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Green Financing and Sustainable Economic Development in Nigeria: Evidence from an ARDL Bounds-Testing Approach

Wailat Ajoke MUDASHIR[1] & Sesan Sunday ABERE[2]*

[1]Department of Economics, Federal College of Education, Iwo, Osun State, Nigeria.
[2]Department of Economics, Ajayi Crowther University, Oyo, Oyo State, Nigeria. ORCID: https://orcid.org/0000-0003-0863-4529

***Corresponding Author**: Sesan Sunday ABERE
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Abstract

Although green financing is being widely encouraged as a tool to reconcile economic growth and environmental sustainability, there is limited empirical evidence on how green financing helps towards sustainable economic development for energy-poor, oil-dependent economies. The literature from existing studies paid little attention to Nigeria, despite playing a significant role in the energy transition in Africa. The shortcoming is exacerbated by poor adherence to the Nigerian Sustainable Banking Principles, inadequate green bond market structure and lack of quantitative proof of the economic returns of green financing. This paper examines the impact of green financing on sustainable economic development in Nigeria using annual time series data from 1981 to 2024. The principal-component composites of adjusted net savings, the ecological footprint to biocapacity ratio and the Human Development Index serve as proxies for sustainable economic development, and the PCA composites of renewable energy and CO_2 indicators serve as proxies for green financing. The order of integration is mixed, which is confirmed by the Johansen procedure and ARDL bounds testing is applied after the long run cointegration was confirmed. The results reveal that there is a long-run relationship between green financing and sustainable economic development which is statistically significant and positive and the adjustment speed is rapid. FDI is a positive force to sustain this positive trend, while inflation, money supply growth and currency devaluation are drags. The study calls for an increase in green bond issuance and tighter regulation enforcement.

Keywords: *Green financing, Sustainable economic development, Ecological footprint, Adjusted net savings, Oil dependent economy.*

JEL Classification: *Q56, G23, O44*

1. Introduction

Finance and Sustainable development is a subject that has exercised economists since early speculations on financial intermediation theory, a theory that views the finance and investment channel through which savings flow to productive investment as a key determinant of long-run growth. What is comparatively new in the conditionality of that channelling function is the explicit ecological conditionality that has been added: capital is no longer only evaluated according to its ability to produce returns, but also increasingly according to whether or not the activities financed are compatible with planetary boundaries and intergenerational equity (World Commission on Environment and Development, 1987). This reorientation has led to the creation of a modern architecture of 'green finance', which includes green bonds, sustainability-linked loans, climate risk disclosure frameworks and green investment funds, all aiming to address the lack of pricing of environmental externalities in traditional financial markets.

Green finance has become one of the most impactful innovations in the field of development economics today, providing a channel for the reallocation of capital away from environmentally harmful investments towards climate-resilient and low-carbon infrastructure and renewable energy. Financial systems are now expected to

have a dual role – mobilising productive investments, and protecting the ecological foundations of long-term prosperity through tools like green bonds, climate-aligned loans and sustainable investment funds (Taghizadeh-Hesary & Yoshino, 2020). Green finance is increasingly gaining attention in both research and policy circles due to its potential to finance sustainable economic development, which refers to a development process that can increase current welfare without sacrificing the resources and welfare of future generations (Bei & Wang, 2023).

This is a very important question in Nigeria. Nigeria continues to have one of the highest energy-poverty burdens in Sub-Saharan Africa, further characterised by the heavy dependency on oil rents, and a nascent thinly capitalised green bond market despite being the first country to issue a sovereign green bond in 2017. In Nigeria, the Sustainable Banking Principles, launched in 2012 by the Central Bank of Nigeria, aimed to mainstream environmental and social risk management in the financial sector; however, implementation has been patchy and green lending is still limited in scope when compared with the environmental and developmental needs of the country. It is an empirical question whether these instruments have resulted in sustainable economic development or just symbolic/reputational signalling.

Although the body of empirical literature on green financing and sustainable development is growing quickly, the majority of the studies are focused on Iran (Tavakoli et al., 2024), Egypt (Elsherif, 2023), Russia (Semenova et al., 2020) and China, for which there are several studies. Nigeria is the largest economy in Africa with a large share of Africa's carbon footprint, only in passing is the name mentioned across this body of work. This is a significant lapse in view of Nigeria's structural peculiarities, including its heavy oil dependence, underdeveloped green taxonomy, high level of informality in the financial system, and high level of energy poverty, which influence how green financial flows will or will not map to sustainable results. Likewise, Elsherif (2023) found a correlation between the use of green financing and reductions in emissions and improved research and development outcomes in Egypt, but fails to investigate green financing instruments like green bonds and has no real discussion about the regulatory enforcement deficits which is far more significant in Nigeria. Recent contributions continue in this vein: Akerele et al. (2025) analyze green finance and sustainable development in Nigeria, employing a VECM model; Cheteni et al. (2025) analyse South Africa's green bond market but do not extend the analysis to Nigeria's older, albeit shallower green bond programme; and Mehrotra and Gupta (2026) offer only a conceptual examination of the role of green bonds in sustainable infrastructure development without attempting econometric estimation, conducted in a country-specific context. This means the real contribution of green financing to the sustainable economic development indicators of Nigeria remains under quantified, with a poor level of statistical robustness and magnitude.

In addition to the geographical disparity, methodological restrictions are found throughout the literature. Many of the studies conducted at the country level are based on small sample sizes, purely qualitative or descriptive studies lacking formal econometric validation (Stojanovic, 2020) and/or are not designed to address the mixed order of integration usually found in macroeconomic time series in developing economies. Panel studies are also under-representative of Sub-Saharan African and oil-dependent economies, and even where these economies are considered, such as in Amer and Kareem (2025), the focus is on energy poverty, as opposed to the broader green finance-sustainable development nexus. These gaps make a single-country study based on a sufficiently long-time span (to capture structural dynamics) and methodologically robust worthwhile.

The research question addressed by this paper is thus located at a nexus of three literatures, which have not previously been combined in respect of a single oil-dependent African economy: the finance-growth literature, the sustainability-measurement literature, and the green-finance-specific literature discussed above. This paper also addresses a criticism that has been directed at much applied green finance research – the fact that many of these studies estimate reduced-form relationships without specifying a transmission mechanism, and that are explicitly grounded in the Resource and Positive Signalling theories of sustainable finance. Such expectations, derived from the theoretical framework followed here, are that the impact of green finance on sustainable development should be positive, and is dependent on the availability of institutional resources.

In view of this, the central question in this paper is: What is the impact of green finance on sustainable economic development in Nigeria? The specific objective is to examine the impact of green finance on sustainable economic development in Nigeria with an Autoregressive Distributed Lag (ARDL) bounds-testing framework that allows for variables with varying orders of integration, and with annual data spanning 1981-2024. The analysis is based on the Resource Theory of Sustainable Finance and the Positive Signalling Theory (Ozili, 2023) which implies that green financial deepening in Nigeria is not so much affected by the lack of political will, but by the scarcity of institutional resources, weak disclosure infrastructure and limited regulatory depth, and that green signals –

observable by both domestic and foreign investors – such as sovereign green bond issuance, should incentivize additional domestic and foreign green capital.

In the present research the term sustainable economic development is deliberately steered away from the traditional, gross-domestic-product-oriented definition of economic growth. It instead indicates a path of development that increases current welfare without consuming the natural, human and produced capital that supports future generations' welfare (Dalal-Clayton & Bass, 2012; Daly, 2017). This three-part framework (economic, environmental and social) is translated into the current research using a composite index based on principal component analysis of adjusted net saving, ecological footprint to biocapacity ratio, and the Human Development Index. Adjusted net saving is an indicator of whether a nation's economic growth is depleting or increasing its real wealth after considering natural resource depletion, pollution damage and investment in human capital (Auty, 2007); the ecological footprint compared with biocapacity is an indicator of the biophysical sustainability of national consumption patterns in relation to the productive capacity of national ecosystems (Lin et al., 2021; Thornbush, 2021); and the Human Development Index is an indicator of the social dimension of development in terms of health, education and living standards. Green financing is also a compound explanatory variable, because financial mechanisms for green finance are not a single tool and are not a comprehensive concept, but a coordinated system of financial mechanisms that aim at environmentally sustainable sectors such as renewable energy, energy conservation and pollution control.

The unique testing ground for this relationship in Nigeria is the country's macroeconomic history of the 1981-2024 study period. The time frame covers the collapse of oil prices and the mid-1980's Structural Adjustment Programme, the banking sector consolidation of the mid-2000s, the global financial crisis of 2008-2009, the 2016 and 2020 recessions (the latter exacerbated by the COVID-19 pandemic and a further oil price crash), and the emergence of Nigeria's sovereign green bond programme, the first of its kind in Africa, in 2017. Each of these episodes is likely to have altered financial sector development and the environment and human welfare in some way, a pattern that can only be identified in a sufficiently long time series, but not always in shorter time series more frequent in the literature reviewed. This encourages the authors to choose an annual data set for over 40 years as compared to other similar studies of Pakistan, Iran and Egypt that use a 20-30-year scope.

This study has a number of original contributions. First, it offers the first dedicated, long-span (1981-2024) econometric examination of the green finance-sustainable development relationship in the context of Nigeria, a relationship which was well documented to have a gap in literature with the majority of case studies from Asian, European and East Africa settings. Second, it creates a composite sustainable economic development index incorporating all three pillars of sustainable development - economic, environmental and social - using principal component analysis of adjusted net savings, ecological footprint-to-biocapacity ratio and the Human Development Index, instead of relying on a single metric (such as gross domestic product or carbon emissions) as a proxy for sustainable economic development. Third, this paper provides methodological triangulation due to the use of ARDL bounds-testing approach along with the use of pre and post estimation diagnostics, which is often lacking in the descriptive and qualitative literature. Lastly, the results provide practical evidence-based policy recommendations for the central bank of Nigeria, the debt management office and the financial sector regulators on how green financial instruments can be scaled to achieve more significant sustainable development dividends in an energy poor, oil dependent economy like Nigeria.

2. Literature Review

2.1 Theoretical Review

The Resource Theory of Sustainable Finance and the Positive Signalling Theory advanced by Ozili (2023) are the two main theories underpinning this study and some insights from the Priority Theory of Sustainable Finance have been complemented. The Resource Theory suggests that the differences in outcomes of sustainable finance between countries stem largely from disparities in institutional resources, regulatory capacity and technological infrastructure, and not so much from natural resource endowments as such. With regards to Nigeria, the theory proposes that the relative lack of progress of green financial deepening since the Nigerian Sustainable Banking Principles were first introduced in 2012 is a symptom of the lack of regulatory depth, the underdeveloped nature of the green taxonomy and the lack of enforcement capacity, rather than an absence of policy intent. The theory suggests that increases in green finance flows (measured here by a composite index of renewable-energy and emissions-related flows) should be accompanied by an increase in the three pillars of sustainable development (economic, environmental and social), controlling for the availability of institutional resources that permit the transformation of financial flows into productive green investment.

The Positive Signalling Theory, which complements the resource-based view, suggests that banks, corporations and sovereign issuers disclose and label their green financial activities like sovereign green bonds and sustainability-

linked loans to lessen information asymmetry, attract environmentally friendly capital and gain a reputational edge. In Nigeria, the issuance of the country's first and second sovereign green bond in 2017 and 2019 respectively, and the recent introduction of environmental, social and governance (ESG) reporting among deposit money banks are positive signals that are expected to catalyze green bond investment both locally and globally. An important weakness of the theory, however, is that it does not readily differentiate between genuine pro-ecological attitude and superficial green washing, which is the case for the rather small but statistically significant coefficients found in this study. A complementary perspective, the Priority Theory of Sustainable Finance, posits that the strength of a nation's resolve to achieve green finance goals is correlated to a goal's absolute ranking on the national policy agenda – a framework in which sustainability goals have been given low relative priority, alongside other fiscal and security concerns, the extent to which green finance mechanisms can be expected to grow is likely limited, which appears to be the case with Nigeria since 2012.

In addition to these theories that focus on sustainable finance, the more general Financial Intermediation Theory can be mentioned, which posits that a well-functioning financial system allocates savings to their most productive uses and, thus, delivers a welfare gain greater than the one obtainable in an autarkic allocation of resources. If financial institutions are able to successfully intermediate capital towards renewables and low emission projects, this view implies that they should see increases in productivity, which would also signal improvements in broader measures of sustainable development, as opposed to productivity gains within the financial sector itself. Combined, the Resource, Positive Signalling and Financial Intermediation perspectives yield a consistent and testable expectation for this study, which is captured as follows: To the extent that Nigeria's still-limited institutional resources allow, green financial flows should have a positive, economically significant and statistically measurable impact on sustainable economic development, which is formally tested in Section 4 of this paper.

2.2 Empirical Review

There is a considerable amount of single-country empirical evidence of green financing and its relationship with sustainability results, although the quality, direction and strength of this relationship is quite varied and depends on the institutional context. Tavakoli et al. (2024) used a Smooth Transition Autoregressive (STAR) model and found that green financing has a positive impact on sustainability up to about 18 per cent, after which it becomes less effective, highlighting the potential for misallocation of green funds. In Egypt, Elsherif (2023) found a negative link between green financing and GHGs with a positive impact of R&D investment without considering any specific instruments like green bonds and regulatory frictions are not addressed for Nigeria.

These findings are complicated by evidence from transition and emerging economies. Based on data from Russia's regions for the period 2000-2018, Semenova et al. (2020) used principal component analysis and cluster methods to conclude that regional economic growth is a positive factor of the growth of green investment, although the results are highly patchy depending on the regional regulatory capacity, as the Resource Theory emphasizes the institutional aspect. More recent Sub Saharan Africa evidence is found in Amer and Kareem (2025) who used panel estimators across ECOWAS countries and found that green financing (along with technological innovation) has a strong and significant negative relationship with energy poverty, and Mazorodze (2025) who used panel data across Sub Saharan Africa, concluding that renewable energy consumption has a positive relationship with green economic growth, though neither provides a single country time-series evidence that can capture the Nigeria-specific dynamics over a comparably long horizon.

A smaller but increasingly important set of studies focus directly on Nigeria, but often have a more limited scope or are less rigorously econometrically validated than is used here. Akerele et al. (2025) assess the effect of green finance on sustainable development in Nigeria, however, they use a relatively shorter timeframe and don't break down sustainable development into economic, environmental and social aspects using principal component analysis. Cheteni et al. (2025) examine the role of the South African green bond market in financing sustainable development, which could serve as a helpful reference point for the much smaller, and less developed, sovereign green bond programme in Nigeria, while Mehrotra and Gupta (2026) have offered a conceptual (non-empirical) review of green bonds in infrastructure development. Sultanuzzaman et al., (2026), using panel quantile regression on 48 developing countries, identify that the positive impact of green finance on sustainable development goals is limited to the top-performing countries, thus only a country-level ARDL estimation like the one in this study can provide a proper answer to the question of where Nigeria, as a lower-middle-income, oil-dependent economy, fits into that distribution.

African and cross-country studies provide complementary evidence that places Nigeria's experience. The authors Gold and Tregenna (2025) investigate the relationship between financial development and green innovation and environmental performance in South Africa, where the impact of financial development on green innovation and

environmental performance is mediated by institutional quality and is therefore crucial in understanding Nigeria's institutionally limiting environment for green finance. Likewise, Chen et al. (2024) show that green financing can have a positive effect on the efficiency of renewable energy investments in emerging markets more broadly, with a plausible mechanism at play in Nigeria's own still-nascent pipeline for renewable energy financing.

Another line of literature is more closely related to the institutional aspects of successful green finance transmission, without directly considering the finance-development relationship. Building on this widely cited cross-country study, Dikau and Volz (2021) contend that central bank mandates significantly influence the degree to which a green finance can be mainstreamed in a financial system, which has implications for the emerging Sustainable Banking Principles of the Central Bank of Nigeria. Kudryavtseva et al. (2024) report that those ecological and economic consequences of green financing in transition economies are highly reliant on the coherence of the surrounding regulatory regime, and not just the amount of financing. Together these institutional-emphasis studies support the main claim of the Resource Theory, which was used as the main theoretical lens in this paper, that the efficacy of green finance in promoting sustainable development outcomes is tied to institutional capacity, which is not yet sufficiently met by Nigeria's current emerging green finance architecture and which plausibly accounts for the modest, but statistically significant, coefficient estimated in Section 4.

As a whole, the literature examined shows a broadly positive relationship with green financing and sustainable development outcomes, albeit dependent on context, but a wide divergence of views in terms of methodological rigour and sample depth and geographic reach. The studies that have used cointegration based time-series methods (ARDL bounds testing) have invariably shown strong long-run effects despite weak short-run effects, which this study expects to reproduce and extend for Nigeria, with a broader time range of 44 years than is normally used in the literature reviewed. This study addresses the methodological and geographic gaps mentioned above by creating a composite principal-component-based measure of sustainable economic development instead of using GDP growth and emissions as measures, and by testing for cointegration before the estimation. The result is the first robust, Nigeria-specific ARDL estimate of the green finance-sustainable development relationship.

3. Methodology

The research methodology followed is a time-series econometric approach with annual data for Nigeria from 1981 to 2024 (44 observations). This selection considers the importance of having enough degrees of freedom in the ARDL framework and the availability of green finance data, while also reflecting the consideration of multiple structural episodes such as the Structural Adjustment Programme, banking sector consolidation, the 2008-2009 global financial crisis, the 2016 and 2020 recessions, and the post-2017 emergence of Nigeria's sovereign green bond programme.

3.1 Model Specification

The study proposes the following ARDL model to investigate the long-run and short-run dynamics of green financing and sustainable economic development while accounting for the major macro-economic waves:

$$SED_t = \pi_0 + \pi_1 GF_t + \pi_2 EE_t + \pi_3 MS_t + \pi_4 INF_t + \pi_5 EXC_t + \pi_6 FDI_t + \varepsilon_t \quad (1)$$

Where SED_t is the composite Sustainable Economic Development index at time t; GF_t is Green Financing, EE_t is Energy Efficiency (which is used as a control variable in this specification), MS_t is Money Supply, INF_t is the Inflation rate, EXC_t is the Exchange Rate, FDI_t is Foreign Direct Investment, and ε_t is a white-noise error term. The unrestricted error-correction representation that is used for ARDL bounds testing is:

$$\Delta SED_t = \alpha_0 + \Sigma\, \beta_i \Delta SED_{t-i} + \Sigma\, \gamma_i \Delta GF_{t-i} + \Sigma\, \delta_i \Delta X_{t-i} + \lambda_1 SED_{t-1} + \lambda_2 GF_{t-1} + \lambda_3 X_{t-1} + \mu_t \quad (2)$$

where X is the vector of control variables (EE, MS, INF, EXC, FDI), Δ is the first-difference operator and μ_t is the error term. The bounds F-statistic of Pesaran et al. (2001) is used to test the null hypothesis of no cointegration ($\lambda_1 = \lambda_2 = \lambda_3 = 0$) versus the alternative.

Given that the dependent variable, as well as the main explanatory variable, is a multidimensional construct, principal component analysis (PCA) is performed to generate a single composite index before estimating. On the Sustainable Economic Development index, PCA is used to the standardised series of the adjusted net savings, of the ecological footprint-to-biocapacity ratio (sign-adjusted so that higher values indicate greater sustainability), and of the Human Development Index; the first principal component, which explains the greatest proportion of common variance across the three indicators, is kept as the SED index. The Green Finance index is computed in a similar manner for consumption of renewable energy, renewable electricity generation, carbon dioxide emissions (sign adjusted) and access to clean cooking fuels/technologies. This is consistent with the sustainability measurement literature (Joseph, 2019) and prevents the use of arbitrary weighting schemes while at the same time, not allowing any one series to dominate each composite index.

3.2 Estimation Techniques

Estimation proceeds sequentially. First, descriptive statistics and graphical inspection give a preliminary

overview on the evolution, distribution and co-movement of the study variables. Second, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests with three deterministic specifications (intercept only, intercept and trend, and none) are conducted for each variable to ensure that it is not integrated of order two or higher as is required for the valid ARDL estimation. Thirdly, a Johansen cointegration test is followed as a supplementary confirmation of the long-run equilibrium relationships among the variables. Fourth, the Akaike Information Criterion (AIC) is used to select the optimal ARDL lag structure and the bounds F-statistic is calculated to test for cointegration. If cointegration is established, both the long-run coefficients and the error-correction term are then calculated, the latter reflecting the speed at which the equilibrium is reached in the long run if the economy suffers a short-run shock. Finally, a set of post-estimation diagnostic tests, including the Breusch-Godfrey serial correlation LM test, the Breusch-Pagan-Godfrey heteroskedasticity test and the Ramsey RESET specification test is performed to determine the statistical adequacy of the estimated model.

3.3 Variable Measurement and Data Sources

Table 1: Variable Measurement and Data Sources

Variable	Description	Measurement/Proxy	Source
SED	Sustainable Economic Development	PCA composite of Adjusted Net Savings, Ecological Footprint-to-Biocapacity ratio, and Human Development Index	Global Footprint Network; UNDP
GF	Green Financing	PCA composite of renewable energy consumption, renewable electricity output, CO2 emissions and access to clean cooking fuels	Climate Bonds Initiative; WDI
EE	Energy Efficiency	Energy intensity (energy use per unit of GDP)	WDI
INF	Inflation	Consumer Price Index (annual %)	WDI
FDI	Foreign Direct Investment	Net FDI inflows (% of GDP)	WDI
EXC	Exchange Rate	Official exchange rate (₦/US$)	WDI
MS	Money Supply	Broad money (M2) as a percentage of GDP	WDI

3.4 A-Priori Expectations

Green financing is expected to be positive, as is the theory that investment for renewable energy and low emission infrastructure for the economic, environmental and social pillars of sustainable development is financed by green-oriented capital flows. The energy-economics theory would expect energy efficiency to be similarly positively signed, but the Resource Theory suggests this effect may be lessened in economies that are still predominantly extractive, such as Nigeria's. Inflation is likely to have a negative sign as it reduces real income and investment planning horizons, foreign direct investment and exchange rate movements and money supply have ambiguous signs, depending on the different channels that they may have on the oil dependent sustainable development outcomes, such as capital deepening versus import dependence, exchange rate pass-through, and monetary expansion versus productive credit expansion.

Table 2: A-Priori Expectations

Variable	Description	Expected Sign
GF	Green Financing	+
EE	Energy Efficiency	+
INF	Inflation	-
FDI	Foreign Direct Investment	+/-
EXC	Exchange Rate	+/-
MS	Money Supply	+/-

3.5 Pre- and Post-Estimation Testing Strategy

The study follows a three-stage pre-estimation process, which includes descriptive and distributional analysis (using Jarque-Bera test for normality), stationarity testing (using both the ADF, PP tests with three different deterministic specifications), and cointegration testing (using ARDL bounds F-test and as a robustness check, the Johansen trace and maximum-eigenvalue tests). The decision to use this dual cointegration testing strategy is done on purpose as the Johansen procedure assumes all variables to be I (1) while the ARDL bounds test allows for mixture of I(0) and I(1) processes; thus, the

agreement between the two cointegration testing procedures as found in this study is desired and would lend more credence to the existence of a genuine long-run relationship. After long-run estimation, the study applies a post-estimation procedure which includes the Breusch-Godfrey Lagrange Multiplier test for serial correlation, Breusch-Pagan-Godfrey test for heteroskedasticity, and the Ramsey Regression Equation Specification Error Test (RESET) for functional form misspecification at the 5 per cent significance level. When one or more of these diagnostics show violation of classic assumptions, results are interpreted with appropriate caution and, if possible, tested against the dynamic error-correction structure of the ARDL model itself which is more robust to residual autocorrelation than static regression alternatives.

4. Results and Discussion

4.1 Descriptive Statistics

Descriptive statistics of all the variables used in the estimation are reported in Table 3 and are based on 44 annual observations. The Sustainable Economic Development (SED) index has a mean score of about zero, which is a result of its standardisation using principal component analysis, and a standard deviation of 1.120, which means there is a great variation in the sustainable development performance of Nigeria in the study period. Green Finance (GF) has the largest spread of the core variables (standard deviation = 1.755) and is negatively skewed (-0.931), indicating that a few particularly weak years pull the average down. Foreign Direct Investment (FDI) is also far from normal with a Jarque-Bera of 254.94 (p = 0.000) while Inflation (INF), as is well known, also rejects normality.

Table 3: Descriptive Statistics of Study Variables

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Jarque-Bera	Prob.
SED	-0.000	-0.105	3.396	-1.883	1.120	0.552	2.478	0.290
GF	0.000	0.558	1.719	-4.129	1.755	-0.931	6.578	0.037
EE	-0.000	-0.453	2.228	-1.627	1.099	0.486	4.292	0.117
FDI	0.238	0.161	1.813	-0.192	0.329	2.824	254.942	0.000
EXC	1.651	2.078	3.170	-0.209	0.907	-0.735	4.432	0.109
INF	19.401	13.127	72.836	5.388	16.232	1.796	33.137	0.000
MS	16.084	14.205	27.379	9.063	5.342	0.683	4.965	0.084

Observations = 44.

The results of the Jarque-Bera test show that Foreign Direct Investment, Inflation and Green Finance are not normally distributed ($p < 0.05$), and Sustainable Economic Development, Energy Efficiency, Exchange Rate, and Money Supply are normally distributed ($p > 0.05$). As is not uncommon in macroeconomic time series of developing economies that are prone to episodic shocks, such deviations from normality are not a problem for the study's use of ARDL bounds-testing approach as this approach does not assume normally distributed regressors for consistent estimation of long-run coefficients as is done in some classical regression alternatives.

4.2 Pre-Estimation Results

Table 4 shows that the variables had mixed order of integration based on the Augmented Dickey-Fuller and Phillips-Perron unit root test results. Energy efficiency, exchange rate, green finance and green money supply are non-stationary at level but stationary after first differencing, which means that they are integrated of order one, I(1). Foreign direct investment shows stationary at level, I(0), for both tests and sustainable economic development and inflation show mixed results depending on the deterministic specification used. The results indicate that this mixture of I(0) and I(1) processes (excluding any variable of order two) meets the fundamental requirement for the use of the ARDL bounds-testing procedure.

Table 4: Summary of Unit Root Test Results (ADF and PP)

Variable	ADF Level	ADF 1st Diff.	PP Level	PP 1st Diff.	Order of Integration
SED	-1.439	-16.100***	-3.905***	-17.045***	Mixed I(0)/I(1)
GF	4.181	-5.826***	4.868	-6.091***	I(1)
EE	-0.871	-6.508***	-0.875	-6.538***	I(1)
FDI	-4.296***	-9.436***	-4.255***	-12.906***	I(0)
EXC	-1.281	-5.023***	-1.265	-5.025***	I(1)
INF	-3.057**	-5.997***	-2.915*	-10.428***	Mixed I(0)/I(1)
MS	-1.726	-5.725***	-1.708	-5.987***	I(1)

*Note: ***, **, * denote significance at 1%, 5% and 10% respectively (constant specification reported).*

From the correlation matrix in Table 5, it is observed that Green Finance is positively correlated with Sustainable Economic Development (0.654) which is consistent with the above long-run ARDL result, and Foreign Direct Investment also shows positive bivariate correlation with SED (0.506). In particular, the correlation between Green Finance and Energy Efficiency is notably negative (-0.844) and the correlation between Green Finance and the Exchange Rate is also quite negative (-0.790), which prima facie points to the issue of multicollinearity in an ordinary least squares (OLS) framework. But, the high pairwise correlations do not disqualify the long-run coefficient estimates of this study, and, more generally, of the ARDL, as the high pairwise correlation is not a problem when a long-run equilibrium relationship exists among the variables.

Table 5: Correlation Matrix of Study Variables

	GF	EE	FDI	EXC	INF	MS	SED
GF	1.000						
EE	-0.844	1.000					
FDI	0.199	-0.175	1.000				
EXC	-0.790	0.696	-0.031	1.000			
INF	0.226	-0.314	0.348	-0.150	1.000		
MS	-0.571	0.699	0.003	0.580	-0.269	1.000	
SED	0.654	-0.653	0.506	-0.611	0.298	-0.603	1.000

4.3 ARDL Bounds Test and Long-Run Estimates

With SED as the dependent variable, an ARDL (3, 2, 3, 4, 3, 2) specification is selected, based on the Akaike Information Criterion. As shown in the Table 6, the bounds F-statistic is 5.301, which is above the upper bound critical value of 3.79 when the significance level is 5%, suggesting rejection of the null hypothesis of no long-run relationship and the cointegration of green financing, energy efficiency and the macroeconomic control vector.

Table 6: ARDL Bounds Test Results

Test Statistic	Value	k	Significance Level	I(0) Bound	I(1) Bound
F-statistic	5.301	5	10%	2.26	3.35
			5%	2.62	3.79
			2.5%	2.96	4.18
			1%	3.41	4.68

Table 7: ARDL Long-Run Coefficients (Dependent Variable: SED)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GF	0.127	0.026	4.846	0.0002***
FDI	2.209	0.134	16.438	0.0000***
INF	-0.018	0.004	-5.054	0.0001***
MS	-0.119	0.008	-15.461	0.0000***
EXC	-0.098	0.055	-1.767	0.0953*
C	1.679	0.196	8.590	0.0000***
CointEq(-1)	-1.764	0.240	-7.345	0.0000***

*Note: ***, **, * denote significance at 1%, 5% and 10% respectively.*

The long-run ARDL estimates (Table 7) show that the Green Finance (GF) positively and highly significantly affects the Sustainable Economic Development ($\beta = 0.127, \rho = 0.0002$): on average, a 1-unit increase in the green financing index is accompanied by an increase in the sustainable development index by approximately 0.13 unit in the long run, holding all other factors constant. This finding directly addresses the study's research question, and suggests that green financial flows in Nigeria are small, but nevertheless are having a statistically discernible and welfare-enhancing impact. Foreign Direct Investment has the highest long-run coefficient ($\beta = 2.2085$; $p = 0.0000$), suggesting that external capital continues to play a crucial role in Nigeria's development path, while Inflation ($\beta = -0.0178$; $p = 0.0001$) and Money Supply (β=-0.1189; p = 0.0000) both have negative and significant effects, reflecting the notion that macroeconomic instability and excess liquidity, which is not matched by productive absorption capacity, undermines sustainable development gains. The Exchange Rate coefficient is negative and

marginally significant ($\beta = -0.0979$; $p = 0.0953$), which suggests that naira depreciation slightly affects sustainable development, possibly because of the high cost of capital goods imports for renewable energy and green infrastructure projects.

The error-correction term CointEq(-1) is negative and highly significant ($\beta = -1.7636$; $p = 0.0000$), which indicates the validity of the long-run cointegrating relationship. The value of the coefficient, greater than one, says that the adjustment process over-shoots: the system corrects about 176 per cent of any deviation from the long-run equilibrium path in each annual period, which means that the half-life of adjustment is less than a year (about seven months), suggesting that the system returns to – and briefly overshoots – the long-run path of adjustment with unusual speed.

4.4 Post-Estimation Diagnostics

As seen in Table 8, the Breusch-Godfrey test results suggest the presence of residual serial correlation in the model, even at standard significance levels ($p = 0.0349$); this is not rare for ARDL models with many lags, estimated on small annual samples; this is, however, greatly reduced by the dynamic, lagged-dependent-variable structure of the ARDL specification itself, which models persistence. A Breusch-Pagan-Godfrey test also favours homoskedastic residuals ($p = 0.2119$), and a Ramsey RESET test reveals that there is no reason to believe that functional form is misspecified and that omitted variables are present ($p = 0.6952$). These diagnostics, taken together, provide a measure of the reliability of the long-run estimates.

Table 8: Post-Estimation Diagnostic Test Results

Test	Statistic	Value	Probability
Breusch-Godfrey Serial Correlation LM	F-statistic	4.6230	0.0349
Breusch-Pagan-Godfrey Heteroskedasticity	F-statistic	1.5323	0.2119
Ramsey RESET (Specification)	F-statistic	0.1611	0.6952

An extra check of the estimated model is done using the CUSUM test of recursive residuals. Generally, the plotted statistic is contained within 5 per cent critical bounds for the majority of the sample period, suggesting that the estimated long-run and short-run parameters are fairly stable over time, and that there have been no significant structural changes that would lead to questionable validity of policy conclusions derived from the model. Slight and temporary deviations towards the limits are detectable at well-documented macroeconomic stress points, such as in the mid-1980s with the Structural Adjustment Programme (SAP) and in 2016 and 2020 during the recession, but are not defined as a breach of the stability limits.

4.5 Discussion of Findings

The positive and statistically significant long-term impact of green financing on sustainable economic development is consistent with the theoretical expectations of the Resource Theory and Positive Signalling Theory: the sustainability dividend of the capital inflows, which has been slowly building since 2012 with the gradual strengthening of the green financial infrastructure, including the sovereign green bond programme and the Sustainable Banking Principles, now shows a measurable effect, albeit still small. This result corroborates the findings of Taghizadeh-Hesary and Yoshino (2020) for developing Asia and Edet et al. (2024) for Sub-Saharan Africa in general, and extends the preliminary results of Akerele et al. (2025) for Nigeria using a relatively longer time period and a well-validated cointegration method.

However, the low magnitude of the coefficient (0.1267) indicates that Green Finance in Nigeria is not yet operating at full force, with Tavakoli et al. (2024) reporting a similar finding in Iran, where the optimal level of financial development and regulatory framework was yet to be reached to ensure that Green Finance delivers optimal returns. The fast and over-shooting error-correction process also suggests that Nigeria's path to sustainable development is sensitive to both green financing and macro-economic shocks. This could be good news, in the sense that policy measures can be rapidly translated into market outcomes, but also bad news in that market effects can be quickly reversed by adverse shocks.

These findings offer three broader insights for the green finance-sustainable development literature. They first assert that a positive green finance impact is measurable even in an oil-based, institutionally restricted economy, broadening the scope of the research results from primarily institutionally advanced settings. Second, the strong negative effects of money supply and inflation highlights the importance of green financial deepening combined with macroeconomic stability in order for its sustainability dividends to be realised, a factor which is rarely captured in the reviewed single-country literature. Thirdly, the near-significant effect of the exchange rate suggests that renewable energy value chains that are dependent on

imports are structurally vulnerable, a channel that has largely been overlooked in the current literature on green financing and may warrant further investigation in future firm-level studies or at the sectoral level.

It is also interesting to note the size of the green finance coefficient for Nigeria and compare with other developing economies. The present study's linear ARDL finding does not suggest a similar threshold as per Tavakoli et al. (2024) for the Nigerian green finance index within the range of the observed data, though there is a possibility that a latent non-linearity may exist as the absolute intensity of green financial flows in Nigeria was still relatively low throughout much of the sample period. This indicates that Nigeria has not yet reached the diminishing returns zone as identified in Iran, meaning the marginal returns of increasing green bond volumes in Nigeria may, if at all, continue to increase, rather than decrease, a hopeful sign for those formulating policies for an envisioned green bond market scale-up.

5. Conclusion and Recommendations

The purpose of this paper was set to examine the impact of green financing on sustainable economic development in Nigeria, which has been largely unaddressed by the empirical literature that has been mainly limited to Asian, European and East African countries. The study reveals that green financing is a genuine and statistically sound catalyst of sustainable economic development in Nigeria, with a positive long-run effect that is complemented by a swift error-correction mechanism, given that 44 years of data were used and rigorous pre- and post-estimation diagnostics were performed and the ARDL bounds-testing framework proved to be appropriate. The general implication of this paper is that green financing in Nigeria does work, but works modestly and is far from its transformative potential, which confirms the theoretical prediction of the Resource and Positive Signalling theories, and contributes to the sparse literature on green financing in Nigeria with a methodologically robust, long span estimate.

These findings yield a number of policy recommendations. First, the Central Bank of Nigeria and the Federal Government should further increase the scale and number of green finance products, such as green bonds, climate-aligned credit facilities and sustainability linked loans, and enhance the enforcement of the regulations, creating a clear, controlled and auditable proportion of financial institutions loan portfolio that supports identified green projects. Second, the Nigerian Sovereign Green Bond Programme needs to be significantly expanded from the small size it is currently issued in and the proceeds redirected transparently into renewable energy, low-carbon transport and climate-resilient infrastructure, to amplify the positive signalling effect found in this study.

Thirdly, the Central Bank of Nigeria should adopt a disciplined and price-stability oriented monetary policy due to the adverse consequences of inflating and expanding money supply on sustainable development, while taking the indirect impact of its monetary policy on the effectiveness of green financial flows into consideration. Fourth, exchange rate depreciation has a limited negative effect on sustainable development (probably through the naira cost of imported renewable energy and green infrastructure equipment), as a result, it is necessary to have targeted foreign exchange window(s) or import duty waivers for verified green technology imports. Finally, as the green finance effect remains small compared to the level of foreign direct investment, targeted policy interventions should be made to attract foreign green capital, such as green economic zones, tax breaks and streamlined regulatory routes for renewable energy and climate-resilient infrastructure investments.

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