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Climate Finance and Renewable Energy Performance in Nigeria

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Abstract

This research investigation looked into the association between (climate finance) and the renewable energy effectiveness performance in the Colony Nigeria (over the year 1990-2024). The dependent variable in the study was renewable energy performance and the operationalization of climate finance included climate finance inflows, green bond proceeds, multilateral funding and the private sector investment. An ex post facto research design was used with the use of secondary time-series data from national and international financial and energy databases. The empirical estimation comprised descriptive statistics, Unit root test, Johansen cointegration analysis, and error correction model to estimate the long-run and short-run dynamics. Results showed that climate finance inflows made a significant contribution to the performance of renewable energy, which makes them key to scaling up renewable energy infrastructure. In contrast, green bond proceeds, multilateral funding and private sector investment were positively but statistically insignificantly dependent on the outcome indicating both bureaucratic bottlenecks, regulatory inefficiencies and financing gaps appear to be the prevailing obstacles to the immediate effect of this intervention. Johansen Cointegration results supported existence of a long-run equilibrium relation between the variables and the error correction mechanism showed that there is a meaningful speed of adjustment to long-run equilibrium. The study concludes that improved governance and better financial structures as well as appropriate incentives are required along with stronger institutional capacities in order to achieve maximum contribution of climate finance to Nigeria's transition to renewable energy.

Keywords: Climate finance; Renewable Energy performance; Green bond; Multilateral funding; Private sector investment

1. Introduction

The worldwide transition to low-carbon development has meant that the role of climate finance in the global acceleration of renewable energy deployment has been raised, especially in developing economies like Nigeria. Climate finance describes local and international financial resources earmarked towards mitigation and adaptation activities, which can, among others, include investments into renewable energy technologies (UNFCCC, 2022). Nigeria operates at constant deficits in energy sources as electricity access levels are consistently below global average, and there are heavy tilling of fossil-fuel-driven power generation (International Energy Agency [IEA], 2023). Although the country is blessed with a great deal of renewable energy resource such as solar, hydro and biomass, their scaling is a task that requires a great deal of and consistent financial inflows. Climate finance has therefore become a need-to-see enabler of Nigeria's energy transition (Ogunleye & Oni, 2021; Okene & Sunday, 2021).

Climate finance inflows into Nigeria are mostly from the multilateral development banks, bilateral partners, climate funds, and the domestic capital market. However, the amount of climate-tagged investment is far below what is deemed necessary compared with an estimated over 10 billion USD in investments per year required to meet Nigeria's renewable energy as well as net-zero pledges by 2050 (Energy Transition Office, 2022). Recent assessments have found

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that climate finance is not flowing into Nigeria, but indicating that it is improving, nevertheless flows are not yet sufficient and are fragmented across donors programmes, concessional loans, and grants (Climate Policy Initiative, 2023). This highlights the idea that there needs to be a greater understanding of his inflows being converted into actual renewable energy results. Green bonds are a constantly expanding source of mobilization of climate finance in Nigeria. The country became the first in Africa to issue a sovereign green bond in 2017 and subsequently it issues green bonds with the goal of financing renewable energy, afforestation and transport projects (Debt Management Office, 2021). While these issuances indicate commitment to green financing, issues abound on the appropriateness of scale of proceeds, efficiency of proceeds disbursement as well as the extent of green bond-funded projects contribution to renewable energy performance indicators such as installed capacity (reliability and access).

Multilateral funding from such institutions as the World Bank, African Development Bank, and the Green Climate Fund play a key role in filling the gap in financing. These institutions provide concessional loans, guarantees and technical assistance when risking investments in the area of renewable energy (World Bank, 2023). However, despite the effect of several large-scale funding commitment, challenges relating to implementation issues such as inconsistent regulation, currency instability and infrastructural deficiency have constrained the conversion of the funding into a measurable performance outcome (Adeniyi, 2020; Olulu-Briggs, 2021; Sunday & Wobo, 2025). Private sector intervention is also necessary in propelling the performance of renewable energy. Private capital has grown in the solar home systems and mini-grid markets of Nigeria but investor confidence is restricted by policy instability, poor offtaker creditworthiness and the lack of long-term financing tools in the market (Oyewole & Afolabi, 2022; Olulu-Briggs, 2023). Because of this, the renewable energy penetration is slow as compared to the available investment opportunities. Given these dynamics, analysing the relationship between climate finance as measured through the climate finance inflows, and green bond proceeds, multilateral funding and private sector investment, and renewable energy performance in Nigeria is important. Such analysis is a source of evidence-based insights in order to strengthen financial mobilisation strategies, improve policy alignment and enhance the progress of Nigeria's sustainable energy goals.

1.1. Statement of the Problem

Even though the number of studies on climate finance and renewable energy in Nigeria is growing, there are still substantial gaps. First, existing studies mostly use descriptive or policy-oriented methods and have focused on the volume of climate finance or the challenges of implementing renewable energy (Ogunleye & Oni, 2021; Adeniyi, 2020). There are few empirical studies to quantify the relationship between specific components of climate finance, e.g green bond proceeds, multilateral funding - and an indicator of performance in renewable energy. Second, previous studies often consider climate finance as a homogeneous phenomenon without addressing the fact that different channels of finance exist and these may differentially affect the implementation of projects (Climate Policy Initiative, 2023). Third, there is little cohesion of domestic and international sources of financing under a single analytical structure which ties finance to tangible measures of renewable energy performance, such as capacity expansion, system reliability and access. Consequently, policy recommendations are very general and do not build on empirical knowledge to an adequate extent. This study address this gaps by disaggregating climate finance in into specific, measurable components and studying these components of different effect on renewable energy performance in Nigeria thereby providing more well-rounded understanding of the effectiveness of climate finance which is data-driven.

2. Literature Review

2.1. Conceptual Framework

2.1.1. Renewable Energy Performance

Renewable energy performance relates to how effectively, reliably and effectively renewable energy systems are at providing, producing and supporting a renewable clean energy output and system over a period of time. In national energy systems, performance is usually measured using such indicators as installed renewable energy capacity, generation output, system stability, cost efficiency, reduction of environmental impact, and contribution to energy access (International Renewable Energy Agency [IRENA], 2022). Renewable energy performance is especially significant to countries committed to decarbonization and energy security policies because it is a measure of the ability of renewable energy technologies (solar, wind, hydro, geothermal, biomass) to satisfy electricity demand with minimal carbon emissions.

In developing economies like Nigeria, renewable energy intelligence includes socio-economic indicators such as rural electrification improvement, electricity affordability, lower sensitivity to fossil fuels as well as an enhancement of local economy as a result of clean energy adoption (International Energy Agency [IEA], 2023). The performance of renewable energy systems is affected by many factors such as technological maturity, availability of financing, enabling regulations, grid infrastructure and institutional capacity. For example, poor flexibility in the grid and lacking transmission - intermittent resources like solar and wind - assembled all together due to poor integration. to poor priorities, reducing performance outcome (World Bank, 2023).

Furthermore, renewable energy performance is closely related to long-term investments on innovation and maintenance. High performing renewable systems need constant upgrade, monitoring technologies and supporting policies for encouraging private sector and reducing investment risks (IRENA, 2022). Therefore, performance of renewable energy is not restricted to technical efficiency; it is a multidimensional concept based upon technological, financial, policy and socio-economic dimensions integrated together. Understanding these dynamics is critical to countries such as Nigeria as they seek to undertake large-scale Energy transitions to clean energy and ambitions to achieve sustainable development and climate.

2.1.2. Climate Finance

Climate finance is referring to public and private, domestic and international financial resources which are numbered specifically for assisting climate mitigation and adaptation activities. It comprises grants, concessional loans and equity investments, guarantees, green bonds, carbon markets, and finance blends for actions for reducing greenhouse gas (Greenhouse gas [GHG]) emissions and enhancing climate resilience (United Nations Framework Convention on Climate Change [UNFCCC], 2022). Climate finance plays a critical role in enabling countries - especially developing economies - to adopt low-carbon technologies, scale competencies (in terms of deploying renewable energy technologies) and increase resilience to climate vulnerabilities.

In the context of renewable energy, climate finance gives essential capital for project development, risk mitigation and building of infrastructure and market stimulation. According to the Climate Policy Initiative (2023), global climate finance flows reached more than US$600 billion annually, but developing regions such as Sub-Saharan Africa continue to receive a fraction of what they need. This funding gap is especially pronounced in Nigeria where to increase the growth of renewable energy, billions in investments are required, which cannot be generated with domestic funding alone (Energy Transition Office, 2022).

Climate finance flows on various channels which include multilateral development banks, bilateral donors, private financial institutions and climate funds like Green Climate Fund and the Global Environment Facility. Following are the functions of these institutions: These institutions offer concessional financing, technical support and policy support for investment risk reduction and private sector participation (World Bank, 2023). Complementary instruments that are the sovereign green bonds and the climate-related credit facilities further boosts the domestic capital mobilisation.

2.2. Theoretical Framework

2.2.1. Resource-based view theories (RBV)

The Resource-Based View RBV, assumes that the ability of an organisation to acquire and leverage valuable, rare, inimitable, and non-substitutable resources is its competitive advantage (Barney, 1991). In terms of the performance of renewable energy, RBV emphasises the way countries or firms that have access to key resources such as financial, technological and institutional resources, are in a better position to develop efficient and high-performing renewable energy systems. Climate finance, if in the form of grants, loans or private investments is a strategic resource which boosts the ability of energy institutions to innovate, install renewable infrastructure and improve system reliability (IRENA, 2022).

RBV also focuses on capability development such as technical expertise, research capacity and regulatory institutions to support establishment of renewable energy. For example, the performance of Nigeria in terms of renewable energy is affected by the institutional capacity for managing climate finance, coordinating donor funded projects and implementing regulatory frameworks. It is necessary that financial resources are accompanied by organizational capabilities in order to achieve a better outcome of renewable energy (World Bank, 2023).' Thus, RBV provides a theoretical base when analysing how different climate finance instruments contribute to improvements in performance through strengthening the resource base of the renewable energy sector.

2.2.2. Modern Portfolio Theory (MPT)

Modern Portfolio Theory (MPT): This theory developed by Markowitz (1952) states that investors can maximise their returns and minimise their risks if they diversify their investment portfolio. This theory is highly relevant to the topic of climate finance because renewable energy investments, namely solar, wind, hydro, biomass, etc., carry different levels of financial and technological risks. Investors, particularly in developing countries such as Nigeria, are exposed to regulatory risks, currency risks, and the challenges of infrastructure to resist investors from capitalizing on the opportunity. Climate finance instruments cover the issuance of green bonds, guarantees, concessional loans and blended finance mechanisms in the process of de-risking investment and facilitating the adequate r-o-r of renewable energy assets (Climate Policy Initiative, 2023).

MPT explains why private investors need risk level mitigation tools prior to allocating their capital to renewable energy projects. Through reduced risk by diversification, blended finance, multilateral guarantees and climate-related insurance, climate finance leads to greater private sector participation (UNFCCC, 2022). Furthermore, renewable energy portfolios - solar mini-grids, utility-scale solar, hydro refurbishments - also have diversification benefits that are consistent with MPT's principles. A well-structured climate finance system therefore is conducive to strengthening investment attractiveness, as it supports the performance of renewable energies by expanding the generation capacity and boosting the adoption of the technology (IEA, 2023).

2.3. Empirical Review

Imandojemu (2025) reported that improved green finance in 11 emerging economies improved environmental quality, for example, increasing clean energy usage and potentially increasing renewable energy penetration. Eke and Emasogbe (2025) researched Green finance instruments in Nigeria and found that green bonds, loans and renewable energy investments significantly contributed to the outcome of sustainable development and can support the relevance of green finance in promoting the performance of renewable energy in Nigeria domestically.

Rosadi and Nazliana (2024) have reviewed the global green finance instruments and discovered that green bonds, subsidies, and concessional finance were effective in promoting the adoption of renewable energy. The effectiveness relied on the quality of institutions and regulations and market maturity. A recent study by Li (2024), in developing countries, it was demonstrated that international green financing had a positive impact on the consumption of hydro and wind energy. Moreover, the digital economy reinforced the impact of green finance and therefore the importance of technology infrastructure on maximising the outcomes of renewable energy.

Zhang, Wang, and Dong (2023) conducted a panel study of 44 countries during 2007-2020, which found out that green finance, especially green bonds, contributed substantially to the increase of renewable energy production. The effect was stronger in countries with higher technological capabilities and higher exposure to climate risk, which suggests that green finance works well in promoting renewable energy growth in favourable institutional settings.

Muhammad et al. (2022) found that green bond issuance had a positive impact on renewable energy generation, especially towards energy from wind. However, there was a weaker effect on hydro and a negligible effect for solar energy during the pandemic of the Coronavirus (Demonstrating Heterogeneity Across Energy Types).

Muhammad et al. (2022), green bonds as a financing mechanism to support renewable energy projects: a call for standards, liquidity and measurement, Sustainable Finance Corporation, have highlighted that although green bonds are a vehicle for raising capital for renewable energy projects there can be a lack of standardisation, issues of liquidity and weak impact measurement mean that they cannot be effective, especially in less-developed financial markets. Truby and Skees (2020) studied 55 countries and found that the overall financial development was a significant factor in renewable energy deployment. However, the impacts were higher in high income countries, whereas in low income countries, the impacts were limited because of poor financial markets and institutional challenges.

3. Methodology

The research design used in the study was ex post facto research, which was suitable in the research because the variables of finance inflows to climate finance, green bond proceeds, multilateral fund, private sector investment, and performance to renewable energy were not even possible to be manipulated by the researcher. Ex post facto design provided the researcher the possibility of studying historical data after the fact and making inferences based on the data that was already known i.e. on numerical records. As referenced by Kerlinger and Lee (2000), ex post facto research was appropriate when the variables already existed and could not be changed. This design was common in studies in which there were no opportunities to conduct experiments given the use of secondary macroeconomic and financial data (Creswell and Creswell, 2018; Olulu-Briggs & Sunday, 2021; Okene & Sunday, 2021). The period 1990 to 2024 allowed for typically long enough period in which to assess trends, long-term association and structural changes in the dynamics of climate finance and renewable energy.

The research was conducted entirely using secondary sources, annual time-series in data on the years 1990-2024. This nature of data was appropriate because climate finance and renewable energy indicators routinely published by governmental and international organisations were credible. Data on climate finance inflows, multilateral funding and private sector renewable investments were taken from organisations such as the World Bank, International Renewable Energy Agency (IRENA), International Energy Agency (IEA) and the Climate Policy Initiative (CPI). Green bond proceeds have been acquired from Debt Management Office (DMO) of Nigeria and Securities and Exchange Commission. Renewable energy performance data including the installed renewable capacity, the generation output, and the renewable energy contribution to the national energy mix were taken from IEA databases and from the Federal Ministry of Power in Nigeria. Secondary sources were used as they had reliable, standardised, and long-term data that could be used in econometric modelling, which was consistent with the recommendations of Saunders et al. (2019). The datasets had high validity and were recognised internationally for their accuracy from an analytical point of view.

The study was conducted using the documentary approach to data collection. This approach involved using data on macroeconomic and energy sector variables that were available in published form in various statistical databases, annual bulletins and institutional reports. Documentary review was suitable for analysis of past trends as well as econometrics analysis based on available secondary data sources (Johnston, 2017; Olulu-Briggs & Sunday, 2021). Each of the datasets was downloaded, cleaned and assembled in structured time-series format. Data observations were organised by year to make the data uniform in variables. The retrieved data were then loaded by statistical software for further processing and analysis. This approach addressed the issues of completeness, consistency, and replicability of the empirical investigation.

The descriptive and inferential statistical methods were used in the study. Descriptive statistics, such as means, standard deviations, minimum and maximum values, and graphs of trends were used to summarize the nature of the data and find historical trends. A unit root test based on Augmented Dickey-Fuller (ADF) procedure was performed in order to identify stationarity of the variables of time series. Unit root testing was necessary to avoid spurious regression results and provide good statistical inference (Dickey & Fuller, 1979). Following stationarity tests, the Johansen co-integration test was used in order to reveal the existence of long-run equilibrium relationship among the variables. The method of Johansen was applicable to multivariate time series analysis and made it possible to find one or more co-integrating vectors (Johansen, 1991). Given the presence of co-integration, an Error Correction Model (ECM) was estimated in the study which aims to capture the long-run relationship and short-run adjustment dynamics. The ECM framework allowed one to measure the speed of adjustment of variables towards LRE following short-run shocks. The inclusion of ECM was in accordance with the methodology suggested by Engle and Granger (1987) who stressed on the suitability of such a methodology in the case of studies involving non-stationary but co-integrated time series variables. All statistical analyses were conducted with econometric software including EViews, which are both very popular in quantitative energy finance research.

The model of the study shows:

$$REP = f\,(CFI, GBP, MUF, PSI) \qquad \ldots\ldots\ldots\ldots\; 3.1$$

$$REP_t = \delta_0 + \delta_1 CFI_t + \delta_2 GBP_t + \delta_3 MUF_t + \delta_4 PSI_t + \epsilon_t \qquad \ldots\ldots 3.2$$

On apriori δ_1, δ_2, δ_3, and $\delta_4 > 0$

Where, REP = Renewable energy performance, CFI = Climate finance inflows, GBP = Green bond proceeds, MUF = Multilateral funding, PSI = Private sector investment, t = Annual time series, δ_1, δ_2, δ_3, and δ_4 = Constant Parameters

4. Results

The average value of REP was 52.23, which suggested that on average, the renewable energy performance in Nigeria was categorised as moderate within the study period. The value of the median (52.59) being close to the mean value is an indication that the distribution is fairly symmetrical and this is supported by a low value for the measure of skewness (0.10). The minimum and maximum values (20.99 and 86.65) indicate ups and downs in the performance of renewable energy, which is related to particular periods of policy efforts and to poor periods related to investments. The standard deviation (19.39) indicates a middle variance of the variation of REP with time. Climate Finance Inflows (CFI) showed a great variation with an average of 2497.64 and very high standard deviation (1552.56) showing wide variation in the inflow of climate finance in Nigeria. The negative minimum value (-194.16) implies either periods of withdrawal, reclassification of funds or net repayment of financial commitments related to climate. The highest value reached at 4926.73 indicates that some periods were characterised by very high inflows, which may be linked to international climate agreements or increased donor assistance. Its skewness (-0.03) and kurtosis (1.84) indicate that it is quite symmetric and has light tails.

Green Bonds Proceeds (GBP) averaged 1232.44 as a result of increasing adoption of green bonds as a tool of sustainable financing in Nigeria. However, the fact that there is a negative minimum data value (-98.84) suggests that there is some strange data year that's probably related to some poor data reporting or deficient years in the early years without green bond issues. The presence of huge fluctuations is confirmed by the standard deviation (734.57). Its skewness (-0.06) and kurtosis (1.83) are also indicators of mild left-skewness and light tails. Multilateral Funding (MUF) with a mean of 1520.04 also exhibited variability as was evident from the standard deviation (878.67). This is to be expected given that multilateral climate-related funding is dependent on international negotiations, donor priorities, and global climate commitments. The distribution was nearly perfectly symmetrical (skewness -0.001), with similarly light kurtosis (1.82); this is suggestive of moderate variability around the mean.

Table 1 Descriptive Statistic Result

	REP	**CFI**	**GBP**	**MUF**	**PSI**
Mean	52.23471	2497.644	1232.441	1520.037	2067.311
Maximum	86.64509	4926.739	2475.807	2993.999	4055.338
Minimum	20.99343	-194.1687	-98.84412	70.40509	7.915118
Std. Dev.	19.39096	1552.561	734.5662	878.6736	1195.914
Skewness	0.101258	-0.034987	-0.062877	-0.001523	-0.040386
Kurtosis	1.825852	1.849129	1.830560	1.819599	1.778286
Jarque-Bera	2.070304	1.938709	2.017463	2.031978	2.186199
Probability	0.355172	0.379328	0.364681	0.362044	0.335176

Source: E-views 10 Output

Private Sector Investment (PSI) had a mean of 2067.31 indicating that there was significant private sector contribution towards financing climate and renewable energy over the period. The large standard deviation (1195.91) indicates significant fluctuations which may indicate macro-economic conditions, changing regulations or foreign exchange shocks. Skewness (-0.04) and kurtosis (1.77) again point to the presence of mild left-skewness and low peakness. All the Jarque Beras are greater than 0.05, which means that we have a normal distribution of the variables, hence we got a valid statistical analysis. The number of observations (35) would indicate that we have a long-enough data span for a good econometric estimation. The large gaps between the minimum and maximum values are due to structural economic changes, policies of global climate change, and local investments. Overall, the descriptive statistics suggest moderate stability of REP, high variability of financing variables and distributions amenable to advanced time series modelling.

4.1. Unit Root Test

Table 2 Unit Root Result

Variables	**T-Stat @ Level**	**T-Critical @ level**	**P-value @ level**	**T-Stat @ 1st Diff.**	**T-Critical @ 1st Diff.**	**P-value @ 1st Diff.**	**Order of Integration**
REP	0.356632	-2.957110	0.9777	-8.504639	-2.957110	0.0000	I(1)
CFI	-0.844639	-2.951125	0.7932	-6.560043	-2.957110	0.0000	I(1)
GBP	-0.491561	-2.963972	0.8795	-8.744365	-2.963972	0.0000	I(1)
MUF	0.064756	-2.957110	0.9578	-6.328620	-2.97853	0.0000	I(1)
PSI	- 0.444731	-2.963972	0.8887	-5.818591	-2.963972	0.0000	I(1)

Source: E-views 10 Output

The results of the unit root tests imply that all the variables viz., REP, CFI, GBP, MUF and PSI were non-stationary at l, but became stationary after taking first difference. At level, the t statistics of all the variables were less negative (greater) than the 5% critical values and p values were significantly more than 0.05. For instance, REP had a t-statistic value of 0.3566 compared to a critical value of -2.957 with a probability value of 0.9777 which is clearly non-stationary at level. Similar trends happened for CFI (t-stat -0.8446; p = 0.7932), GBP (t-stat -0.4915; p = 0.8795), MUF (t-stat 0.0648; p = 0.9578), and PSI (t-stat -0.4447; p = 0.8887).

At first difference, however, all variables became significant at the level of 1% of significance with the t statistic values more negative than the critical values. REP gave us a t-statistic of -8.5046 (p = 0.0000), and this confirms stationarity. CFI also became stationery with the t-statistic of -6.5600, there is strong evidence of a first difference stationery relationship. GBP, MUF and PSI all showed similar results with highly significant p-values of 0.0000. This means that all the variables were integrated of order one, I(1).

The implication of the unit root outcome is important from the aspect of methodological reliability. Time-series data that are non-stationary will produce spurious results if the data is analysed in levels. Therefore, recognition of the fact that the variables are I(1) explains the appropriateness of using Johansen co-integration and ECM. The confirmation of a common order of integration provides the setting up for the setting up whether the variables share a long run equilibrium relationship.

The non-stationarity at level may be a reflection of the unstable macroeconomic activity of the Nigeria and fluctuations in investments in relation to renewable energy financing. Climate finance variables tend to be affected by policy cycles, donor commitments, changing geopolitical interests, exchange rate volatility and world energy trends. The renewable energy performance data are also likely to reflect the changes in energy policies, national investment trends and infrastructural development phases.

The results of the unit root tests prove that all data series were I(1) and hence accepted the application of co-integration and error correction modelling. This result is in line with the common characteristic of macroeconomic and financial time series data, which appear to be non-stationary at level but stationary in first differences.

Table 3 Result of Johansen Co-integration

Series: REP CFI GBP MUF PSI				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		**Trace**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.622295	95.05497	69.81889	0.0001
At most 1 *	0.583612	62.92477	47.85613	0.0011
At most 2 *	0.503496	34.01220	29.79707	0.0154
At most 3	0.279012	10.90682	15.49471	0.2173
At most 4	0.003372	0.111448	3.841466	0.7385
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.583612	28.91257	27.58434	0.0336
At most 1 *	0.503496	23.10537	21.13162	0.0260
At most 2	0.622295	32.13020	33.87687	0.0796
At most 3	0.279012	10.79537	14.26460	0.1648
At most 4	0.003372	0.111448	3.841466	0.7385

Source: E-views 10 Output

The Johansen co-integration results indicate the existence of a long-run relationship between the different variables: Renewable energy performance (REP), climate finance inflows (CFI), green bonds proceeds (GBP), multilateral funding

(MUF) and private sector investment (PSI). The Trace statistic identifies three co-integrating equations at the 5% level of significance while the Maximum Eigenvalue test identifies at least two co-integrating vectors, both significant at 5%.

The Trace test shows that the null hypothesis of "no co-integrating vector" was rejected as the Trace statistic (95.0549) was greater than the 5% critical value (69.8189) with a probability of 0.0001. This suggests at least one long run relationship equilibrium. In addition to this the hypothesis of no more than one and no more than two co-integrating vectors respectively were also rejected with Trace values of 62.9248 and 34.0122 respectively. The results confirm three stable long run relationship among the variables. The co-integration test in terms of the Max Eigenvalue test two co-integer equations. For example, the null of no co-integration was accepted with a Max-Eigen statistic of 28.9126, which is greater than the critical value of 27.5843 (p = 0.0336). The second equation (23.1054 > 21.1316) was also significant at 5%. These results serve to validate the existence of a stable equilibrium relationship between the performance of renewable energy and the four indicators regarding climate finance.

Existence of co-integration suggests that although each variable is I(1), they move together in the long run, and there is mutual interdependence. In the realities, hedging on the amounts of Climate finance inflow, green bonds issued by governments, multilateral climate support and private will influence the performance of renewable energy in Nigeria in the long run. This finding is consistent with the theoretical proposition that for long-term renewable energy development, there have to be sustained financial flows, diverse financing mechanisms and private-sector participation. The stability implied by the co-integrating vectors implies that when shocks to climate finance or investment variables affect climate finance, these permanent derailments in terms of weathering off the trajectory of renewable energy are not permanent but are gradually adjusted back to equilibrium. This is of relevance for policy: it is important to keep a long-term trajectory of renewable energy up to date only with the help of consistent streams of finance from climate change. The Johansen test proves the existence of a long-run relationship, which warrants the application of the Error Correction Model in the rest of the analysis to extract short run dynamics whilst preserving the integrity of the long run equilibrium.

Table 4 Parsimonious ECM Result

Dependent Variable: REP				
Method: Least Squares				
Sample (adjusted): 1991 2024				
Included observations: 34 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CFI)	0.005045	0.002217	2.275538	0.0307
D(GBP)	0.005800	0.003474	1.669603	0.1061
D(MUF)	0.005967	0.003760	1.587130	0.1237
D(PSI)	0.001735	0.002306	0.752568	0.4580
ECM(-1)	-0.253043	0.106795	-2.369433	0.0242
C	19.77238	1.017119	19.43960	0.0000
R-squared	0.983148	Mean dependent var		53.15358
Adjusted R-squared	0.980138	S.D. dependent var		18.89332
S.E. of regression	2.662670	Akaike info criterion		4.955321
Sum squared resid	198.5147	Schwarz criterion		5.224678
Log likelihood	-78.24045	Hannan-Quinn criter.		5.047179
F-statistic	326.6965	Durbin-Watson stat		1.823124
Prob(F-statistic)	0.000000			

Source: E-views 10 Output

The results presented by the ECM pick up the short-run dynamics as well as the speed of adjustment into long-run equilibrium between renewable energy performance (REP) and climate finance components. The coefficient of error correction term (ECM-1) was -0.2530 and it was found to be significant at 5% level (p =0.0242), which shows speed of adjustment (25.3%) for every period. This means that if there is any deviation from long-run equilibrium 25% on average of the disequilibrium will be corrected every year, confirming a moderate and statistically significant convergence process.

In terms of short-run effects climate finance inflows (CFI) had a positive and significant coefficient of 0.005045 (p = 0.0307). This implies that increases in climate-related financial inflows had an immediate and positive impact on the performance of renewable energy. This relationship is in line with empirical expectations that the availability of funds will help to improve the development of energy infrastructure and renewable technology. Green bonds proceeds (GBP) had a positive and insignificant coefficient of 0.005800 (p = 0.1061). Although it seems that green bonds show a positive impact on renewable energy, insignificance of the impact implies that the green bond market in Nigeria may not be mature with the required market scale to achieve a significant short-run impact.

Multilateral funding (MUF) also had a positive but insignificant coefficient (0.005967; p = 0.1237). This implies that though the support of renewable energy through multilateral funds is helpful, there may be delays in disbursement, bureaucratic processes and conditionalities which may weaken immediate effects. Private sector investment (PSI) had very small coefficient; the result is positive insignificant (0.001735; p = 0.4580). This points to the reality that private investment, while an important part of financing energy transitions, is in the short term constrained by regulatory uncertainties, risks in markets or the lack of infrastructures.

The model overall showed a good goodness-of-fit as evidenced by R-squared value of 0.9831 and adjusted R-squared value of 0.9801 which in turn mean about 98% of the variations of renewable energy performance has been explained by the model. The F-statistic (326.70; p = 0.0000) is statistically significant, confirming that the whole model was statistically significant. The Durbin-Watson statistic (1.823) indicates that there is no serious autocorrelation, and therefore there is reliability of the model estimates. In conclusion, the ECM suggests that the climate finance inflows had an important effect on renewable energy performance in the short run, while other dimensions of climate finance had statistically weak positive effects. The existence of these stable long-run relationship can be confirmed by the significant error correction term, being consistent with the Johansen co-integration results.

5. Discussion of Findings

The discovery of a positive and significant relationship between climate finance inflows (CFI) and renewable energy performance (REP) implies that expansion in the amount of climate related funding into Nigeria made a significant contribution to improvements in renewable energy output, capacity or share. This result is corroborated by the empirical evidences obtained from studies that seek the link between green/ climate-related finance and improved renewable energy deployment and energy transition results (e.g., cross-country analyses that find that green finance significantly promotes renewable energy production over time) (Alharbi, Mamun, Boubaker & Rizvi, 2023). The interpretation in significance is that there is likely to be more to climate finance than just a coincidental association, since it has been a source that contributed substantively in allowing Mexico's renewables to take off, taking into account the role that finance in climate finance provided in enhancing finance provision essential to project development, de-risking new businesses, enabling infrastructure expansion, and supporting financing infrastructure - in fact underwriting costs that otherwise may have constrained the growth of renewables in Nigeria's context where private investment, and where private investment proves to be limited, and where domestic funding may also be limited. The high R-squared value and goodness-of-fit model confirm that the contribution of climate finance flows accounted for a significant amount of unequal variation in renewable energy performance over the study period. The result suggests that climate finance is a critical driver which could lead to the scale-up of generation, installation of renewable capacity, and reliability.

The positive but statistically insignificant coefficient on green bonds proceeds (GBP) suggests that, while there may be some association between the two variables, in the short run the effect of bond issuance on increases in renewable energy performance is weak if it exists at all. This might reflect structural limitations of the green bonds market in Nigeria: Although green bonds, be it sovereign or corporate, can be issued, the scale and maturity of the bonds, and the mechanism for disbursing them can be inadequate to significantly impact energy infrastructure on a scale. International literature highlights the capacity of green bond to stimulate renewable energy -- often, the efficiency of this category of bonds does depend on the level of the financial market maturity, the quality of the regulations and the presence of high-quality institutional frameworks (Alharbi et al., 2023; Green bond efficiency studies). For instance, a recent global study showed that green finance had helped to prominently share renewable energy deployment, however the impact associated was higher in countries with well developed financial sector and stronger institutions (Alharbi et al., 2023). The financial and regulatory environment in Nigeria may be a limiting factor in the immediate potency of green bonds in Nigeria. Alternately, time may elapse between issuing bonds and actually implementing a project which may dilute the significance of short term results. Thus, although green bonds have the promise, the shortcoming of the market and the structure may have hindered the efficacy of green bonds in improving renewable energy performance in Nigeria during the period of this sample.

The positive but insignificant coefficient on multilateral funding (MUF) indicates that despite the fact that private and public multilateral contributions appear to have been associated with renewable energy performance improvements, it did not result in a statistically distinguishable short-run effect in the model. This may be due to a number of factors. First, multilateral funds come with often long project cycles with conditionalities and delays in disbursement or implementation which may dilute short run impacts. Second, even with committed funds, bottlenecks like regulatory approval, institutional capacity and project preparation could delay the realisation of these funding commitments into actual deployment of renewable energy projects with some countries such as Nigeria where institutional and policy uncertainty is as a challenge (Dioha & Abraham-Dukuma, 2023). Third, multilateral funding may have been used partially on capacity building, policy reforms, or adaptation instead of immediate generation infrastructure so its immediate impacts on REP may be removed. These dynamics are broadly consistent with literature noting that while climate-related development finance does increase renewable energy use in some contexts (things like African basin studies for example), the effect may be variable and dependent on the effectiveness of funds being translated into projects. Therefore, while the sign is as expected, the fact that results are not statistically significant signals that there will be a need to address structural and institutional bottlenecks to ensure that funding commitments result into tangible renewable energy outputs.

The positive, but insignificant impact of private sector investment (PSI) on renewable energy performance implies that private capital inflows have not, during the period for which the analysis is conducted, translated into detectable improvements in renewable energy output / capacity. This may be attributable to continued institutional, market and structural barriers in the Nigerian energy sector that prevent private investment from reaching full completion. For instance, lack of stable power purchase agreements, weak regulatory environments, currency risk and high cost of borrowing among others as well as poor infrastructure have been documented as major obstacles to private sector engagement in renewable energy across Sub-Saharan Africa (Ifanayozie-Nwaoha, 2025). Even where there is private investment to date, it has been to do small-scale or pilot projects with limited aggregate effect, or has encountered difficulties in scaling up. Such constraints can make it impossible to consistently improve performance and explain why PSI's coefficient is not statistically significant. The literature on private investment on renewables in Africa captures these issues, which have been noted that private participation remains limited due to financial and regulatory risks (Ifanayozie-Nwaoha, 2025), making the impact of private capital on leading to sector-wide energy transition outcomes limited.

6. Conclusion

This study examined the impact of climate finance on the performance of renewable energy in Nigeria between 1990 and 2024 in respect of climate finance flows, green bond proceeds, multilateral finance and private sector investments. The findings showed that climate finance flows had a positive and significant impact on renewable energy performance, showing the importance of this financial instrument in the growth in renewable generation capacity and increased efficiency in the sector. In contrast, the proceeds of green bonds, multilateral funding and investments by the private sector showed positive but statistically insignificant effects suggesting the presence of institutional, regulatory and structural constraints making their short-term effects weak. The evidence of cointegration confirmed the fact that climate finance and renewable energy performance have a long-run equilibrium relationship while the error correction mechanism showed meaningful short-run adjustments. Overall, the results show that Nigeria's renewable energy transition is highly reliant on the effective mobilization and expenditure of climate finance, with support by good institutions and governance structures. The study concludes that improvement of climate finance architecture as well as enhancing transparency, private sector incentives, and multilateral fund utilisation need to be strengthened to optimise the outcome of renewable energy and accelerate Nigeria's low-carbon development pathway.

6.1. Limitations

This study is limited as it uses secondary data that may have measurement inconsistencies due to the differences in data reporting from one institution to another and year to year. The analysis included aggregates for the country, which may not represent the minimum/maximum this phenomenon in disparity of renewable energy deployment at the state level. Additionally, some components of climate finance, for example, private green equity and concessional loans might not have been fully accounted for due to data unavailability. The study also prioritized the analysis of linear relationships without exploring the possible non-linear or threshold phenomenon in climate finance relationships. Finally, the ex-post facto design limits the causal inference because the study could not manipulate anything but only rely on the observed data in the past. Despite all the shortcomings, the study offers compelling empirical knowledge on climate finance - renewable energy dynamics in the Nigerian context.

Recommendations

Based on the research results these following recommendations have been established:

- The Federal government of Nigeria and regulations should formulate and institutionalise a separate national fund that channels all climate finance inflows directly to the renewable energy infrastructure projects with proper, transparent tracking and disbursement. This fund should have high impact focus (e.g on grid connected renewables, mini grids), to create maximum gain in performance.
- The Federal government of Nigeria should reinforce the developed green bond setup -- enforce transparency in the application of proceeds, assure credible projects pipelines prior to issuance, and add long-term incentives (i.e. tax breaks, guarantees) to encourage institutional and private donors to commit.
- Multilateral agencies and government should work together on a streamlined project preparation and disbursement facility to minimise bureaucratic delays, coordinate regulatory approval and ensure a clarity of fund to project pipelines to avoid overcommitting resources.
- The Federal government of Nigeria should introduce regulatory reforms and incentive schemes (e.g., feed-in tariffs, guarantees, local-currency financing, stable PPAs) to lower risk and enhance the attractiveness of renewable energy investments to get funds from the private sector to translate more effectively into gains in performance.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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