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Analysis of CO_2 Emission and Economic Growth as Potential Determinants of Renewable Energy Demand in Nigeria: A Nonlinear Autoregressive Distributed Lags Approach

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ABSTRACT

Concerned by the environmental and economic threats posed by fossil fuels as the source of energy, this study uses the case of Nigeria economy to understand the extent to which economic growth and carbon emissions matters for renewable energy demands. Exploring both the linear and nonlinear ARDL modelling framework, the main empirical findings are that the amplified responsiveness of the consequence of climate change has led to increase in the demand for renewable energy particularly when the underlying source of the emissions is attributable to activities in the transport sector. However, in addition to our findings of oil prices as viable for explaining renewable energy demand, this study further pointed out the economic growth as another potential for explaining renewable energy demand but vary for the boom and recession phases of the business cycle.

Keywords: Renewable Energy Demand, CO_2 Emission, Economic Growth, Nonlinear Autoregressive Distributed Lags, Nigeria
JEL Classifications: C22; F64; Q21; Q42, Q53

1. INTRODUCTION

It is only a commonplace knowledge, that energy anywhere is critical to fostering the quest for industrialization (see Chukwu et al., 2014, Saeed and Sharma, 2012). However, it must be pointed out, that while traditional (non renewable) energy sources such as; oil, natural gas and coal has over time proven to be a stimulant of growth, they also double as emitters of carbon dioxide (CO_2) into the atmosphere (Stern, 2006). Hence, while acknowledging the demand for energy has been on the increasing trend, it is instructive that the search for new energy source (i.e. renewable energy) has also been intensified partially due to the environmental deterioration and adverse climate effects often associated with the non-renewable energy source -led growth. This concern over issues related to energy security and global warming is an indication of potential greater shift from reliance on fossil fuel (nonrenewable) energy in the production process to renewable energy sources (i.e. solar, biomass, wind, geothermal, wave and tidal). Saying it differently, the quest for renewable energy sources such as listed herein for generation of electricity has increases globally from 14% to 24% or thereabout between the period of 2002 and 2017 (see British Petroleum Statistic, 2018). Given its reliability, cost and environmentally friendly features, the demand for renewable energy is becoming more prevalent not only in the developed economies but also in emerging and developing markets (IEA, 2015).

Nigeria is one of the few countries richly endowed with not only nonrenewable energy but also with abundant renewable energy resources, namely; solar radiation, biomass, wind, hydropower, among others. However, the fact that a number of these resources have been left untapped tends to make energy a major priority in the country. Thus, beyond the known energy potential of the Nigerian economy, the country's future energy plans as well as the quest for sustainable economic growth and development cannot be in isolation of good understanding of factors that matter for enhancing the accessibility and utilization these resources. Notwithstanding the proliferation of empirical studies on renewable energy consumption and CO_2 emission relationship (see for example, Sadorsky, 2009; Menegaki, 2011; Bengoche and Faet, 2012; Apergis and Payne, 2014; Omri and Nguyen, 2014; Mehrara et al., 2015, Omri et al., 2015; Ackah and Kizys, 2015, Da Silva et al., 2017; Lau et al., 2018; Olanrewaju et al., 2019), only few of these studies have explored the extent to which the quest for economic growth and concerns related to the adverse effects of CO_2 emission matter for demand for renewable energy.

More so, the majority of the above mentioned studies predominantly focused on the case of emerging and the developed countries with only little consideration for developing economies such as Nigeria. Also, the literature is far from conclusive remarks on the direction of relationship among economic growth, CO_2 emission and renewable energy demand /consumption. For instance, while inference from studies such as: Akar (2016); Saidi and Hammami (2015); Nasreen and Anwar (2014); Omri and Nguyen (2014); Salim and Rafiq (2012); Apergi and Payne (2012); Bengoche and Faet (2012); and Sadorky (2009), unanimously identified with economic growth and CO2 emission as determinants of renewable energy demand, Tugcu et al. (2012) on the other hand found no relationship between economic growth and renewable energy consumption. In the case of Ergun et al. (2019), they found negative relationship between economic growth and renewable energy consumption thereby contradicting some of the previous studies whose findings suggest positive relationship (see Attiaoui et al., 2017; Ackah and Kizys (2015).

In addition to the inconsistency of the extant studies on the direction of the relationship as well the significance or otherwise of the economic growth and CO_2 emission as determinant of renewable energy demand, largely unexplored in the literature is whether the effectiveness or otherwise of economic growth as determinant of demand for renewable energy is sensitive to the period of booming compared to the period of recession. Equally a neglected issue in the literature is whether the potential of CO_2 emission as determinant of renewable energy demand is sensitive to the underlying source of the emission in the first place. To this end, the contribution of this study is in two fold. First, is to determine whether the role of economic growth as determinant of renewable energy demand vary for the period of booming compared to the period of recession using a nonlinear autoregressive distributed lags (NARDL) approach. The second involves the disaggregation of the underlying source of CO_2 into transport and manufacturing sectors and in turn comparatively determine the extent to which they matter for the potential of CO_2 determinant of renewable energy demand.

Beyond this introductory section, the rest of the paper is structured as follows: Section 2 presents the methodology; Section 3 explains the data offers some preliminary analysis; Section 4 presents the empirical results and discusses the findings; while Section 5 concludes the paper and proffers some policy remarks.

2. THE MODEL

Following Narayan and Singh (2007) as well as Sadorsky (2009) approach, we adopt a model that relates renewable energy demand/consumption to level of income, own price of the substitute. The level of income in this case is measure as log of real GDP per capita, while log of world oil price is explored as the proxy for the price of substitute and that is because oil or product derived from oil are often considered as substitute for renewable energy. The inclusion of CO_2 emission in the model as additional determinant of renewable energy demand was motivated by the societal concern related to global warming challenges (see Rafiq and Salim, 2010; 2009). We also control for population growth (POP) as well as trade openness (TOP) as among the potential determinants of renewable energy demand (see Olanrewaju et al., 2019; Ergun et al., 2019). With respect to the renewable energy variable, this study used the same measure as Olanrewaju et al. (2019), where renewable energy was reflected in composite form as ratio of renewable energy consumption to total energy consumption. Thus, the equation for renewable energy demand would take the following form:

$$RE_t = \alpha + \beta_1 Y_t + \beta_2 CO_{2t} + \beta_3 OP_t + \beta_4 POP_t + \beta_5 TOP + \varepsilon_t \quad (1)$$

Equation (1) is the study's baseline model where RE denotes renewable energy, Y is income (economic growth), CO_2 is carbon emission, OP represents oil prices, POP is population growth, while TOP is trade openness.

The carbon emission variable (CO_2) is singly captured both from the aggregate and disaggregated perspectives. The essence is to determine whether the significance of CO_2 as determinant of renewable energy demand depends on whether the carbon emission is due to activities in transport compared to emission due to manufacturing activities. However, to determine the relative significance of the economy growth as determinant of renewable energy demand in the boom period compared to the recession period, the variable Y in equation (1) would is partition into positive (Y^+) and negative (Y^-) changes in economic growth as defined below:

$$Y_t^+ = \max\left(Y_t, 0\right)$$

and

$$Y_t^- = \min\left(Y_t, 0\right)$$

Where the series Y_t^+ equal the boom phase of the business cycle while Y_t^- on the other hand represent the recession of business cycle. Consequently, our extended model or the proposed nonlinear version of the baseline model, where the variables Y_t^+ and Y_t^- are partial sums of positive and negative changes in Y_t representing boom and recession phases of business cycle is given as below.

$$\begin{aligned} RE_t &= \alpha + \beta_1 (Y_t^+ + Y_t^-) + \beta_2 CO_{2t} + \beta_3 OP_t \\ &+ \beta_4 POP_t + \beta_5 TOP + \varepsilon_t \end{aligned} \quad (2)$$

Equation (2) is our extended model or the proposed nonlinear version of the baseline model, where the variables Y_t^+ and Y_t^- are partial sums of positive and negative changes in Y_t.

3. DATA AND PRELIMINARY RESULTS

This study uses 30 annual observations covering the period between 1990 and 2019. All the data are obtained mainly from World Bank Development Indicator (WDI). However, while economic growth (Y) remain as earlier defined and measured, the carbon emission variable (CO_2) from the aggregate is measure in metric tons per capita, while the disaggregated CO_2 emission from transport and manufacturing are measured in million metric tons, respectively. Hence, they are expressed in their natural logarithm form. The renewable energy (RE) demand variable is proxied using renewable energy consumption (% of total final energy consumption). To capture the peculiarity of the investigated economy, we control for the role oil prices (OP) measures as log of WTI. We also control for population growth (POP) and trade openness (TOP), with the former measured as log of total population and the latter is expressed as the sum of import and export as a ratio of GDP.

The summary statistics in Table 1 shows that the average renewable energy consumption as a ratio of total energy consumption in Nigeria is 86% for the period under consideration. The mean statistic in the table further reveal the average carbon emission in metric tons per capita to be 0.56, while average emission from transport measured in million metric seems to overwhelm those from manufacturing activities. Regarding the standard deviation statistics, comparing the value for the individual variables in absolute term is likely to be biased since the variables are expressed in varying unit of measurement. Thus, for the purpose of just comparison, we instead normalize the standard deviation statistic and the indication in the table shows that the renewable energy demand is the most volatile given its relative higher value of standard deviation statistics compared to that of other variables under consideration. With respect to the statistical distribution of the series, RE, CO_2, TRP and TOP all appears to be negatively skewed, while the result seems otherwise (i.e. positively skewed) for economic growth (Y), MAN, OP and POP. For the kurtosis statistic, we find it to be mostly platykurtic for all the series but but RE. Finally, we find the computed probability values attached to the Jarque-Bera normality test statistic be larger than various conventional chosen levels of significance (i.e. 1%, 5% and 10%), which by implications suggest the non-rejection of the no normality across the individual series under consideration.

In line with standard procedure in the literature, particularly when modelling with time series, each of the variables was subjected to unit root and stationarity test. Essentially, both the Augmented Dickey-Fuller (ADF) tests as well as its modified version in the form of Dickey-Fuller GLS (DF-GLS) test were explored. The unit root tests are performed on the earlier defined measures for each of the variables and represented in Table 2 is the outcomes of the unit root test. In what appears to have strengthened our preference for the ARDL estimation technique, a cursory look at the table shows that the order of integration for the variables hovered around I(0) and I(1) nonetheless the choice of unit root test considered.

4. ECONOMETRIC TECHNIQUE AND ESTIMATION PROCEDURE

4.1. The Linear (Symmetric Approach)

In attempt to simultaneously capture both the short and long run dynamics of economic growth and CO_2 emission as determinants of

Table 1: Summary statistic

Statistic	RE	Y	CO2	MAN	TRP	OP	POP	TOP
Mean	86.34	1861.20	0.56	77.61	400.61	47.47	139.14	37.39
Maximum	88.83	2563.90	0.77	116.80	538.14	99.67	195.87	53.28
Minimum	82.96	1348.68	0.33	43.20	232.80	14.42	95.21	20.72
Std. Dev.	1.38	451.67	0.15	21.03	100.20	29.09	30.53	8.67
Normalize Std. Dev.	62.56	4.12	3.73	3.69	3.99	1.63	4.55	4.31
Skewness	−0.59	0.28	−0.26	0.06	−0.39	0.58	0.29	−0.08
Kurtosis	3.04	1.46	1.66	1.88	1.67	1.89	1.89	2.45
Jarque-Bera (JB test)	1.68 (0.43)	3.25 (0.19)	2.49 (0.28)	1.54 (0.46)	2.89 (0.23)	3.08 (0.21)	1.92 (0.38)	0.40 (0.81)

The term Std. Dev. denotes standard deviation while the normalize version was computed as Std. Dev./mean. Also, the values in parenthesis are the probability values associated with the JB test

Table 2: Unit root test results

	ADF test			DF-GLS test		
	Level	First Difference	I (d)	Level	First Difference	I (d)
RE_t	−2.7956[a]**	-	I (0)	−2.5999[a]**	-	I (0)
Y_t	−2.0826[b]	−2.6477[b]*	I (1)	−2.3539[a]**	-	I (0)
CO_{2t}	−1.7076[b]	−4.4658[a]***	I (1)	−1.7738[b]	−4.5471[a]***	I (1)
MAN_t	−3.3908[b]*	-	I (0)	−3.5163[b]**	-	I (0)
TRP_t	−2.6380[b]*	-	I (0)	−2.0381[b]**	-	I (0)
OP_t	−1.8733[b]	−4.6861[a]***	I (1)	−1.8628[b]	−4.6826[b]***	I (1)
POP_t	−2.9830[b]	−3.2788[a]*	I (1)	−0.9127[b]	−3.6936[b]**	I (1)
TOP_t	−3.0371[a]**	-	I (0)	−2.9356[a]***	-	I (0)

The Schwarz info criteria was used in determine the exogenous lags while the superscripts a and b represent model with constant and model with constant and trend, respectively. The asterisks ***, ** and * implies that series is stationary at 1%, 5% and 10% levels of significance, respectively renewable energy demand, we explore the ARDL model developed by Pesaran et al. (2001) given its flexibility to accommodate variables with mixed order of integration. More importantly, the Bound cointegration testing component of the ARDL model have been proven as capable of providing robust long run estimates even in the presence of some endogenous variable in the model (see Narayan, 2005). Thus, the ARDL specification for the renewable energy demand model earlier represented in equation (1) is as below.

$$\Delta RE_t = c + \alpha_1 RE_{t-1} + \alpha_2 Y_{t\_1} + \alpha_3 CO_{t\_1} + \alpha_4 OP_{t\_1} + \alpha_5 POP_{t-1} + \alpha_6 TOP_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta RE_{t-j} + \sum_{i=0}^{q_2} \beta_{2i} \Delta Y_{t-i} + \sum_{i=0}^{q_3} \beta_{3i} \Delta CO_{t-i} + \sum_{i=0}^{q_4} \beta_{4i} \Delta OP_{t-i} + \sum_{i=0}^{q_5} \beta_{5i} \Delta POP_{t-i} + \sum_{i=0}^{q_6} \beta_{6i} \Delta TOP_{t-i} + \mu_t \quad (3)$$

While all the variables remain as earlier defined, it must be further pointed out that the term *CO* implying carbon emission will be singly analyze both from the aggregate and the disaggregated perspectives. Starting with the long run parameters for the intercept as well as the slope coefficients can be computed as follows: $-\frac{c}{\alpha_1}, -\frac{\alpha_2}{\alpha_1}, -\frac{\alpha_3}{\alpha_1}, -\frac{\alpha_4}{\alpha_1}, -\frac{\alpha_5}{\alpha_1}$ and $-\frac{\alpha_6}{\alpha_1}$. It is instructive that in the long run, it is assumed that $\Delta RE_{t-i} = 0$ and $\Delta(Y, CO, OP, POP, TOP)_{t-j} = 0$, such that the short run estimates can be obtained as: $\beta_{1j}, \beta_{2i}, \beta_{3i}, \beta_{4i}, \beta_{5i}$ and β_{6i}.

The fact that series in first difference can accommodate more than one lag meaning it is necessary to determine the optimal lag combination for the ARDL model using. Essentially, the Schwartz Information Criterion (SIC) is used in the context of this study to determine the optimal lag length for the estimated ARDL model, where the lags combination with the least SIC value was given preference as the optimal lag among the competing lag orders. Haven determined the optimal lag length and by implication the preferred ARDL model, we then proceed on to validate or refute the null hypothesis of no cointegration or long run relationship using Bound cointegration testing procedure. In line with the term 'bound', the Bound cointegration test usually involve upper and lower bounds procedure following an F distribution, such that; if the calculated F-statistic is greater than the upper bound, the null of no cointegration, but the hypothesis hold if the calculated F-statistics is less than the lower bound. In the context of this present study, the null hypothesis of no long run relationship (i.e. no cointegration) is expressed as: $H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ while the alternative hypothesis suggesting there is long run relationship (cointegration) can be symbolized as: $H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$. Equation (3) can, however, re-specified to include an error correction term as follows:

$$\Delta RE_t = c + \xi \upsilon_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta RE_{t-j} + \sum_{i=0}^{q_2} \beta_{2i} \Delta Y_{t-i} + \sum_{i=0}^{q_3} \beta_{3i} \Delta CO_{t-i} + \sum_{i=0}^{q_4} \beta_{4i} \Delta OP_{t-i} + \sum_{i=0}^{q_5} \beta_{5i} \Delta POP_{t-i} + \sum_{i=0}^{q_6} \beta_{6i} \Delta TOP_{t-i} + \mu_t \quad (4)$$

Where υ_t-1 is the linear error correction term while the parameter ζ is the speed of adjustment.

4.2. The Nonlinear (Asymmetric Approach)

One of the main objectives of this study is to test whether the extent to which economic growth matter for renewable energy demand vary for the boom period when compared to the recession period. To achieve this, we follow the nonlinear ARDL (NARDL) method proposed by Shin et al. (2014) such that the economic growth variable is further portioning into positive and negative partial sum as demonstrated in equation (5) below:

$$\Delta RE_t = c + \alpha_1 RE_{t-1} + \alpha_2^{+}(Y_{t-1}^{+} + Y_{t-1}^{-}) + \alpha_3 CO_{t\_1} + \alpha_4 OP_{t\_1} + \alpha_5 POP_{t-1} + \alpha_6 TOP_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta RE_{t-j} + \sum_{j=0}^{q_2} \beta_{2i}^{+}(\Delta Y_{t-i}^{+} + \Delta Y_{t-i}^{+}) + \sum_{i=0}^{q_3} \beta_{3i} \Delta CO_{t-i} + \sum_{i=0}^{q_4} \beta_{4i} \Delta OP_{t-i} + \sum_{i=0}^{q_5} \beta_{5i} \Delta POP_{t-i} + \sum_{i=0}^{q_6} \beta_{6i} \Delta TOP_{t-i} + \mu_t \quad (5)$$

Where Y_t^{+} (economic growth) with positive sign subscript) and Y_t^{-} (economic growth with negative sign subscript) captured positive (boom) and negative changes (recession) in economic changes, respectively. The long run (elasticity) coefficients for renewable energy demand due to positive and negative changes in economic growth are calculated as: $-\frac{\alpha_2^{+}}{\alpha_1}$ and $-\frac{\alpha_2^{-}}{\alpha_1}$. The nonlinear economic growth determinant of renewable energy demand will be computed as positive and negative partial sum decomposition of economic growth as defined below:

$$Y_t^{+} = \sum_{k=1}^{t} \Delta Y_{ik}^{+} = \sum_{k=1}^{t} \max(\Delta Y_{ik}, 0) \quad (6a)$$

$$_t^{-} = \sum_{k=1}^{t} \Delta e_{ik}^{-} = \sum_{k=1}^{t} \min(\Delta e_{ik}, 0) \quad (6b)$$

Again, the procedure above for computing long run (elasticity) coefficients for the asymmetric pass-through will also be observed when the exchange rate is endogenously represented by interacting each of the decomposed exchange rate fluctuations with changes in oil prices. Similar to the symmetric pass-through modelling approach, the error correction version of equation (5) can be represented as follows:

$$\Delta RE_t = c + \tau_i \xi_{i,t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta RE_{t-j} + \sum_{j=0}^{q_2} \beta_{2i}^{+} (\Delta Y_{t-i}^{+}$$
$$+ \Delta Y_{t-i}^{+}) + \sum_{i=0}^{q_3} \beta_{3i} \Delta CO_{t-i} + \sum_{i=0}^{q_4} \beta_{4i} \Delta OP_{t-i}$$
$$+ \sum_{i=0}^{q_5} \beta_{5i} \Delta POP_{t-i} + \sum_{i=0}^{q_6} \beta_{6i} \Delta TOP_{t-i} + \mu_t \qquad (7)$$

The error correction term ($\zeta_{i,t-1}$) in equation (7) capture the long run equilibrium in the asymmetric panel ARDL specification, while its associated parameter (τ_i) is the speed of adjustment term that measures how long it takes the system to revert to its long-run equilibrium in the presence of a shock.

To refute or validate the significance of asymmetric in the pass-through effects of exchange rate fluctuations on the inflations of the investigated economies, the Wald restriction test which is considered. Depending on the preferred estimator, the null hypothesis of no asymmetry for instance, $H_0 : \alpha_i^{+} = \alpha_i^{-}$ will be tested against the alternative $H_1 : \alpha_i^{+} \neq \alpha_i^{-}$ to establish the long run asymmetric cointegration. On the other hand, the the short run asymmetric conitegration is tested with: : $H_{0:}\ \beta^{+}_{2i} = \beta^{-}_{2i}$ while the alternative hypothesis is stated as $H_1 : \beta_{2i}^{+} \neq \beta_{2i}^{-}$.

5. EMPIRICAL RESULTS AND DISCUSSION

The empirical estimates in Table 3 explore the potential of economic growth and CO_2 emission as determinants of renewable

Table 3: Empirical result for CO2 –economic growth as determinants of RE in Nigeria

Regressor	*ARDL*	*NARDL*	NARDL with disaggregated CO_2: MAN sector	NARDL with disaggregated CO_2: TRP sector
Short run				
c	8.306*** (2.945)	7.865** (2.119)	9.580*** (3.886)	3.067 (5.779)
ΔY_t	2.269 (1.537)			
Y_t^{+}		0.317 (5.479)	−2.757 (6.095)	1.814** (0.057)
Y_t^{-}		−12.591 (9.166)	−11.877 (9.928)	0.729 (10.565)
ΔCO_{2t}	1.959*** (0.215)	1.734*** (0.046)	0.752*** (0.011)	3.884** (0.167)
ΔOP_t	1.391** (0.638)	1.132 (0.696)	2.420** (0.851)	1.997*** (0.784)
ΔPOP_t	4.566** (2.151)	−1.892 (7.168)	−9.683 (7.483)	11.811 (9.011)
ΔTOP_t	−0.067*** (0.023)	−0.064** (0.023)	−0.129*** (0.027)	−0.102** (0.025)
ECT_t	−0.820*** (0.094)	−0.794*** (0.088)	−0.599*** (0.074)	
Long run				
Y_t	5.202 (3.264)			
Y_t^{+}		0.399 (6.904)	−4.603 (10.047)	1.139** (0.009)
Y_t^{-}		−15.841 (12.403)	−19.826 (17)	0.996 (14.362)
CO_{2t}	2.698*** (0.563)	1.930*** (0.019)	0.181*** (0.004)	3.580*** (0.285)
OP_t	1.695* (0.845)	1.425 (0.907)	4.040** (1.542)	2.728** (1.110)
POP_t	5.565** (2.579)	−2.381 (9.131)	−1.1642 (3.339)	6.135 (11.325)
TOP_t	−0.082** (0.033)	−0.081** (0.035)	−0.216 (0.061)	−0.140** (0.042)

Cointegration testing result

Level of Significance	ARDL F-stat	ARDL I (0)	ARDL I (1)	NARDL F-stat	NARDL I (0)	NARDL I (1)	NARDL -MAN F-stat	NARDL -MAN I (0)	NARDL -MAN I (1)	NARDL -TRP F-stat	NARDL -TRP I (0)	NARDL -TRP I (1)
10%	8.39	2.08	3.00	7.42		2.94	6.02	1.99	2.94	6.42	1.99	2.94
5%		2.39	3.38		2.27	3.28		2.27	3.28		2.27	3.28
1%		3.06	4.15		2.88	3.99		2.88	3.99		2.88	3.99

	NARDL	NARDL-MAN	NARDL-TRP
$W_{SR}\ F-stat$	1.855 (0.182)	2.532 (0.104)	1.944** (0.050)
$W_{LR}\ F-stat$	1.527 (0.241)	1.944 (0.169)	3.243* (0.060)

Diagnostic test/Post estimation result

	ARDL	NARDL	NARDL -MAN	NARDL -TRP
Post estimation results				
AdjR^2	0.70	0.70	0.65	0.66
F-stat.	11.58 (0.00)	10.00 (0.00)	8.19 (0.00)	8.70 (0.00)
SIC	2.10	2.89	3.04	3.00
Q-stat. (2)	0.173 (0.917)	0.303 (0.859)	0.648 (0.723)	2.064 (0.356)
Q^2*-stat.* (2)	1.798 (0.407)	1.717 (0.424)	7.043** (0.030)	7.192** (0.027)
ARCH−LM (2)	0.725 (0.494)	0.685 (0.513)	2.966* (0.071)	3.285* (0.055)

The term W denotes Wald restriction test distributed as χ (5) for testing the null hypothesis of no asymmetry in the estimate. The subscripts SR and LR denotes short run and long run situations. The value in parenthesis are standard error for the estimates but probability values in the cases of the post estimation tests while ***, ** and * denotes 1%, 5% and 10% levels of significance energy demand across three alternatives estimation approaches. First is the baseline model using ARDL estimation technique, the second is a non-linear ARDL model (i.e. NARDL), where the economic growth variable was partitioned into positive and negative changes. The third and last approach is the model that tests whether the viability of CO_2 as determinant of renewable energy is sensitivity to the underlying sources of the emission such as emission due to manufacturing activity (MAN) when compared to those attributed to transportation activity (TRP). To ascertain the reliability of our empirical findings, we performed a number of post estimation and/or diagnostic namely, serial correlation test (using correlogram Q-statistic and the squared version) and heteroscedasticity test (using ARCH LM test). Starting with the Bound cointegration testing results, the null hypothesis of no long run relationship appears to be consistently rejected across all the alternation estimation approaches. What this portends, is that there is nonetheless the mixed integration property of the series, there is potential of a long run relationship between economic growth, CO2 emission and renewable energy demand in Nigeria. Further supporting this position is the negative sign on the error correction term (ECT) coefficients and the fact that the coefficient are statistically reported as significant is an indication that any forms of disequilibrium due to shocks in the previous year is likely to be corrected for in the present year. This evidence seems to hold estimates obtained from both the linear and nonlinear ARDL model and irrespective of whether the carbon emissions are from manufacturing sector or transport sector.

However, a further look at the empirical results in Table 3 seems to be suggesting that irrespective of the short run or long run dynamics of the relationship, we find the economic exhibiting little or no significant potential as determinant of renewable energy demand in Nigeria. Although, the sign of the relationship appears to be positive for a positive economic change and negative for a for a negative economic change, but the insignificance of these relationship seems to be suggesting that the fact renewable energy in Nigeria is not statistically influenced by the level of economic growth is not sensitive to whether the economy is in boom or recession phase. Confirming this scenario is the Wald test result, where the null hypothesis of no asymmetry tends to hold for both the short and long run situations. Similar to our findings is the study by Tugcu et al. (2012) whose findings also reveal that there is no causal relationship between renewable energy demand and GDP in countries such as France, Italy, Canada, and the USA.

The aforementioned notwithstanding, we find the increasing concern over issues related to energy security and global warming as probable determinant of renewable energy demand in Nigeria. For instance, we find positive and statistically significant impact of CO_2 emissions on renewable energy demand. The fact that this evidence hold consistently for both the linear and nonlinear models find support in the growing assertion that the amplified responsiveness of the consequence of climate change has led to increase in the demand for renewable energy. This has been particularly attributed to the increasing distress associated to consequences of global warming which is the release of carbon dioxide (CO_2), Nitrous oxide (N_2O) and Methane (CH_4) into the atmosphere which has resulted into climate change. To this end, many developing countries, Nigeria inclusive have started to explore the utilization of renewable energy, namely; wave, tidal, geothermal, solar, wind, biomass and hydro as a substitute to current energy sources for instance, fossil fuel.

Equally an interesting finding is the fact that while carbon emissions attributed to both manufacturing and transport activities tends to matter for renewable energy demand in Nigeria, the magnitude of the impact seems to be relatively for the transport sector compared to emissions from manufacturing sector. More so, we find the nonlinear feature of the economic growth to be statistically viable in its determination of renewable energy demand but mainly when the source carbon emission is transport sector. For instance, when transport sector is the source of carbon emissions in the nonlinear model, we find the null hypothesis of no asymmetric to be rejected thus implying that the potential of economic growth as determinant of renewable energy demand may vary for the boom period compared to the recession period or for positive economic change compared to negative economic change. To put it differently, we find a positive change in economic growth with potential to cause increasing renewable energy demand but same cannot be said of negative change in economic growth. On the whole, we find the potential of economic growth as determinant of renewable energy demand to be sensitive to the period of boom relative to recession phase but mainly when the source of carbon emissions in the estimated nonlinear models is transport sector. Also worthy of note is our finding of positive relationship between oil prices and renewable energy demand in Nigeria. The significance of the evidence tends to be pointing out the fact that increasing oil prices is likely to fuel the quest for alternative source of energy leading to increase in renewable energy demand.

6. CONCLUSION

Partially, due to the environmental and economic threats posed by fossil fuels, attention to the determinants of renewable energy demand has increased over the last few years globally due to these challenges. Using the case of Nigeria economy, we explore both the linear and nonlinear ARDL modelling framework to evaluate the potential of economic growth –carbon emissions as the determinants of renewable energy demands in Nigeria. The main empirical findings are that the amplified responsiveness of the consequence of climate change has led to increase in the demand for renewable energy particularly when the underlying source of the emissions is attributable to activities in the transport sector.

In addition to our finding of oil prices as another important potential for explaining renewable energy demand, we also find the potential of economic growth as determinant of renewable energy demand to be sensitive to the period of boom relative to the recession phase, particularly when the source of carbon emissions in the estimated nonlinear models is transport sector. To this end, economic policies that can promote economic growth to a level where it may actually foster demand for modern renewable energy consumption are recommended.

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