the need for broader reserve management strategies that will maximize the gains from oil export revenue by utilizing more of the earned oil resources to boost domestic investment. A similar study by Chinaemerem (2012) using VAR and time series data for the period 1980 – 2009 found a negative relationship between external reserves and exchange rates in Nigeria.

In another study on Nigeria, Nwude (2012) examined factors assumed to be determinants of foreign exchange rate movement using annual data from 1960-2011 and OLS regression. The factors investigated were economic growth as proxied by Gross Domestic Product (GDP), Balance of Payment (BOP) and external reserves. He used exchange rate movement as the

dependent variable and adopted Composite Consumer Price Index (Inflation rate), deposit rate and lending rate as the independent variables. Using the least square regression method, the results show that, there is no statistically significant relationship between the dependent and the independent variables. Besides other methodological inadequacies of the study (such as the failure to determine the order of integration of the variables), the results may be suggestive of the need to model the relationship among the variables in a non-linear manner.

Olayungba and Akinbobola (2011) accommodated the issue of structural breaks in their modelling approach of the relationship between exchange rate and external reserves in Nigeria during 1970 – 2006. However, the unit root test with structural break conducted failed to produce different results from the standard ADF test conducted on the variables. Having confirmed the existence of linear cointegration between the first difference stationary variables, they estimated a linear error correction model. The model results showed faster adjustment of foreign exchange reserves to changes in nominal exchange rate than changes in the real exchange rate.

Overall, a review of studies conducted to investigate the relationship between external reserves and exchange rate in Nigeria showed that most of them are based on linear models, except for Ahmad and Pentecost (2009) who applied the threshold cointegration procedure. As earlier noted, the estimation period of Ahmad and Pentecost (2009) predated the 2008/09 global financial crisis. Therefore, the need to reinvestigate the exact relationship between these two variables of concern using appropriate methodology and current data set is of significant relevance.

4.0 Methodology and Data

The Central Bank of Nigeria intervenes in the foreign exchange market with a view to either getting a more realistic value for the Naira or ensuring exchange rate stability, albeit at certain thresholds. The threshold cointegration approach was chosen for this study to enable us capture the non-linear relationship between the exchange rate and the foreign reserves, such that the mean reverting dynamic behaviour of the variables can be expected only after certain thresholds are exceeded.

Following the work of Ahmad and Pentecost (2009), this research project models the short and long run relationships between exchange rates and foreign reserves in Nigeria, within the frameworks of threshold cointegration and threshold vector error correction model. This is based on the fact that the transition mechanism between the two variables is governed by official interventions in the market. Such interventions are driven by policy makers' perspective on how realistic the value of the currency is as well as its stability. As argued by Ahmad and Pentecost (2009), the impact of intervention during periods of high external reserves may not be same as during period of low external reserves. Such differences in impacts are effectively captured by the threshold models.

Engle and Granger (1987) showed that variables that are cointegrating can be represented by an error correction model and argued that deviation from the equilibrium are corrected in the long run by an adjustment process which is captured by the coefficient of the error correction term. However, Balke and Fomby (1997) argued that correction to equilibrium in the case of exchange rates does not take place at every time period due to the presence of adjustment costs incurred by economic agents, which could be quite large at times. Also, policy makers do not intervene in the foreign exchange market unless the exchange rate approaches or crosses a predetermined band. Thus, the idea of threshold cointegration is based on the fact that cointegrating relationship exists between and among variables, only when deviations from the equilibrium have reached certain thresholds.

Thus, following Balke and Fomby (1997), the threshold vector of log of exchange rates and log of external reserves is of the form:

$$\chi_t = (e_t, r_t)' \tag{1}$$

where e_t and r_t denote exchange rate and external reserves, respectively and are both I(1). Equation (1) assumes a long-run relationship between the two series with a cointegrating scalar of β. A linear VECM of order $l + 1$ takes the following form:

$$\Delta X_t = A' X_{t-1} + u_t \tag{2}$$

Where,

$$X_{t-1} = \begin{pmatrix} 1 \\ \varepsilon_{t-1} \\ \Delta x_{t-1} \\ \Delta x_{t-2} \\ \cdot \\ \cdot \\ \cdot \\ \Delta x_{t-l} \end{pmatrix} \quad (3)$$

Where Δ denotes the first order difference operator, the independent variable X_{t-1} is k ×1 and $\boldsymbol{A}$ is $k \times 2$ and $k = 2L + 4$. The error term (μ_t) is assumed to be a (2×1) with finite covariance matrix $\Sigma = E(\mu_t, \mu'_t)$. **A,** a coefficient matrix, describes the dynamics in each of the regimes. If log of exchange rate is I(1), then equation (1) represents a cointegrated system where $\varepsilon_{t-1} = e_{t-1} - \beta r_{t-1}$ is a stationary error correction term. Equation (2) is extended as follows based on Hansen and Seo (2002):

$$\Delta X_t = \begin{cases} A_1' X_{t-1}(\beta) + \mu_t & if \ \varepsilon_{t-1}(\beta) \leq \gamma \\ A_2' X_{t-1}(\beta) + \mu_t & if \ \varepsilon_{t-1}(\beta) > \gamma \end{cases} \quad (4)$$

where γ is the threshold parameter, X_t is a p-dimensional I(1) time series which is cointegrated with one $p \times 1$ cointegrating vector, β. Equation (4) can also be written as:

$$\Delta \chi_t = A_1' X_{t-1} d_{1t}(\gamma) + A_2' X_{t-1} d_{2t}(\gamma) + \mu \quad (5)$$

Where

$$d_{1t}(\gamma) = I(\varepsilon_{t-1}(\beta) \leq \gamma) \quad \text{and} \quad d_{2t}(\gamma) = I(\varepsilon_{t-1}(\beta) > \gamma) \quad (6)$$

where $I(.)$ is an indicator function defining the behaviour of the error correction term. Thus, the threshold model in (5) has two regimes, defined by the value of the error correction term, ε_{t-1}. The coefficient matrices A_1 and A_2 in (5) governs the dynamics in the two regimes. Model (5) allows all coefficients, apart from the cointegrating vector, to switch between these two regimes. When the error correction term is allowed to switch, threshold effect exists only if $0 < P(\varepsilon_{t-1} \leq \gamma) < 1$, otherwise the model simplifies to linear cointegration.

If the deviations from the equilibrium are lower or equal to the threshold parameter, γ, the variables χ_t may not revert towards the equilibrium. In other words, the variables would not be cointegrated. On the other hand, if the deviations are greater than the threshold, the variables would adjust towards equilibrium, implying cointegration.

After testing for stationarity in the series, equation (5) is estimated in order to determine the parameters for the two regimes as well as the threshold value, beyond which adjustments to equilibrium takes place.

The study used quarterly data on the exchange rate of the Naira to the US dollar (NER) and external reserves (RES) for the period 1990:Q1 – 2012:Q4. These data were sourced from the Statistics Database of the CBN as well as various editions of the CBN Statistical Bulletin. The choice of this period is based on data availability as well as the need to capture post global financial crisis developments in the relationship between the two variables.

5.0 Results

5.1 Test for Stationarity

The two series used were log-transformed and subjected to unit root test in order to determine their order of integration. The results of both the Augmented Dickey Fuller and Phillips Perron tests are presented in Table 2. At the 5 per cent significance level, the null hypothesis of unit root in the variables could not be rejected for both series. However, at first difference, the series attained stationarity, implying that the variables are integrated of order one.

Table 2: Unit Root Test

Variables	Levels				First Difference			
	ADF^c	PP^c	ADF^{ct}	PP^{ct}	ADF^c	PP^c	ADF^{ct}	PP^{ct}
LNER	-1.6979	-1.8600	-2.3501	-2.3003	-9.9786	-10.0065	-9.9727	-10.0017
LRES	-1.3815	-1.6005	-0.9234	-1.1556	-6.0145	-10.8319	-6.1056	-10.9327

ADF^c and PP^c represent unit root test with constant while ADF^{ct} and PP^{ct} represent unit root test with constant and trend

**MacKinnon (1996) critical values with constant are -3.4717 (1%), -2.8796 (5%) and -2.5765 (10%)*

**MacKinnon (1996) critical values with constant and trend are -4.0168 (1%), -2.8796 (5%) and -3.1435 (10%)*

5.2 Optimal Lag Selection

In order to guide our specification of the model dynamics and avoid the risks associated with under-specification and over-specification of the lag length in

testing for cointegration, an optimal lag length test is conducted. Table 3 presents the results of the lag length selection criteria. While the Schwarz criterion selected one lag, all other criteria suggested two lags. Thus, we choose two lags to explain the dynamic part of the model.

Table 3: Optimal Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	644.7205	NA	6.14E-07	-8.627121	-8.586799*	-8.610739
1	654.3349	18.84166	5.70E-07	-8.702482	-8.581518	-8.653336
2	661.8027	14.43437*	5.44e-07*	-8.749029*	-8.547422	-8.667120*
3	663.0628	2.401928	5.64E-07	-8.712253	-8.430003	-8.597579
4	665.7697	5.086794	5.74E-07	-8.694896	-8.332003	-8.547459
5	667.0996	2.46329	5.95E-07	-8.659055	-8.215519	-8.478853
6	670.3325	5.901668	6.02E-07	-8.648758	-8.124579	-8.435793
7	671.1932	1.548201	6.28E-07	-8.60662	-8.001799	-8.360891
8	673.4694	4.032881	6.43E-07	-8.583481	-7.898017	-8.304988
9	674.772	2.273069	6.67E-07	-8.547275	-7.781168	-8.236018
10	675.1515	0.652102	7.01E-07	-8.498678	-7.651928	-8.154658
11	675.6262	0.802821	7.36E-07	-8.451359	-7.523966	-8.074574
12	677.6046	3.292922	7.57E-07	-8.424223	-7.416188	-8.014675

**** indicates lag order selected by the criterion***

5.3 Test for Cointegration

Having established that the two series are individually integrated of order one, we proceed to test whether there exist a linear combination of them that is stationary. To investigate the existence or otherwise of a linear co-integration between the variables, the residual-based test proposed by Engle-Granger and the Johansen tests are conducted. The results of the Engle-Granger co-integration test are presented in Table 4. At 5 per cent significance level, the null hypothesis of non-stationarity in the residuals of the static model could not be rejected. This implies that there is no linear cointegration between the two variables.

For robustness of analysis, the Johansen co-integration test (based on two lags) was also conducted on the variables and the results are shown in Table 5. Both the trace test and max-eigen values confirm the non-existence of linear cointegration in the variables. Thus, both the Engle-Granger and Johansen tests failed to reject the null of no linear cointegration between the variables.

The two tests conducted above assume that the cointegrating vector is constant and linear during the study period. However, events such as economic crises, changes in preferences of economic agents, policy shifts as well as factors such as structural rigidities and adjustment costs may cause cointegration to occur in a non-linear manner. Such non-linearity could be due to structural breaks and regime switching effects (Liu, 2008). A useful test for such behaviour is the threshold cointegration, which is explored as an alternative in this study. We proceed to investigate the existence of non-linear cointegration as against linear cointegration between the variables based on the SupLM test of Hansen and Seo (2002). Both the Residual Bootstrap and Fixed Regressor Bootstrap p-values were significant confirming the existence of threshold co-integration between the variables. Table 6 summarises the result of the SupLM test.

Table 4: Engle Granger 2 Stage Cointegration Test

	t-Statistic	Prob.*
ADF test statistic	-1.1753	0.6845
1% critical value	-3.4715	
5% critical value	-2.8795	
10% critical value	-2.5764	

MacKinnon (1996) one-sided p-values.

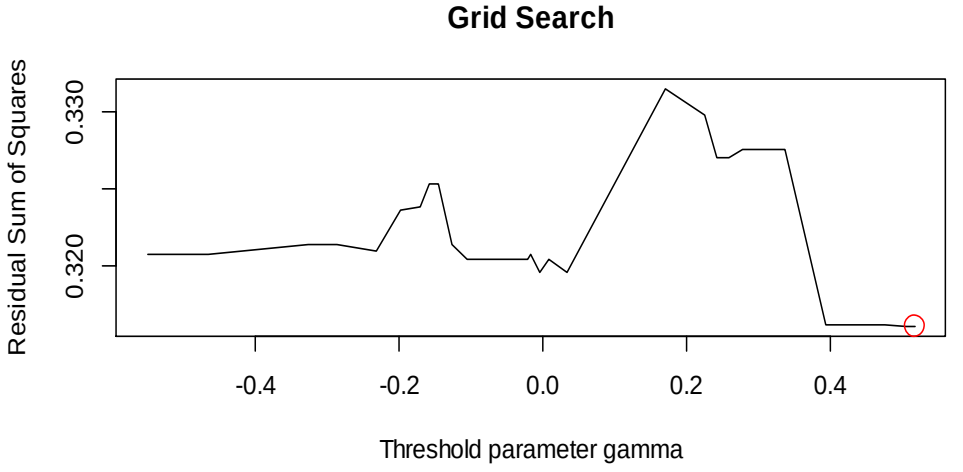
Table 5: Johansen Cointegration Test

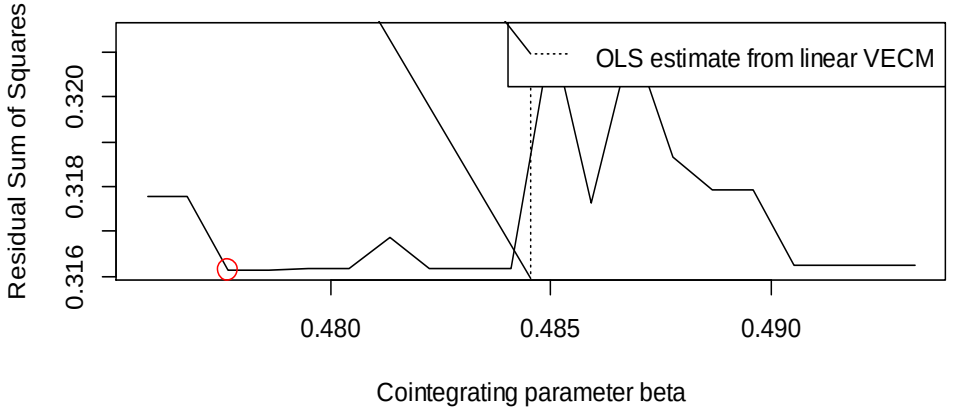
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.0357	8.2056	15.4947	0.4437
At most 1	0.0151	2.4190	3.8415	0.1199
Trace test indicates no cointegration at the 0.05 level				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.0357	5.7866	14.2646	0.6408
At most 1	0.0151	2.4190	3.8415	0.1199
Max-eigenvalue test indicates no cointegration at the 0.05 level				

**** denotes rejection of the hypothesis at the 0.05 level***

*****MacKinnon-Haug-Michelis (1999) p-values***

Thus, the use of threshold vector error correction model (TVECM) is justified. However, in order to further ascertain the optimal lag for the TVECM and ensure model adequacy, we estimated the TVEMs for lags one to five. Again, the AIC and BIC selected model 2 (Table 7). Thus, we proceed to estimate a TVECM with a lag order of two.





5.4. Threshold Vector Error Correction Model

Table 8 presents the result of the two regime vector error correction model. The estimated threshold parameter was about 0.52, on which basis the model was divided into two regimes. This was lower than the threshold of 0.97 estimated by Ahmad and Pentecost (2009) for Nigeria during 1980 – 2004. The first regime is associated with the period in which the deviation from long run equilibrium is below the threshold parameter while the second regime captures the dynamics of the cointegrating relationship when the threshold parameter is exceeded. About 87.4 per cent of the observations in the estimation period fell under the first regime. Thus, this regime is termed the

'usual regime'. On the other hand, the second regime has 12.6 per cent of the observations and is therefore referred to as the 'unusual regime'. Chart 2 presents the grid search for both the threshold and cointegrating parameters.

Table 6: Hansen and Seo (2002) Sup LM Test Result

Fixed Regressor Bootstrap				**Residual Bootstrap**			
Test Statistic	23.8436	p value	0.0200	Test Statistic	23.8436	p value	0.0040
Critical Values	0.90%	21.0100		Critical Values	0.90%	14.3974	
	0.95%	22.2825			0.95%	17.2919	
	0.99%	25.9207			0.99%	22.4060	

p values are calculated by bootsrap with 1000 replications

Chart 2: Grid Search for the Threshold and Cointegrating Parameters

Table 7: Model Selection

	AIC	BIC
Model 1 (Lag 1)	-2292.15	-2215.43
Model 2 (Lag 2)	-2327.57	-2275.29
Model 3 (Lag 3)	-2287.46	-2186.39
Model 4 (Lag 4)	-2268.58	-2143.28
Model 5 (Lag 5)	-2234.39	-2084.95

The estimated error correction terms of the threshold vector error correction model allows us to understand the behaviour of the disequilibrium between exchange rate and external reserves. The results indicate that significant error correction occurs in the reserves equation in the second regime (i.e. whenever the deviation from equilibrium is above the 0.5173 threshold) while there is no evidence that exchange rate equation adjusts in the same regime. The implication of this is that correction to equilibrium between the two variables in the second regime occurs via adjustments in the external reserves. This finding is similar to that of Ahmad and Pentecost (2009) who found that adjustments in the usual regime is primarily more on external reserves. A disequilibrium between exchange rate and external reserves, which is above the threshold, would lead to an accretion pressure on the external reserves in the next period. However, the error correction effects in the usual regime (regime 1) for both the exchange rate and reserves equations are not significant. This implies that equilibrium error persists for exchange rates and external reserves in the first regime.

Table 8: Threshold Vector Error Correction Model (TVECM) Result

Variable	Regime 1 (≤ γ)		Regime 2 (> γ)	
	NER Model	RES Model	NER Model	RES Model
ε_{t-1}	0.004	0.0227	0.1337	0.8486**
	(0.4704)	(0.1213)	(0.2089)	(0.0025)
Constant	0.0037*	0.0065	-0.0739	-0.4799**
	(0.0230)	(0.1192)	(0.2319)	(0.0032)
$\Delta LNER_{t-1}$	0.4026***	-0.1018	-0.2948	-0.297
	(0.0000)	(0.6800)	(0.0767)	(0.4907)
$\Delta LNER_{t-2}$	-0.1772	-0.1309	-0.2371	-0.7672
	(0.0618).	(0.5936)	(0.1374)	(0.0650).
$\Delta LRES_{t-1}$	-0.0035	0.1905*	0.0092	0.2725
	(0.9195)	(0.0353)	(0.8964)	(0.1398)
$\Delta LRES_{t-2}$	-0.0724*	0.2205*	-0.0665	0.0415
	(0.0322)	(0.0123)	(0.3934)	(0.8377)
Threshold Parameter	***0.5173***			
% of observations	87.4%		12.6%	

Standard errors are between parentheses

****, **, *** denote statistical significance at the 10%, 5% and 1% levels, respectively***

6.0 Conclusion

In this study, we examined the long run relationship between exchange rates and external reserves in Nigeria during the period 1990Q1-2012Q4. In particular, the question of whether there exists linear or threshold cointegration between the two variables was investigated. In an initial analysis, the two popular tests for linear cointegration based on Engle and Granger (1987) and Johansen (1995) were conducted to investigate the existence of linear cointegration between the variables. However, these tests failed to reject the null hypothesis of no linear cointegration. We proceeded to employ the supLM test for linear versus threshold cointegration proposed by Hansen and Seo (2002). Based on both the fixed regressor bootstrap and residual bootstrap of the supLM test, we confirmed the existence of threshold cointegration as against linear cointegration. This suggests that adjustments to the equilibrium path suggested by the cointegrating relationship do not take place all the time, hence, the long run relationship between exchange rates and external reserves in Nigeria is better described within the framework of a threshold cointegration analysis.

Having confirmed that the variables were cointegrated but in a non-linear manner, we estimated a two regime threshold vector error correction model. The estimated threshold parameter was 0.5173 on which basis the TVECM was partitioned into two regimes. The first regime prevails when the

equilibrium error was below or equal to the estimated threshold and this has 87.4 per cent of the total number of observations. Consequently, regime one was termed the usual regime. On the other hand, the second regime occurred when the equilibrium error exceeds the threshold. Since only 12.6 per cent of the total number of observations fell under this category, the second regime was referred to as the unusual regime.

In the first regime, the error correction coefficients for both the exchange rate and external reserves equations were not statistically significant at the 5 per cent significance level. This implies that the two variables did not respond to equilibrium error when such divergence was below the estimated threshold of 0.5173. Although in terms of magnitude, external reserves seemed to adjust more than the exchange rate. In the second regime, a very strong and statistically significant error correction coefficient was found for the external reserves equation (0.8486). However, the adjustment coefficient for the exchange rate was statistically insignificant and of a lower magnitude. The implication of this is that while external reserves responded to equilibrium error in regime two, exchange rates did not. These results confirm that the long run relationship exchange rate and external reserves in Nigeria is non-linear. While external reserves failed to adjust in restoring equilibrium in the cointegration relationship in the first regime, it responded significantly in the second regime. Overall, during the estimation period, external reserves adjusted to correct the equilibrium error while exchange rates did not. This seemed to confirm the assertion of Calvo and Reinhart (2002) that developing countries respond more to exchange rate volatility than external reserves variations.

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