



Linkages between External Reserves and Economic Performance in Nigeria, 1981-2018: Bounds Test and ARDL Approaches

Ifeanyi A. Ojiako^{1*}

¹Department of Agriculture and Agro-Industry, African Development Bank, Immeuble CCIA, Avenue Jean-Paul II, Abidjan Plateau, 01 BP 1387 Abidjan 01, Cote d'Ivoire.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: This study seeks to explore a two-way relationship between Nigeria's economic performance, measured by the GDP, and her stock of foreign reserves over time.

Study Design: It uses secondary data - documented time series of Nigeria's gross domestic product (GDP) and foreign exchange reserves (FER) – collected from various volumes of the Central Bank of Nigeria (CBN) Statistical Bulletin. The annual time series data cover a period of 38 years, from 1981-2018.

Methodology: The time series properties of the variables were verified using the Augmented Dickey-Fuller (ADF) unit roots' test procedure. Also, the Bounds test technique was used to test for cointegration while the autoregressive distributed-lag (ARDL) and error correction models were estimated to analyze short- and long-run relationships between the variables. Relevant diagnostic tests were carried out to validate the resultant model estimates.

Results: Results of unit roots' test reveal both GDP and foreign reserves as I(1) series. Bounds test for the GDP model revealed an observed F-statistic (.421) that is less than the critical lower bound F-statistic (4.94) at P=.05 and cointegrating relationship was not confirmed. However, Bounds test for the foreign reserves revealed an observed F-statistic (6.445) larger than the critical upper bound F-statistic (5.73) at P=.05 and cointegration was established leading to specification

*Corresponding author: Email: iojiako2008@live.com;

of a long-run error correction model (ECM). Result of ARDL model estimation shows that only one-year-lag of GDP was significant ($P=.05$) and positive in explaining variations in the current GDP. Previous year's values of both GDP and foreign reserves have positive influence on the long-run foreign exchange with over 81.8% explanatory power. The adjustment coefficient of the error correction equation is highly significant ($P=.001$) with the desired negative sign, implying that previous periods' errors are correctable by adjustments in the subsequent periods, and convergence is attainable. Granger-Causality test result revealed a unidirectional causality that runs from GDP to the external reserves.

Conclusion: The study establishes a long-run relationship between stock of foreign reserves and economic performance in Nigeria. The finding corroborates the view that a booming economy has the propensity to attract foreign direct investment thereby boosting the stock of the country's foreign reserves. To attract more FDI in the critical sectors of the Nigerian economy, the government should create enabling and investment-friendly environment, implement policies and programmes capable of amplify ease-of-doing-business, and boost investors' confidence in the economy.

Keywords: External reserves; economic performance; bounds test; cointegration; ARDL; error correction model; granger-causality; Nigeria.

1. INTRODUCTION

1.1 Introductory Comment

"Foreign Exchange Reserves" (FER) is also called "external reserves" (ER), "foreign reserves" (FR) or "international reserves" [1]. It consists of the official readily-available external assets controlled and used by the monetary authority for direct financing of external payments imbalances, currency exchange rate regulations, and other resolutions [2]. It is a key element of every nation state's macroeconomic management [3]. Theoretically, FER results from accumulation of surpluses of foreign exchange receipts over foreign exchange disbursements [4], although for the less developed countries (LDCs) and lower income countries (LICs), stockpiling of FER also results from "donations and aids" [1].

Different reasons explain nations' interests in conserving FER [1]. International observers identify these to include desire to: even out random and temporary balance of payments shocks, sustain parity of the exchange rate, circumvent the macroeconomic costs of adjusting to the impact of temporary shocks, ease adjustment to the impact of permanent shocks, and level out exchange rate instability in illiquid foreign exchange markets [3]. The International Monetary Fund (IMF) as cited in [5] believes that stockpiling FER is necessary "...for financing balance of payment disequilibrium and maintaining competitive exchange rate level capable of achieving macro-economic objectives." Among other benefits, FER serves

as a monetary policy instrument, a liquidity buffer during the period of crash of the international financial market, a tool for easing the vulnerability to external factors, and an apparatus for advancing the steadiness and confidence in financial markets during crisis periods.

In Nigeria, the specific benefits of stockpiling FER outlined by the Central Bank of Nigeria (CBN) include: (a) supporting settlement of foreign trade transactions to sustain equilibriums in the nation's Balance of Trade (BOT) and Balance of Payments (BOP); (b) serving as safety measure for shocks and instability occurring from time to time in the oil market; (c) supporting the holding of the country's "Sovereign Wealth Fund" (SWF); and (d) acting as support or backing for the domestic currency, the naira [1]. Other identified benefits are: (e) bolstering Nigeria's credit ratings and credit worthiness; (f) serving as shock absorber during periods of traumas and unprecedented natural calamities; and (g) serving as a gizmo for managing exchange rates' instability/volatility. Notwithstanding the aforementioned enormous economic benefits, accumulation and consolidation of FER come with certain sacrifices, including that it attracts very low returns and obfuscates the CBN's monetary management program [5].

The gross domestic product (GDP) is an acceptable measure of output, income and economic development of nations. It reflects the "monetary value of goods and services"

produced within a country during a time period, usually one year, notwithstanding the producers' nationalities [6]. Otherwise, it reflects all expenditures on "final goods" and "services" created inside an economy during a year period, and is computed without deductions for depreciation. In 2018, Nigeria's GDP posted a growth rate of 1.9%, which was higher than the 0.8% growth rate posted in 2017. Three key factors responsible for the growth are foreign exchange market steadiness, execution of the 2018 capital budget, and CBN's mediation in the real and other sectors of the economy [7].

Empirical evidence supports the view that some nature of relationship exists between FER and economic advancement of countries. It is opined that suitable management of FER is imperative for attainment of economic progress [8], which corroborates the view elsewhere that countries with increasing FER to GDP ratio have higher capital productivity and growth rates [9]. In the same vein, it is held that the state of a nation's FER influences its global rating given that the creditors, donors, and all others associate a country's financial responsibility and creditworthiness to the degree of robustness of its FER [10]. Stockpiling FER would lead to reduced exchange rates and increased export-led growth while swiftly rising FER-to-GDP ratio would lead to equally rising investment-to-GDP and trade-to-GDP ratios, capital productivity, and economic growth rates [11]. Through stockpiling the foreign reserves, governments encourage depreciation of "real exchange rate" and restructuring of production in favor of the "tradable sector" thereby enhancing growth [12]. Similarly, in the emerging economies, the governments build up FER as part of an export-instigated development model [13]. Consequently, FER stockpiling reflects an export-promotion policy that seeks to create jobs/employment, so as to put its abundant labor into productive use in basic sectors of the economy, particularly agriculture.

It is in the light of this that this study seeks to explore the relationship between Nigeria's FER and economic performance, determine the nature of the relations where it exists, and causality direction. It is expected that findings from this study shall guide the policy direction of the monetary authority and central government of Nigeria towards optimizing the foreign sector potentials in achieving a sustainable economic growth and development.

1.2 Literature Review

Several research have attempted to explore the relatedness of economic performance to stocks of foreign reserves in different countries [9-12]. For instance, the dynamic relationship between economic growth and FER was analyzed in Brazil from 1980-2014, using the error correction mechanism [10]. Results affirmed that a long-run relationship existed between both variables. The estimated model had a speed of adjustment in excess of 40%, meaning that within a year the Brazil's economic growth moved towards eliminating disequilibrium in FER by that magnitude. In another investigation twenty principal reserves-holding countries – 10 from the advanced and 10 from the emerging countries – were analyzed applying the Granger-causality technique on panel data from 1980-2008 [14]. Results showed unilateral causality running from FER to economic growth for the emerging nation-states, but no such causal linkage was established for the advanced countries. The finding of the study in respect of the emerging nations failed to agree fully with findings of a similar Nigeria-based research, which although discovered that FER had a positive influence on economic growth, suggested a unidirectional causality that ran from economic growth to FER, but not on the reverse direction [11]. Another study conducted in Nigeria set out to determine the factors affecting economic growth during the 1981-2014 period [5]. Using an ordinary least square (OLS) technique, which included FER among the explanatory variables, the researcher revealed that a significant positive relationship existed between FER and economic growth in Nigeria.

Elsewhere, the influences of real GDP, market capitalization, and agricultural output on Nigeria's FER were studied for 1980-2016 period, using a wide range of tools, including cointegration analysis, OLS regression, and Granger causality techniques [8]. Findings showed that FER had significant positive relationship with both the real GDP and market capitalization while its relationship with agricultural output was negative and insignificant [8]. In the same vein, the effects of several macroeconomic variables – including GDP, inflation, exchange rate, investment, external debt, total trade, and unemployment – on Nigeria's FER buildup was appraised, using time series data from 2004-2014 [15]. Results indicated that the GDP and exchange rate had positive and significant effect on FER, and the

authors concluded that FER was an essential instrument for achieving macroeconomic steadiness in Nigeria. An effort was also made to contrast the relevance of “precautionary” and “mercantilist” instincts for which emerging nations conserve their FER [16]. The study identified “precautionary motives” as key drivers, noting that a significant bulk of the “precautionary” need for FER emanated from “self-insurance” to guide against unwarranted disruption of “long-term” programs and projects during periods of economic hardship. The goal of another research was to determine whether or not accumulation of reserves was an optimal development policy [17]. But then, in what seemed to be more of a deviation from the general stance, the researchers concluded that stockpiling reserves was not the best pro-development policy, insisting that alternative policies were needed to achieve financial stability, policy autonomy, and a better performance in terms of development.

The foregoing review points to the fact that a wide range of analytical tools have previously been adapted to the analysis of the relationships between economic performance and foreign reserves. But, without prejudice to the method applied and country/region studied, there are mixed results and conclusions in respect of the nature of relationships and direction of causality. Nigeria-based studies also point to this quagmire in the midst of debate on how to optimize the country’s foreign sector potentials for sustainable economic growth and advancement. This present study seeks to further explore the relationship between Nigeria’s FER and economic performance over the thirty-eight years’ period, 1981-2018. Using the Bounds test approach to cointegration [18], a two-way relationship is modeled between both variables. Although this technique has been rarely used in this area, it has an advantage in using its inbuilt mechanism to guide the researcher’s choice of modeling a short-run or long-run relationship, as well as simultaneously building different models for as many different variables. The following research questions are of interest: what is the nature of the relationship between FER and GDP in Nigeria? Does FER determine GDP or vice versa? Is there causality in the relationship between FER and GDP? Consequently, on the one hand, the paper sought to determine the influence of economic performance on FER and on the other the influence of FER on economic performance using macroeconomic data for Nigeria during the period covered by the study.

2. METHODOLOGY

2.1 Study Area

Nigeria is in West Africa within latitudes 4.67°N–13.87°N and longitudes 2.82°E–14.62°E. She is a member of the Economic Community of West African States (ECOWAS) with a population of about 200 million persons. She shares geographical frontiers with Cameroon and Chad in the east, Republic of Benin in the west, Chad in the northeast, and Niger in the north. Also, Nigeria borders Lake Chad in the northeast and the Gulf of Guinea by the southern coast. The country has a land area measuring 923,768 square kilometers, of which 13,000 square kilometers comprise of water bodies. Also, it has 7 principal topographical features – the Niger Delta, River Niger, River Benue, Jos Plateau, Mambilla Plateau, Obudu Plateau and Adamawa Highlands. Geopolitically, Nigeria comprises of 6 zones: South-east, south-west, south-south, north-east, north-west and north-central. She has 36 states (each with a capital territory), the Federal Capital Territory (FCT) and 774 local government area councils. The country is endowed with massive natural resources and has great potential for agriculture and agribusiness activities.

With a daily crude oil production output of around 1.9 million barrels per day, Nigeria ranks as the topmost producer of crude oil in Africa and sixteenth globally. Oil remains the principal foreign exchange earner with over 90% contribution. However, in respect of contribution to the nation’s GDP, the services sector is the key driver of the economy with over 50% contribution. The National Bureau of Statistics (NBS)’s contribution to GDP estimates for first quarter of 2018 reveal the shares of the six uppermost contributors to Nigeria’s GDP as agriculture (21.65%), trade (17.06%), information and communication (12.41%), manufacturing (9.91%), mining and quarrying (9.67%) and oil (9.61%). Each of real estate services, construction, finance and insurance, and professional scientific and technical services contribute between 3.5% and 5.6% to the GDP in the first quarter of 2018 [19].

2.2 Study Data

This study uses time series data covering 1981-2018 periods. The documented GDP and FER data are collected from the Statistical Bulletin of the Central Bank of Nigeria [20]. The graphs

showing growth trends in the data are depicted in Fig. 1. The growth trends reveal some similarity suggesting possibility of some relationship between them. Both have positive intercepts and negative slopes while the r-squared associated with the time trend equations (injected in the graphs) are close to 3% for both graphs. This emerging similarity will be verified further through the analysis of the time series properties of both data series.

2.3 Methods of Data Analysis

2.3.1 Augmented Dickey-Fuller (ADF) test of “stationarity”

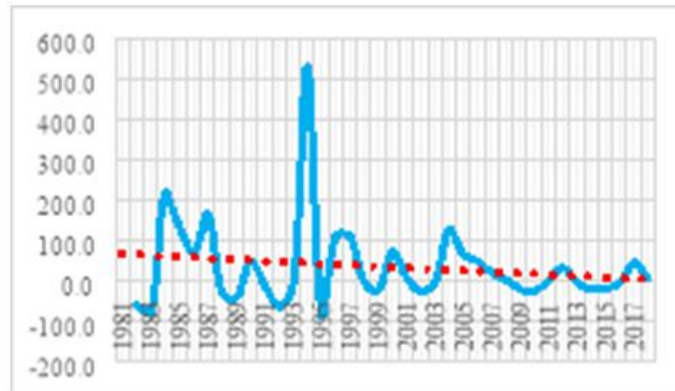
The basis for statistical “estimation and forecasting” hinges on “covariance stationarity” of the time series of interest. Covariance stationarity exists when all roots of an “autoregressive lag polynomial” are greater than 1. The Augmented Dickey-Fuller (ADF)

stationarity test [21] for a given series, x_t is expressed as:

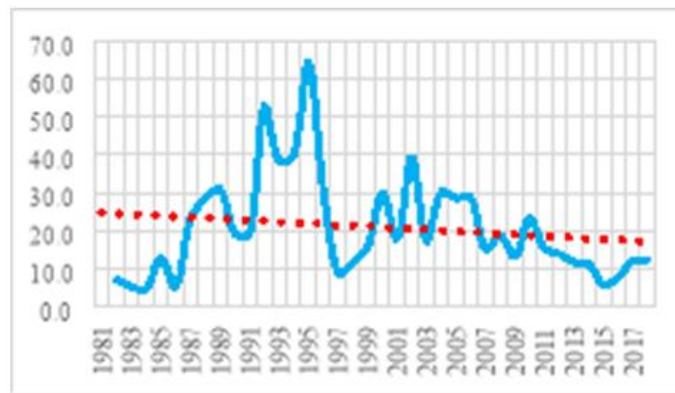
$$\Delta x_t = \alpha x_{t-1} + \sum_{i=1}^k \beta_i \Delta x_{t-i} + \delta + \gamma t + \varepsilon_t \tag{1}$$

$$\Delta \Delta x_t = \alpha \Delta x_{t-1} + \sum_{i=1}^k \beta_i \Delta \Delta x_{t-i} + \delta + \gamma t + \varepsilon_t \tag{2}$$

where equation (1) is for the data in levels and equation (2) is for the data in first difference; x_t is the time series; $\Delta x_t = X_{t+1} - x_t$ is the first difference of x_t ; α , β , δ , and γ are unknown parameter estimates, t is a deterministic trend, k is the lag length designated for ADF test, and ε_t is an error term selected to ensure that ε_t is “empirical white noise.” In selecting the lag length ‘k’ it is a good practice to retain a lag length small enough to prevent loss of degrees of freedom but large enough to avoid the problem of autocorrelation in ε_t [21].



(A). Growth trend in Nigeria’s external reserves (FER), 1981-2018



(B). Growth trend in Nigeria’s gross domestic products (GDP), 1981-2018

Fig. 1. Growth trend in Nigeria’s FER and GDP, 1981-2018

The null hypothesis (H_0 : x_t has a unit root or x_t is non-stationary) is tested against the alternative hypothesis (H_1 : x_t does not have a unit root or x_t is stationary). The null hypothesis is the same as saying that $\beta = 1$ in equations (1) and (2). The decision criteria is that if the absolute value of the computed t-statistics (/t-statistic/) is greater than the absolute value of the critical ADF-statistic (/critical ADF-statistic/) at 5% level, then H_0 is rejected with the conclusion that $\beta \neq 1$ and x_t does not have a unit root. Rejecting H_0 means that the series passes stationarity test at the level of rejection. Contrarily, if the result causes the failure to reject H_0 at levels the ADF-test of stationarity will be extended to the first difference, applying the same rule and decision criteria. The process will continue until stationarity is established.

2.3.2 “Bounds” test technique for cointegration

The “Bounds test” [18] is an alternative tool for testing cointegration. It is used for times series that are established to be stationary in level, I(0), and/or at first difference, I(1), but is not recommended for times series that are stationary in second difference, I(2).

A two-variable (y_t and x_t) model of the “Bound test” for cointegration is specified in equations (3) and (4):

$$\Delta \ln y_t = \alpha_{01} + \beta_{11} \ln y_{t-i} + \beta_{21} \ln x_{t-i} + \sum_{i=1}^p \alpha_{1i} \Delta \ln y_{t-i} + \sum_{i=1}^q \alpha_{2i} \Delta \ln x_{t-i} + e_{1t} \tag{3}$$

$$\Delta \ln x_t = \alpha_{02} + \beta_{12} \ln y_{t-i} + \beta_{22} \ln x_{t-i} + \sum_{i=1}^p \alpha_{1i} \Delta \ln x_{t-i} + \sum_{i=1}^q \alpha_{2i} \Delta \ln y_{t-i} + e_{2t} \tag{4}$$

In equations (3) and (4), y_t and x_t are vectors serving as dependent variables. It means that two cointegration tests should be conducted for y_t and x_t respectively as dependent variables. The null hypothesis to be tested is H_0 of “no cointegrating equation” (or $H_0 : \beta_{1j} = \beta_{2j} = \dots = 0$) against the alternative hypothesis, H_1 of “a cointegrating equation,” that is “ H_0 does not hold true” (or $H_1 : \beta_{1j} \neq \beta_{2j} \neq \dots \neq 0$).

Bounds test requires the use of the raw data or their log transformed versions. Inferences are drawn from the standard F-statistic and t-statistic of the significance of the lagged values in a

“univariate equilibrium correction mechanism” [18]. Rejection can be at 10%, 5% and 1% levels. The decision criteria is to: (a) reject H_0 if the calculated F-statistic (or t-statistic) is greater than the critical value of the “upper bound” I(1) F-statistic (or t-statistic), and conclude that cointegration (long-run relationship) exists; (b) fail to reject H_0 if the calculated F-statistic (or t-statistic) is lower than the critical value of the “lower bound” I(0) F-statistic (or t-statistic), and conclude that there is no cointegration or that long-run relationship does not exist; and (c) neither reject nor fail to reject H_0 if the calculated F-statistic (t-statistic) falls between the lower bound I(0) and the upper bound I(1), and conclude that the test is inconclusive. If conclusion favours criterion (a), the long-run model or error correction model (ECM) is estimated, but if it favours criterion (b), the short-run autoregressive distributed-lag (ARDL) model is estimated.

2.3.3 Autoregressive distributed-lag (ARDL) model

2.3.3.1 Conceptual ARDL model specification

The “ARDL Bounds testing” technique is a newly-emerged and evolving “cointegration” procedure credited for its merits over the classical cointegration testing method. The advantages of the ARDL-Bounds testing” technique include: (a) its conformity to use of time series that are either I(0) or I(1) or both, so long as none is I(2); (b) its ability to produce an “unrestricted error correction model” (UECM), with both “short- and long-run dynamics,” through a simple linear transformation; (c) its capability to produce estimates whose properties are more efficient (superior) to those of “Gregory and Hansen cointegration procedures” for small and finite samples [22]; (d) its joint use of the lagged values of dependent variable with present and lagged values of the regressors. For this research, the choice of ARDL-Bounds testing model is underscored by the need to ascertain the effects of the previous values of both the GDP and FER on the economic performance and foreign reserves models. It has been succinctly argued, the model is capable of providing “unbiased estimates of the long-run parameters even in the presence of “endogeneity” problem among the regressors [22]. This makes it an ideal model for this study.”

In its generalized form, an ARDL (p, q) model is given as:

$$y_t = \gamma_{0i} + \sum_{i=1}^p \delta_i y_{t-i} + \sum_{i=0}^q \beta_i' x_{t-i} + \varepsilon_{it} \quad (5)$$

where: y_t' is a vector and the variables in $(x_t)'$ are allowed into the model purely as I(0) or I(1) or cointegrated series; β and δ are coefficients; γ is the constant; $i=1\dots k$ is the number of variables in the model; p, q are optimal lag orders; ε_{it} is a vector of the error terms, which are unobservable zero white noise vector process that are serially uncorrelated and independent.

From equation (5), it should be noted that: (a) the dependent variable (y_t) is a function of its lagged values and the current and the lagged values of other exogenous variables in the model; (b) the lag lengths for p, q may not necessarily be equal (or of the same order) – “ p ” lags are used for the dependent variable and “ q ” lags are used for the exogenous variables. Generally, the result of the Bounds test of cointegration gives indication as to whether the (V)EC or ARDL or neither will be modeled [18]. When cointegration is not detected, the short-run ARDL (p, q) model takes the form depicted in equation (6) while in the presence of cointegration, the long-run ECM model assumes the form illustrated in equation (7).

$$\Delta \ln y_t = \gamma_{01} + \sum_{i=1}^p \delta_{1i} \Delta \ln y_{t-i} + \sum_{i=1}^q \beta_{2i} \Delta \ln x_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta \ln y_t = \gamma_{01} + \sum_{i=1}^p \delta_{1i} \Delta \ln y_{t-i} + \sum_{i=1}^q \beta_{2i} \Delta \ln x_{t-i} + \psi ECT_{t-i} + \varepsilon_t \quad (7)$$

where all variables are as previously defined; γ are constants; δ, β and ψ are parameters to be estimated, and ECT_{t-1} captures the long-run error correction mechanism.

2.3.3.2 Empirical ARDL Models for GDP and FER in Nigeria

The conditional ARDL (p, q) two-variable models reflecting the linkages between the GDP and FER are represented in equations (8) and (9):

$$\Delta \ln GDP_t = a_{01} + b_{11} \ln GDP_{t-1} + b_{21} \ln FER_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^q a_{2i} \Delta \ln FER_{t-i} + e_{1t} \quad (8)$$

$$\Delta \ln FER_t = a_{02} + b_{12} \ln GDP_{t-1} + b_{22} \ln FER_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln FER_{t-i} + \sum_{i=1}^q a_{2i} \Delta \ln GDP_{t-i} + e_{2t} \quad (9)$$

If a cointegrating relationship is not revealed after the Bound test, the ADRL (p, q) model of forms depicted in equation (10) and equation (11) is specified and estimated.

$$\Delta \ln GDP_t = a_{01} + \sum_{i=1}^p a_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^q a_{2i} \Delta \ln FER_{t-i} + \zeta_t \quad (10)$$

$$\Delta \ln FER_t = a_{01} + \sum_{i=1}^p a_{1i} \Delta \ln FER_{t-i} + \sum_{i=1}^q a_{2i} \Delta \ln GDP_{t-i} + \zeta_t \quad (11)$$

However, if a cointegrating relationship is revealed, the long run model becomes a combination of the short-run model and the ECT_t as depicted in equations (12) and (13):

$$\Delta \ln GDP_t = a_{01} + \sum_{i=1}^p a_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^q \beta_{2i} \Delta \ln FER_{t-i} + \gamma ECT_{t-i} + \zeta_t \quad (12)$$

$$\Delta \ln FER_t = \mu_2 + \sum_{i=1}^q \alpha_{2i} \Delta \ln FER_{t-i} + \sum_{i=1}^p \beta_{2i} \Delta \ln GDP_{t-i} + \gamma_1 ECT_{t-i} + \zeta_{2t} \quad (13)$$

The following characteristics exist for the long-run model [22]:

- $\gamma = (1 - \sum_{i=1}^p \delta_i)$ is the speed of adjustment parameter having a negative sign to show that there is convergence in the long-run.
- $ECT_t = (\ln gdp_{t-1} - \theta x_t)$ is the error correction term;
- $\theta = (\sum_{i=0}^q \beta_i) / \alpha$ is the long-run parameter;
- α_{1i}, α_{2i} are the short-run dynamic coefficients of the model's adjustment long-run equilibrium.

2.3.3.3 Diagnostic tests

It is an acceptable practice to conduct relevant diagnostic tests on the estimated model output. For this study, four diagnostic tests were conducted:

- The “Breusch-Godfrey serial correlation LM test” is used to test for serial correlation. It tests the null hypothesis (H_0) of “no serial correlation” against the alternative hypothesis (H_1) of “presence of serial correlation. Decision rule is to reject

- (H_0) if the observed F-statistic and Obs*R-squared statistic have associated probability values that are less than 5% level; otherwise, fail to reject H_0 .
- The “Breusch-Pagan-Godfrey Heteroskedasticity test” is used to test for heteroskedasticity. This tests the null hypothesis (H_0) of “equality of the error variances” against the alternative hypothesis (H_1) of “inequality in variance.” Decision rule is to reject (H_0) if the the associated probability values of the observed F-statistic and Obs*R-squared statistic are less than 5%, otherwise fail to reject H_0 .
 - The “histogram normality test” for normality in distribution is used to test the null hypothesis that “data is normally distributed” against the alternative that “data does not come from a normal distribution.” Decision criteria are to reject the null hypothesis if probability of the observed “Jarque-Berra statistic” is less than 5%, otherwise fail to reject the H_0 .
 - The “cumulative sum” (“CUSUM”) test and “cumulative sum of squares” (“CUSUM of Squares”) test are used to test for the stability of the recursive residual estimates of a model. Each tests the null hypothesis that the model is stable against the alternative hypothesis that the model is not stable. Decision rule is to reject H_0 if the estimates fall within the 5% significance bands, otherwise, fail to reject H_0 . In a case where the “CUSUM” or “CUSUM of squares” tests lead to conclusion of model instability, it may be an indication of existence of “structural breaks” in the data series. The “Breakpoints test” is conducted to determine the periods when the structural breaks occurred in the series and desirable corrective actions are taken to restore stability before re-estimating the model. Finally, the diagnostic tests are conducted again on the re-estimated model.

2.3.3.4 Analyzing the causal effects

The causal effects can be observed from the significance of the t-statistics associated with the estimated parameters: (a) if the t-statistic of a_{1i} is significant it means that GDP_{t-1} (lagged GDP) has a significant causal effect on the current level; (b) if the t-statistic of a_{2i} is significant it implies that the external reserves (FER) has a

significant causal effect on the current GDP; (c) the long-run relationship between the variables indicates that there is Granger-Causality in at least one direction, and it is determined by the t-statistic of the coefficient of the lagged error correction term (γ) – if γ is significant it says that there is a long-run causality among the variables; (d) the short-run parameters are given ceteris paribus interpretation and inferences are based on the usual OLS standard errors and test statistics.

2.4 Software for Model Estimation

All analysis and estimations are carried out using Microsoft Excel and EViews (Version 11) Standard Edition for Windows Statistical Software.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics of the Variables

The descriptive statistics of both variables are presented in Table 1. The GDP has a mean of ₦27.57 trillion (US\$90.69 billion) and median of ₦6.19 trillion (US\$20.02 billion). The recorded GDP ranged from minimum of ₦144.83 billion (US\$0.47 billion) in 1981 to maximum of ₦127.76 trillion (\$418.89 billion) in 2018. Also, FER has mean and median values of US\$17.42 billion and US\$7.59 billion respectively. The minimum value (US\$0.224 billion) was reported in 1983 while the maximum (US\$53.0 billion) was reported in 2008. The Jarque-Bera statistics calculated to be 10.54 for the GDP is statistically significant ($P=.005$) implying lack of normality in distribution. The FER’s Jarque-Bera of 4.99 is statistically not significant ($P=.082$) suggesting normality in distribution.

3.2 Time Series Properties of GDP and FER

3.2.1 Spurious OLS regression results

The virtual observation of the growth graphs and time trend equations for GDP and FER are already depicted in Fig. 1. They suggest existence of possible linkage between both variables. To further verify the variables’ time series properties, the researcher performed an ordinary least square (OLS) regression involving both – first, GDP was used as a dependent variable in a regression model that has FER as an explanatory variable; and second, the positions were swapped so that FER entered the

model as a dependent variable while GDP entered as an explanatory variable. The regression outputs presented in Appendix 1 have the observed Durbin-Watson statistic (DW=.282) that is less than the coefficient of determination (adjusted $R^2=.585$) for both models. The implication is that both models indicate spurious regression highlighting the need to verify the stationarity of both time series.

3.2.2 Augmented Dickey-Fuller unit roots test result

The output of the ADF unit roots tests is reported in Table 2 for GDP and FER. The logarithm transformed values are used for the tests. Results show that stationarity is not established at levels for either variable. At levels, the absolute values of the observed t-statistic are calculated as 0.027 for GDP and 1.400 for FER, each being less than the absolute ADF critical value given as 2.943 at $P=.05$ levels for each variable. The t-statistics are not statistically significant. In first differences, the absolute values of the observed t-statistics are calculated to be 3.180 for GDP and 7.212 for FER while the absolute ADF critical value is given as 2.948 at $P=.05$ levels. Since the observed t-statistics is bigger than the ADF critical values, stationarity exits for each variable at first difference. This causes the rejection of the null hypothesis for both variables in first difference. The implication and conclusion is that both GDP and FER is $I(1)$ time series.

3.3 Output of the Bounds Test and Lag Length Selection for GDP and FER

3.3.1 Bounds test output

The selected model is ADRL (1, 0) using the third case of “unrestricted constant and no trend.” The output result is displayed in Table 3. It shows that when GDP is the dependent variable, the observed F-statistic (.421) is less than the lower bound $I(0)$ statistic given as 4.04 at $P=.10$ and 4.94 at $P=.05$. Also using the observed t-statistics (.360), it is clearly less than the lower bound $I(0)$ t-statistic given as 2.57 at $P=.10$ and 2.86 at $P=.05$ levels. Thus, the null hypothesis cannot be rejected and the conclusion is that there is no cointegrating equation when $\ln GDP_i$ is a dependent variable. For FER_i as a dependent variable, the observed F-statistics (6.445) exceeds the critical upper bound $I(1)$ F-statistic (5.73) at $P=.05$ level. In the same manner, the absolute value of observed t-statistic (3.587) is

larger compared to the absolute value of the critical upper bound t-statistic (3.22) at $P=.05$ level. The case has led to rejection of the null hypothesis of “no cointegrating equation” and conclusion that there is cointegration if and when FER_i is a dependent variable. It follows from the results that it is possible to specify and estimate the long-run ECM in the case involving FER_i because cointegration was established. However, this is not so in the case of GDP_i , where the result indicates that only the short-run ARDL (p, q) model can be specified and estimated, because cointegration could not be proven.

3.3.2 Determining the appropriate lag lengths

This study uses the “optimal length selection criteria” technique to determine the lag length for each variable. The tests’ results are presented in Table 4 for the GDP_i and Table 5 for the FER_i . The results show that for GDP_i the appropriate lag length flagged/asterisked across majority of the selection criteria is 2. However for FER_i , the indicated lag length across the selection criteria is 1. The implication of this finding is that the identified lag length ($p=2$) will be used for variables when estimating the short-run (ARDL) model of the GDP_i while lag length ($q=1$) will be used for estimating the long-run ECM model of FER_i .

3.4 Estimated Short-run ARDL Model for the GDP

3.4.1 Output of the short-run ARDL model for GDP

After the initial estimation the model was subjected to all necessary diagnostic tests of serial correlation, heteroskedasticity, normal distribution and stability. Specifically, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM of squares) tests of stability were carried out. The former revealed stability while the latter revealed existence of structural breaks at certain stage. The “Multiple Breakpoints” test technique was used to determine the periods when the structural breaks happened. Results reveal it occurred in 2005, and corrective step was taken. It involved the introduction of a dummy variable “z” defined as $z=0$ for 1981-2004 and $z=1$ for 2005-2018, the interaction of the introduced dummy variable with the key variables (GDP and FER), and re-estimation of the model.

The full output of the re-estimated ARDL short-run model for the GDP is presented in Appendix 2, but summary model is shown in equation (14).

$$\Delta \ln GDP_t = 0.1069 + 0.3981(\Delta \ln GDP_{t-1}) + 0.1275(\Delta \ln GDP_{t-2}) + 0.0315(\Delta \ln FER_{t-1}) + 0.0257(\Delta \ln FER_{t-2}) + 0.7705(z) - 0.0176(z * \ln GDP_t) - 0.0595(z * \ln FER_t) + e_t \quad (14)$$

[0.044] [0.194] [0.185]
[0.024] [0.024] [1.438]
[0.052] [0.119]

$R^2 = 0.4266$; $Adj. R^2 = 0.2779$; $DW = 1.9417$; “z” is dummy defined as z=0 for 1981-2004 and z=1 for 2005-2018; values in parentheses “[]” are associated standard errors.

The short-run estimation reveals only the previous year’s GDP as statistically significant at P=.05 in explaining the current value of GDP. A percentage increase in the previous year’s GDP leads to 0.398% increase in current GDP, ceteris paribus. Neither the dummy variable (z_i=0 for 1981-2004; z_i=1 for 2005-2018) introduced to correct the observed structural break nor its interactions with the exogenous variables (z*GDP and z*FER) was statistically significant. Elsewhere, an examination of the linkage

between economic growth and foreign exchange reserves using a “neoclassical growth” approach has also reported the significance and positive influence of external reserves on Nigeria’s economic growth [5]. The report of the study is also supported by other findings [23]. However, the study used the current values as against lagged values of GDP and FER used for ARDL model estimation in this context.

3.4.2 Diagnostic tests for the short-run ARDL model for GDP

3.4.2.1 Breusch-Godfrey serial correlation LM test for the ARDL (GDP) model

The comprehensive output of the Breusch-Godfrey serial correlation LM test for the ARDL model is presented summarized in Table 6. The observed F-statistic (0.215) and Obs*R-squared statistic (0.591) have associated probability values of P=0.808 and P=0.743 respectively. Each of the observed probability values is greater than the acceptable P=0.05 level of rejection of the null hypothesis that “there is no serial correlation at up to 2 lags.” Thus, the null hypothesis cannot be rejected, leading to the

Table 1. Descriptive statistics of variables

Statistic	Gross Domestic Product (GDP) (₦ billion)	External reserves (FER) (US\$ million)
Mean	27569.37	17429.50
Median	6102.422	7592.844
Maximum	127762.5	53000.36
Minimum	144.8312	224.4000
Std. Dev.	37734.90	17393.99
Skewness	1.279906	0.698916
Kurtosis	3.322978	1.904201
Jarque-Bera	10.54017	4.994956
Probability	0.005143	0.082292
Sum	1047636.	662320.9
Sum Sq. Dev.	5.27E+10	1.12E+10
Observations	38	38

Present official exchange rate is ₦305/US\$1.00 (approx.)

Table 2. ADF unit roots’ test output

ADF-statistic	lnGDP		lnFER	
	Level: (intercept only)	First difference intercept only	Level: (intercept only)	First difference: (Intercept only)
t-statistics	-0.9276	-3.1804	-1.4004	-7.2129
ADF C.V. (1%)	-3.6210	-3.6268	-3.6210	-3.6329
ADF C.V. (5%)	-2.9434	-2.9458	-2.9434	-2.9484
ADF C.V. (10%)	-2.6103	-2.6115	-2.6103	-2.6128

=significant at P=0.01; =significant at P=0.05; C.V.=Critical value; Lag Length: 2 (Automatic that is based on AIC, maxlag=2)

Table 3. Output of the “bounds test” of cointegration

Dependent variable	Test type								Decision
	F-statistic				T-statistic				
	Observed F-stat.	Crit. value	Lower I(0)	Upper I(1)	Observed F-stat.	Crit. value	Lower I(0)	Upper I(1)	
Ingdp _i	0.4207	10%	4.04	4.87	-0.3603	10%	-2.57	-2.91	No cointegration; Estimate a short-run/ARDL model
		5%	4.94	5.73		5%	-2.86	-3.22	
		1%	6.84	7.84		1%	-3.43	-3.82	
Inxres _i	6.4447	10%	4.04	4.87	-3.5873	10%	-2.57	-2.91	Cointegration; Estimate a long-run/ ECM
		5%	4.94	5.73		5%	-2.86	-3.22	
		1%	6.84	7.84		1%	-3.43	-3.82	

Note. Model used (Constant): Unrestricted Constant and No Trend

Table 4. Maximum VAR lag order selection criteria for the “GDP” series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-48.72053	NA	1.266482	3.073972	3.164669	3.104488
1	34.07132	150.5306*	0.008911	-1.883110	-1.747064	-1.837335
2	36.11426	3.590616	0.008371*	-1.946319*	-1.764924*	-1.885285*
3	36.53815	0.719338	0.008678	-1.911403	-1.684660	-1.835111
4	36.63877	0.164647	0.009180	-1.856895	-1.584803	-1.765344
5	36.66385	0.039517	0.009763	-1.797809	-1.480368	-1.691000

indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion; Endogenous variable: lnGDP; Exogenous variable: lnFER; included number of observation: 33

conclusion that the model is free from the serial correlation problem.

3.4.2.3 Histogram normality test for the ARDL (GDP) model

3.4.2.2 Breusch-Pagan-Godfrey heteroskedasticity test for the ARDL (GDP) model

The “histogram normality test” output is presented in Fig. 2. The null hypothesis is that the “data is normally distributed” while the alternative is that the “data does not come from a normal distribution.” The result gives the observed Jarque-Berra as 1.192 ($P=.551$). Since the observed probability is greater than $P=.05$ level of rejection, then the null hypothesis of “normality in distribution” cannot be rejected. The conclusion is that the data comes from a normal distribution.

The summary of the test output is presented in Table 7. From the result, the F-statistic is 1.469 ($P=.219$) while the Obs*R-squared statistic is 9.657 ($P=.208$). Thus, the associated probability values exceed the $P=0.05$ level of rejection of the null respectively. The null hypothesis of “no heteroskedasticity” cannot be rejected implying that model is not heteroskedastic.

Table 5. Maximum VAR lag order selection criteria for the FER series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-29.62425	NA	0.398078	1.916621	2.007319	1.947138
1	-25.12082	8.188049*	0.322039*	1.704292*	1.840339*	1.750068*
2	-25.11936	0.002579	0.342368	1.764810	1.946204	1.825843
3	-24.91259	0.350877	0.359644	1.812884	2.039628	1.889177
4	-23.54998	2.229722	0.352438	1.790908	2.063000	1.882459
5	-23.19708	0.556087	0.367434	1.830126	2.147567	1.936935

indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion; Endogenous variable: lnFER; Exogenous variable: lnGDP; included number of observation: 33

Table 6. Breusch-Godfrey serial correlation LM test output

H₀: No serial correlation at up to 2 lags			
F-statistic	0.2150	Prob. F(2,25)	0.8080
Obs*R-squared	0.5918	Pro. Chi-Square(2)	0.7439

Table 7. Breusch-Pagan-Godfrey heteroskedasticity test output

H₀: “No heteroskedasticity” at up to 2 lags			
F-statistic	1.4699	Prob. F(4,30)	0.2199
Obs*R-squared	9.6576	Pro. Chi-Square(4)	0.2088
Scaled explained SS	7.8815	Pro. Chi-Square(4)	0.3432

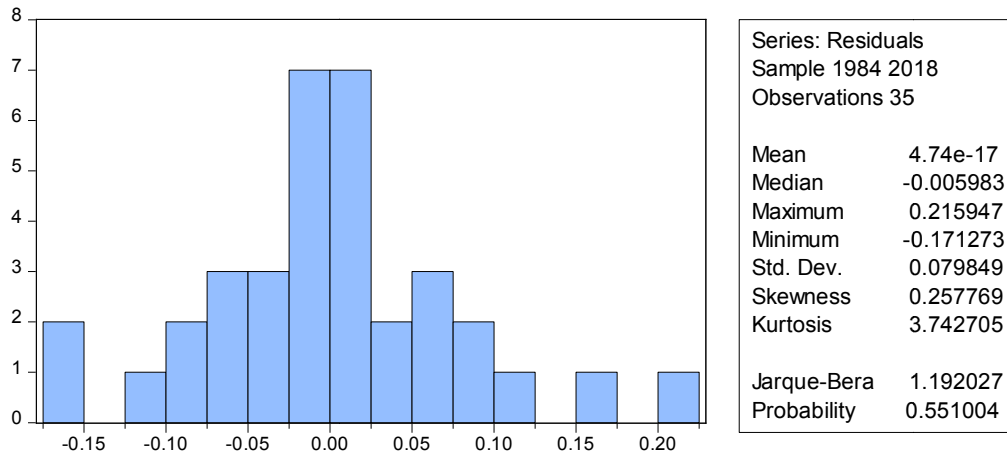


Fig. 2. Histogram normality test output of the ARDL model of GDP

3.4.2.4 Stability test for the short-run ARDL (GDP) model

$R^2 = 0.8287$; $Adj. R^2 = 0.8187$; $DW = 1.7784$; values in parentheses “[]” are standard errors.

The output of the “CUSUM Test” and “CUSUM of Squares” tests of the recursive residual estimates” performed to verify the stability of the GDP model, which was adjusted to correct the observed structural breaks, are displayed in Fig. 3. Both tests reveal that the estimates are within the 5% significance bands, which is an indication that they are statistically significant at $P=.05$ levels. It implies that the models are stable. Thus, although the introduced dummy variable (z) and its interactions with GDP and FER are not significant in explaining the short-run ARDL GDP, its introduction is able to restore stability in the model.

The result reveals the significance of one-period lag of FER ($P=.004$) and one-period lag of GDP ($P=.002$) in explaining the long-run variations in the foreign reserves ($\ln FER_i$). Each of the variables has a positive signs, and both explain 81.87% of the long-run variation in foreign reserves as depicted by the observed R^2 . The importance of the long run representation is that the residuals series it produces are, upon extraction, inputted as a variable into the “error correction” equation that is reported in the following section.

3.5 Estimated Long-run Model of the Foreign Reserves

3.5.2 Error correction model specification for foreign reserves

3.5.1 Long-run representation of the foreign reserves model

The “error correction model” is a combination of the “short-run” equation and the “long-run” representation. Since the identified lag length is 1 for FER, $p=1$ is used for the estimation. After an initial estimation, diagnostic tests were conducted. Among these is the model stability tests using cumulative sum (CUSUM) and cumulative sum of squares (CUSUM of squares) tests procedures. The CUSUM of squares test reveals the presence of structural breaks, and further investigation using the “Multiple Breakpoints” test technique indicated that the break had occurred in 2002. This prompted necessary adjustments and correction through introduction of a dummy variable “w” (defined as $w=0$ for 1981-2001 and $w=1$ for 2002-2018). Both the dummy and its interactions with the key variables (GDP and FER) were also included as exogenous variables before re-

The long-run model is estimated for the foreign reserves having confirmed that cointegration existed for foreign reserves. The model requires the use of lag-length 1, as indicated from the result of the optimal length selection explained in Section 3.3.2. The full output of the long-run model representation is presented in Appendix 3 while the resulting equation is shown below in equation (15).

$$\ln FER_t = 2.4565 + 0.4530 (\ln FER_{t-1}) + 0.3008 (\ln GDP_{t-1}) + e_t$$

[0.769]
[0.149]
[0.091]

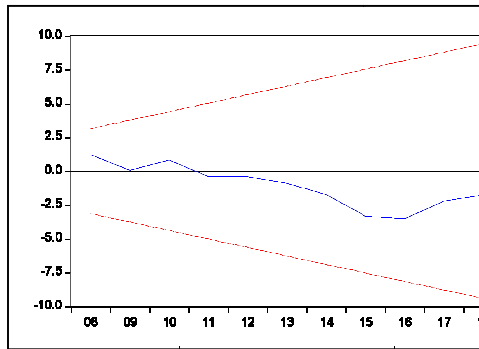
(15)

specification of the model. The resultant ECM equation is shown below in equation (16) – the full output is presented in Appendix 4.

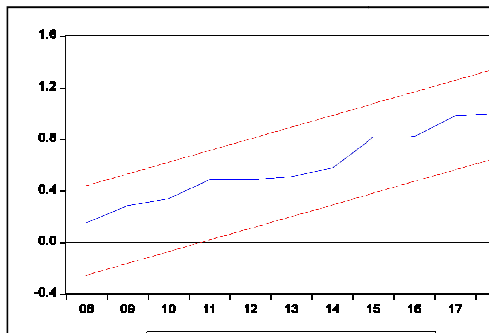
$$\begin{aligned} \Delta \ln FER_t = & 0.0481 + 0.7380 (\Delta \ln FER_{t-1}) - 0.0804 (\Delta \ln GDP_{t-1}) \\ & [0.255] \quad [0.275] \quad [1.035] \\ & - 2.4206 (w) + 0.7492 (w * \ln FER_t) - 0.4896 (w * \ln GDP_t) \\ & [2.758] \quad [0.363] \quad [0.284] \\ & - 1.3161 (ECT_{t-1}) + \zeta_t \\ & [0.333] \end{aligned} \tag{16}$$

$R^2 = 0.3799$; $Adj. R^2 = 0.2516$; $DW = 1.8033$; values in parentheses “[]” are standard errors.

From the result, the “error correction term” or “adjustment coefficient” has the desired negative sign. This implies that a long-run convergence is attainable. The ECT_t is also statistically significant at 1% levels ($t=-3.946$; $P=.001$), signifying that the previous errors are correctable in the subsequent periods.



(A). CUSUM test and significance for GDP



(B). CUSUM of squares test its significance for GDP

Fig. 3. CUSUM and CUSUM of squares tests of stability of the GDP model

Apart from the ECT_t , the lagged FER value is also statistically significant at 5% ($t=2.679$; $P=.012$) with a positive sign. It indicates that the previous year’s values have a significant positive impact on the current values of the foreign exchange reserves. However, the elasticity coefficient (0.738) is less than unity. Also statistically significant ($t=2.06$; $P=.047$) is the interaction of the dummy and the FER, revealing the impact of the structural breakpoint identified in the initial model.

3.5.3 Diagnostic tests for the long-run (error correction) model for FER

3.5.3.1 Breusch-Godfrey serial correlation LM test for the FER model

The extract from the output of the Breusch-Godfrey serial correlation LM test is presented in Table 8. The observed F-statistic is 0.371 while Obs*R-squared statistic is 0.471. The associated probabilities are $P=.547$ and $P=.492$ respectively. Each observed probability value is greater than the acceptable $P=.05$ level for rejection of the null hypothesis that “there is no serial correlation at up to 1 lag.” Since the null hypothesis cannot be rejected at $P=.05$ level it is concluded that the model is free from “serial correlation.”

3.5.3.2 Breusch-Pagan-Godfrey heteroskedasticity test for long-run FER model

The null hypothesis of “equality of the error variances” in the error correction model against the alternative hypothesis of “inequality in variance” is tested, and summary presented in Table 9. The observed F-statistic (probability of F-statistic) is 1.181 ($P=.344$) while the Obs*R-squared statistic (probability of Obs*R-squared) is 7.069 ($P=.314$). The probabilities are larger than the $P=.05$ level for rejection of the null respectively, hence the conclusion that the model is not heteroskedastic.

3.5.3.3 Histogram normality test for the FER model

The “histogram normality test” result (Fig. 4) gives the observed Jarque-Berra as $J-B=19.04$ ($P<0.001$). The result leads to rejection of the null hypothesis that the “data come from a normal distribution” at 5% level of significance. The conclusion is that the data that produced the FER model is not normally distribution.

Table 8. Breusch-Godfrey serial correlation LM test output

H₀: No serial correlation at up to 1 lag			
F-statistic	0.3717	Prob. F(1,28)	0.5470
Obs*R-squared	0.4716	Pro. Chi-Sq. (1)	0.4922

Table 9. Breusch-Pagan-Godfrey heteroskedasticity test output

H₀: “No heteroskedasticity” at up to 1 lag			
F-statistic	1.1808	Prob. F(6,29)	0.3437
Obs*R-squared	7.0686	Prob. Chi-Sq. (6)	0.3145
Scaled explained SS	11.8472	Prob. Chi-Sq. (6)	0.0655

Table 10. Pairwise Granger-Causality tests output

Null hypothesis:	Obs.	F-statistic	Prob.
InFER does not Granger Cause lnGDP	36	2.0187	0.1499
lnGDP does not Granger Cause InFER	36	4.4670	0.0197

Number of lags=2

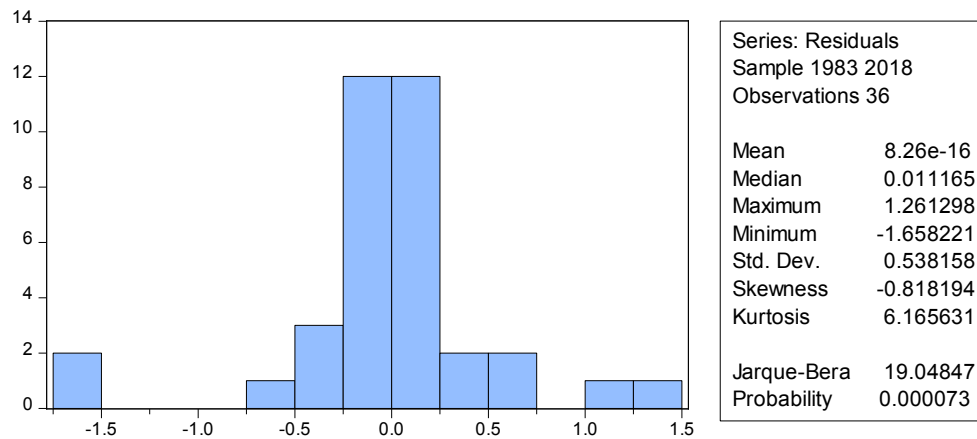


Fig. 4. “Histogram normality” test output of the error correction model of FER

3.5.3.4 Stability test for the FER model

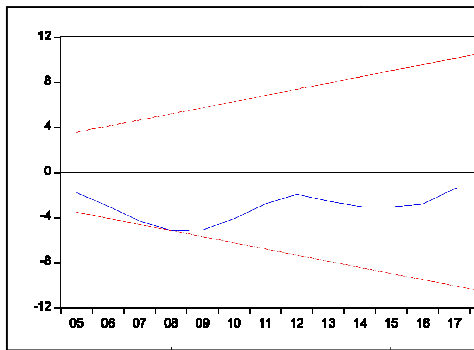
The outputs of the “CUSUM Test” and “CUSUM of Squares” tests of the recursive residual estimates” performed to verify the stability of the FER model, which was adjusted to correct for the observed structural breaks, are presented in Fig. 5. Both tests indicate that the estimates fall within the 5% significance range, indicating them to be statistically significant at P=.05 levels. It is concluded that the model is stable. It follows that the introduction of the dummy variable “w” (w=0 for 1981-2001 and w=1 for 2002-2018) helped to restore stability of the long-run FER model.

In summary, following the results from diagnostic tests reported in Section 3.4.2 and Section 3.5.3, it is concluded that both the short-run GDP model and the long-run FER model passed all relevant investigative tests in line with

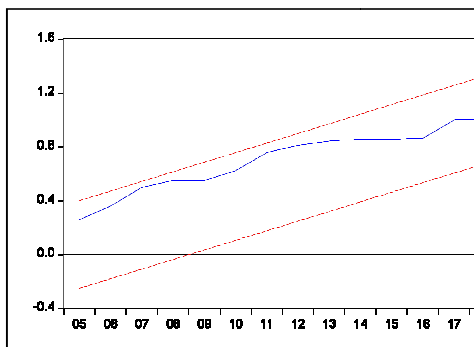
recommended best practice [24]. Among other things, the results reveal no evidence of multicollinearity among the included variables. The models’ functional forms are well-specified and show no suspicion of heteroscedasticity.

3.6 Granger-Causality Test Output

The output of the Granger-Causality test is displayed in Table 10. With observed F-statistic of 4.467, which is significant at P=.019, it shows that the null hypothesis that “GDP does not Granger cause FER” is rejected at .05 level. Contrarily, the null hypothesis that “FER does not Granger cause GDP” cannot be rejected at .05 level with an observed F-statistic of 2.018 and P=.1499. The finding can be interpreted to mean that there is a unidirectional causality that runs from the GDP to FER, but not from FER to GDP. This relationship corroborates previous findings [8,11].



(A). CUSUM test and significance for FER



(B). CUSUM of squares test and significance for FER

Fig. 5. Output of the CUSUM and CUSUM of squares tests of stability of the FER model

4. CONCLUSION

The key finding of this study is the possibility of attainment of equilibrium and long-run convergence between foreign reserves and economic advancement in Nigeria. A positive relationship persists between economic performance and accumulation of foreign exchange while the previous year's GDP values have a significant positive impact on the current values of the foreign exchange reserves. This finding is supported by the Granger-causality analysis that revealed a unidirectional causality that runs from the GDP to FER, but not from FER to GDP. Similar findings have been reported by a study in Brazil [10] and some other previous Nigerian studies [5,8,11,25]. Some of the Nigeria-based studies have suggested the need for judicious management of Nigeria's external reserves, as well as institution of pro-reserves accumulation policies to enhance economic growth. Further, the outcome of this investigation corroborates the argument that a well performing

economy is a positive indication of the inward flow of "foreign direct investment" that has positive influence on the stock of the nation's foreign reserves [25]. A high-performing economy through attracting "foreign direct investment" (FDI) aids the stockpiling of foreign reserves. In Nigeria, available data [26] reveal that the FDI had fluctuated over time, albeit with global increasing trend from 1981-2009, but had dropped substantially from 2010-2018. Similar instability had been recorded in Nigeria's FDI-GDP ratio over time since 1981. To attract more FDI in the critical sectors of the Nigerian economy, there is need for government to create enabling and investment-friendly environment, implement policies and programmes capable of amplifying ease of doing business, so as to boost investors' confidence in the economy.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDIX

Appendix 1. Spurious OLS regression output swapping FER and GDP as dependent and explanatory variables

Variable	Dependent variable: FER				Dependent variable: GDP			
	Parameter	Std. error	t-value	Prob.	Parameter	Std. error	t-value	Prob.
Constant	7612.395	2260.232	3.3679	0.0018	-1640.491	5616.435	-0.2921	0.7719
GDP	0.3561	0.0488	7.2991	0.0000	-	-	-	-
FER	-	-	-	-	1.6759	0.2296	7.2991	0.0000
Log-likelihood				-407.184				-436.613
R-squared				0.5967				0.5967
Adj. R ²				0.5856				0.5855
F-statistic				53.2773				53.2773
Prob (F-stat.)				0.0000				0.0000
Akaike info criterion				21.5360				23.0849
Schwarz criterion				21.6221				23.1711
Hannan-Quinn criter.				21.56667				23.1155
D-W statistic				0.2819				0.1836

Note. GDP is the only explanatory variable for the FER model while FER is the only explanatory variable for the GDP model

Appendix 2. Short-run ARDL model for the GDP

Variable	Coefficient	Std. error	t-statistic	Prob.
Constant	0.1069	0.0443	2.4086	0.023
d[lnGDP(-1)]	0.3981	0.1945	2.0466	0.050
d[lnGDP(-2)]	0.1275	0.1854	0.6880	0.497
d[lnFER(-1)]	0.0315	0.0239	1.3134	0.200
d[lnFER(-2)]	0.0257	0.0236	1.0864	0.286
z	0.7705	1.4384	0.5356	0.596
z*lnGDP	-0.0176	0.0517	-0.3404	0.736
z*lnFER	-0.0595	0.1192	-0.4994	0.621
R-squared	0.4266	Mean dependent var.		0.1904
Adjusted R-squared	0.2779	S.D. dependent var.		0.1054
S.E. of regression	0.0896	Akaike Info. criterion		-1.7892
Sum squared residual	0.2167	Schwarz criterion		-1.4336
Log likelihood	39.3110	Hannan-Quinn criterion		-1.6664
F-statistic	2.8700	Durbin-Watson statistic		1.9417
Prob(F-statistic)	0.0224			

Dependent variable= d(lnGDP_t); z is a dummy variable (z_t = 0 for 1981-2004; z_t=1 for 2005-2018)

Appendix 3. Long-run representation component of the FER model

Variable	Coefficient	Std. error	t-statistic	Prob.
Constant	2.4565	0.7693	3.1928	0.0030
lnFER(-1)	0.4530	0.1491	3.0363	0.0046
lnGDP(-1)	0.3008	0.0908	2.2021	0.0022
R-squared	0.8287	Mean dependent var.		9.0722
Adjusted R-squared	0.8187	S.D. dependent var.		1.4149
S.E. of regression	0.6024	Akaike Info. criterion		1.9018
Sum squared residual	12.3391	Schwarz criterion		2.0325
Log likelihood	-32.1851	Hannan-Quinn criterion		1.9479
F-statistic	82.2961	Durbin-Watson statistic		1.7784
Prob(F-statistic)	0.0000			

Dependent variable= lnFER_t

Appendix 4. Long-run error correction model for FER

Variable	Coefficient	Std. error	t-statistic	Prob.
Constant	0.0481	0.2549	0.1886	0.8516
d[lnGDP(-1)]	-0.0804	1.0346	-0.0777	0.9386
d[lnFER(-1)]	0.7380	0.2754	2.6796	0.0120
w	-2.4206	2.7584	-0.8775	0.3874
w*lnFER	0.7492	0.3626	2.0659	0.0479
w*lnGDP	-0.4896	0.2840	-1.7238	0.0954
ECT(-1)	-1.3161	0.3335	-3.9463	0.0005
R-squared	0.3799	Mean dependent var.		0.1030
Adjusted R-squared	0.2516	S.D. dependent var.		0.6834
S.E. of regression	0.5912	Akaike Info. criterion		1.9593
Sum squared residual	10.1365	Schwarz criterion		2.2672
Log likelihood	-28.2690	Hannan-Quinn criterion		2.0668
F-statistic	2.9612	Durbin-Watson statistic		1.8033
Prob(F-statistic)	0.0222			

Dependent variable= d(lnFER_t)

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