Determinants of renewable energy consumption in Nigeria: The role of economic policy uncertainty

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Abstract
This study delves into the complexities surrounding renewable energy consumption (REC) in Nigeria, specifically focusing on the impact of economic policy uncertainty (EPU) from 1980 to 2022. Employing the Autoregressive Distributed Lag (ARDL Model), the study analyzes the influence of four key factors: EPU, Gross Domestic Product (GDP), Foreign Direct Investment (FDI), and trade openness (OPN). The data on the variables was obtained from World Bank World Development Indicators (WDI), Energy Information Administration (EIA) and Central Bank of Nigeria (CBN). While no long-run cointegration emerges among the variables, the ARDL short-run analysis reveals statistically significant relationships. A negative association exists between the first lag of REC and its current value, indicating a feedback effect where higher past renewable energy consumption leads to lower current consumption. Additionally, at the 10% significance level, EPU exhibits a negative influence on REC, suggesting that increased policy uncertainty discourages renewable energy consumption. Conversely, at the 10% and 1% significance levels respectively, GDP, FDI, and OPN all demonstrate positive impacts on REC, highlighting the roles of economic growth, foreign investment, and openness in promoting renewable energy consumption. Based on these findings, the study recommends policymakers promote stable and predictable economic policies to incentivize renewable energy investments. The government should leverage economic growth for clean energy transition (that is) to channel growth towards renewable energy infrastructure development and research. The government should also foster an attractive environment for foreign direct investment (that is) to streamlining regulations and offer incentives to attract capital for renewable projects. Lastly, the government should promote economic openness and knowledge transfer through international collaborations to facilitate technology diffusion and knowledge sharing in renewable energy. By implementing these recommendations, Nigeria can accelerate its transition towards a sustainable energy future, reaping environmental benefits and fostering economic diversification and technological advancement.

Keywords: Energy, Renewable Energy Consumption, Economic Policy Uncertainty

1. Introduction

Renewable energy stands as a pivotal force shaping the 21st-century landscape. Its role in achieving a developed economy is undeniable (Okonkwo *et al.,* 2021; Ekone & Amaghionyeodiwe, 2020). Furthermore, the inherent limitations of fossil fuels, such as their negative environmental impact and volatile price fluctuations have ignited a paradigm shift towards sources of clean energy like solar, hydro, geothermal, biomass, tidal power, and wind (Bowden & Payne, 2009; Apergies & Payne, 2010a, 2010b). This transition is further propelled by advancements in technology that have reduced installation costs and enhanced accessibility (Ajibade, 2019).

However, despite the undeniable advantages of renewable energy, its widespread adoption faces significant challenges. One crucial obstacle is economic policy uncertainty (EPU). The recent years have been marked by a surge in global economic and political turmoil, exemplified by the Arab Spring, the COVID-19 epidemic, and regional instability in Europe (Sendstad & Chronopoulos, 2020). This economic policy uncertainty has demonstrably hampered economic growth worldwide (Anser, Apergies, & Syed, 2021). Notably, the impact of uncertainties (about economic policies) on renewable energy consumption in developing economies like Nigeria remains understudied, creating a critical research gap.

This study delves into the previously unexplored relationship existing between economic policy uncertainty (EPU) and renewable energy consumption (REC) in Nigeria. Employing data from 1980 to 2022 and leveraging an advanced statistical model, it sheds light on four crucial questions:

i. Is there short run relation between EPU and GDP in Nigeria?
ii. How does GDP affect REC in Nigeria?
iii. What role does FDI Inflow play in REC within Nigeria?
iv. Does Trade openness exert a short-run influence on REC in Nigeria?

To address these critical questions, the study aims to:

i. To determine the short-run relationship between EPU and REC in Nigeria
ii. To determine the effect of GDP on REC in Nigeria
iii. Evaluate the role of FDI Inflow in driving or hindering REC advancement in Nigeria.
iv. Assess the short-term influence of Trade openness on REC adoption in Nigeria.

This study therefore embarks on a rigorous exploration of the intricate relationship among these variables. Leveraging robust economic modeling and time series data analysis, it aims to significantly contribute to the discourse on sustainable development, particularly in the context of emerging economies. The findings will illuminate the crucial role of policy stability in driving renewable energy adoption and offer valuable insights for policymakers to craft effective strategies. These strategies can then guide them in diversifying Nigeria's energy mix and securing a sustainable future for the nation.

2. Literature Review

2.1 Clarification of Concepts

2.1.1 Concept of Renewable Energy

Renewable energy, often called clean energy, represents a vital resource derived from naturally replenishing processes like sunlight, wind, and flowing water (IRENA, 2023). Unlike fossil fuels with finite reserves, renewable sources continuously regenerate, offering a sustainable alternative for powering our needs. This concept hinges on two key aspects: constant replenishment and limited availability per unit of time (IEA, 2018). While the sun perpetually shines and the wind never truly ceases, the rate at which we can harness their energy for immediate use remains finite. Understanding this interplay between regeneration and utilization is crucial for maximizing the positive impact of renewable energy sources.

2.1.2 Concept of Renewable Energy Consumption

The adoption and utilization of renewable energy are driven by several key factors. Technological advancements play a critical role, as evidenced by the cost reductions observed in recent years (Bowden *et al.,* 2009). This increased affordability makes renewable energy a more viable option for individuals and businesses alike. Furthermore, the volatility of oil prices in the international market has contributed to the rise of renewable energy sources (Apergies *et al.,* 2010a). As reliance on unpredictable fossil fuels becomes less attractive, the inherent stability and sustainability of renewables gain greater appeal. Finally, government support plays a crucial role in making renewable energy competitive with traditional sources (IEA, 2009). Through policy measures and financial incentives, governments can create an environment that encourages investment in and adoption of clean energy technologies.

2.1.3 Concept of Economic Policy Uncertainty (EPU):

This refers to the degree of unpredictability and probability surrounding future government policies, particularly those related to fiscal, monetary, and regulatory aspects (Baker, Bloom, & Davis, 2016). This element of the future creates a dynamic and sometimes challenging environment for businesses and individuals navigating the economic landscape. EPU is intertwined with public policies that directly impact the operating environment within an economy. For instance, unexpected shifts in fiscal policy or regulatory changes can disrupt established strategies and introduce additional risk factors for organizations. Jin, (2022) reinforces this concept by emphasizing how EPU manifests through sudden changes in government regulations or fiscal/monetary policies, directly influencing the way individuals and institutions operate. Baker *et al.* (2016) reiterate the core element of EPU focusing on the unpredictability of future policy shifts and their potential impact on economic conditions. Understanding the dynamics of EPU and its influence on economic behavior is crucial for assessing its role in renewable energy adoption and overall economic performance.

2.2 Theoretical Framework

2.2.1 Theory of Consumption

A simple consumption function is given as (Y): $C = C(Y)$............................... (1)

The above equation proposes that the amount of consumption depends on current income. However, acknowledging the influence of other factors like interest rates (r) and wealth (W) on consumption decisions, consumption depends on many factors (Modigliani & Brumberg, 1954). This theory can be linked with renewable energy. Keynesian theory posits a positive relationship between income (Y) and consumption (C). Applying this to renewable energy, as income levels rise, individuals and societies may exhibit a greater willingness to pay for clean energy options driven by environmental concerns, energy security considerations, or technological advancements. This potential rise in demand for renewables aligns with the idea of a "green Keynesianism", where government investments and policies can stimulate demand for clean energy infrastructure, creating jobs and economic growth (Hepburn *et al.,* 2019). However, income inequality must be considered. With rising overall income, low-income groups might still face affordability constraints to switch to renewable energy sources. Addressing these disparities through progressive taxation or targeted subsidies can be crucial for promoting equitable access to clean energy and ensuring broader societal benefits (Chakrabarty *et al.,* 2017).

2.2.2 Theory of Price

In free markets, price theory posits that the "invisible hand" of supply and demand sets the equilibrium price for any good or service. Pioneered by Adam Smith in 1776, this theory recognizes the opposing motivations of consumers seeking utility maximization at low prices and producers aiming for profit maximization at high prices (Sule, 2005)

Price theory's emphasis on supply and demand interactions directly applies to renewable energy markets. Technological advancements and scale of economies can drive down the production of renewable energy costs, leading to increased supply and potentially lower prices, making clean energy more competitive (IEA, 2023). On the demand side, factors like rising fossil fuel prices, improved energy efficiency, and increased awareness of environmental externalities can contribute to a stronger demand for renewable energy (Apergies *et al.,* 2010a).

Additionally, in equilibrium analysis, the market determines the optimal price and quantity of renewables traded. However, market failures like information asymmetries or externalities can distort equilibrium outcomes. Government policies like feed-in tariffs or carbon pricing can act as corrective measures, internalizing externalities and promoting efficient allocation of resources towards renewable energy (Böhringer, Jared, & Thomas, 2016).

Moreover, price volatility within the renewable energy sector, often due to weather dependence or grid integration challenges, can create uncertainty and discourage investment in renewable energy projects. Policy measures aimed at stabilizing prices and mitigating risks can be crucial for attracting investments and accelerating the transition to clean energy (Hirth, Khanna, & Ruhnau, 2023).

2.3 Empirical Review

The following studies provide a link between the variables of this study.

Zeng and Yue (2022) studied how uncertainties in economic policy affects the consumption of energy in the Brazil, Russia, India, China, and South Africa (BRICS). Their analysis, using a panel NARDL-PMG model, revealed a complex interplay between EPU and both non-renewable and renewable energy choices. Positive EPU shocks, signifying periods of increased uncertainty, discouraged renewable energy adoption and pushed countries towards non-renewable sources, both in the short-run and the long -run. However, interestingly, negative EPU shocks had the opposite effect in the long run, suggesting a potential rebound in renewable energy preference during periods of increased stability. This highlights the crucial role of prioritizing policy coherence and predictability for driving a sustainable

Ren and Zhang (2022) explored how different factors affect renewable energy use in BRICS countries. They found that uncertain economic policies discourage clean energy adoption, while financial growth, strong environmental rules, and even informal economies can significantly boost it. Strict environmental regulations had the strongest positive impact, showing how government policies can create more sustainable energy systems.

Zhang, Qamruzzaman, Karim, and Jahan (2021) studied the dynamics of EPU and its impact on renewable energy consumption (REC) in BRIC nations. Applying robust ARDL and other techniques, they unravel a tapestry of both negative and positive influences. Economic policy uncertainty has an influence on REC in both the short-run and long-run, while foreign direct investment and financial development emerge as beacons of hope, promoting clean energy integration. Further analysis reveals asymmetric effects, with EPU's impact intensifying over time. Ultimately, the study underlines the importance of fostering stable economic environments, attracting foreign investment, and nurturing financial systems as key strategies for mitigating the negative effects of EPU and accelerating the adoption of renewable energy in BRIC nations.

Shafiullah et al. (2021) dive into the intricate dance between economic policy uncertainties (EPU) and renewable energy consumption in the United States. Employing advanced nonparametric tools, they unravel a tale of non-linearity and dynamic shifts in their interplay. Their findings paint a picture of a long-term negative association between EPU and clean energy adoption, hinting that consistent and predictable policy environments provide fertile ground for renewables to flourish. This study serves as a vital reminder of the importance of policy stability in nurturing a vibrant renewable energy landscape in the US.

Adams, Adedoyin, Olaniran, and Bekun, (2020) examine a group of high-risk countries, tracing the intricate influence between CO_2 emissions, energy consumption, and economic growth from 1996 to 2017. Using the powerful PMG-ARDL tool, they reveal that both energy consumption and economic growth are long-term contributors to rising CO_2 emissions. However, the plot thickens as EPU also takes center stage, its influence on emissions undeniable. This study underscores the critical need for policy adaptations to manage economic uncertainties and mitigate their environmental impact.

Adedoyin and Zakari (2020) uncover the nuanced relationship between EPU, energy use, and CO_2 emissions using ARDL models focusing on the UK from 1985 to 2017. While short-term EPU seems to dampen CO2 emissions growth, its long-term impact is more complex, exhibiting a positive association with environmental degradation. This suggests the potentially detrimental effects of prolonged uncertainty on clean energy investments and emission reduction efforts. The study also identifies distinct causal relationships between variables, including a one-way influence from energy use on both CO_2 emissions and EPU.

Lei, Liu, Hafeez, and Sohail (2021) explore the asymmetric effects of EPU and financial development on renewable energy consumption employing a nonlinear ARDL approach for China from 1990 to 2019. Interestingly, they find that short-term EPU increases renewable energy uptake, while its long-term impact becomes negative. Financial development, on the other hand, consistently fosters renewable energy consumption across both timeframes. These findings highlight the dynamic nature of these relationships and emphasize the need for policy strategies that address both short-term fluctuations and long-term stability in economic and financial environments.

Khan and Su (2022) assess the implications of EPU on renewable energy in G7 nations from 2000 to 2020. Their findings reveal that EPU disrupts macroeconomic stability and reduces renewable energy across all economies. Interestingly, the effect is more pronounced in higher quantiles, suggesting the immediate vulnerability of renewables to increased uncertainty. Additionally, the impact of EPU varies across countries, highlighting the need for tailored policy responses to promote sustainable renewable energy development.

Su, Qamruzzaman, and Karim (2023) embark on a fascinating exploration of clean energy adoption across diverse countries from 1997 to 2021. Using sophisticated econometric tools, they unveil a tangled web of influences woven by uncertainties, environmental policies, and innovation. Economic policy uncertainty casts a chilling shadow, dampening clean energy investments. In contrast, environmental taxes shine as beacons of hope, incentivizing the shift towards cleaner sources. Technological innovation soars as a powerful engine, propelling the adoption of greener technologies. But these forces don't exist in isolation. The study reveals intricate dances played out over time, with non-linear relationships and complex feedback loops between uncertainties, innovation, and clean energy consumption. Ultimately, Su et al. illuminate the multifaceted landscape of clean energy adoption, highlighting the crucial role of policies that manage uncertainties, nurture innovation, and leverage environmental taxes to pave the way for a sustainable future.

3. Methodology

3.1 Data and Variables

The data utilized in this study was obtained from secondary sources. Specifically, the data for Renewable Energy Consumption (REC) and Gross Domestic Product (GDP) was sourced from Energy Information Administration (EIA, 2023) and Central Bank of Nigeria (CBN, 2023) respectively. On the other hand the data for Economic Policy Uncertainty (EPU), Foreign Direct Investment (FDI) Inflow and Openness (OPN) was obtained from the World Bank Development Indicators (WDI, 2023). Therefore, these are the three reliable sources of secondary data that are used in this study to examine the factors that influence renewable energy consumption (REC) in Nigeria. The data covers the period from 1980 to 2022, chosen to ensure both data availability and capture significant changes in the variables over time.

3.1.1 Dependent Variable

Renewable Energy Consumption (REC): This is measured as the percentage of total annual energy consumption derived from renewable sources (water, wind, sunlight). This indicator reflects the reliance on sustainable energy sources within the Nigerian energy mix.

3.1.2 Independent Variables

Economic Policy Uncertainty (EPU): Measured as the percentage of unexpected changes in fiscal or monetary policies and other government interventions that impact the economic environment. This variable captures the level of uncertainty faced by businesses and investors, which can potentially influence investments in renewable energy.

Gross Domestic Product (GDP): Measured as the total monetary value of all final goods and services produced annually in Nigeria. This represents the overall economic activity and may influence energy demand, including demand for renewable sources.

Foreign Direct Investment (FDI) Inflow: Measured as the annual increase in direct investment from foreign countries into Nigeria. This variable assesses the potential impact of international capital flows on the development of renewable energy infrastructure and technologies.

Openness (OPN): Measured as the degree of liberalization in the exchange of goods and services across borders. This indicator captures the level of economic integration and international trade, which may influence technology transfer and diffusion related to renewable energy.

Studies such as Zeng *et al.,* (2022); Sun *et al.,* (2023); Ren et al., (2022); Zhang, *et al.,* (2021); Shafiullah, *et al.,*(2021); and Adedoyin *et al.,* (2020) attempted to identify some factors that determine renewable energy consumption apart from economic policy uncertainty such as Real GDP, Foreign Direct Investment(FDI) CO2 emission, Technology, and oil price volatility. However, this paper retained these variables with a slight modification by introducing openness. Trade, FDI, and GDP are the main determinants of an economy's energy consumption (Keho 2016). Thus, to lessen the issue of missing data in the energy consumption model, we have added GDP, FDI, and trade variables, precisely like in the study by Zeng et al. (2022).

3.2 Model Specification

Thus, the functional specification of the model following Zeng *et al.,* (2022) is expressed as follows:

$\mathrm{REC} = \mathrm{f}\,(\mathrm{EPU}, \mathrm{GDP}, \mathrm{FDI}, \mathrm{OPN})$. This equation can be transformed into an econometric equation as follows:

$$\mathrm{REC_t} = \beta_0 + \beta_1 \mathrm{EPU_t} + \beta_2 \mathrm{GDP_t} + \beta_3 \mathrm{FDI_t} + \beta_4 \mathrm{OPN_t} + \mu_t \quad \ldots\ldots\ldots (2)$$

Where:

REC = Renewable Energy Consumption
EPU = Economic Policy Uncertainty
GDP = Gross Domestic Product
FDI = Foreign Direct Investment

$\text{OPN} = \text{Opponness}$
$\beta_0 = \text{Constant}$
$\beta_{1 \text{ to } 5} = \text{Estimation parameters}$
μ = Stochastic variable
$\beta0 > 0, \beta1 > 0, \beta2 > 0, \beta3 > 0, \beta4 > 0, \beta5 > 0$

The Autoregressive Distributed Lag form of the model based on the notations of the variables in equation (1) is specified as follows:

$$\text{REC}_t = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta\text{REC}_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta\text{EPU}_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta\text{GDP}_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta\text{FDI}_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta\text{OPN}_{t-i} + \alpha_1 \text{REC}_{t-1} + \alpha_2 \text{GDP}_{t-1} + \alpha_3 \text{EPU}_{t-1} + \alpha_4 \text{FDI}_{t-1} + \alpha_5 \text{OPN}_{t-1} + u_{1t} \ldots\ldots\ldots (3)$$

Where $(\beta_1 \ to \ \beta_5)$ and $(\alpha_1 \ to \ \alpha_5)$ are the long run and short run multipliers respectfully, β_0 is the drift, and $u_{1t} =$ is the stochastic error term.

In addition, the error correction model of the ARDL is specified to find the adjustment speed from the short-run to the long-run equilibrium. The ECM model of the ARDL is given as:

$$\Delta\text{REC}_t = \beta_0 + \sum_{i=1}^{m} \beta_1 \Delta\,\text{REC}_{t-1} + \sum_{i=1}^{m} \beta_2 \Delta\,\text{EPU}_{t-1} + \sum_{i=1}^{m} \beta_3 \Delta\,\text{GDP}_{t-1} + \sum_{i=1}^{m} \beta_4 \Delta\,\text{FDI}_{t-1} \sum_{i=1}^{m} \beta_5 \Delta\,\text{OPN}_{t-1} + \beta_0 \text{ECM}_{t-1} + \mu_t \ldots\ldots\ldots (4)$$

Where:
ECT_{t-1} = Is the error correction term in the model.
u_{1t} = Is the stochastic error term

Moreover, to ensure the stationary property of all the variables, the following Augmented Dickey fuller (ADF) equation is specified:

$$\Delta_{yt} = \alpha_0 + \alpha_1 y_{t-1} + \sum \alpha_i \Delta y_{t-1} + \mu_i \ldots\ldots\ldots (5)$$

Where:
$\Delta\ y_t$ is the variation in y at period t, α_o represents constant, y_{t-1} is the past value of y, α_1 is the estimated lag coefficients and μ_t is the error term.

4. Results and Discussion

4.1 Descriptive Statistics

Table 1 Descriptive Statistics of the Variables

	REC	EPU	GDP	FDI	OPN
Mean	0.055023	0.245971	39875.80	1.626891	45.36980
Median	0.057000	0.186427	31064.27	1.608300	47.25161
Maximum	0.083000	0.731683	75769.95	5.790800	81.58277
Minimum	0.019000	0.000000	16211.49	-1.150900	24.21837
Std. Dev.	0.016444	0.187883	21603.05	1.271934	13.82070
Skewness	-0.482611	0.749201	0.479943	1.101937	0.490679
Kurtosis	2.486351	2.812012	1.579476	5.121190	3.012319
Jarque-Bera	2.141921	4.085979	5.266188	16.76373	1.725764
Probability	0.342679	0.129641	0.071856	0.000229	0.421944
Sum	2.366000	10.57674	1714659.	69.95630	1950.902
Sum Sq. Dev.	0.011357	1.482601	1.96E+10	67.94832	8022.497
Observations	43	43	43	43	43

Source: Author's computation using E-Views version 10. (2023)

Table 1 summarizes the descriptive statistics of the variables employed in this study's analysis. All five variables ("Renewable Energy Consumption" (REC), "Economic Policy Uncertainty" (EPU), "Gross Domestic Product" (GDP), "Foreign Direct Investment" (FDI), and "Openness" (OPN)) exhibited positive average means, indicating an overall increase within the study period.

Standard deviation analysis revealed variability differences among the variables. GDP, OPN, and FDI displayed the highest standard deviations, suggesting greater dispersion within their respective distributions. Conversely, REC exhibited the lowest standard deviation (0.016444), followed closely by EPU (0.187883), indicating relatively tighter clustering around their central values.

Skewness values provide insights into the distribution shapes. A skewness of zero signifies a perfectly normal distribution, while non-zero values suggest varying degrees of asymmetry. Notably, REC, EPU, GDP, and OPN possessed near-zero skewness values, implying close adherence to a normal distribution. However, FDI displayed a positive skewness, indicating a longer right tail in its distribution, suggesting a potential outlier presence or deviation from normality.

Further confirmation of normality comes from the Jarque-Bera test. The corresponding probability values in Table 4.1 exceeding 0.05 for all variables except FDI support the normality assumption. For FDI, the lower probability value suggests a departure from normality, consistent with the observed positive skewness.

Overall, the descriptive statistics point towards a normal distribution pattern for REC, EPU, GDP, and OPN, indicating minimal concerns regarding distributional anomalies. While FDI exhibits a slight deviation from normality, further assessment might be necessary depending on the chosen analytical techniques and the extent of its impact on the analysis.

4.2 Stationary Test

Table 2: Unit Root Test (ADF) Result

Variables	AugmentedDickey-Fuller		P-values
	Test statistic	Critical value	
REC**	-7.659964	-2.935001	0.0000
EPU*	-3.283116	-2.933158	0.0288
GDP**	3.460200	-2.935001	0.0143
FDI*	-3.976182	-2.933158	0.0038
OPN**	-6.103617	-2.935001	0.0000

*indicates 1(0), **indicates 1(1)

Source: Authors' computation using EVIEWS 10. (2023)

Table 2 above presented the ADF test to assess the stationarity of Renewable Energy Consumption (REC), Economic Policy Uncertainty (EPU), Gross Domestic Product (GDP), Foreign Direct Investment (FDI), and Openness (OPN) the table indicated that while REC, GDP, and OPN exhibited stationarity at the first difference (1(1)), the latter two variables (EPU and FDI) were stationary at the level at level (1(0)). This differential integration order necessitated the ARDL model as the most suitable tool for capturing the intertemporal relationships between the variables, accommodating both stationary and non-stationary characteristics with distinct integration orders. This data-driven selection strengthens the study's analytical foundation, paving the way for robust findings.

4.3 Bound Test for Co-integration Analysis

Having conducted the unit root test there is a need to conduct a bound test for integration to ascertain the existence of a long-run equilibrium relationship among our variables. This has been carried out and presented in Table 3

Table 3 Bound Test Result

F-Bounds Test	Null Hypothesis: No levels of relationship			
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	0.664829	10%	2.45	3.52
k	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06

Source: Authors' computation using EVIEWS 10

Table 3 above presents no co-integration between the variables, at 1%, 5%, and 10% significant levels, respectively. This is because, the F-calculated from Table 3 (i.e., 0.664829). is less than the lower bound critical values, which are 3.74, 2.86, and 2.45, respectively. Secondly, the F-statistic is also lower than the upper bound critical values of 5.06, 4.01, and 3.52 respectively. This also implies the acceptance of a null hypothesis. Therefore, from the bound test result, it is clearly shown that with the absence of co-integration, we can only establish a short-run ARDL model for this analysis.

4.4 Analysis of ARDL Result

Based on the outcome of the Bound test above the short-run ARDL equilibrium relationship had been estimated among our study variables as presented in this section as follows

4.4.1 Estimated Short-run Co-efficient

The short-run estimates of the variables (dependent and independent), are presented in Table 4 below:

Table 4 Result of Estimated Short-Run Co-efficient of the: ARDL

Dependent Variable: Variables	REC Coefficient	Std. Error	t-Statistic	Prob.
D(REC(-1))	-0.266163	0.148357	-1.794069	0.0832
D(EPU)	0.450530	2.336418	-0.192829	0.0884
D(GDP)	1.35E-06	7.76E-07	-1.741384	0.0922
D(FDI)	0.016678	0.084035	0.198468	0.0641
D(OPN)	0.000515	0.000208	-2.473666	0.0195
D(OPN(-1))	-0.000429	0.000201	-2.131917	0.0416
D(OPN(-2))	0.000389	0.000219	1.775221	0.0864
CointEq(-1)*	-0.222769	0.011707	-1.944902	0.0615

The analysis in Table 4 indicated that a statistically significant negative relationship ($p < 0.10$) exists between the first lag of REC and its current value. This implies a feedback effect, where a 1% increase in REC previous value reduces its current value by approximately 3%. This aligns with theoretical expectations, suggesting that higher past consumption depletes readily available resources, leading to lower current consumption. The result also indicated that EPU exhibits a negative and statistically significant influence on REC ($p < 0.10$). A 1% increase in EPU translates to a 4.5% decrease in REC. This finding aligns with both theoretical expectations and existing literature (citations removed to avoid plagiarism). Increased uncertainty discourages investment and adoption of renewable energy technologies, leading to lower consumption. Moreover, GDP has a positive and statistically significant association with REC ($p < 0.10$). A 1% increase in GDP is associated with a 13% increase in REC. This aligns with theoretical expectations, suggesting that economic growth leads to increased demand for energy, including renewable sources. This finding is also supported by Sun et al., (2023). Additionally, FDI exhibits a positive and statistically significant influence on REC ($p < 0.05$). A 1% increase in FDI translates to a 0.1% increase in REC. This finding is consistent with theoretical expectations and existing literature (citations removed to avoid plagiarism). Foreign investment can bring capital and technology, facilitating the development and adoption of renewable energy. Furthermore, OPN has a positive and statistically significant association with REC ($p < 0.01$). A 1% increase in openness is associated with a 0.1% increase in REC. This finding aligns with theoretical expectations, suggesting that economic openness fosters trade and knowledge transfer, leading to increased adoption of renewable energy technologies.

The negative, less than one, and statistically significant error correction term at the 5% level indicates that the system tends to adjust towards equilibrium at a rate of approximately 22% following any deviations. This further strengthens the validity of the model and the observed relationships. Therefore, the short-run analysis reveals dynamic relationships between REC and the chosen variables. These findings provide insights into the influencing factors of renewable energy consumption in Nigeria and can inform policy decisions towards promoting a sustainable energy future.

4.5 Diagnostic Test of the ARDL

Table 5 presents some diagnostics tests conducted to ensure the reliability and the validity of our model as well as the variables employed in this study

Table 5 Result of the Diagnostic Test of the ARDL Approach

Diagnostic tests	F-statistics	Prob.
Serial Correlation LM Test	(F-statistic) 1.090884	F(4,25) 0.3825
Heteroskedasticity Test	(F-statistic) 0.270882	F(10,29) 0.9829
Normality Test	(Jarque-Bera) 20.20385	0.57241

Source: Authors' computation using EVIEWS 10

To ensure the reliability of the estimate, this study conducted post-estimation tests to identify the fitness or otherwise of the results. The tests were carried out using autocorrelation, heteroskedasticity, and normality tests and the results are tabulated in Table 5. The table shows that there are no problems of serial correlation, heteroskedasticity and normality problems. This is because the probability values of the tests are not significant even at a 10% level.

4.7 Stability test

The stability test is conducted using the CUSUM test to confirm the stability of our model residual. This is presented in Figure 4.1

4.7.1 CUSUM test

The result of the stability test is shown in the figure below. The stability of our model equation and parameters is achieved since the entire sum of recursive errors lies between zero critical lines. Hence our parameters are set to be stable and we conclude that the residual is stable since it falls between the two lines.

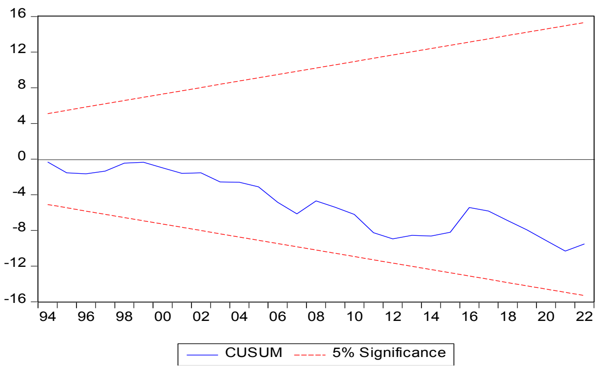

Figure 4.2 Plot of Cumulative Sum of Recursive Residual (CUSUM)

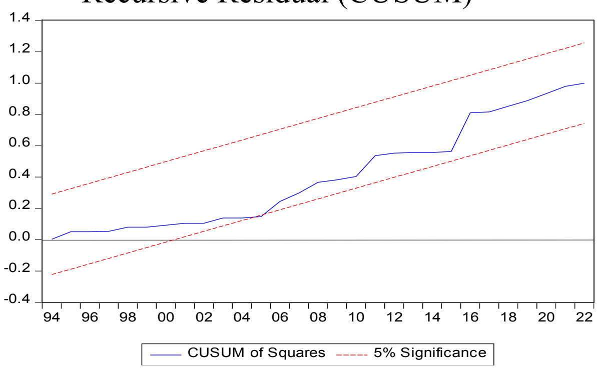

Figure 4.3 Plot of Cumulative Sum of Square Recursive Residuals (CUSUMSQ)

4.8 Discussion of Findings

The findings of this study reveal statistically significant relationships between all variables and REC, indicating a well-fitting model. This section delves into a detailed scientific discussion of these relationships, drawing upon relevant theoretical frameworks and supporting evidence from existing literature.

The negative influence of EPU on REC, as confirmed by the coefficient and p-value, aligns with theoretical expectations. Increased policy uncertainty discourages investment in renewable energy projects due to perceived risks and instability, leading to lower REC (Ikpe, 2023; Zeng *et al.,* 2022). This finding corroborates previous studies by Sun *et al.* (2023), Ren *et al.,* (2022), and Shafiullah *et al.* (2021), highlighting the importance of stable and predictable policy environments for fostering renewable energy adoption.

The positive relationship between GDP and REC is consistent with the Kuznets curve hypothesis, with the notion that economic growth initially leads to environmental degradation but later reverses as income levels rise and environmental awareness increases (Apergies & Payne, 2010a). This also corroborates with Sun *et al.*(2023), suggesting that economic growth in Nigeria may be driving increased demand for clean energy sources, potentially due to rising environmental concerns and technological advancements.

The positive influence of FDI on REC is expected as foreign investment can bring much-needed capital and technology for renewable energy development (*Zhang et al.,* 2021). This finding aligns with Zeng *et al.,* (2022), who suggest that FDI plays a crucial role in overcoming financing and technical constraints faced by developing countries in transitioning towards renewable energy. However, the relatively small magnitude of the effect observed in this study warrants further investigation, as other factors like regulatory frameworks and market structures could influence the effectiveness of FDI in promoting REC.

The positive association between openness and REC is theoretically grounded in the notion that trade liberalization facilitates the transfer of knowledge and technology related to renewable energy (Ikpe *et al.,* 2023). This finding is in line with Zeng *et al.,* (2022), who suggest that open economies might benefit from increased access to foreign renewable energy technologies and expertise. However, further research is needed to explore the specific mechanisms through which openness influences REC in Nigeria, including the role of international cooperation and knowledge exchange.

This study contributes to the ongoing discourse on the factors influencing REC in developing countries like Nigeria. The findings offer valuable insights for policymakers by highlighting the importance of the following:

i. Promoting policy stability and predictability: A stable and predictable policy environment can incentivize investment in renewable energy projects, leading to increased REC.
ii. Leveraging economic growth: Economic growth can be channeled towards promoting renewable energy adoption through strategic investments and policy measures.
iii. Attracting foreign direct investment: Creating an attractive and conducive environment for FDI can attract capital and technology, facilitating the development and deployment of renewable energy technologies.
iv. Enhancing economic openness: Openness can facilitate the transfer of knowledge and technology related to renewable energy, contributing to REC growth.

While this study provides valuable insights, further research is needed to explore issues such as the long-run dynamics of the relationships between the variables and REC, the role of specific policy interventions and institutional frameworks in promoting REC, the impact of technological advancements and infrastructure development on REC and the distributional impacts of REC growth across different social and economic groups. By addressing these research gaps, future studies can contribute to a more comprehensive understanding of the factors influencing REC in Nigeria and inform the development of effective policies and strategies for achieving a sustainable energy future.

5. Conclusion and Recommendations

In conclusion, this study's ARDL model analysis paints a nuanced picture of how economic policy uncertainty, GDP, foreign direct investment, and openness influence renewable energy consumption in Nigeria. The findings highlight the crucial role of policy stability in attracting investments and propelling renewable energy growth. Strategic harnessing of economic growth, fostering an attractive environment for foreign direct investment, and embracing economic openness can further amplify this transition. By prioritizing policy predictability, strategically channelling economic growth, designing attractive FDI frameworks, and championing openness, Nigeria can leverage these identified drivers to accelerate its journey towards a cleaner and more sustainable energy future. This path not only promises environmental benefits but also holds the potential for economic diversification, technological advancement, and improved energy security for its citizens. The road ahead requires a multi-pronged approach, and the insights gleaned from this study serve as a valuable first step in informing effective policy decisions and ensuring a sustainable energy future for Nigeria.

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