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Research Paper

The Role of Asymmetries and Choice of Causality Testing Procedure in Energy Consumption – Growth Nexus in Nigeria

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Abstract
This study investigates the role of asymmetries in the nexus between renewable energy consumption and economic growth in Nigeria. The study also tests whether the dynamics of the nexus between renewable energy consumption and economic growth is sensitive to the choice of the causality testing procedure considered. Beyond the question of whether the causality between renewable energy consumption and economic growth support growth hypothesis, conservation hypothesis, feedback hypothesis or neutrality hypothesis; we find the dynamics of the causality to be sensitive to the choice of the Granger causality testing procedure considered. More so, we find the dynamics of the causality to be relatively more pronounced when the estimated model is modified to accommodate the role of asymmetries in the nexus. On the whole, we find that irrespective of whether the model is linear or nonlinear ARDL, causality between economic growth and energy consumption predominantly supports the growth hypothesis.
Keywords: *Renewable energy; Asymmetries; Toda-Yamamoto; Nigeria*

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I. Introduction

Irrespective of whether a country is developed or developing, the importance of energy in economic development cannot be over-emphasized. The use of renewable energy resources has been acknowledged as relatively desirable compared to fossil fuels and nuclear energy because they are abundant and environmentally friendly. Given the increasing thrust on renewable energy across the world, there has been equally increasing efforts in the literature to understand the nature of the relationship between the consumption of renewable energy and economic growth (see for example, Masih & Masih; 1995; Lee & Chang, 2008; Apergis & Payne, 2009; Esso, 2010; Ouedraogo; 2013; Enu & Havi, 2014; Lu, 2016; Yasar, 2017; Haseeb, Abidin, Hye & Hartani, 2019). The fact that the knowledge of the dynamic of causality between renewable energy and economic growth is prerequisite to unraveling appropriate energy policies and energy conservation measures cannot be overemphasized. However, while the relationship between renewable energy consumption and economic growth has been the essence of academic studies in the field of energy, the debate on the direction of causality between renewable energy and economic growth has been grossly unexplored, especially in countries that are huge exporters of conventional energy sources, for example, Nigeria. In addition to her known abundance in nonrenewable energy resources, namely; crude oil, natural gas, coal, etc., Nigeria is equally endowed with renewable energy resources such as solar, wind, hydro and biomass.

Beyond the paucity of empirical literature on renewable consumption – growth nexus particularly in the context of the Nigerian economy, what further constitute source of concern in this study is the fact that the debate on the direction of causality between renewable energy and economic growth yet remain inconclusive. This may not be unconnected to differences in sample periods, methods, and model specifications employed in the literature. Motivated by the widespread inconsistency of empirical findings on the nexus between energy consumption and economic growth, one of the focal point of this study is to offer evidence –based insight on whether the dynamic of causality between energy –consumption and economic growth varies for different causality testing procedures. That said, it is instructive that economic events and regime shifts such as; changes in economic environment/condition and/or changes in energy policy are capable of altering the dynamic of the nexus between energy consumption and economic growth. What this portends is the likelihood of the presence of nonlinearity in the energy consumption –growth nexus, yet inferences from the extant literature on the subject matter are predominantly based on estimates from the linear models.

In addition to mixed finding and lack of consensus in the literature which as earlier presumed might be sensitive to the choice of causality testing procedure that is under consideration, only a small body of the literature have examined the potential of nonlinearities (asymmetries) in the nexus between renewable energy consumption and economic growth (Namahoro et al., 2021; Jiang & Chen, 2020; Tuna & Tuna, 2019; Baz et al., 2019; Bayramoglu & Yildirim 2017). Thus, using the case of the Nigerian economy, the contributions of this study to literature are in twofold. First, we explore both the single and multivariate –based testing procedure to hypothesize that the dynamic of the nexus between energy consumption and economic growth is sensitive to the choice of causality testing that is under consideration. Secondly, we explore the Shin et al. (2014) nonlinearity to account for the role of asymmetries in the nexus between energy consumption and economic growth. Compared to the conventional procedure to testing causality, the nonlinear ARLD (NARDL) enable us to simultaneously captured asymmetries in both the short and long run dynamics of the causality between energy consumption and economic growth in Nigeria.

The choice of Nigeria as the investigated economy hinge on the fact that Nigeria is among the few economies endowed with both renewable and nonrenewable sources of energy, yet energy situation in Nigeria has not been able to produced and managed in a way that ensure sustainable growth and development. For instance, average electricity generation in Nigeria hovers around an abysmally low 4420 MW as against installed capacity of over 11,000MW. This low consumption of energy in Nigeria amidst of abundant energy resources may as well explain the basis for the slow pace that have characterized the quest to embark on full-fledged large scale industrial (manufacturing) activity. Given this paradoxical feature of the Nigerian economy, it does become imperative to understand the extent to which the causality between energy consumption and economic growth is sensitive to different economic conditions, such as; boom and recession phases of business cycle as well as positive shock compared to negative shock to energy consumption pattern. It on this note come the motivation to account for the role of asymmetries (nonlinearities) in the nexus between energy consumption and economic growth, and the essence is to provide the policymakers with evidence –based on the likelihood of different energy consumption –economic growth initiatives required for different economic conditions.

In addition to this introductory section, the rest of the paper is structured as follows: Section 2 present the literature review. Section 3 discuss the data and present the methodology. Section 4 present the results and discuss the findings while section 5 concludes the paper.

II. Theoretical and Empirical Literature

Theoretically, the nexus between energy consumption and economic growth can be evaluated under four testable hypotheses, namely; Growth Hypothesis, Conservation Hypothesis, Feedback Hypothesis and Neutrality Hypothesis. According to the Growth Hypothesis, the increase in energy consumption accelerates the economic growth. To this end, there should be a one-way causality from the energy consumption to the economic growth so that this hypothesis would be valid. With respect to the Conservation Hypothesis, an increase in income level leads to higher energy consumption. Hence, the validity of this theory holds when there is a one-way relationship from the economic growth to the energy consumption. For instance, we expect conservative energy policy to exhibit no impact on the economic growth. In the midst of these two extremes come the Feedback Theory which predicts bidirectional causality between the economic growth and energy consumption. According to this theory, it is argued that economic growth would reduce due to the conservative energy policy. It is emphasized that this reduction will affect the energy consumption negatively. According to the Neutrality Hypothesis, energy consumption has either a little or no effect on the economic growth. Again, this hypothesis implies that conservative energy policy does not negatively affect the economic growth. Rather, policy geared towards energy conservation would have no effect on real GDP or retard economic growth (George & Nickoloas, 2011).

Mahadevan & Asafu-Adjaye (2006); Chontanawat, et al. (2008); Odhiambo (2009); Apergis & Payne (2010)) are some of the studies whose empirical findings find support in growth hypothesis. Using the case of China for example, Fang (2011) estimates Cobb–Douglas production functions via a multivariate ordinary least squares method and concludes that renewable energy consumption has positive impact on economic growth.

Despite focusing on different economies as well as exploring different dataset using different methodologies, Halicioglu (2011), Silva, et al., (2012), Lotz (2013), Leitao (2014), Cetin (2016) Bhattacharya, et al., (2016), among other, appears to be unanimous in their validation of energy –led growth hypothesis. Even in a more recent time, Soava, et al., (2018), Singh, et al., (2019), Venkatraja (2019), Shbaz, et al., (2020), and Shastri, et al., (2020) have not only confirmed the viability of energy consumption for explaining increasing growth, but they also ascertained their biasness for renewable as the most appropriate in the quest for energy –led growth. This position in particular finds support in Tiwari (2011), whose analysis of comparative impacts of renewable and non-renewable energy consumption on economic growth show that the relationship is negative in the case of the former and positive in the case of the latter.

However, not only did literature using Nigeria dataset focused mainly on the nonrenewable energy perspective of the nexus, finding from these studies has been hugely mixed and far from consistency, particularly on the dynamic of the direction of causality between energy consumption and economic growth. On the one hand are studied whose finding of positive impact of energy consumption on economic growth support growth hypothesis (Gbadebo & Okonkwo, 2009; Bright & Machame, 2011; Kehinde, et al., 2012; Onakoya, et. al., 2013; Abalaba & Dada, 2013). However, Ogundipe & Apata (2013) finding of bidirectional causality tends to support the feedback hypothesis, while Oyaromade, et al., (2014) and Kemisola, et al., (2014) on the other hand finds no evidence of relationship statistically. To the best of our knowledge, Maji (2015) and Alege, et al., (2016) are the few notable exceptions whose findings reveal renewable energy as capable of impacting economic growth both negatively and positively depending on the indicator(s) of renewable energy that is under consideration.

In addition to the dearth empirical literature using Nigeria data from the perspective of renewable energy, the innovations in the current includes whether the dynamic of causality between renewable energy consumption and economic growth is sensitive to the choice of causality testing procedure under consideration. More so, there have been little or no substantial efforts in the literature to answer the question of whether asymmetries matter in the dynamic of causality between renewable energy consumption and economic growth.

III. Data and Methodology

3.1 Variable description and data source

Variable used in the context of this study are selected based on their theoretical importance, performance measures of the economy, and also their uses and findings in the previous empirical literature. Essentially, our key variables of interest are economic growth (YG) and renewable energy consumption (REC). Starting with the former, log of GDP per capita measured in constant 2010 US dollars and inflationary adjusted to reflect the real value of all domestically produced goods and services in Nigeria was used as a proxy for economic growth. Quite a number of the extant studies on the subject matter have also favoured this approach to measuring economic growth in literature (see for example, Chen et al., 2020; Marinaş et al., 2018; Fatai, 2014; Hung-Pin, 2014). With respect to the renewable energy consumption variable, there are a number of alternative measures in the literature, however; renewable energy in the context of this study is composite in nature as it reflect renewable energy from several different sources (i.e., biomass, solar and wind) and measured as renewable energy consumption as a % of the total/final energy consumption (see also, Olanrewaju, Olubusoye, Adenikinju & Olalekan, 2019).

In additional to the above, we control for some conventional determinant of economic growth in the growth model namely, capital (CAP) and labour (LAB). The log of gross fixed capital formation (formerly gross domestic fixed investment) which includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings is used as the proxy for capital. For labour, the log of total labor force comprises people ages 15 and older who meet the International Labor Organization definition of the economically active population is used for LAB in the growth model. From the view point of energy consumption model, we control for urbanization (URB) and energy prices (EP). The ratio of urban population to total population was used to capture the urbanization, while the energy prices was capture using the log of the composite index of the various international crude oil prices in US dollar per barrel.

Table 1: Exhibition of the variables

Variable	Description	Period	Source
Real GDP (Y)	Real Gross Domestic Product is the market value of all final goods and services produced in the economy during a given period of time. It is measured in billions of constant US$ (2010).	1980-2019	World Development Indicators
Renewable energy (REC)	Renewable energy consumption from several different sources (i.e., biomass, solar and wind) and measured as a % of the total/final energy consumption.	1980-2019	World Development Indicators
Capital (CAP)	Measured using gross fixed capital formation which includes land improvements, plant, machinery and equipment purchases; and the	1980-2019	World Development Indicators

	construction of roads, railways and the like, including schools, offices, hospitals, private residential dwellings and commercial and industrial buildings. It is measured in billions of constant US$ (2010).		
Labour (LAB)	Total labor force comprises people ages 15 and older who meet the International Labor Organization definition of the economically active population. It refers to the supply of labour for the production of goods and services. It is measured in millions	1980-2019	World Development Indicators
Urbanization (UBN)	Urban population as a ratio of total population	1980-2019	World Development Indicators
Energy prices (EP)	composite index of the various international crude oil prices in US dollar per barrel	1980-2019	World Bank Group Database

Source: Author's compilation with data sourced from WDI (2020)

3.2 Estimation technique procedure

One of the main innovations is to test whether the dynamic of the causality between renewable energy consumption and economic growth is sensitive to the choice of causality testing procedure that is under consideration. To this end, we consider two alternatives approaches to Granger causality testing, namely; the multiple regression modelling procedure using Auto-regressive and Distributed Lag (ARDL) model, and the multivariate modelling procedure using Toda-Yamamoto –based Granger causality testing. The preference for each of these modelling approach to causality testing hinge on the fact that they can be applied regardless of whether the variables under consideration are stationary or differenced series. Presented in equation (1) is ARDL representation of economic growth and renewable energy consumption.

$$\Delta \ln YG_t = \alpha + \sum_{i=1}^{p} \lambda_{1i}\Delta \ln YG_{t-i} + \sum_{i=0}^{q} \lambda_{2i}\Delta \ln REC_{t-i} + \sum_{i=0}^{k} \lambda_{3i}\Delta X_{t-i} + \varphi_1 \ln YG_{t-1} + \varphi_2 \ln REC_{t-1} + \varphi_3 \ln X_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta \ln REC_t = \beta + \sum_{i=1}^{p} \gamma_{1i}\Delta \ln REC_{t-i} + \sum_{i=0}^{q} \gamma_{2i}\Delta \ln YG_{t-i} + \sum_{i=0}^{k} \gamma_{3i}\Delta X_{t-i} + \delta_1 \ln REC_{t-1} + \delta_2 \ln YG_{t-1} + \delta_3 \ln X_{t-1} + \varepsilon_t \quad (2)$$

While all the variable remains as earlier defined, the term X_t is a vector controlling for the capital (CAP) and labour (LAB) in the growth model (equation 1) and urbanization (URB) and energy prices (EP) in the energy consumption model (equation 2). The long run parameters for the intercept and slope coefficients are computed as: $-\frac{\alpha}{\varphi_1}$, $-\frac{\varphi_2}{\varphi_1}$, and $-\frac{\varphi_3}{\varphi_1}$ for the growth model. For energy consumption model, the long run parameters for the intercept and slope coefficients are computed as: $-\frac{\beta}{\delta_1}$, $-\frac{\delta_2}{\delta_1}$, and $-\frac{\delta_3}{\delta_1}$. However, since in the long run, it is assumed that $\Delta YG_{t-i} = 0$ and $\Delta (REC, X)_{t-j} = 0$, respectively, then the short run estimates for growth model are obtained as $\lambda_{1j}, \lambda_{2i}$ and λ_{3i} .Similarly, since since in the long run it is assumed also assumed in the case of renewable energy consumption model that $\Delta REC_{t-i} = 0$ and $\Delta (YG, X)_{t-j} = 0$, respectively, then the short run estimates for growth model are obtained as γ_{1j}, γ_{2i} and γ_{3i} .

Since the variables in first differences can accommodate more than one lag, determining the optimal lag combination for the ARDL becomes necessary. The optimal lag length was selected using Schwartz Information Criterion (SIC). The lag combination with the least value of the chosen criterion among the competing lag orders is considered the optimal lag. Consequently, the preferred ARDL model is used to test for long run relationship in the model. This approach of testing for cointegration as earlier described is referred to as bounds testing as it involves the upper and lower bounds. The test follows an F distribution such that, if the calculated F-statistic is greater than the upper bound, there is cointegration; if it is less than the lower bound, there is no cointegration and if it lies in between the two bounds, then, the test is considered inconclusive. Equations (1) and (2) can be re-specified to include an error correction term as follows:

$$\Delta \ln Y_t = \alpha + \eta ECT_{t-1} + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln Y_{t-i} + \sum_{i=0}^{q} \lambda_{2i} \Delta \ln EC_{t-i} + \sum_{i=0}^{k} \lambda_{3i} \Delta X_{t-i} + \varepsilon_t \quad (3)$$

$$\Delta \ln EC_t = \beta + \xi ECT_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln EC_{t-i} + \sum_{i=0}^{q} \gamma_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{k} \gamma_{3i} \Delta X_{t-i} + \varepsilon_t \quad (4)$$

where ECT_{t-1} is the linear error correction term while the coefficients η and ξ represent the speed of adjustment to long run equilibrium in the growth (YG) model and energy consumption (REC) model, respectively. If each of these coefficients is in the (-1, 0) range, then the error correction mechanism is stable and ECT helps to adjust the long-run relationship due to the impact of a specific exogenous shock. In the case of positive η and ξ coefficients, the ECT model leads to the model deviation from the long-run equilibrium so that a certain shock will no longer be neutralized. If those ratios are closer to 0, then the exogenous shock adjustment is performed at low speed, while the closeness to -1 corresponds to a high shock adjustment in one period taken into account (for example, one year in the case of annual data, a quarter for quarterly data etc.

3.2.1 Granger causality testing procedure –based on ARDL model

In additional to the short and long run dynamics of the nexus between economic growth and renewable energy consumption nexus, this study also followed the Marinaş et al. (2018) procedure in the application of Granger causality principles via the estimated coefficients of equations (1) & (2). Thus, the null hypothesis (H_0) of no short-run causality from REC to YG holds when $\lambda_{2i} = 0$ and from YG to REC for $\gamma_{2i} = 0$. Regarding the long-run Granger causality, the hypothesis (H_0) is tested based on the associated coefficients on ECT_{t-1}, for instance $\eta = 0$ for growth (YG) model and $\xi = 0$ for energy consumption (REC) consumption models. On the whole, there is a strong Granger causality running from REC to YG and from YG to REC if the null hypotheses (H_0) $\lambda_{2i} = \eta = 0$ and $\gamma_{2i} = \xi = 0$ are rejected.

3.2.2 Granger causality testing procedure –based on Toda-Yamamoto VAR model

This study further complements the single equation –based techniques explored so far with a multivariate –based estimation technique. Unlike the ARDL model, the multivariate model namely, vector autoregression (VAR) model allows both economic growth (YG) and renewable energy consumption (REC) to be treated as endogenous such that, there is no apriori distinction between endogenous and exogenous variables. Essentially, we favour a VAR model with the Toda & Yamamoto (1995) and Dolado & Lutkepohl (1996) [TYDL; henceforth] causality testing approach to determine the direction of relationship between YG and REC.

Although, there are others multivariate modeling approaches to implement causality testing in the literature including a VAR model in the level data; a VAR model in the first difference data (VARD); and a vector error correction model (VECM). But the simulation results by Yamada and Toda (1998) suggest the TYDL is relatively the more stable when compared to these alternative causality procedures. The main rationale behind TYDL is to artificially augment the correct VAR order, say *k*, with d_{max} extra lags, where d_{max} is the maximum likely order of integration of the series contained in the system. In the case of this present study however, we follow the TYDL framework and the given lag augmented VAR (k + d_{max}) for economic growth – renewable energy consumption nexus.

$$YG_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} YG_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} YG_{t-j} + \sum_{i=1}^{k} \beta_{1i} REC_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} REC_{t-j} + \sum_{i=1}^{k} \lambda_{1i} X_{t-i} + \sum_{j=k+1}^{k+d_{max}} \lambda_{2j} X_{t-j} + \varepsilon_{1t}$$

$$REC_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} REC_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} REC_{2t-j} + \sum_{i=1}^{k} \alpha_{1i} YG_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} YG_{t-j} + \sum_{i=1}^{k} \lambda_{1i} X_{t-i} + \sum_{j=k+1}^{k+d_{max}} \lambda_{2j} X_{t-j} + \varepsilon_{2t}$$

$$X_t = \lambda_0 + \sum_{i=1}^{k} \lambda_{1i} X_{t-i} + \sum_{j=k+1}^{k+d_{max}} \lambda_{2j} X_{2t-j} + \sum_{i=1}^{k} \alpha_{1i} YG_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} YG_{t-j} + \sum_{i=1}^{k} \beta_{1i} REC_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} REC_{t-j} + \varepsilon_{3t}$$

(5)

The multivariate VAR model in equation (5) would be considered where the two series are different orders of integration says I(0) and I(1) which is the case in the context of this study. The VAR specification can be further re-represented in matrix form as follows:

$$\begin{bmatrix} YG_t \\ REC_t \\ X_t \end{bmatrix} = \begin{bmatrix} \delta_{10} \\ \delta_{20} \\ \delta_{30} \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{11,i} & \delta_{12,i} & \delta_{13,i} \\ \delta_{21,i} & \delta_{22,i} & \delta_{23,i} \\ \delta_{31,i} & \delta_{32,i} & \delta_{33,i} \end{bmatrix} \begin{bmatrix} YG_{t-i} \\ REC_{t-i} \\ X_{t-i} \end{bmatrix} + \sum_{j=1}^{d_{max}} \begin{bmatrix} \delta_{11,k+j} & \delta_{12,k+j} & \delta_{13,k+j} \\ \delta_{21,k+j} & \delta_{22,k+j} & \delta_{23,k+j} \\ \delta_{31,k+j} & \delta_{32,k+j} & \delta_{33,k+j} \end{bmatrix} \begin{bmatrix} YG_{t-k-j} \\ REC_{t-k-j} \\ X_{t-k-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_Y \\ \varepsilon_{EC} \\ \varepsilon_X \end{bmatrix} \quad (6)$$

The above three variables TYDL VAR approach modified the original bivariate form of Toda and Yamamoto (1995) to accommodate our variables of interest, where *k* represents optimal lag length determined using SIC while d_{max} is the maximum order of integration. The direction of causality running from energy consumption (REC) to economic growth (YG) and from economic growth (YG) to energy consumption (REC) and so on can be established through rejecting the null hypothesis of no causality which requires finding the significance of the Modified Wald (MWald) statistics for the group of the lagged independent variables identified above.

$H_{01} : \delta_{12,1} = \delta_{12,2} = \ldots\ldots = \delta_{12,k} = 0$, Implies that R*EC* does not granger cause YG.

$H_{02} : \delta_{21,1} = \delta_{21,2} = \ldots\ldots = \delta_{21,k} = 0$, Implies that YG does not granger cause REC.

$H_{03} : \delta_{13,1} = \delta_{13,2} = \ldots\ldots = \delta_{13,k} = 0$, Implies that variable X which is vector of the control variable does not granger cause YG/REC.

$H_{04} : \delta_{31,1} = \delta_{31,2} = \ldots\ldots = \delta_{31,k} = 0$, Implies that YG/REC emission does not granger cause X.

3.3 Nonlinear ARDL (NARDL) Model

To test whether the dynamics of causality between economic growth and renewable energy consumption is sensitivity to the presence of nonlinearity in the nexus, we employed the nonlinear variant of the ARDL model developed by Shin et al. (2014) for the estimation of the nonlinear growth model and renewable energy consumption model, respectively. Thus, equations (7) & (8) are the nonlinear variants of the linear ARDL models, where the indicator for energy consumption (REC) in the economic growth model was further decomposed into positive and negative changes and same for the indicator for economic growth (YG) in the energy consumption model.

$$\Delta \ln YG_t = \alpha + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln YG_{t-i} + \sum_{i=0}^{q} \lambda_{2i} (\Delta \ln REC^{+}_{t-i} + \Delta \ln REC^{-}_{t-i}) + \sum_{i=0}^{k} \lambda_{3i} \Delta X_{t-i} + \varphi_1 \ln YG_{t-1} + \varphi_2 \ln REC^{+}_{t-1} + \varphi_3 \ln REC^{-}_{t-} + \varphi_4 \ln X_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta \ln REC_t = \beta + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln REC_{t-i} + \sum_{i=0}^{q} \gamma_{2i} (\Delta \ln YG^{+}_{t-i} + \Delta \ln YG^{-}_{t-i}) + \sum_{i=0}^{k} \gamma_{3i} \Delta X_{t-i} + \delta_1 \ln REC_{t-1} + \delta_2 \ln YG^{+}_{t-1} + \delta_3 \ln YG^{-}_{t-1} + \delta_4 \ln X_{t-1} + \varepsilon_t \quad (8)$$

where REC^{+}_t with positive sign subscript and REC^{-}_t with negative sign subscript captured positive and negative changes in energy consumption, respectively. The long run (elasticity) coefficients for nonlinearity in causality running from renewable energy consumption to economic growth due to positive and negative changes in the level of energy consumption can be calculated as: $-\frac{\varphi_2^{+}}{\varphi_1}$ and $-\frac{\varphi_3^{-}}{\varphi_1}$. Similarly, YG^{+}_t with positive sign subscript and YG^{-}_t with negative sign subscript captured positive and negative changes in economic growth, respectively. Hence, the long run (elasticity) coefficients for nonlinearity in causality running from economic growth (YG) to energy consumption due to positive and negative changes in the level of economic growth can be calculated as: $-\frac{\delta_2^+}{\delta_1}$ and $-\frac{\delta_3^-}{\delta_1}$.

The decomposed economic growth variables are defined theoretically as:

$$YG_t^+ = \sum_{k=1}^{t} \Delta YG_{ik}^+ = \sum_{k=1}^{t} \max(\Delta YG_{ik}, 0) \quad (9a)$$

$$YG_t^- = \sum_{k=1}^{t} \Delta YG_{ik}^- = \sum_{k=1}^{t} \min(\Delta YG_{ik}, 0) \quad (9b)$$

Following similar procedure, the decomposed energy consumption can also be theoretically defined as below.

$$REC_t^+ = \sum_{k=1}^{t} \Delta REC_{ik}^+ = \sum_{k=1}^{t} \max(\Delta REC_{ik}, 0) \quad (10a)$$

$$REC_t^- = \sum_{k=1}^{t} \Delta REC_{ik}^- = \sum_{k=1}^{t} \min(\Delta REC_{ik}, 0) \quad (10b)$$

Similar to the linear (symmetric) ARDL models, the error correction version of equations (9) & (10) can be represented as follows:

$$\Delta \ln YG_t = \alpha + \eta ECT_{t-i} + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln YG_{t-i} + \sum_{i=0}^{q} \lambda_{2i} (\Delta \ln REC_{t-i}^+ + \Delta \ln REC_{t-i}^-) + \sum_{i=0}^{k} \lambda_{3i} \Delta X_{t-i} + \varepsilon_t \quad (11)$$

$$\Delta \ln REC_t = \beta + \xi ECT_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln REC_{t-i} + \sum_{i=0}^{q} \gamma_{2i} (\Delta \ln YG_{t-i}^+ + \Delta \ln YG_{t-i}^-) + \sum_{i=0}^{k} \gamma_{3i} \Delta X_{t-i} + \varepsilon_t \quad (12)$$

The error correction term (ECT) in equations (11) and (12) remains as earlier defined and so is the associated parameters for instance η and ξ.

To refute or validate the significance of nonlinearity in the causality rumnning from energy consumption to economic growth the null hypothesis of no nonlineaity (asymmetry) for instance $H_0 : \varphi_i^+ = \varphi_i^-$ is tested against the alternative $H_1 : \varphi_i^+ \neq \varphi_i^-$ using Wald restriction test. For the short run situation, the null hypothesis of no nonlinearity is tested with: $H_0 : \lambda_{2i}^+ = \lambda_{2i}^-$ against $H_1 : \lambda_{2i}^+ \neq \lambda_{2i}^-$.

The above Wald restriction test procedure only applicable to the economic growth model and when the assumption is that the causality runs from energy consumption to economic growth. With respect to the energy consumption model, the null hypothesis of no nonlinaity (asymmetry) be tested as follows: $H_0 : \delta_i^+ = \delta_i^-$ against the alternative $H_1 : \delta_i^+ \neq \delta_i^-$ for the long run situation. For short run situation, the null hypothesis of no nonlineaity will be tested with: $H_0 : \gamma_{2i}^+ = \gamma_{2i}^-$ against the alternative hypothesis stated as $H_1 : \gamma_{2i}^+ \neq \gamma_{2i}^-$.

More importantly, the Granger causality testing procedure in the NARDL model is same as those earlier established in the case of causality testing based on ARDL.

IV. Empirical Result and Discussion of Finding

4.1 Preliminary results

Represented in Table 2 are the descriptive statistics of the variables under consideration, namely; the mean, the maximum, the minimum and the corresponding standard deviation statistics of the variables. The distributional properties of the variables are also examined via skewness and kurtosis statistics, while the Jarque-Bera test statistics is used to test for normality in the distribution. Starting with the mean statistic, the average economic growth in Nigeria measured in terms of GDP (YG) in billion US dollar was 34.2 for the period under consideration, while the average renewable energy consumption was 86.33% ratio of the total energy consumption. A further look at the table shows that the gross fixed capital formation which is a measure for physical capital in this study was on average $57.32 billion for the period under consideration. With respect to other variables under consideration, the mean statistics shows that the average world annual energy prices were 42.34 US dollar per barrel while the average ratio of urban population to total population as 35.83%.

Moving to the standard deviation statistics which tells us the degree of dispersion between the maximum and the minimum values of the respective variables, it is instructive that the standard deviation statistics for the individual variables cannot be compared in absolute terms and that is because they are expressed in varying units of measurement. To arrive at an unbiased comparison, we therefore normalized the standard deviation statistic and consequently show that energy prices and not labour force is the most volatile variable given its relative higher value of the normalized standard deviation statistic while both the renewable and nonrenewable energy consumption variables appear to be the least volatile compared to other variables in the table. With respect to the statistical distribution of the variables, all the series appear to be positively skewed with renewable energy consumption (*REC*) the only exception. The results for the kurtosis statistics are however mixed, as it appears to be platykurtic for *REC* and *CAP* but leptokurtic for other variables. On the whole, the computed probability values associated with the Jarque-Bera normality test statistics appear to be less than 0.10 and 0.05 for the case of YG, *CAP* and *EP* thus suggesting the rejection of the hypothesis that the series are normally distributed at 5% level of significance.

Table 2: Descriptive/Summary Statistics

Statistics	*YG*	*REC*	*CAP*	*LAB*	*EP*	*UBN*
Mean	34,211.67	86.33	57.32	1,862,347.00	42.34	35.83
Maximum	71,387.83	88.83	105.06	3,048,887.00	105.01	51.16
Minimum	13,779.26	82.96	37.72	673,560.60	13.06	21.97
Standard Deviation	20,205.03	1.24	13.29	713,106.20	28.74	8.56
Normalise Standard Deviation	0.59	0.01	0.23	0.38	0.68	0.24
Skewness	0.71	-0.47	1.29	0.03	1.00	0.18
Kurtosis	1.93	3.39	5.57	1.83	2.74	1.90
J-Berra	5.27 (0.07)	1.73 (0.42)	22.06 (0.00)	2.30 (0.32)	6.73 (0.03)	2.21 (0.33)

Note: the normalize standard deviation is computed as: standard deviation/mean

As a precondition for most time series analyses, this study also conducts unit root tests on all the variables under consideration and the essence is to determine the stationary status of the series and in turn the suitability of the chosen estimation techniques. For robustness and consistency purposes, this present study considered both the basic Augmented Dickey-Fuller (ADF) test and its extended variant for instance Dickey-Fuller GLS test. Starting with the ADF results, we find the non-rejection of the null hypothesis of unit root for the economic growth series both in the model with constant only and model with constant and trend. For renewable energy consumption, the null hypothesis of unit root was rejected in the model with constant only but otherwise in the model with both constant and trend.

Table 3(a): ADF Unit Root Test Results

	Model with Constant			**Model with Constant & Trend**		
Variable	**Level**	**First Difference**	**I(d)**	**Level**	**First Difference**	**I(d)**
GDP (Y)	-0.699	-3.1793**	I (1)	-2.289	-3.655***	I (1)
REC	-2.982**	-	I (0)	-3.091	-6.690***	I (1)
CAP	-2.148	-5.021***	I (1)	-5.241***	-	I (0)
LAB	-8.842***	-	I (0)	-4.099***	-	I (0)
EP	-1.038	-5.957***	I (1)	-2.221	-5.949***	I (1)
UBN	0.704	-1.555**	I (1)	-1.954	-8.437***	I (1)
Table 3(b): DF-GLS Unit Root Test Results						
GDP (Y)	-0.926	-2.876***	I (1)	-1.850	-9.580***	I (1)
REC	-2.996***	-	I (0)	-3.187*	-	I (0)

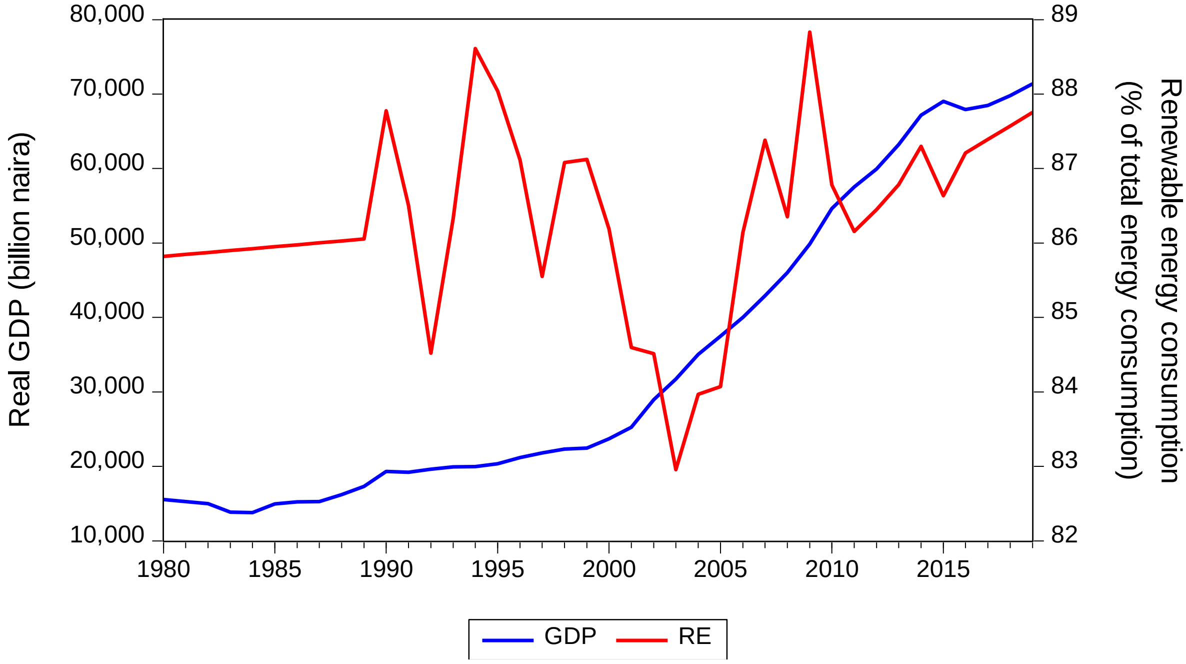
CAP	-1.057	-1.584**	I (1)	-1.520	-2.733**	I (1)
LAB	0.399	-3.741*	I (1)	-1.095	-4.304***	I (1)
EP	-1.084	-5.966***	I (1)	-1.827	-6.102***	I (1)
UBN	0.032	-1.549*	I (1)	-2.193	-3.807**	I (1)

Note: The exogenous lags are selected based on Schwarz info criteria while ****, **, * imply that the series is stationary at 1%, 5% and 10% respectively. The null hypothesis is that an observable time series is not stationary (i.e., has unit root).

Despite the prominence of the ADF as the workhorse of unit root testing in the literature, the low power associated with the ADF null against the stationary alternative, particularly when trend is included in the specification has been the major shortcoming of the ADF test. Thus, Eliott, Rothenberg and Stock (1996) proposed an extension to the conventional ADF and the outcome of the augmented ADF test which has come to be known as DF-GLS which shows a significant greater power than the traditional ADF. Consequently, this study considered in addition to the ADF test, the DF-GLS unit root test. Same as the ADF results, the unit root test results obtained from DF-GLS test also revealed the integration properties of series to hover between I(0) and I(1). This by implications further re-enforces our preference for ARDL technique as the most appropriate to accommodate the mixed order of integration exhibited by the series.

We further compliment the preliminary analysis with graphical illustration on the possible co-movement between the variables of interests. Presented in Figure 1 is the trend between economic growth and renewable energy consumption. Deciphered from the figure is potential of both positive and negative co-movements between economic growth and renewable energy consumption. For instance both the renewable energy consumption and economic growth appears to be trending on the same direction for the period between 1980 and 1988, but the movement is mainly in the opposite direction starting from 1989 and not until 2010 before they started moving in the same direction once again. However, while this illustrations of mixed evidence of co-movements between economic growth and renewable energy consumption gives little or no statistical credence, it however, strengthen our argument for the likelihood of the asymmetries in the nexus.

Figure 1: Trends in Economic Growth and Renewable Energy Consumption



4.2 Regression results

The empirical estimates presented in Table 4 mainly centered on the short run and long run dynamics of the economic growth and renewable energy consumption nexus. Starting with the Bound cointegration testing results, the decision on whether to reject the null hypothesis of no long run relationship appears to be statistically indistinct in the case of the REC model with the F-statistics hovering between the upper and lower bounds of the critical values at 10% level of significance. However, the hypothesis of no cointegration is significantly rejected in the growth model. What this portends, is that the probable of long run relationship between economic growth and renewable energy consumption seems to be statistically viable when the causality runs from renewable energy consumption to economic growth. Complementing the Bound cointegration testing results is the cointegrating equation coefficient for instance the error correction term (ECT). The ECT for both the growth model and renewable energy consumption model are correctly signed and statistically significant which is an indication that the two models are stable, particularly since their respective speed adjustment coefficients of exogenous shocks are negative and different from zero (0).

Regarding the elasticities of the coefficients, we find a 1% increase in the level of renewable energy consumption capable of explaining 0.01% increase in the economic but mainly in the short run situation. However, the consumption of renewable energy seems to be mainly driven by changes in energy prices with economic growth exhibiting no evidence of significant impacts on the consumption of renewable energy in Nigeria. That said, our finding of weak impact of renewable energy (REC) on economic growth is similar to that reported for India by Shastri, Mohapatra & Geri (2020). More so, the fact that labour and not capital is the factor of production that exhibits the potential for explaining economic growth in Nigeria further confirm the assertion that developing economies such as Nigeria are still predominantly labour intensive. That is, economic activities in Nigeria are characterized by the use of labor-intensive production processes and relatively less renewable energy and capital intensities.

Table 4: ARDL estimates on economic growth - energy consumption nexus

	Dependent variable					
	Economic Growth (YG)			**Renewable Energy (REC) Consumption**		
Long Run Equation	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
YG_t				-0.6400	6.7492	-0.0948
REC_t	0.1282	0.1085	1.1815			
CAP_t	0.0163	0.0426	0.3830			
LAB_t	2.0239***	0.5522	3.6650			
EP_t				0.3350**	0.0031	2.2404
UBN_t				0.9704	0.6716	1.4449
Short Run Equation						
Constant	-2.1463	2.2119	-0.9703	37.3398	31.2494	1.1948
ΔYG_{t-1}	0.0656*	0.0346	1.8929			
ΔYG_t				-0.3331	3.5392	-0.0941
ΔREC_{t-1}				0.5204***	0.1519	3.4259
ΔREC_t	0.0086*	0.0048	1.7950			
ΔCAP_t	0.2489	0.7353	0.3385			
ΔLAB_t	0.1329***	0.0412	3.2207			
ΔEP_t				0.1743*	0.0051	1.2438
ΔUBN_t				0.5051	0.3847	1.3127
ECT_{t-1}	-0.0656***	0.0075	-8.7176			
Bound Test Cointegration Results						
Level of Significance	**Growth (Y) Model**			**Renewable Energy (RE) Model**		
	F-stat	***I (0)***	***I (1)***	***F-stat***	***I (0)***	***I (1)***
10%	11.33	2.37	3.20	2.2154	2.20	3.09
5%		2.79	3.67		2.56	3.49
1%		3.65	4.66		3.29	4.37

Diagnostic and Post-Estimation Results					
			Linearity test	***Autocorrelation test***	***Heteroscedasticity test***
Model	**Adj-R^2**	**F-statistic**	**Ramsey RESET**	**Q-Statistic**	**ARCH-LM test**
Growth Model	0.96	2474.74*** (0.0000)	0.8713 (0.3573)	3.3456 (0.188)	0.2496 (0.7805)
RE Model	0.53	4.7887	2.7212	0.8332	1.2892

		(0.0021)	(0.1088)	(0.659)	(0.2886)

Note: The value in parenthesis represents the probability values for the various post estimation tests performed, while ***, ** and * denote 1%, 5% and 10% level of significance. The SE represents standard error.

Beyond the short run and long run dynamics of the nexus, also of particular interest to this study is the direction of causality of the nexus presented in Table 5. Supporting the growth hypothesis is our finding of a short run unidirectional Granger causality running from renewable energy consumption to economic. Ikhide & Adjasi (2015) is one of the recent Nigerian studies whose finding also supported the growth hypothesis. However, one of the main contributions of this present study is whether the direction of the causality varies across the short run and long run situations. Thus, a further look at table 5 shows that the causality is bidirectional in the long run, which is an indication that while the growth hypothesis, holds in the short run what appears to be obtainable in the long run is feedback hypothesis. Similar to our study is the study by Hung-Pin (2014) who use the case of G7 countries to show that the direction of causality between economic growth and renewable energy consumption relationship varies for short run and long run (see also, Amri, 2017; Matei, 2017).

Table 5: ARDL -based Granger causality results for economic growth &renewable energy consumption

	Hypothesis H_0 (no Granger causality)		t-statistic/F-statistic*		Probability of rejecting H_0	
	$RE \rightarrow Y$	$Y \rightarrow RE$	$RE \rightarrow Y$	$Y \rightarrow RE$	$RE \rightarrow Y$	$Y \rightarrow RE$
Short run Granger causality	$\lambda_{2i} = 0$	$\gamma_{2i} = 0$,	3.1034*	0.0088	0.0871	0.9256
Long run Granger causality	$\eta = 0$	$\xi = 0$	3.5832*	11.737***	0.0669	0.0017

Note: (***, ** & *) implies the rejection of the null hypothesis of no causality at 1%

On whether the dynamic of the causality is sensitive to the choice of the causality testing procedure that is under consideration, we further extended the Granger Causality test from single –based ARDL technique to a Multivariate VAR model using the TYDL approach that also allows for mixed order of integration as exhibited by the variables. Given the sensitivity of TYDL-VAR causality testing approach to the choice of lag length, we performed a series of nested likelihood ratio tests on level VARs to determine the optimal lag length (p) prior to performing causality test based on TYDL-VAR estimates. Using Schwarz information criterion (SIC), our preferred multivariate model as shown in Table 6 is VAR(3).

Table 6: VAR lag order selection criteria

Endogenous Variables: Log(GDP) Log(CAP) Log(LAB) REC Log(EPI) UBN
Exogenous Variable: C
Included Observation: **37**

	LR	FPE	AIC	SC	HQ
0	-62.54968	NA	1.64e-06	3.705388	3.966618
1	251.7956	509.7491	4.92e-13	-11.34030	-9.511692*
2	300.8204	63.59975*	2.86e-13*	-12.04435	-8.648356
3	338.3735	36.53817	4.16e-13	-12.12830*	-7.164929

* 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

To estimate the chosen multivariate VAR model via TYDL causality testing approach, we select 1 as our maximum order of integration (d_{max}) and this is due to the outcomes of our unit root test results which hovered between I(0) and I(1), hence $K+d_{max}=4$ when energy consumption source is renewable and $K+d_{max}=2$ when energy consumption source is nonrenewable with K denoting the value of the optimal lag length which is based SIC lag selection criteria. Presented in Table 7 is the causality testing results on economic growth and renewable energy consumption relationship.

Table 7: TYDL-VAR –based Granger causality test results

Equation / Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6
	Log(GDP)	***Log(CAP)***	***Log(LAB)***	***REC***	***Log(EPI)***	***UBN***
Log(GDP)	*D.V*	0.1406 (0.7076)	0.2058 (0.6500)	0.4520 (0.5011)	0.8818 (0.3477)	0.2733 (0.6011)
Log(CAP)	0.9995 (0.3174)	*D.V*	1.3475 (0.2457)	0.3961 (0.5291)	0.0157 (0.9002)	1.7446 (0.1866)
Log(LAB)	9.3803*** (0.0022)	0.2144 (0.6433)	*D.V*	0.1839 (0.6680)	1.3766 (0.2407)	10.6541*** (0.0011)
REC	0.4140 (0.5199)	0.3001 (0.5838)	0.6844 (0.4080)	*D.V*	3.3207* (0.0608)	0.7878 (0.3748
Log(EPI)	7.7206*** (0.0055)	0.1898 (0.6630)	0.3990 (0.5276)	0.4913 (0.4833)	*D.V*	2.5531 (0.1101)
UBN	2.5751*** (0.0000)	0.5537 (0.4568)	6.3883** (0.0115)	0.2409 (0.6236)	7.9540*** (0.0048)	*D.V*

Note: D.V. denotes dependent variable and the probability values are in in parentheses

Compared ARDL model –based Ganger causality testing results where we found mixed evidence of unidirectional and bidirectional dynamics of causality between economic growth and energy consumption, causality testing base on the multivariate TYDL-VAR model rather support the neutrality hypothesis which predicts there is no causal relationship between economic growth and energy consumption. This seems to have validated our assumption that the dynamic of causality between renewable energy consumption and economic growth may be sensitive to the choice of Granger causality testing procedure that is under consideration.

4.2.1 Does asymmetries matter in the nexus between economic growth and renewable energy consumption

Another main innovation of this study is whether the dynamics of causality between energy consumption and economic growth is sensitive to the presence of nonlinearity in the variables. The Wald statistics in table 8 and their corresponding p-values in parenthesis are meant to evaluate the hypothesis of no nonlinearity in the economic growth and renewable energy consumption relationship. The terms W_{SR} and W_{LR} denotes Wald restriction testing for the null hypothesis of no short and long run nonlinearities. Starting with the short run null hypothesis of no asymmetries, we found it rejected in the case of the economic growth model but the reverse appears to be the case in the REC model. Regarding the null hypothesis of no asymmetries in the long run, it is rejected in the REC model but otherwise in the growth model.

With respect to the elasticities of the nonlinearity (asymmetric) coefficients, both the positive and negative changes in the level of renewable energy consumption tend to exhibit significant impact on economic growth. Essentially, we found that a 1% increase in renewable energy consumption has the potential of increasing economic growth in Nigeria by 2.3% whereas a 1% decline in the consumption of renewable energy will only cause declining economic growth by 0.39%. It must be pointed however, that these evidence of asymmetric impact of renewable energy consumption on economic growth is only statistically significant in the short run. That said, we find little or no significant impact of economic growth on renewable energy consumption irrespective of whether the estimated model is linear ARDL (symmetric) or nonlinear ARDL model (asymmetric).

Table 8: Nonlinear ARDL estimates on economic growth -renewable energy consumption nexus

Long Run Equation	**Dependent variable**					
	Economic Growth (YG)			**Renewable Energy (RE) Consumption**		
	Coefficient	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Y_t^+				**Not Applicable (No long run relationship)**		
Y_t^-						
RE_t^+	2.8510	1.3225	0.9210			
RE_t^-	-4.8518	4.8226	-1.0060			
CAP_t	0.4403	0.6221	0.7078			
LAB_t	1.37E-06	3.07E-06	0.4473			
EP_t						
UBN_t						
Short Run Equation						

Constant	0.5132	0.5614	0.9140	31.8978**	13.2489	2.4075
ΔY_t^+				1.1832	11.1535	0.1060
ΔY_t^-	-0.0817	0.0688	-1.187656	-5.9970	8.6861	-0.6904
ΔRE_t^+	2.3576**	0.9865	2.3898			
ΔRE_t^-	-0.3964**	0.1659	-2.3892			
ΔCAP_t	0.0359	0.0496	0.7247			
ΔLAB_t	1.12E-07	2.87E-07	0.3902			
ΔEP_t				-0.1124	1.3605	-0.0826
ΔUBN_t				1.0739	0.6941	1.5471
ECT$_{t-1}$	-0.0817***	0.0091	-8.8890	-0.5250***	0.1308	-4.0135
Bound Test Cointegration Results						
Level of Significance	**Growth (Y) Model**			**Renewable Energy (REC) Model**		
	F-stat	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	9.50***	2.08	3.00	1.9379	2.08	3.00
5%		2.39	3.38		2.39	3.38
1%		3.06	4.15		3.06	4.15
Wald(W) Test for the Role of Asymmetries in GDP (Y) -RE Nexus						
	Growth Model			**REC Model**		
W_{SR}:F-statistic	3.1702** (0.0554)			0.2451(0.7840)		
W_{LR}:F-statistic	0.8102 (0.3748)			NA		

Diagnostic and Post-Estimation Results

Model	**Adj -R^2**	**F-statistic**	***Linearity test*** Ramsey RESET	***Autocorrelation test*** Q-Statistic	***Heteroscedasticity test*** ARCH-LM test
Growth Model	0.96	1594.02*** (0.0000)	**NA**	3.5327 (0.171)	0.8557 (0.4339)
RE Model	0.32	4.0081 (0.0041)	**NA**	0.8691 (0.648)	1.1017 (0.3438)

Note: The term W represents Wald restriction test distributed as $\chi(5)$ while subscripts SR denotes short run and *LR* long run. The value in parenthesis represent the probability values for the various post estimation tests performance, while ***, ** and * represent 1%, 5% and 10% level of significance, and the term NA means not applicable.

Further presented in Table 9 are the Granger causality results obtainable from the nonlinear ARDL model. We found that irrespective of whether the change in energy consumption was positive or negative, the null hypothesis of no causality was consistently rejected at 5% level of significance both in the short and long run situations. However, we found that the causality mainly runs from energy consumption to economic growth both in the short and long run thus validating our earlier submission. That is, irrespective of whether the model is linear or nonlinear ARDL, the causality between economic growth and energy consumption predominantly support the growth hypothesis which predicts that causality run from energy consumption to economic growth. This by implication suggests that energy consumption plays an important role in economic growth in Nigeria which also conforms to some of the previous findings in the literature (see for example, Acaravci, 2010; Altinay & Karagol, 2005; Shiu & Lam, 2004).

Table 9: Granger Causality testing results -based on Nonlinear ARDL estimates

Causality relationship between positive changes in Y and positive changes in RE						
	Hypothesis H_0 (no Granger causality)		**t-statistic/F-statistic***		**Probability of rejecting H_0**	
	$RE^+ \rightarrow Y$	$Y^+ \rightarrow RE$	$RE^+ \rightarrow Y$	$Y^+ \rightarrow RE$	$RE^+ \rightarrow Y$	$Y^+ \rightarrow RE$
Short run Granger causality	$\lambda_{2i} = 0$	$\gamma_{2i} = 0$,	5.7115**	0.0115	0.0229	0.9152
Long run Granger causality	$\eta = 0$	$\xi = 0$	7.0300**	NA	0.0155	NA
Causality relationship between negative changes in Y and negative changes in RE						
	Hypothesis H_0 (no Granger causality)		**t-statistic/F-statistic***		**Probability of rejecting H_0**	

	$RE^{-} \rightarrow Y$	$Y^{-} \rightarrow RE$	$RE^{-} \rightarrow Y$	$Y^{-} \rightarrow RE$	$RE^{-} \rightarrow Y$	$Y^{-} \rightarrow RE$
Short run Granger causality	$\lambda_{2i} = 0$	$\gamma_{2i} = 0$,	5.7085**	0.4873	0.0229	0.4901
Long run Granger causality	$\eta = 0$	$\xi = 0$	7.0101**	NA	0.0102	NA

Note: (*, ** & *) implies the rejection of the null hypothesis of no causality at 1% while the NA means not applicable**

V. Conclusions

This study investigates the role of asymmetries in the nexus between renewable energy consumption and economic growth and also test whether the dynamic the nexus is sensitive to the choice of causality testing procedure consider. Beyond the question of whether the causality between renewable energy consumption and economic growth support growth hypothesis, conservation hypothesis, feedback hypothesis or neutrality hypothesis, the study find the dynamic of the causality to be sensitive to the choice of the Granger causality testing procedure consider. Also, the dynamics of the causality appears to be relatively more pronounced when the estimated model is modified to accommodate the role asymmetries in the nexus. On the whole, irrespective of whether the model is linear or nonlinear ARDL, causality between economic growth and energy consumption predominantly support the growth hypothesis. To this end, it is herein recommended that, an energy conservation policy, such as rationing of electricity consumption which is a common practice in Nigeria is likely to harm the country's quest for robust and sustainable economic growth. To avoid any possible adverse effect of such energy policy, the Ministry of Energy in Nigeria should continue to encourage the use of modern energy resources, namely; Solar energy, Wind energy, Hdro energy, Tidal energy, Geothermal energy, among other, towards satisfying the country's total energy demand.

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