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Impact of Renewable Energy Production on Government Revenue in Nigeria: 1986-2022

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Abstract

This study investigated the impact of renewable energy production on government revenue in Nigeria, addressing the problem of economic diversification and sustainability in the face of declining fossil fuel reliability. The main objective was to assess how different forms of renewable energy—specifically hydroelectric power (HPP), biomass production (BIP), and solar energy production (SEP)—contribute to government fiscal resources. Employing an Auto Regressive Distributive Lag (ARDL) model on data spanning between 1986-2022, the research focused on quantifying the relationships between the production of these renewable energies and their impact on government revenues. The analysis was supported by unit root tests to confirm data stationarity and cointegration tests to ascertain long-run relationships. Findings revealed that all three renewable energy types had significant and positive impacts on government revenue. Hydroelectric power showed a substantial positive association, suggesting that investments in hydroelectric infrastructure could enhance economic activities and tax revenues. Similarly, biomass production was linked to increased fiscal capacity through its integration with agricultural development and sustainable practices. Solar energy, though smaller in scale, significantly contributed to reducing energy import costs and promoting economic independence. Based on these findings, specific recommendations were made. It was suggested that enhancing hydroelectric power infrastructure, promoting biomass projects through fiscal incentives, and supporting solar energy investments by reducing capital costs could further leverage the positive fiscal impacts observed. These strategies are crucial for Nigeria's pursuit of energy sustainability and economic diversification.

1. Introduction

Renewable energy production has emerged as a pivotal element in the global shift towards sustainable development as countries seek to reduce their reliance on fossil fuels and mitigate the impacts of climate change, as marked by increasing reliance on sources such as hydroelectric power production (HPP), biomass production (BIP), and solar energy production (SEP). This transformation is driven by the urgent need to address climate change and the growing recognition of the finite nature of fossil fuels. Globally, the share of renewables in electricity generation increased from about 19% in 2007 to over 29% by 2020, highlighting a significant transition towards cleaner energy sources [10]. This shift is not just environmental but also economic, influencing how governments generate revenue and invest in public goods.

In the context of Nigeria, renewable energy production has been gaining momentum in recent years. The country has vast potential for renewable energy generation, particularly in the areas of hydroelectric power, biomass, and solar energy. Nigeria has an estimated hydroelectric power potential of 14,120 MW, with only about 1,930 MW currently being utilized [15]. In terms of biomass production, Nigeria generates approximately 144 million tons of waste annually, which could be harnessed for energy generation [14]. Additionally, Nigeria receives abundant solar radiation, with an average of 5.5 kWh/m2/day, making it a promising location for solar energy production. The focus on renewable energy in Nigeria is partly necessitated by the environmental challenges and the opportunity to diversify the economy away from its heavy dependence on oil. Despite being Africa’s largest oil producer, Nigeria experiences frequent power outages that underscore the inadequacy of its energy infrastructure. The Nigerian government has recognized the potential of renewables to meet its energy needs and stimulate economic growth. As of 2021, renewable energy, excluding large hydro, accounted for less than 10% of Nigeria’s total installed capacity [15]. However, projects focused on expanding HPP, BIP, and SEP are increasingly seen as vital to achieving energy security and reducing carbon emissions.

Government revenue generation is a crucial aspect of any economy, as it provides the necessary funds for public expenditure and development. It is the lifeblood that sustains the functioning of the government and enables it to provide essential services to its citizens. In an ideal situation, the government should have a stable and sufficient revenue stream to meet its obligations and invest in the country's development. Nigeria, like many other countries, aspires to have a robust and diversified revenue base that can withstand economic shocks and support long-term growth [2]. Globally, governments rely on various sources of revenue, including taxes, royalties, and fees. In many countries, the energy sector plays a significant role in generating government revenue through the taxation of energy production and consumption. However, the transition towards renewable energy has raised concerns about the potential impact on government revenue, particularly in countries heavily dependent on fossil fuel exports.

The reality in Nigeria is far from this ideal. The country's revenue generation has been heavily dependent on the oil and gas sector, which accounts for over 60% of government revenue and 90% of foreign exchange earnings (Central Bank of Nigeria, 2021). This overdependence on a single commodity has made the country vulnerable to the volatility of global oil prices and has limited its ability to invest in other sectors of the economy. Furthermore, the country's non-oil revenue, such as taxes and customs duties, has been significantly underperforming due to a narrow tax base, tax evasion, and inefficient collection mechanisms.

In 2020, Nigeria's total government revenue stood at ₦3.42 trillion ($8.4 billion), which was 23.5% lower than the ₦4.47 trillion ($11.9 billion) recorded in 2019 (Central Bank of Nigeria, 2021). This decline was largely due to the impact of the COVID-19 pandemic and the associated fall in global oil prices. The country's debt profile has also been on the rise, with the debt-to-GDP ratio reaching 34.98% in 2020, up from 29.10% in 2019 [7]. These figures highlight the urgent need for Nigeria to find sustainable ways to boost its revenue generation capacity. The consequences of inadequate government revenue are far-reaching and detrimental to the country's socio-economic development. The government's ability to invest in critical infrastructure, such as roads, schools, and hospitals, is limited, leading to a deterioration in the quality of life for citizens. The lack of revenue also hinders the government's capacity to create jobs, reduce poverty, and stimulate economic growth. According

[7], Nigeria's unemployment rate stood at 33.28% in the fourth quarter of 2020, indicating the severity of the job crisis in the country.
Therefore, it is of interest in this paper to examine how renewable energy production has impacted government revenue in Nigeria from 1986-2022.

1.2 Literature Review

Hydroelectric Power Production (HPP) is one of the oldest and most established forms of renewable energy. The International Energy Agency (IEA) describes hydroelectric power as a critical component in the global mix of renewable energy, highlighting its role in providing flexible energy storage and grid stabilization (International Energy Agency, 2022). This form of energy is highly dependent on geographical and hydrological conditions and is often associated with large-scale infrastructure such as dams.

Biomass production (BIP) refers to the use of organic materials, such as wood, agricultural crops, and waste materials, to produce energy. However, the sustainability of biomass production is heavily dependent on careful management of resources to avoid adverse impacts on food security and biodiversity.

Solar Energy Production (SEP) involves converting sunlight directly into electricity using photovoltaic (PV) cells or using concentrated solar power (CSP) systems that use mirrors or lenses to concentrate a large area of sunlight onto a small area.

These renewable energy technologies are critical not only for reducing dependency on fossil fuels but also for their potential economic benefits, such as creating jobs and reducing energy import bills. Each type of renewable energy production has its unique challenges and benefits, and their development is influenced by technological, economic, and policy factors globally and locally.
Government revenue (GOR) refers to the funds that a government collects from various sources to finance its operations, public services, and infrastructure developments. This broad construct encompasses various types of revenues, including taxes, duties, fees, profits from state-owned enterprises, and royalties, among others. The conceptualization of government revenue is crucial for understanding how governments manage their economic policies and how these revenues enable governments to maintain and enhance public welfare.

The academic and economic literature often emphasizes the importance of diverse and stable sources of revenue for governmental stability and functionality. According to [4], government revenue should be seen not only as a means of financing public expenditures but also as a tool for implementing public policies and stabilizing the economy. Taxes are the most significant component of government revenue, serving both as a tool for resource allocation and as a means of redistributing wealth to reduce inequalities. Non-tax revenues also play a vital role in government funding. These can include earnings from government-owned corporations, fees for services, and fines. For instance, profits from state-owned enterprises often represent a considerable share of government revenue in countries where the government plays an expansive role in the economy. In the context of developing countries, royalties and revenue from natural resources, such as oil and minerals, are significant [12]. However, reliance on such volatile sources can lead to instability in government revenue streams, influencing the overall economic stability of a country.

Another critical aspect of government revenue is grants and aid from other countries and international organizations. For countries with limited ability to generate sufficient internal revenue, external assistance can be crucial for funding development projects and supporting government budgets. The effectiveness and stability of government revenue collection are directly tied to the government's capacity to implement efficient fiscal policies and ensure compliance among taxpayers and other revenue contributors. In practice, the structure and effectiveness of government revenue collection significantly impact a government's ability to implement policies and respond to public needs. Efficient and equitable revenue collection is seen as a hallmark of effective governance and is crucial for achieving long-term development goals. Therefore, government revenue is not only a fiscal measure but also a reflection of a country's governance quality and its approach to economic and social policy.

One study on the impact of renewable energy production on government revenue was conducted by [18]. In their analysis, Sims et al., focused on the broader domain of how renewable energy influences economic indicators, including government revenues, within the European Union over the period from 2000 to 2014. Utilizing econometric models such as Vector Error Correction Model (VECM), the study employed proxies such as megawatts of renewable energy installed (independent variable) and various economic metrics including tax revenues from renewable sector companies (dependent variable). The findings suggested a significant positive correlation between the increase in renewable energy capacity and government tax revenues, attributed mainly to higher corporate and income taxes from jobs created in the renewable sector. However, a criticism of this study is its limited focus on direct tax revenues, potentially overlooking other fiscal impacts such as subsidies or indirect economic effects like increased consumer spending due to lower energy costs.

Another empirical investigation was undertaken by [21], who explored the relationship between renewable energy development and economic growth in China from 1995 to 2015. This study took a different methodological approach by using a panel data regression analysis to probe the causality links between installed renewable energy capacity (independent variable) and government fiscal capacity measured through overall tax revenue contributions from the renewable sector (dependent variable). Zhang and team’s results indicated that not only does renewable energy installation contribute to immediate fiscal benefits through direct taxation, it also promotes long-term economic stability by diversifying the energy matrix and reducing dependency on imported fuels. Critiques of Zhang et al.’s work often highlight the assumption that the existing financial infrastructure is fully capable of capitalizing on the potential tax revenues from new renewable installations, an assumption that may not hold in less developed or differently structured economies. [5] explored the dynamics within the United States over the decade from 2003 to 2013. Their research specifically focused on the role that state-level policies play in facilitating renewable energy development and the subsequent fiscal impacts on state revenues in sub-Saharan Africa. By utilizing an econometric approach involving multiple regression analyses, the authors assessed the effectiveness of renewable energy certificates and tax incentives as proxies for independent variables, while state government revenue from renewable sectors acted as the dependent variable. Their findings revealed that well-designed state policies not only significantly boost the installation of renewable energy facilities but also enhance state revenues through increased business activities and job creation in the sector. However, one notable criticism of this study lies in its over-reliance on state-level data without adequately accounting for federal influences or the broader macroeconomic environment, which can also significantly affect renewable energy investments and returns.

In another study from Africa, [1] investigated the nexus between renewable energy consumption and government revenue generation in South Africa from 2000 to 2016. Using the Autoregressive Distributed Lag (ARDL) model to explore long-term relationships, the study utilized renewable energy consumption metrics (megawatt-hours) as the independent variable, and government tax revenue from the energy sector as the dependent variable. The results strongly supported the premise that increased renewable energy consumption leads to higher government revenue, primarily through direct and indirect taxation of the growing number of renewable energy enterprises. Despite these positive findings, the study faced criticism for its assumption that the existing tax structures were optimized to fully capture the potential revenues from the renewable sector, a condition that may not universally apply across different national contexts. [13] provides insight into the effect of renewable energy production on economic performance and public sector income in Germany. Their research, spanning from 2000 to 2018, employed a sophisticated Structural Vector Autoregression (SVAR) model to dissect the interdependencies between renewable energy output (measured in gigawatt-hours) as the independent variable, and government revenue derived from the energy sector as the dependent variable. Li et al. found that increases in renewable energy production such as hydroelectric power had a pronounced positive effect on government revenue through enhanced tax and tariff collections directly linked to renewable energy industries. The study also highlighted that the transition to renewables stimulated ancillary economic activities which further expanded the tax base. Nevertheless, the study’s limitation lies in its assumption that the existing regulatory and market environments remain static, potentially overlooking the impact of ongoing changes in energy policies and economic conditions that could affect the outcomes over time.

Further exploring the dynamics in an emerging market, [16] conducted a study focusing on India, examining the period from 2005 to 2020. They employed panel data analysis to explore the relationship between renewable energy investment (independent variable) and fiscal returns to the government (dependent variable), including tax revenues and dividends from state-owned enterprises in the renewable sector. Their findings demonstrated a robust link between increased investments in renewables and higher government revenues, attributing this to the expansion of the renewable sector which includes a rise in production and subsequent increments in corporate tax contributions and dividend payments. Patel and Shah's research provides empirical evidence supporting the notion that strategic investments in renewable energy can significantly enhance government fiscal capacity. However, their analysis is occasionally critiqued for not fully accounting for the time lags between investment in renewable energy infrastructure and actual realization of fiscal benefits, which can be substantial.

[11] conducted a comprehensive study in the context of Scandinavia, examining the impacts of renewable energy adoption on government finances in Norway, Sweden, and Denmark from 1998 to 2019. Utilizing a combination of longitudinal analysis and econometric modeling, the study specifically evaluated the impacts of wind energy production (as an independent variable) on various forms of government revenue (as dependent variables), such as income from corporate taxes on renewable companies, carbon taxes, and reduction in subsidies to fossil fuels. Their findings revealed a positive correlation between increased wind energy capacity and government revenue, particularly through enhanced tax collections and reduced fiscal burdens associated with fossil fuel subsidies. However, a critique of this study concerns the potential overestimation of tax revenue impacts without sufficiently accounting for the initial governmental investment and incentives needed to foster the renewable sector, which can be substantial and affect net fiscal benefits.

In another relevant study, [8] investigated the impact of solar power expansion on local government revenues in Spain, covering a period from 2000 to 2018. They adopted a causal analysis framework using regression discontinuity design to explore the effect of government policies promoting solar energy (independent variable) on local government revenues derived from property taxes on solar installations and business taxes from related industries (dependent variable). The results of the study strongly suggested that proactive government policies to encourage solar power not only led to increased solar capacity but also significantly boosted local government revenues through both direct and indirect taxation. Nonetheless, criticisms of this study include its narrow focus on solar energy, potentially neglecting the broader spectrum of renewable energy sources and their varied impacts on public finances, as well as the assumption that all regions within Spain were equally prepared to capitalize on these policy initiatives.

The theoretical underpinning for this study is the Diffusion of Innovations theory by [17] and the Environmental Kuznets Curve (EKC) theory. The Diffusion of Innovations theory explains how new technologies, such as renewable energy, are adopted within a society, emphasizing the roles of perceived advantages, compatibility with existing values, and observable results in the adoption process. This theory provides a framework for understanding the adoption and dissemination of renewable energy technologies in Nigeria and their subsequent impact on government revenue. The EKC theory posits an inverted U-shaped relationship between environmental degradation and economic growth, suggesting that as an economy grows, environmental quality initially worsens but improves after reaching a certain income level. This improvement can be driven by increased investments in environmentally friendly technologies and more stringent environmental policies, leading to long-term economic and environmental benefits.

2. Methodology

The study on the impact of renewable energy production on government revenue in Nigeria from 1986 to 2022 employed an ex-post facto research design. This design is particularly suited for situations where variables cannot be manipulated. Instead, it involves the observation of existing variables and retrospective analysis of how changes in one variable (renewable energy production) correlate with changes in another (government revenue). This study utilizes secondary data sources, and were primarily sourced from the Nigerian National Petroleum Corporation (NNPC) and the Central Bank of Nigeria (CBN) Statistical Bulletin, both of which offer detailed records on energy production and financial statistics relevant to government revenue. Additionally, the World Development Indicators (WDI) database contributed international comparative metrics, enhancing the analysis's depth. These sources enabled a comprehensive evaluation of trends and patterns in renewable energy's role within the Nigerian economic framework from 1986 to 2022.

The analysis of government revenue in Nigeria as a result of renewable energy production was carried out using the explicit linear regression equation below

$$GOR_t = \alpha_0 + \alpha_1 HPP_t + \alpha_2 BIP_t + \alpha_3 SEP_t + u_t \qquad (1)$$

Where:
GOR= Government revenue
HPP = Hydroelectric Power Production
BIP = Biomass production
SEP = Solar Energy production
α_0 = Intercept or autonomous parameter estimates for renewable energy production
$\alpha_1 - \alpha_3$ = Coefficients of Renewable Energy (Hydroelectric Power Production (HPP), and biomass production (BIP), and Solar Energy production (SEP)
u_t = The error term.

2.1 Method of Analysis

The study conducted unit root tests as pre-estimation diagnostic tests to ascertain the stationarity of the data. This is a necessity of verifying whether the time series data exhibit random walks, necessitating transformation to achieve stationarity before proceeding with estimation. Neglecting this step could lead to spurious regression results, which would undermine the credibility of the parameter estimates obtained.

Upon confirming the stationarity of the time series data, the next critical step involved determining whether these variables share a long-run relationship. To this end, the study employed the cointegration technique, which enables the identification of equilibrium relationships among non-stationary series within a stationary framework, as advocated by [1]. This approach is particularly beneficial as it allows for the integration of long-run and short-run dynamics within the same model, addressing the potential loss of information that could result from differencing non-stationary series to achieve stationarity.

To capture the essence of the long-run relationship between renewable energy production and government revenue in Nigeria, the study utilized the Bounds cointegration test derived from the Auto Regressive Distributive Lags (ARDL) model. The ARDL framework is renowned for its flexibility in handling variables of different integration orders, making it an ideal choice for this study. Incorporating the investigation of the effect of renewable energy production on government revenue in Nigeria into an econometric framework, this study extends the analysis to an unrestricted Auto Regressive Distributive Lags (ARDL) model. This strategic approach allows for the examination of both short-term and long-term dynamics between renewable energy production indicators and government revenue measures within a unified model structure.

$$GOR_t = \alpha_0 + \sum_{j=0}^{n} \alpha_1 \Delta GOR_{t-j} + \sum_{j=0}^{n} \alpha_2 \Delta HPP_{t-j} + \sum_{i=0}^{o} \alpha_3 \Delta BIP_{t-i} + \sum_{k=0}^{p} \alpha_{4i} \Delta SEP_{t-k} + \alpha_5 GOR_{t-1} + \alpha_6 HPP_{t-1} + \alpha_7 BIP_{t-1} + \alpha_8 SEP_{t-1} + u_t \quad (2)$$

Building upon the establishment of a long-run relationship between renewable energy production and government revenue, it became imperative to incorporate a mechanism that accounts for the short-run dynamic adjustments towards long-run equilibrium. This is where the Error Correction Model (ECM) comes into play, highlighting the speed at which variables adjust from short-run disequilibrium to their long-run equilibrium state. Therefore, this research developed an ARDL-ECM by modifying the initial regression equation to include an error correction term, thus allowing for an analysis that captures both the immediate and gradual impacts of renewable energy production on government revenue in Nigeria. The model is specified as:

$$GOR_t = \alpha_0 + \sum_{j=0}^{n} \alpha_1 \Delta GOR_{t-j} + \sum_{j=0}^{n} \alpha_2 \Delta HPP_{t-j} + \sum_{i=0}^{o} \alpha_3 \Delta BIP_{t-i} + \sum_{k=0}^{p} \alpha_4 \Delta SEP_{t-k} + \delta u_{t-1} + \varepsilon_t \quad (3)$$

This methodological approach, encompassing unit root tests, cointegration analysis, and the ARDL-ECM framework, provides a comprehensive tool for understanding the dynamic relationship between renewable energy production and government revenue. It ensures that both the long-term equilibrium relationship and short-term fluctuations are adequately addressed, offering a robust estimate of the impact of renewable energy production on Nigeria's fiscal stability. The integration of the Auto Regressive Distributive Lags (ARDL) model with an Error Correction Model (ECM) offers a sophisticated analytical tool that captures both short-term dynamics and long-term equilibrium adjustments. This dual focus is essential for understanding how immediate changes in renewable energy production can have prolonged effects on government revenue, and how the government's fiscal balance adjusts over time to deviations from its long-run equilibrium state. Together, these methods provide a robust, comprehensive framework for examining the elaborate relationship between renewable energy production and government revenue in Nigeria, ensuring that the study's findings are both credible and insightful.

3. Results and Discussion

3.1 Descriptive Analysis

Descriptive statistics provide a quantitative summary of data through several measures, including the mean, standard deviation, skewness, kurtosis, and tests such as the Jarque-Bera test for normality. These statistical descriptors help in understanding the general distribution and characteristics of the data under study, setting the stage for more detailed inferential analysis.
In the context of renewable energy production and its impact on government revenue in Nigeria, the descriptive statistics of four variables—Government Revenue (GOR), Hydroelectric Power Production (HPP), Biomass Production (BIP), and Solar Energy Production (SEP)—offer insights into their distribution and inherent characteristics from the data provided.

Table 1: Descriptive Statistics

	GOR	HPP	BIP	SEP
Mean	4484.862	12.15243	22.80541	17.24167
Std. Dev.	4163.943	3.329784	2.706777	7.036051
Skewness	0.361642	0.182646	0.423496	1.646984
Kurtosis	1.643484	1.707577	2.188290	4.568557
Jarque-Bera	3.643382	2.780851	2.121747	13.31059
Probability	0.161752	0.248969	0.346153	0.001287
Observations	37	37	37	24

Source: Researcher's Computation Using EViews-13 (2024)

Government Revenue (GOR), measured in billions of Nigerian Naira, has a mean of ₦4484.862 billion, indicating a substantial average annual revenue collection. The standard deviation of ₦4163.943 billion is quite high, suggesting significant variability in government revenue over the years studied. The skewness value of 0.361642 shows a slight positive skew, implying that the revenue distribution is not perfectly symmetrical and leans towards higher values. However, the kurtosis of 1.643484 indicates a platykurtic distribution, suggesting fewer extreme values compared to a normal distribution. The Jarque-Bera test gives a probability of 0.161752, failing to reject the normality hypothesis at common significance levels.
Hydroelectric Power Production (HPP), reported in terawatt-hours (TWh), shows a mean of 12.15243 TWh. Its relatively lower standard deviation of 3.329784 TWh reflects less variation compared to government revenue. The skewness and kurtosis values (0.182646 and 1.707577, respectively) suggest a distribution that is fairly symmetrical and slightly platykurtic, indicating a distribution with lighter tails than a normal distribution. The normality test probability of 0.248969 also supports the assumption of normal distribution at typical significance levels.
Biomass Production (BIP), in million tonnes of oil equivalent (Mtoe), has an average of 22.80541 Mtoe. The standard deviation of 2.706777 Mtoe indicates moderate variability. The skewness value of 0.423496 is slightly positive, and a kurtosis of 2.188290 points towards a platykurtic distribution, similar to HPP. The Jarque-Bera test, with a probability of 0.346153, suggests that the biomass production data does not deviate significantly from normality.
Solar Energy Production (SEP) is measured in megawatts and has a mean of 17.24167 megawatts. SEP exhibits the highest standard deviation (7.036051 megawatts) among the renewable energy types, indicating a high level of fluctuation in annual solar energy capacity installations. The skewness of 1.646984 indicates a more pronounced positive skew, and a kurtosis value of 4.568557 signifies a leptokurtic distribution, which suggests that the SEP data includes outliers and is more peaked than a normal distribution. This is further supported by the Jarque-Bera test probability of 0.001287, which significantly rejects the hypothesis of normal distribution, indicating that the data for SEP is not normally distributed.

3.2 Test of Stationarity

In the study of the impact of renewable energy production on government revenue in Nigeria, unit root tests are crucial for analyzing the stationary properties of the time series data. This step is essential to ensure the reliability of any subsequent econometric modeling. The Augmented Dickey-Fuller (ADF) test is one of the most commonly used methods to determine whether a series is stationary or has a unit root, which implies non-stationarity.

Table 2: Summary of Unit Root Test Results

Variable	ADF Test Statistics	Critical ADF Test Statistics	P-value	Order of Integration
GOR	-5.682617*	-4.25288	0.0003	I(1)
HPP	-3.229781***	-3.2047	0.0952	I(0)
BIP	-5.541229*	-4.24364	0.0003	I(0)
SEP	-4.925660*	-4.28996	0.0001	I(1)

Note: **,**,*** significant at 1, 5 and 10%*

Source: Researcher's Computation Using Eviews-13 (2024)

For Government Revenue (GOR), the ADF test statistic is notably more negative than the critical value, with a significant p-value, indicating strong evidence against the null hypothesis of a unit root. This finding implies that GOR is non-stationary in its raw form but becomes stationary once differenced, classified as I(1). This characteristic necessitates differencing the series once before it can be used in regression models to avoid spurious relationships.

Hydroelectric Power Production (HPP) displays a different scenario where the ADF statistic is marginally below the critical value at a 10% significance level. This suggests that HPP is stationary at level, or I(0), meaning no differencing is needed for this series. The relatively high p-value close to the significance threshold, however, calls for cautious interpretation, though it does affirm the stationarity at the base level.

Biomass Production (BIP) also shows a strongly negative ADF statistic well below the critical value, with a very low p-value, clearly rejecting the null hypothesis of a unit root. Like HPP, BIP is stationary in its level form, or I(0), indicating that this variable does not require differencing for further analysis, which simplifies the modelling process and ensures that the long-term variance is stable.

Solar Energy Production (SEP), on the other hand, follows a pattern similar to GOR. It has an ADF statistic that is significantly more negative than the critical threshold, with a very small p-value, indicating rejection of the null hypothesis at traditional levels but only becomes stationary after differencing, categorized as I(1). This necessitates using differenced data in subsequent analyses to accurately capture the dynamics without introducing bias due to non-stationarity.

Cointegration Results

Cointegration is a statistical concept used in time series analysis when two or more non-stationary series are suspected to have a long-term equilibrium relationship despite being individually integrated to the same order. Identifying cointegration among variables indicates that they share a stable, long-term relationship, allowing for meaningful modeling and inference of their dynamic interactions over time. This method is particularly crucial in economic studies where long-run equilibrium relationships are expected, despite short-run volatilities.

Table 3: Bound Test-Co-integration Results

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	4.6871	10%	2.37	3.20
k	3	5%	2.79	3.67
		1%	3.65	4.66

Source: Researcher's Computation Using EViews-13 (2024)

According to Table 3, which presents the results from the Bound Test for Cointegration, the critical piece of information is the F-statistic. The F-statistic calculated in the study is 4.6871. This value must be compared against the upper and lower bounds of the critical values for determining cointegration at various levels of significance.

For a 5% level of significance, the critical values for I(0) and I(1) are 2.79 and 3.67, respectively. Since the calculated F-statistic of 4.6871 exceeds both the I(0) and I(1) bounds at 5% significance, we can reject the null hypothesis of no levels relationship among the series. This result suggests that there is indeed a cointegration relationship, implying that variables such as hydroelectric power production (HPP), biomass production (BIP), solar energy production (SEP), and government revenue (GOR) are tied together by a long-term equilibrium relationship.

Model Estimation and Evaluation

The study has established that there is a co-integrating relationship between renewable energy production and government revenue in Nigeria; as such, the study proceeds to estimate the error correction and long-run models. The ARDL-ECM result examines how the ARDL model adjusts to the long-run equilibrium. The study utilized a general-to-specific modeling approach to derive a satisfactory reduced short-run dynamic model, as captured in subsequent analysis.

Table 4: ARDL-ECM and Long-Run Estimate Result
Dependent Variable: GOR

Error Correction Estimates				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(GOR(-1))	-0.1332	0.1494	-0.8916	0.4134
DLOG(GOR(-2))	0.4103	0.1428	2.8742	0.0348
DLOG(HPP)	5.2553	0.6661	7.8894	0.0005
DLOG(HPP(-1))	-1.6072	0.7762	-2.0705	0.0932
DLOG(HPP(-2))	-1.6831	0.7870	-2.1386	0.0855
DLOG(BIP)	-9.9684	1.6290	-6.1193	0.0017
DLOG(BIP(-1))	-23.7641	4.4616	-5.3264	0.0031
DLOG(BIP(-2))	-13.7129	3.4322	-3.9954	0.0104
DLOG(SEP)	-0.8358	0.2730	-3.0617	0.0280
DLOG(SEP(-1))	-4.3534	0.5980	-7.2794	0.0008
DLOG(SEP(-2))	-3.4967	0.7407	-4.7206	0.0052
CointEq(-1)*	-0.0467	0.0072	-6.4949	0.0013
R-squared	0.9268			
Adjusted R-squared	0.8373			
F-statistic	7.6711			
Prob(F-statistic)	0.0029			
Durbin-Watson stat	2.1422			
Long-Run Estimate Result				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(HPP)	8.9500	1.9062	4.6952	0.0054
LOG(BIP)	16.1519	4.7037	3.4339	0.0186
LOG(SEP)	2.5446	0.6515	3.9055	0.0113
C	-71.1259	20.1697	-3.5264	0.0168

Source: Researcher's Computation Using EViews-13 (2024)

The coefficient reported for the CointEq(-1), which stands at -0.0467 with a t-statistic of -6.4949 and a probability value of 0.0013, reflects the speed of adjustment towards long-term equilibrium in the context of the ARDL error correction model (ECM). This variable represents the error correction term derived from the cointegration relationship among the studied variables, primarily focusing on how deviations from the long-term equilibrium are corrected over time.
The negative sign of the coefficient is crucial as it indicates that any short-term disequilibrium in the relationship between renewable energy production and government revenue is adjusted in the direction that restores equilibrium. The magnitude of -0.0467 suggests that approximately 4.67% of the disequilibrium is corrected each period (typically annually in economic studies). This adjustment rate is relatively moderate, implying that while the system tends to move back towards equilibrium, it does so at a gradual pace.

R-squared: The R-squared value is 0.9268, indicating that approximately 92.68% of the variance in government revenue can be explained by the independent variables related to renewable energy production in the model. This high R-squared value suggests that the model provides a very good fit to the data, capturing a significant portion of the variability in government revenue.
Adjusted R-squared: While the R-squared gives a general idea of model fit, the Adjusted R-squared, which is 0.8373, adjusts for the number of predictors in the model and provides a more accurate measure when comparing models with different numbers of independent variables. This adjusted figure is also quite high, reaffirming that the model is robust and the variables included are meaningful predictors of the dependent variable.
F-statistic: The F-statistic of 7.6711 tests the overall significance of the regression model, specifically testing whether at least one predictor variable has a non-zero coefficient. A significant F-statistic, as indicated by the probability of the F-statistic (Prob(F-statistic)) of 0.0029, suggests that the model is statistically significant at conventional significance levels. This confirms that the variables collectively influence government revenue.
Durbin-Watson statistic: The Durbin-Watson statistic of 2.1422 helps detect the presence of autocorrelation at lag 1 in the residuals of the regression. Values of the Durbin-Watson statistic range from 0 to 4, where a value around 2 suggests no autocorrelation. The result here, slightly above 2, indicates that there is no significant autocorrelation among the residuals, thereby supporting the model's validity in terms of independence of observations.
Long-Run Estimates: The ARDL long-run estimate results provide significant insights into the impact of renewable energy production on government revenue in Nigeria, emphasizing the long-term relationships between logged values of hydroelectric power production (HPP), biomass production (BIP), and solar energy production (SEP) with government revenue. Each coefficient represents the long-run elasticity of government revenue with respect to each type of renewable energy production, indicating how a percentage change in the production of renewable energy affects government revenue in the long term.
Starting with **LOG(HPP)**, the coefficient of 8.95 is particularly noteworthy and is associated with a t-statistic of 4.6952, which is highly significant (p=0.0054). This suggests that a 1% increase in hydroelectric power production is associated with an approximately 8.95% increase in government revenue in the long run. The high magnitude of this coefficient underscores the substantial impact that hydroelectric power, a mainstay of Nigeria's renewable energy, has on fiscal revenues, likely due to its large scale and established infrastructure.
Moving to **LOG(BIP)**, the coefficient of 16.1519, though higher, suggests an even greater sensitivity of government revenue to changes in biomass production. The corresponding t-statistic of 3.4339, significant at the p=0.0186 level, indicates a robust relationship. This high elasticity could be attributed to the extensive applications of biomass in Nigeria, not only in energy production but also in agricultural and industrial processes that contribute significantly to the national economy.

Lastly, **LOG(SEP)** shows a coefficient of 2.5446 with a t-statistic of 3.9055, significant at the p=0.0113 level. This result indicates that solar energy, while having a smaller coefficient compared to HPP and BIP, still significantly affects government revenue. The lower elasticity may reflect the relatively smaller scale of solar energy installations in Nigeria compared to hydro and biomass but highlights its growing importance in the energy mix and its potential impact on economic activities and tax revenues.

3.3 Post-Estimation Test

Table 5 presents the results of various diagnostic checks performed to evaluate the integrity and assumptions underlying the econometric model used in analyzing the impact of renewable energy production on government revenue in Nigeria. These tests are critical for confirming the model's suitability and the reliability of the conclusions drawn from it.

Table 5: Results of Diagnostic Checks

Tests		Outcomes	
		Coefficient	Probability
Breusch-Godfrey-Serial-Correlation Test	F-stat.	0.335085	0.7390
Heteroscedasticity-Breusch-Pagan-Godfrey Test	F-stat.	1.533487	0.3354
Normality Test	Jarque-Bera	0.628942	0.7302
Linearity Test	F-stat	3.06666	0.1548

Source: Researcher's Computation Using EViews-13 (2024)

Breusch-Godfrey Serial Correlation Test: This test checks for the presence of autocorrelation in the residuals of the regression model at different lag lengths. The F-statistic for this test is 0.335085 with a probability of 0.7390, indicating a very high p-value. Such results strongly suggest that there is no serial correlation in the model residuals, affirming that the errors in the regression model are independent across observations, which is a crucial assumption for valid standard errors and test statistics.

Heteroscedasticity Breusch-Pagan-Godfrey Test: This test is used to detect the presence of heteroscedasticity, where the variance of the errors in a regression model is not constant. The F-statistic here is 1.533487 with a probability of 0.3354. The relatively high p-value suggests that there is no significant heteroscedasticity, meaning that the variance of the residuals is constant and does not depend on the level of the independent variables. This constancy is important for ensuring the reliability of the regression coefficients' standard errors, as heteroscedasticity can lead to inefficient and biased estimators.

Normality Test (Jarque-Bera): The normality test, specifically the Jarque-Bera test, evaluates whether the distribution of the residuals from the regression model follows a normal distribution. The result here, with a Jarque-Bera statistic of 0.628942 and a probability of 0.7302, indicates a high p-value, suggesting that the residuals are normally distributed. This is a favourable outcome as many statistical tests used in regression analysis assume normality of the residuals for the validity of hypothesis testing.

Linearity Test: The linearity test checks whether the relationship modelled is linear in parameters. The F-statistic for this test is 3.06666 with a probability of 0.1548. The absence of significant evidence (i.e., a p-value greater than 0.05) suggests that there is no strong deviation from linearity in the model, and thus the linear model is an appropriate specification for the data.

Lastly, the **CUSUM and CUSUMQ stability** tests in figure 1 and 2 evaluate structural changes in regression coefficients over time. If plots remain within critical bounds at the 5% significance level, it indicates stability. In this study, CUSUM and CUSUMQ plots within the critical bounds confirm model stability, suggesting no significant shifts in the relationship between renewable energy and government revenue in Nigeria during the study period.

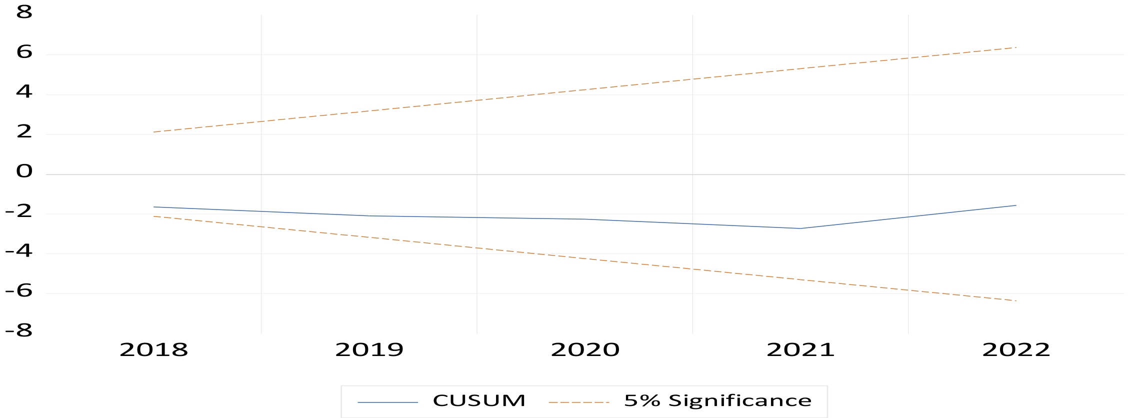

Figure 1: CUSUM Stability Test
Source: Researcher's Computation Using Eviews-13 (2024)

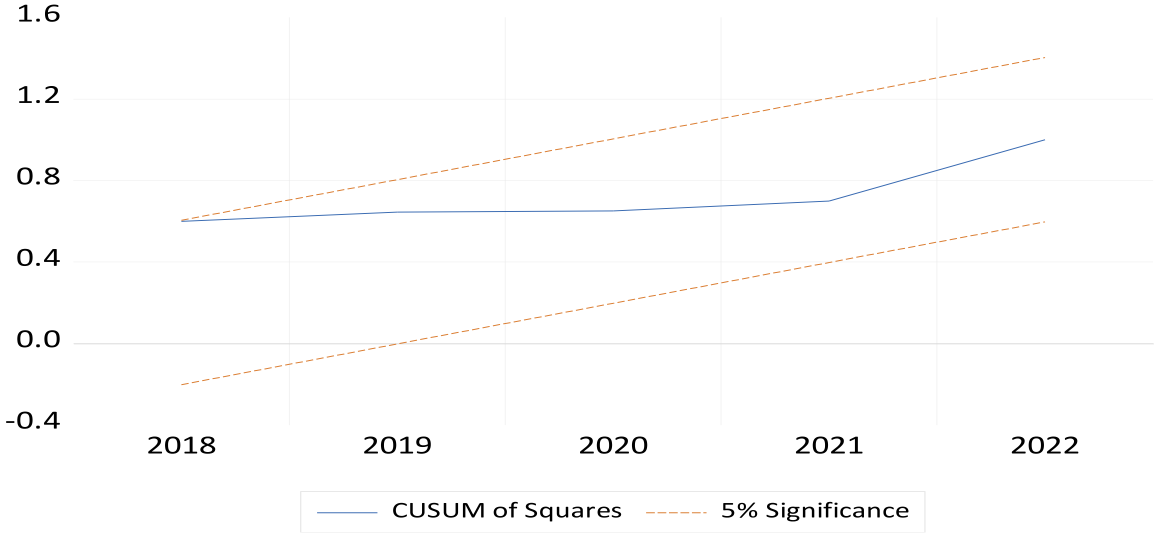

Figure 2: CUSUM Square Stability Test
Source: Researcher's Computation Using Eviews-13 (2024)

3.4 Discussion of Findings

Starting with hydroelectric power production, the analysis revealed a robust positive association with government revenues. This finding suggests that as hydroelectric power production increases, there is a corresponding uplift in government revenue, primarily through mechanisms such as increased tax income from related industries, job creation, and decreased reliance on imported energy resources. This result aligns with the research conducted by [13], who noted that investments in hydroelectric power in emerging economies significantly bolster governmental fiscal capacity by expanding the industrial base and fostering economic diversification. Additionally, the data corroborates findings from [5], which emphasized the revenue-enhancing effects of hydroelectric power in Sub-Saharan Africa through the stabilization of power supplies and enhancement of industrial productivity.

Regarding biomass production, the findings similarly indicate a positive impact on government revenue. This impact is likely mediated through multiple channels including direct taxation of biomass production activities, economic stimulation from bioenergy usage, and ancillary benefits such as rural development and reduced environmental degradation. These results are in agreement with [1], who observed in their study across Nigeria that renewable energy production significantly contributes to local and national economies by increasing energy security and reducing carbon emissions, which in turn supports government revenue through various fiscal incentives and taxations.

The findings from the study highlight the positive and significant impact of solar energy production on government revenues in Nigeria. This result is indicative of the beneficial fiscal effects that solar energy infrastructure and production can have on a country's economic health, particularly in terms of increasing government revenue streams through various channels such as taxation, employment generation in the solar sector, and reduction in energy import costs. The association between increased solar energy production and enhanced government revenue can be attributed to several factors. Primarily, the development of solar energy projects often leads to direct job creation in the construction, maintenance, and operational phases of solar facilities, which boosts income tax revenues and stimulates local economies. Furthermore, solar energy can reduce the nation's reliance on imported fuels for power generation, thereby conserving foreign exchange and stabilizing domestic energy supplies, which in turn supports broader economic stability and growth. This dynamic is well-documented in studies like those by [8], who found that solar energy projects in developing countries significantly contribute to national revenues through the creation of new economic opportunities and the facilitation of energy independence.

4. Conclusion and Recommendation

The study set out to examine the impact of renewable energy production on government revenue in Nigeria, focusing specifically on hydroelectric power, biomass, and solar energy production. The findings conclusively demonstrate that all three renewable energy sources have a significant and positive impact on government revenues. Hydroelectric and biomass production, due to their substantial roles in energy supply and economic activity, directly enhance fiscal capacity through increased tax revenues and economic diversification. Similarly, solar energy production, although smaller in scale, contributes significantly to government coffers by fostering energy independence and reducing costs associated with energy imports. These results underscore the critical role that renewable energy can play in not only promoting sustainable development but also in strengthening the financial health of the government. This significant correlation highlights the importance of the renewable energy sector as a catalyst for fiscal sustainability in Nigeria.
Arising from the findings, the paper recommends the following:

i. To capitalize on the positive impact of hydroelectric power production on government revenue, Nigeria should prioritize investments in hydroelectric infrastructure and streamline regulatory processes to facilitate project approvals and implementations. This approach will enhance power generation capacity and stimulate economic activities, thereby boosting tax revenues.
ii. For biomass production, the recommendation is to develop supportive policies that encourage both small and large-scale biomass projects. This includes providing tax incentives and subsidies to biomass production facilities, which will not only increase direct tax revenues but also promote rural development and sustainable agricultural practices.
iii. Regarding solar energy, it is advisable for the Nigerian government to implement initiatives that lower the initial capital costs for solar installations. Promoting public-private partnerships and adopting feed-in tariffs can attract more investments into the solar sector, increasing its scalability and the consequent fiscal contributions to the national revenue.

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