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Application of Auto-Regressive Distributed Lag Model (ARDL) Bound Test on Selected Macroeconomic Variables

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Abstract

This study examined the application of Auto-regressive distributed lag model (ARDL) bound test on some selected macroeconomic variables spanning from 1981-2017 obtained from the statistical Bulletin of Central Bank of Nigeria (CBN). The data were analyzed using the E-views 9.0 software. F-statistic of 5.9167 was found to be higher than the critical value of 3.79 in the Lower Bound I(0) and 4.85 in the Upper bound I(1) at the 5 % level, thus null hypothesis was rejected. ARDL (1, 2, 0) was found to be the best fit model for showing a long-run and short-run relationship between Gross Domestic Product (GDP), Exchange rate, and Interest rate. There is a long-run relationship among GDP, Exchange rate, and Interest rate which means that the variables under study are co-integrated. Also, a unidirectional relationship running from exchange rate to GDP exist. The study recommends the use of supportive fiscal and monetary policies that will tighten the local currency market and provide a set of incentives aimed at removing anti-export bias barriers so as to promote exports and boost GDP, particularly non-oil exports and discourage import of consumer goods to stabilize the exchange rate.

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INTRODUCTION

Causality can be described as the relationship between cause and effect on two sets of variables, say, F and T. According to Pearl (2012), causality is a relationship between events, processes or entities in the same time series subject to several conditions. This relationship can be called Granger causality, (one variable is said to Granger-cause the other if it helps to make a more accurate prediction of the other variable than had we only used the past of the latter as predictor). Assuming we have two times series variables F and T, F is said to Granger-cause T if T can be better predicted using the histories of both F and T than it can by using the history of T alone.

In applied econometrics, instead of applying Granger causality only, Autoregressive Distributed Lag (ARDL) cointegration technique or bound test of cointegration is used as the solution to determining the long run relationship between series that are non-stationary and reconciling the short run dynamics with long-run equilibrium. Many researchers have worked extensively on ARDL like Granger (1981); Engle & Granger (1987); Pesaran & Shin (1999); Pesaran et al. (2001); Johansen & Juselius (1990). With this background, this paper aims at examining the impact and conditions that necessitate the application of the Autoregressive

Distributed Lag (ARDL) cointegration or bound test of cointegration technique and its interpretation on some selected macroeconomic variables. The objective would be achieved by analytically examining the theorized relationships to see if they hold in Nigeria. To achieve this objective which this paper has set for itself, the next section examines the concept and theoretical underpinnings of Auto-regressive distributed lag model (ARDL) bound test on some selected macroeconomic variables, the third section describes the method to be adopted in data analysis. In the fourth section, data is analyzed using Pairwise Granger causality analysis as proposed by Granger (1969). The paper is concluded in the fifth section.

Many researchers in the field of Time Series Econometrics have used Granger causality procedure to study the causal interactions that exist among economic indicators in various countries of the world. Moreover, several intelligent articles have surfaced in the literature on the use of Granger causality tests to analyze time series data since its introduction by Granger (1969). Some of the articles include: Granger (1969); Granger (1980); Granger (1988); Swanson & Granger (1997); Entner et al. (2010), Mohammed & Nishida (2010); Chu & Glymlour (2008); Arnold et al. (2007); Eichler & Didelez (2007); Clarke & Mirza (2006); Erdal et al. (2008); Pearl (2012). Others include: Shajoaie & Michailidis (2010); Moneta et al. (2011), Chen & Hsiao (2010); Zou et al. (2010); Haufe et al. (2010); Toda & Phillips (1994); Toda & Yamamoto (1995) just to mention a few. Although, many of the works carried out were based on comparison among smaller groups of variables. This study tends to contribute to the theoretical and empirical literature on the topic and examines the Pairwise Granger causality analysis of selected economic indicators in Nigeria. We also infer some theoretical economic underpinnings from the observed relationships between these variables.

Musa & Yohanna (2017) investigated the close link between the real effective exchange rate and economic growth for Turkey spanning period 1970-2015 using time series data. The study used the autoregression distributed lag model (ARDL) and Toda–Yamamoto (TY) Granger non-causality tests to achieve the research objective. All the variables were found stationary after first differencing with drift except GDP growth which is stationary at level. The empirical result demonstrated that the real effective exchange rate negatively affects economic growth in the short run; however, it exerts a significant positive impact on growth in the long-run. We also found a uni-directional causality running from real exchange rate to GDP growth rate. The value of the error correction parameter turns out to be negative (-1.34) and statistically significant at 0.0 level as expected. This is supported by the bound test of long-run relationship. The overall conclusion is that based on the substantial dependence of Turkish economy on the import of critical factor inputs for domestic production, maintaining a comparatively strong exchange would possibly exert a positive impact on economic growth in the long-run. Sani et al. (2016) examined the dynamics of the inflationary process in Nigeria over the period 1981 – 2015, using the bounds testing approach to cointegration. Empirical results indicated that inflation in Nigeria proxied by CPI exhibited a strong degree of inertia. The econometric results showed that past inflation and average rainfall appeared to have been the main determinants of inflationary process in Nigeria over the study period. They also found strong evidence of the importance of money supply in the inflation process, lending credence to the dominance of the monetarist proposition on inflation dynamics in Nigeria. Thus, the paper recommended among others, the continuous moderation of growth in the money supply by the central bank and adopting consumers' expectations of inflation as an input into the monetary policy process.

METHOD

This study employs annually data for the period spanning 1981 to 2017 of Interest rate, Exchange rate, and Gross Domestic Product (GDP). The data for the study were sourced from the various issues of the Statistical Bulletin of the Central Bank of Nigeria (CBN). The graphical representation of data is given in Figure 1.

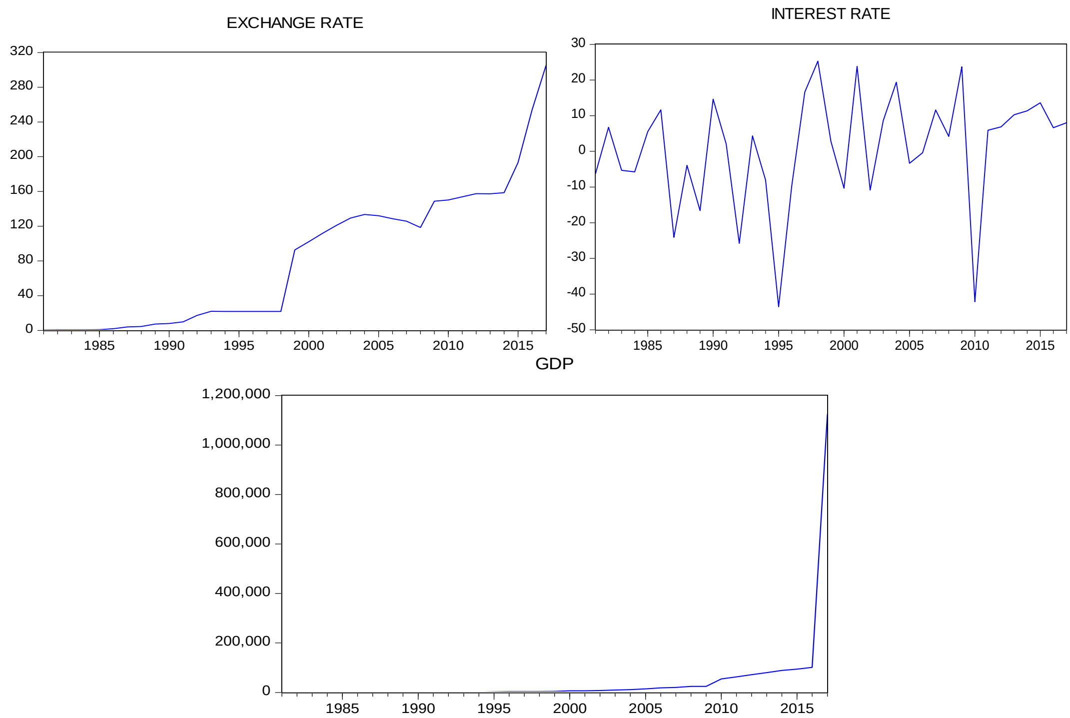

Figure 1. Graphs showing the Interest rate, Exchange rate, and GDP.
Source: Authors (2018)

The model of Interest rate, Exchange rate, and GDP are formulated as:

$$\Delta IR_t = \delta_1 + \sum_{i=1}^{p} \beta_{1i} \Delta IR_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta ER_{t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta GDP_{t-i} + \mu_{1t} \quad (1)$$

$$\Delta ER_t = \delta_2 + \sum_{i=1}^{p} \alpha_{1i} \Delta IR_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ER_{t-i} + \sum_{i=1}^{p} \alpha_{3i} \Delta GDP_{t-i} + \mu_{2t} \quad (2)$$

$$\Delta GDP_t = \delta_3 + \sum_{i=1}^{p} \lambda_{1i} \Delta ER_{t-i} + \sum_{i=1}^{p} \lambda_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{p} \lambda_{3i} \Delta IR_{t-i} + \mu_{3t} \quad (3)$$

Where, δ, β, and λ are the short-run coefficients, IR represents Interest Rate, ER Exchange Rate, GDP Gross Domestic Product and μ are the stochastic error terms.

RESULTS AND DISCUSSION

Unit Root Test Results

Traditionally, most economic variables are non-stationary; hence we test for the presence of unit roots using the Augmented Dickey-Fuller tests. Dickey & Fuller (1976) noted that the least squares estimator of the VAR model in the Granger causality analysis is biased in the presence of unit root and this bias can be expected to reduce the accuracy of forecasts.

Table 1. ADF test for unit root

GDP	Augmented Dickey-Fuller test statistic	t-Statistic	Prob.*
		3.624459	0.0000
	Test critical values		
		1% level	-3.724070
		5% level	-2.986225
		10% level	-2.632604
Exchange Rate	Augmented Dickey-Fuller test statistic	t-Statistic	Prob.*
		-8.543043	
	Test critical values		
		1% level	-3.639407
		5% level	-2.951125
		10% level	-2.614300
Interest Rate	Augmented Dickey-Fuller test statistic	t-Statistic	Prob.*
		-6.234537	
	Test critical values		
		1% level	-3.659194
		5% level	-2.971853
		10% level	-2.625121

Source: Authors (2018)
Note: *MacKnnon (1996) one-sided p-values.

Table 1 is the summary of results of Augmented Dickey-Fuller test. According to (Table 1.), we conclude that there is the absence of unit root according to the P-values of all the three variables as the P-values are significant. Since the values of computed ADF test-statistic of the three variables are smaller than the critical values at 1%, 5% and 10% levels of significance respectively. So, the null hypotheses can be rejected that means all the three variables do not have a unit root. From the unit root test, we conclude that the three variables are stationary at first difference.

Johansen test of cointegration

In Johansen test, data or variable must be non- stationary and integrated of same order. When we convert them to the first difference, they become stationary. Hence Johansen Cointegration test can be applied to examine long-run relationship between the variables.

Table 2. Cointegration Test Analysis result (Trace)

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.662536	57.70467	29.79707	0.0000
At most 1 *	0.435952	20.77055	15.49471	0.0073
At most 2	0.037560	1.301627	3.841466	0.2539

Source: Authors (2018)
Note: Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

The Johansson cointegration test results in table 3 shows that there is a long run relationship between Interest rate, Exchange rate, and GDP as the trace statistic value of 57.70467 is more than the critical value of 29.79707 and is significant as the probability value of 0.0000 is less the 0.05, this is in line with Acha & Amalahu (2017). Hence the null hypothesis of no long-run relationship between Interest rate, Exchange rate, and GDP was rejected. In other words, they move together in the long run. Since the variables are found to be co-integrated, we can specify an ARDL model and estimate. Once there is co-integrating vector, a long run relationship is concluded Gujarati (2004).

Table 3. Cointegration Test Analysis Result (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.662536	36.93412	21.13162	0.0002
At most 1 *	0.435952	19.46892	14.26460	0.0069
At most 2	0.037560	1.301627	3.841466	0.2539

Source: Authors (2018)

Note: Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Pairwise Granger Causality Test Results

As Johansen cointegration test revealed that there is long-run equilibrium relationship exists between Interest rate, Exchange rate, and GDP, the study employed Granger causality test to see whether Interest rate does Granger cause Exchange rate and GDP, Exchange rate and Interest rate or GDP does Granger cause Interest rate and Exchange etc. cointegration indicates that causality exists between the three variables but it fails to show us the directions of the causal relationship. Granger suggests that if cointegration exists between two variables in the long run, then, there must be unidirectional, bi-directional or non-directional.

Table 4. Granger causality test

Null Hypothesis:	Obs	F-Statistic	Prob.
D(GDP) does not Granger Cause D(EXCHANGE_RATE)	34	0.24794	0.7820
D(EXCHANGE_RATE) does not Granger Cause D(GDP)		8.47248	0.0013
D(INTEREST_RATE) does not Granger Cause D(EXCHANGE_RATE)	34	0.67859	0.5152
D(EXCHANGE_RATE) does not Granger Cause D(INTEREST_RATE)		3.17447	0.0567
D(INTEREST_RATE) does not Granger Cause D(GDP)	34	0.00804	0.9920
D(GDP) does not Granger Cause D(INTEREST_RATE)		0.67812	0.5154

Source: Authors (2018)

Granger Causality tests showed that there is uni-directional causality from Exchange rate to GDP (0.013), while there is non-directional causality from Interest rate to Exchange rate, Interest rate to GDP and GDP to the Interest rate.

Table 5. Application of Autoregressive Distributed Lag Model (ARDL) Approach to Cointegration Testing

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
D(GDP(-1))	1.272630	5.037629	0.252625	0.8024
D(EXCHANGE_RATE)	2032.516	1483.042	1.370505	0.1814
D(EXCHANGE_RATE(-1))	4521.131	1697.752	2.663010	0.0127
D(EXCHANGE_RATE(-2))	2796.595	2028.029	1.378972	0.1788
D(INTEREST_RATE)	122.6302	1212.239	0.101160	0.9201
C	-38432.56	31577.33	-1.217093	0.2337
R-squared	0.419397	Mean dependent var		33085.00
Adjusted R-squared	0.315718	S.D. dependent var		175091.5
S.E. of regression	144838.0	Akaike info criterion		26.76340

Sum squared resid	5.87E+11	Schwarz criterion	27.03276
Log-likelihood	-448.9779	Hannan-Quinn criter.	26.85526
F-statistic	4.045152	Durbin-Watson stat	1.431831
Prob(F-statistic)	0.006884		

Error Correction:	D(EXCHANGE_ RATE,)	D(GDP,2)	D(INTEREST_R ATE,2)
CointEq1			
	0.012752	-13.62486	-0.027157
	(0.00522)	(50.2417)	(0.00555)
	[2.44395]	[-0.27119]	[-4.89437]

Source: Authors (2018)
*Note: p-values and any subsequent tests do not account for model selection.

Table 5 presents both the short and long form of the ARDL error correction model. Our parameter estimates generally demonstrate strong significance at 0.0 5 levels of significance. Exchange rate and Interest rate measured by GDP deflator in the short run influence economic growth positively. Error correction mechanism of (0.013) is positive and statistically significant. This means that disequilibrium in the short run is corrected, adjusted and tied to the long run equilibrium position with speed of 1.27 annually.

Table 6. Bounds test for cointegration

Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	5.916730	2
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	3.17	4.14
5%	3.79	4.85
2.5%	4.41	5.52
1%	5.15	6.36

Source: Authors (2018)

We examined the long run relationship amongst the variables in the model by conducting the ARDL bounds test proposed by Pesaran et al. (2001). The critical values for the bounds test are documented in Pesaran et al. (2001) and are based on assumptions regarding whether the variables in the model are I(0) or I(1). The results of the ARDL bounds test are presented in Table 6. The results indicated no cointegration, as it was inconclusive at the 5 per cent level, with the calculated F-statistics falling between the lower and upper critical values. The F-statistic was 5.92, which was higher than the upper bound of the critical values at the 5 per cent level (4.85) and implies the presence of a long run relationship amongst the variables. A maximum lag of 4 was chosen in the ARDL cointegration test since the study utilized yearly series. The optimal lag length was chosen in line with Schwarz Bayesian Criterion (SBC) and the selected ARDL representation for the model was ARDL (1, 2, 0).

CONCLUSION

The goal of most empirical studies in econometrics and other social sciences is to determine whether a long-run and short-run relationship between variables.

This study examines the relationship between Gross Domestic Product (GDP), Exchange rate, and Interest rate. In this paper, Granger causality and Auto-regressive distributed lag model (ARDL) bound test were employed in the empirical modeling of three economic indicators in Nigeria. Based on the findings, it was found to be the best fit model for showing a long-run and short-run relationship between Gross Domestic Product (GDP), Exchange rate, and Interest rate. There is a long-run relationship among GDP, Exchange rate, and Interest rate which means that the variables under study are co-integrated. Also, a unidirectional relationship running from exchange rate to GDP exist. The study recommends the use of supportive fiscal and monetary policies that will tighten the local currency market and provide a set of incentives aimed at removing anti-export bias barriers so as to promote exports and boost GDP. Particularly, promoting non-oil exports and discouraging import of consumer goods were suggested to stabilize the exchange rate.

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