IMPACT OF RENEWABLE ENERGY CONSUMPTION ON ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

This study examined the impact of renewable energy consumption on economic growth in Nigeria from 1990-2022. The data for this study were obtained from World Bank Development Indicators, the Central Bank Statistical Bulletin, and the World Carbon Budget. The study Non-linear Autoregressive Distributed Lag (NARDL) model. The NARDL Wald test result shows that an asymmetric relationship exists between renewable energy consumption and economic growth in the long run. The short-run and long-run results for the NARDL revealed that both the positive and negative changes in renewable energy consumption are significant at a 5% significance level. Still, the positive change exhibited a positive relationship between renewable energy consumption and economic growth, while the negative change exhibited a negative relationship. Also, the long-run results revealed that positive change is significant while negative change is not. It was observed that the impact of positive change is negative while that of negative change is positive, as shown in their respective coefficients of -0.526016 and 0.184204, respectively. Based on the findings, the study recommended that the government, policymakers, and all stakeholders in the energy sector support policies that will help increase the consumption of renewable energy in the country.

***Keywords**: Renewable energy, economic growth, non-linear autoregressive distributed lag, carbon emission, climate change.*

1.0 Introduction

Nigeria has abundant renewable energy resources, including wind, solar, hydro, biomass, and geothermal energy, which have the potential to boost power generation and economic activities significantly. While the country has substantial wind energy potential, its development is still in the early stages, with no wind farm connected to the national grid (Adedipe et al., 2018. Small-scale wind turbines are used for domestic applications such as battery charging, water pumping, and small enterprise electrification.

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The country's only large-scale onshore wind turbine, with a 10kW capacity, is located in Rimi, Katsina State (Mohammed et al, 2017), and other small turbines are installed in Sokoto, Bauchi, and Katsina for water pumping (Ebhota & Tabakov, 2018). The potential for wind energy generation in Nigeria is vast but underutilized.

Nigeria has significant biomass and bioenergy potential, estimated at 200 billion kg/year and 2.58 billion GJ, which could account for about 51% of the country's total energy consumption by 2015 (Oyedepo 2012). However, only a small fraction (5% to 12%) of the fuel wood used annually for cooking is exploited for energy. Despite this potential, Nigeria remains one of Africa's lowest consumers of renewable energy per capita, heavily relying on gas-fired power plants, which supply around 75% of its energy (Nweke-Eze, 2022). The country’s energy mix is dominated by inefficient thermal power, with minimal contributions from renewables like wind and solar. This dependence on fossil fuels causes environmental issues, including climate change risks, pollution, and resource depletion (Ncheke and Akpalaoka, 2022).

Climate change has heavily impacted Nigeria's economy despite contributing minimally to global greenhouse gas emissions (0.34% of global CO_2) (WB, 2019). Ranked among the world's ten most vulnerable nations, Nigeria has faced severe climate effects, such as the 2012 drought and widespread floods that caused nearly $7.3 billion in damages. To address these challenges and maintain a reliable power supply, Nigeria requires significant investment in renewable energy. The United States Trade Administration estimates that it will cost up to $100 billion over the next 20 years to maintain current energy services, with the investment needed for universal energy access being even higher, Nigeria Century Commercial Guide (NCCG, 2023).

This paper aims to examine the impact of renewable energy consumption on economic growth in Nigeria using a Non-linear Autoregressive Distributed Lag Model (NARDL). The study highlights the non-linear relationship between renewable energy and economic growth, providing valuable policy insights. The paper is structured as follows: Section 2 offers an overview of renewable energy in Nigeria, Section 3 covers the theoretical framework and literature review, Section 4 presents the model, Section 5 discusses the data and econometric results, and the concluding section highlights key inferences and policy implications.

2.0 Conceptual literature

2.1 Renewable Energy

Renewable energy can be broadly defined as any energy generated from natural processes, including hydropower, geothermal, solar, tides, wind, biomass, and biofuels. Natural endowments are rich sources of adaptation, innovation, and inspiration for numerous power generation technologies. Renewable energy often displaces conventional fuels in four areas: electricity generation, hot water/space heating, transportation, and rural (off-grid) energy services (Renewable Energy Policy Network for the 21st Century, 2010).

2.2 Greenhouse Gas Emissions in Nigeria

Nigeria remains the country with the highest percentage of greenhouse emissions in Africa due to the activity of oil and gas flaring. It is one of the top gas-flaring countries in the world, with about 65% of the total global flare and GHG emissions (Etimere, 2021). The gas flares give rise to atmospheric pollutants. These atmospheric pollutants comprise oxides of nitrogen (NO_2), carbon dioxide (CO2) and sulfur dioxide (SO2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulfide (H2S) (Shahab-Deljoo et al.,2023).

Through gas flaring alone, Nigeria contributes an estimated 48 million metric tons of GHG emissions into the atmosphere more than sub-Saharan Africa combined (Etemire, 2021). Coincidentally, the gas flaring sites responsible for these emissions are located in the southern parts of the country, in the Niger Delta, as that is where most deposits of oil and gas are found. The Niger Delta, and indeed the entire country, has for decades experienced first-hand the negative impacts of unmitigated GHG emissions through gas flaring (Afinotan, 2022).

2.3 Theoretical Framework

2.3.1 Endogenous Growth Theory

In the 1980s, Paul Romer developed endogenous growth theory to address neoclassical growth theory's limitations, ignoring key internal factors. Endogenous growth theory argues that economic growth can be influenced by government policies that promote innovation, research, and development (R&D). Unlike neoclassical models, which attribute long-term growth to exogenous factors like population growth and technological progress, endogenous growth theory treats technological progress as an internal factor driven by investment, capital stock, and human capital. It emphasizes that improvements in innovation, knowledge, and human capital boost productivity and foster economic growth.

2.3.2 Empirical Literature Review

Several studies have explored the relationship between renewable energy consumption and economic growth. Nosheen et al. (2023) found that renewable energy positively contributes to long-term economic growth in most studied nations. Rahaman et al. (2023) used the NARDL approach to show that both positive and negative changes in renewable energy consumption positively impact GDP in South and East Asian countries, while urbanization has a negative effect. Jia et al. (2023) found that renewable energy consumption directly contributes to economic growth in 90 Belt and Road countries, influencing growth indirectly through gross capital formation and trade. Dissanayake et al. (2023) found no Granger-causal relationship between GDP and renewable energy consumption outside Economies in Transition but noted a one-way relationship between GDP and CO2 emissions. Alnabulsi et al. (2023) showed that renewable energy consumption, along with CO2, capital formation, and population growth, positively impacts GDP in Jordan. Ezenwa et al. (2021) found a bi-directional causality between renewable energy consumption and GDP in Nigeria, with negative effects on GDP between 1990 and 2007, but positive impacts from 2009 to 2015. Azeakpono and Lloyd (2020) reported that although renewable energy consumption and economic growth increased in Nigeria from 1990 to 2016, renewable energy had no significant positive impact on economic growth, with no causality between the two.

3.0 Data and Methodology

To achieve the objective of this study, annual time series data from 1990 to 2022 was employed. Data on renewable energy consumption, foreign direct investment, gross domestic product and population growth were obtained from World development indicators. In contrast, data on Carbon emission and trade openness were obtained from the World Carbon Budget and Central Bank statistical Bulletin, respectively.

Building on the endogenous growth framework, the neoclassic production function is therefore stated as follows:

$$Y = F\ (A, K, L) \tag{1}$$

Where:

Y=Aggregate real output

K=Stock of capital

L=Stock of labour

A=Technology or technological advancement

3.1 Model Specification

The study explores the impact of renewable energy consumption, carbon dioxide emission, Population Growth, foreign direct investment, and Trade openness on economic growth in Nigeria using the NARDL model, see Mighri & Alsagaf, 2022.

In this study, the proposed linear equation is stated below:

$$GDP = f(RE, CO2, POG, FDI, TOP,) \quad (2)$$

3.2 Econometric form for the equation

$$GDP = \beta_0 + \beta_1 RE + \beta_2 CO2 + \beta_3 lnFDI + \beta_4 TOP + \beta_5 + \beta_6 lnPOG + \mu_t \quad (3)$$

Where:

GDP= Gross Domestic Product, proxy for Economic Growth
RE= Renewable Energy
Co2= Carbon Dioxide emission
POG= Population Growth
FDI= Foreign Direct Investment
TOP= Trade openness
β_0, β_1, .. β_6= *parameter estimates*

μ= *stochastic error term*

Formally, Shin et al. (2014) introduced the following regression:

$$\begin{aligned} \Delta lnGDP = \beta_0 & + \beta_1 lnGDP^{+}_{t-i} + \beta lnREC^{+}_{t-1} + \beta + \beta_{REC}\, REC^{-} + \beta lnCO2^{+}_{t-i} + \beta lnCO2^{-}_{t-i} + \beta lnFDI^{+}_{t-i} \\ & + \beta lnFDI^{-}_{t-i} + \beta lnTOP^{+}_{t-i} + \beta lnTOP^{-}_{t-i} + \beta lnPOG^{+}_{t-i} + \beta lnPOG^{-}_{t-i} + \sum_{i=1}^{p} \beta lnREC^{+}_{t-1} \\ & + \sum_{i=1}^{p} \beta i^{+} \Delta REC^{+}_{t-1} + \beta i^{-} \Delta REC^{-}_{t-1} + \sum_{i=1}^{p} \Delta\beta lnCO2^{+}_{t-i} + \Delta\beta lnCO2^{-}_{t-i} \\ & + \sum_{i=1}^{p} \Delta\beta lnFDI^{+}_{t-i} + \Delta\beta lnFDI^{-}_{t-i} + \sum_{i=1}^{p} \Delta\beta lnTOP^{+}_{t-i} + \Delta\beta lnTOP^{-}_{t-i} \\ & + \sum_{i=1}^{p} \Delta\beta lnPOG^{+}_{t-i} + \Delta\beta lnPOG^{-}_{t-i} + \mu_t \end{aligned}$$

In the above equation (10), the movements of REC are broken into its increasing and decreasing partial sum i.e REC_t=REC+ $REC_t^+ + REC_t^-$ whereas $REC_t^+ + REC_t^-$ are the partial sum of the positive and negative changes in theREC_t, that is, the increasing and the decreasing relationship. The following formulas are generated to show the positive and the negative changes in REC_t

$$GDP_t^+ = \sum_{q=1}^{t} \Delta REC_q^+ = \sum_{q=1}^{+} max(\Delta REC^+ q, 0)$$

$$GDP_t{}^- = \sum_{=1}^{t} \Delta REC_q^- = \sum_{q=1}^{-} min(\Delta RE^- q, 0)$$

The following is the nonlinear ARDL (*p*,*q*) model developed by Shin et al 2014:

$$Y_t = \sum_{j=1}^{p} \emptyset j Y_t + \sum_{j=0}^{q} \left(\emptyset_j^+ X_{t-j}^+ + \emptyset_j^- X_{t-j}^- \right) + et$$

$$GDP_t = \sum_{j=1}^{p} \emptyset j gdp_t + \sum_{j=0}^{q} \left(\emptyset_j^+ REC_{t-j}^+ + \emptyset_j^- REC_{t-j}^- \right) + et$$

Where: Y_t= is the dependent Variable

x_t Is a $k \times 1$ vector of multiple regressors defined such that $x_t = x_0 + x_t^+ + x_t^-, \emptyset_j$ is the Autoregressive parameter, $\emptyset_i^+$ and $\emptyset_j^-$ are the asymmetric distributed lag parameters, and ε_t is an $i.i.d.$ process with zero mean and variance. Shin et al (2014) focus on the case in which x_t is decomposed into $x_t^+ \ and \ x_t^-$ a threshold zero, thereby distinguishing between positive and negative changes in the rate of growth of x_t

4.0 Results and Discussion

4.1 Unit Root Tests

This study performed the ADF and PP unit root tests to determine whether the time series data are stationary.

Table 1. Unit root tests of variables

Variable		**Phillips Perron**			**Augmented Dickey-Fuller**	
	AT LEVEL	**1st DIFF.**	**I(d)**	**AT LEVEL**	**1ST DIFF**	**I(d)**
GDP	-3.809980**	-19.55703***	I(0)	-3.683300**	-9.338412***	I(0)
REC	--1.52946	-5.997985***	I(1)	-1.539142	-5.9855504***	I(1)
CO_2	-0.327559	-15.51179***	I(1)	-4.379375**	-7.536680***	I(0)
LNFDI	-3.887041**	-7.769829***	I(0)	-3.700060**	-7.070577***	I(0)
LNPOG	-	-1.093865	I(0)	-7.230239***	-7.070577	I(1)
TOP	9.142203*** -0.298924	-6.300972***	I(1)	-0.504016	-5.975728***	I(1)

Where *, **, *** indicate significance at 10%, 5%, and 1%, respectively, and LN is the logarithm operator. **Source:** *Computed by the Author using Eviews 10*

The outcomes of the unit root tests performed on the variables are summarized in Table 2 for both ADF and PP testing. PP test for unit root reveals that Gross Domestic Product, Foreign Direct Investment and Population Growth are stationary at level. At the same time, Renewable Energy Consumption, Carbon emission and Trade openness are stationary at first difference. The ADF test result for unit root indicates that GDP, CO_2 and LNPOG are stationary at a level while REC, LNFDI and TOP are all stationary at first difference.

4.2 Cointegration bound test

NARDL BOUND TEST

Following the confirmation that the series consisted of both integration of orders 0 and 1, a necessary condition for NARDL model estimation, the long-run bound test based on the NARDL technique is presented in Table 2 below.

Test Statistic	Value	Significance Level	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	13.25700	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Table 2 shows the result of the NARDL bounds test for co integration, that is, the NARDL equation. The estimated F- statistics (13.25700) exceed the critical value of the upper bound I (1) at 5%. Hence, the null hypothesis of no long-run relationship among the variables in the equation is rejected. This implies that there is a long-run relationship in the asymmetric model.

Table 4.3 Long Run Asymmetric Test Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REC_POS	-0.526016	0.100100	-5.254918	**0.0002**
REC_NEG	0.184204	0.125520	1.467526	**0.1586**
CO2_POS	-0.198059	0.074103	-2.672744	**0.0150**
CO2_NEG	0.063422	0.043472	1.458894	**0.1609**
LNFDI _POS	0.470601	0.185362	2.538826	**0.0200**
LNFDI _NEG	0.081094	0.024313	3.335488	**0.0059**
TOP_POS	0.159132	0.073162	2.175067	**0.0403**
TOP_NEG	0.102140	0.076486	1.335419	**0.2065**
LNPOP_POS	-0.272517	0.072689	-3.749078	**0.0028**
LNPOP_NEG	-0.295336	0.107166	-2.755862	**0.0174**
C	0.159132	0.033936	4.689187	**0.0005**

The long-run results from the NARDL model on the impact of renewable energy consumption (REC) in Nigeria show a negative relationship with GDP, indicating that a unit increase in REC decreases GDP by 0.52%, while a negative change in REC results in a 0.18% increase in economic growth, though not statistically significant. This contradicts Salisu (2023), but aligns with Somoye et al. (2022). Regarding CO2 emissions, a positive change in CO2 reduces GDP by 0.19%, suggesting the detrimental effects of increased carbon emissions from dirty energy sources on economic growth and climate vulnerability. The impact of foreign direct investment (FDI) shows that a 1% increase in FDI boosts economic growth by 0.47%, while a 1% decrease lowers it by 0.08%, with positive changes having a stronger effect, consistent with Sijuwola (2023). Trade openness (TOP) has a positive long-term impact on carbon emissions, aligning with Iorember et al. (2019). Population growth shows a negative effect on economic growth, with 1% increases or decreases reducing growth by 0.27% and 0.29%, respectively, supporting the Malthusian theory and aligning with Ochinyabo (2021), but contradicting Olatunji et al. (2022).

Table 4.4: Short Run Asymmetric test result

Variable	Coef	Std. Error	t-Statistic	Prob.
REC_POS	0.195539	0.014075	13.89272	**0.0000**
REC_NEG	-0.797120	0.222598	-3.580991	**0.0043**
CO2_POS	0.585731	0.228561	2.562690	**0.0264**
CO2_NEG	-0.216161	0.092669	-2.332604	**0.0315**
LNFDI _POS	0.077407	0.185898	0.416394	**0.6820**
LNFDI _NEG	0.344768	0.128588	2.681182	**0.0171**
TOP_POS	0.846555	0.156290	5.416576	**0.0000**
TOP_NEG	0.052033	0.007745	6.718377	**0.0011**
LNPOP_POS	-0.669314	0.135958	-4.922933	**0.0044**
LNPOP_NEG	0.858622	0.384968	2.230369	**0.0395**
ECM(-1)	-0.153136	0.034098	-4.491007	**0.0004**
R-squared	0.640606			
Adjusted R-squared	0.637599			

The coefficient of ECMt-1 shows the speed of adjustment back to the long-run equilibrium after a short-run shock. Here, it can be deduced that the disequilibrium that occurred in the short run can revert to equilibrium in the long run at the speed of -0.153136. The R^2 shows that the independent variables in the model explain 64% of the variation in GDP.

The short-run results reveal that a positive shock in renewable energy consumption (REC) increases GDP by 0.19%, while a negative shock decreases GDP by 79%, both statistically significant. CO2 emissions show mixed effects, with positive changes increasing GDP by 58% and negative changes reducing it by 21%. Foreign direct investment (FDI) inflows have a positive but insignificant short-term impact, suggesting that while they can stimulate growth, volatility may dampen the effects over time. Negative FDI shocks significantly boost economic complexity. Trade openness (TOP) shows that both positive and negative changes in TOP increase the economy, with 1% increases boosting GDP by 84% and 52%, respectively. Population growth has a negative impact, with a 1% increase in population reducing GDP by 66%, while a negative change in population growth increases the economy by 85%.

4.5 NARDL Wald Test

Table 5:

Test Statistic	Value	Df	Probability
t-statistic	-3.093333	12	**0.0093**
F-statistic	9.568709	(1, 12)	**0.0093**
Chi-square	9.568709	1	**0.0020**

Table 9.1, Based on the results above, suggests that there is a long-run asymmetric relationship between the dependent and independent variables.

4.6 NARDL Diagnostic Test Results

Table 6: NARDL Diagnostic Test Results

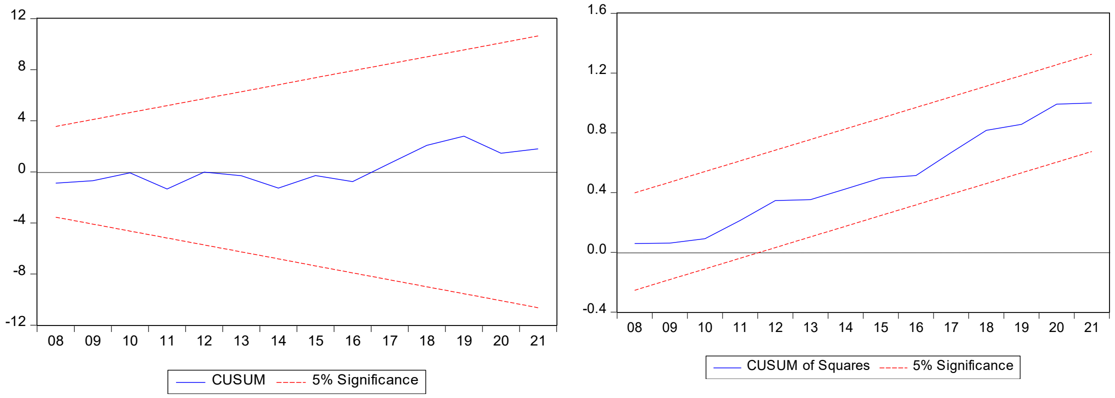
Test Statistics	Probability Value
χ2 Serial correlation LM test	0.1045
Heteroscedasticity	0.9154

Source: *Author's Computation using EViews*

Table 6 depicts the results of the diagnostic checks. The study examined the consistency of the coefficients of the estimates based on the chi-square and Lagrange Multiplier (LM) tests as well as the stability test using recursive residuals suggested by Brown et al. (1975). All test statistics on each null hypothesis could not be rejected at any conventional level of significance. Hence, there is no serial correlation, non-normality, or heteroscedasticity.

4.7 NARDL SATBILITY TEST

Figure 1: CUSUM and CUSUMQ



The tests and results displayed in Figures 1 and 2 are utilized in this investigation on the consistency of the Non-linear Autoregressive Distributed Lag (NARDL) model estimates. The graph of the CUSUM and the CUSUMQ statistics for both equations fall comfortably within the bound.

Recommendations

The following recommendations are given to be considered by policymakers in Nigeria: The findings highlight that renewable energy consumption is a key driver of economic growth, urging the government to implement policies that promote its use. These policies will support economic growth and address climate change by reducing reliance on non-renewable energy sources. To combat the negative effects of non-renewable energy on health and the environment, the government should launch awareness programs educating the public about these consequences, using media such as radio, flyers, and face-to-face interactions. Additionally, the government should focus on harnessing the country's renewable energy potential by encouraging the exploration and development of renewable energy sources to enhance their availability.

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