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DETERMINANTS OF LOAD CAPACITY FACTOR IN NIGERIA: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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Abstract

Research purpose: Motivated by the growing level of ecological degradation and the need to accomplish sustainable development, this study examines the influence of energy consumption, institutions, urbanization, education, and economic growth on the load capacity factor (LCF) of Nigeria.

Methodology: The study uses data from the Nigerian time series between 1984 and 2020. The Autoregressive Distributed Lag (ARDL) is utilized to analyse the level of cointegration and short- and long-run impact among the variables. Furthermore, Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) were used as robustness checks for the long-run estimates of ARDL.

Findings: The results suggest that in the short run, per capita income, institutions, and urbanization positively influence the LCF. However, in the long run, per capita and institutions have an insignificant effect on the LCF. On the other hand, energy consumption and primary school enrolment negatively impact the LCF in both periods. Similarly, urbanization has a negative long-run influence on the LCF, thus decreasing the environmental quality.

Practical implications: Based on the study's outcome, the study offers significant policy implications, such as changing consumption and production patterns to green ones to achieve green growth and sustainable development.

Keywords: Load capacity factor; energy consumption; institutions; urbanization; education; economic growth; SDGs

JEL codes: O10; O44; O52, Q01; Q40

Introduction

This study investigates the determinants of load capacity factor in Nigeria, and it is motivated by development in the policy circles and the literature. In policy circles, different international and local

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initiatives have evolved to find solutions to environmental problems. Starting with the Brundtland Commission in 1987, to the Sustainable Development Goals (SDGs), and recently, the Conference of Parties (COP29) meeting held in Azerbaijan in 2024, recognizes the importance of addressing the problem of climate change and anthropogenically induced environmental degradation, which is essential in realizing sustainable development.

Specifically, the SDGs acknowledge the significance of halting poverty, improving policies that promote health and education, and reducing inequality and economic growth while addressing climate change and preserving the environment. These led to the seventeen SDGs, out of which six are of interest to this present study: education (SDG-4), energy consumption (SDG-7), economic growth (SDG-8), urbanization (SDG-11), environment (SDG-13), and institutions (SDG-16). The six chosen goals are essential to achieving a sustainable environment, which metamorphosed into sustainable development. For instance, quality education (SDG-4), affordable and clean energy (SDG-7), sustainable growth and decent workplace (SGD-8), sustainable cities and communities (SDG-11), and peace, justice, and strong institutions influence climate action (SDG-13) (Arnaut et al., 2023; Chen et al., 2022; Sinha et al., 2022).

However, in the literature, different inferences have been established on the influence of these factors on the environment (Adebayo & Rjoub, 2022; Dada et al., 2022c; Danish et al., 2019; Nathaniel & Khan, 2020). While the literature generally acknowledges the negative impact of economic growth and dirty energy on ecological quality in the long run (Ahmed et al., 2020; Arnaut et al., 2023; Dada et al., 2022a; Mensah et al., 2019; Sarkodie et al., 2020; Zhang et al., 2021), the effects of urbanization, education, and institutions remain mixed. For instance, strong institutions could instil objectivity and unbiased distribution of resources, boost investors' confidence, and promote ecological sustainability (Biswas et al., 2012; Dada et al., 2021; Fahimi et al., 2020; Jutting, 2003; North, 1990). Nevertheless, these strong institutions in terms of implementing strict ecological laws and regulations could intensify the size of firms working in the informal economy to lessen the cost associated with regulation, which further worsens the long-run environmental sustainability (Baklouti & Boujelbene, 2020; Baksi & Bose, 2010). Equally, apart from the positive externalities, such as the economies of scale that urbanization provides, it also produces undesirable externalities, such as a rise in energy consumption via transportation and industrialization, which influence the ecosystem (Dada et al., 2025a; Danish & Wang, 2019; Kihombo et al., 2021).

However, one major thing that is common to most of these studies is that environment, or environmental quality is captured either using nitrogen oxide emissions, sulphur dioxide, carbon emissions, etc., which are usually classified as traditional measures of the environment, and the material and ecological footprints (Dada & Al-Faryan, 2024; Hanif, 2018; Huynh & Ho, 2020). These traditional measures of the environment have been criticized as too restrictive, as they focus on air pollution and do not provide comprehensive gauges of other aspects of pollution (Alola et al., 2019; Pata & Isik, 2021; Solarin & Bello, 2018;). Likewise, the material and ecological footprints only captured the demand side of the ecosystem without accounting for the supply aspect. This study thus uses a new measure, "load capacity factor," to assess the environment.

Given the foregoing, this research aims to broaden the frontier of knowledge in the ecological literature in the following areas. First, the study applies a robust indicator-load capacity factor (LCF) to proxy environmental sustainability. The LCF, first advocated by Siche et al. (2010), provides a better valuation of the environment. It encapsulates both the demand and supply side of the environment. The LCF reveals the capability of a nation to support its population, given its lifestyles (Pata & Isik, 2021). It measures the ratio of biocapacity (supply side) to the ecological footprint (demand side). The ecological footprint encapsulates the human pressure on the environment, while the biocapacity centres on the regenerative ability of nature to meet the demand. A value of LCF less than one suggests that the current ecosystem is not sustainable, while a value more than one hints that the environment is sustainable (Siche et al., 2010). The sustainable threshold level of LCF is one. Thus, LCF provides an accurate sustainability assessment by comparing the biocapacity to ecological footprints.

Second, the study is situated in the light of the SDGs. The study scrutinized the effect of five critical SDGs on a sustainable environment in Nigeria, which can give policymakers a clue as to whether they are on or off track in achieving sustainable development. Third, the scope of the study- Nigeria provides exciting features. Based on Global Footprint Network data, Nigeria witnessed ecological imbalance throughout the study period, with the ecological footprint exceeding the biocapacity. Figure 1 presents the trend of LCF in Nigeria. The Figure shows that the load capacity value decreases at an increasing rate, as demonstrated by the blue-coloured line. Specifically, the LCF decreases from 0.74 in 1984 to 0.61 in 2000 and continues to 0.47 in 2020, indicating that the current supply of natural resources is insufficient to support Nigeria's consumption and production trends. Thus, the country has an ecological deficit in its account. Further, Nigeria was among the fastest-growing economies, with a GDP of USD 472.6 billion in 2022. Thus, the level of industrialization and the economic development process put pressure on the environment. In addition, Nigeria is the most populous African country, with a population of 229 million and a growth rate of 2.39% as of 2023.

On the other hand, the urban population grows at an average of 4% annually, thus putting pressure on the urban facilities. Regarding CO2 emissions, Nigeria is among the highest emitters of CO2 emissions in SSA countries, with an average of 0.56 tons per person in 2022. In 2022, The majority of CO_2 emissions in the energy sector resulted from burning fossil fuels for electricity generation and to power vehicles and machinery (IEA, 2022). Furthermore, extant studies using Nigerian data have proxied environmental quality using traditional measures and, recently, ecological footprint (Dada et al., 2022a; Solarin et al., 2021; Udemba, 2020). Yet, these studies neglected the supply aspect of the ecology, which is the hallmark of this study.

Lastly, the study applies techniques that provide short- and long-term results essential for policy prescriptions. Specifically, the autoregressive distributed lag (ARDL) is deployed to give the short and long-run effects, while fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and canonical cointegrating regression (CCR) are utilized to validate the long-run estimates of ARDL.

Apart from this introductory section, the paper is designed as follows. The next section focuses on the data and methodology. The results and discussion are reported in section three. Sensitivity analysis is presented in section four, while section five concludes the study.

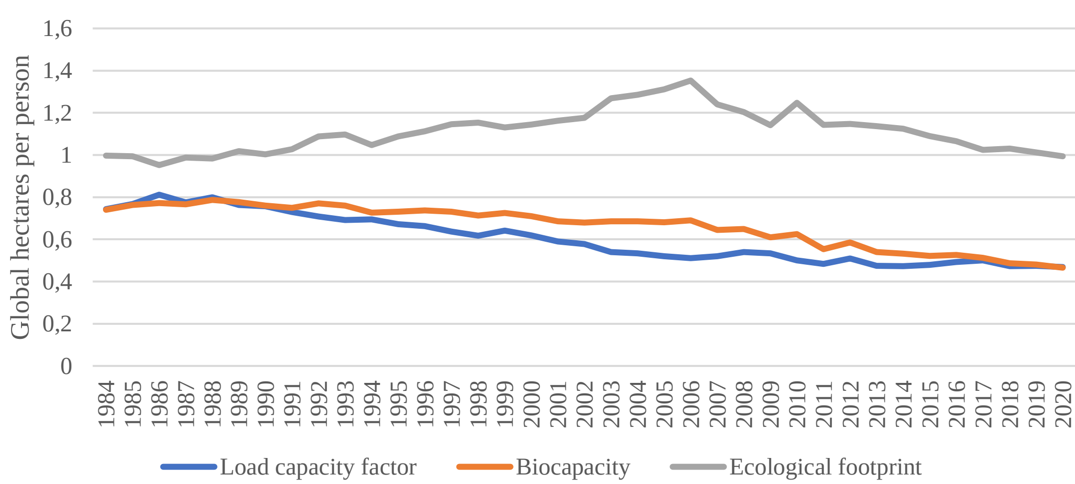

Fig. 1. Nigeria's ecological footprint, biocapacity, and load capacity factor (Source: Global Footprint Network)

Research methodology

Data description

The primary objective of this study is to examine the determinants of load capacity factor in Nigeria. Specifically, the study examines the effect of energy consumption, institution, urbanization, primary school enrolment, and per capita income on the LCF for Nigeria between 1984 and 2020. Data availability, particularly on essential variables, drives the scope of the study. Table 1 presents the description and sources of the data. The institutional indicators data are rescaled on an ordinal scale of 0 – 10 following the works of Dada et al. (2025b) and Olaniyi and Adedokun (2022) as follows:

- Democratic accountability, corruption control, and law and order are on a scale of 0-6 from ICRG. These are rescaled to 0-10 as $\frac{x}{6} \times 10$.
- Bureaucratic quality is on a scale of 0 – 4, and it is rescaled as $\frac{x}{4} \times 10$.
- Government stability is originally 0-12 from the ICRG database. This is rescaled as $\frac{x}{12} \times 10$.

Where x is Nigeria's score from the indicators, out of the maximum point. Thereafter, the mean of the indicators is obtained thus:

$$INS_t = \frac{1}{n}\sum_{i=1}^{n} INS_{j,t}$$

INS is the institutional quality index, n is the number of institutional quality measures, j denotes each institutional quality index, and t is the time series observations.

Table 1. Description and sources of data (Source: Authors)

Acronyms	Description	Measurement/unit	Source
LCF	Load capacity factor	Biocapacity divided by ecological footprint	Global Footprint Network
GDPP	GDP per capita	Constant 2015 USD	World Bank Development Indicators
ENC	Energy consumption	kt of oil equivalent	
URB	Urbanization	% of the total population	
PSE	Primary school enrolment	% of gross	
INS	Institution	The institutional quality variable is generated from the average value of corruption control, law and order, government stability, bureaucracy quality, and democratic accountability after they have been rescaled.	International Country Risk Guide

The descriptive analysis of the series used in the study is reported in Table 2. The descriptive statistics report hints that the LCF has an average value of 0.602, which ranges between the minimum and maximum values of 0.469 and 0.812, respectively. Its average value for GDP per capita is 1832.34, with a minimum value of 1324.297 and a maximum value of 2736.98. For energy consumption, institutions, urbanisation, and primary school enrolment, their average value is 735.123, 3.950, 37.663, and 90.876, respectively. In terms of deviation, Table 2 hints that GDP per capita is the most unstable series with a standard deviation value of 499.015, followed by energy consumption with a statistical value of 48.363. For the skewness statistics, the result hints that all the variables are positively skewed except institutional quality, which is negatively skewed. Furthermore, the kurtosis reveals that LCF, GDP per capita, energy consumption, and urbanization are platykurtic since their values are less than three, while institutions and primary school enrolment are leptokurtic (values greater than three). The skewness and kurtosis statistics also hint that the variables are normally distributed, backed up by the Jarque-Berra test statistics and their probability value.

Table 2. Descriptive statistics (Source: Authors)

	LCF	GDPP	ENC	INS	URB	PSE
Mean	0.602	1832.336	735.123	3.950	37.663	90.876
Median	0.578	1607.238	722.402	4.083	36.508	90.057
Maximum	0.812	2736.982	829.814	4.611	52.190	111.800
Minimum	0.469	1324.297	671.907	2.681	24.872	71.385
Std. Dev.	0.113	499.015	48.363	0.434	8.086	8.140
Skewness	0.405	0.512	0.457	-0.947	0.218	0.178
Kurtosis	1.712	1.648	1.969	3.442	1.847	3.400
Jarque-Bera	3.572	4.437	2.928	5.826	2.342	0.442
Probability	0.168	0.109	0.231	0.054	0.310	0.802
Observations	37	37	37	37	37	37

The correlation matrix in Table 3 reveals that the series are fairly correlated. Hence, this suggests the nonappearance of multicollinearity (or exact) in the data set. Specifically, the value of the correlation ranges from -0.640 to 0.754. Regarding the direction of correlation, all the variables negatively correlate with the LCF except primary school enrolment.

Table 3. Pairwise correlation (Source: Authors)

	LCF	GDPP	ENC	INS	URB	PSE
LCF	1					
GDPP	-0.456	1				
ENC	-0.573	0.241	1			
INS	-0.481	0.373	0.448	1		
URB	-0.640	0.754	0.448	0.519	1	
PSE	0.033	-0.123	-0.065	-0.349	-0.179	1

Model and estimation technique

To achieve the objective of the study, the study adopted the modelling style used in existing studies to investigate the determinants of LCF in Nigeria (Guloglu et al., 2023; Pata et al., 2023; Pata et al., 2024; Sun et al., 2024).

$$LCF_t = \alpha + \beta GDPP_t + \gamma ENC_t + \delta INS_t + \eta URB_t + \theta PSE_t + \varepsilon_t \tag{1}$$

LCF is the load capacity factor, GDPP is GDP per capita, ENC is energy consumption, INS is institutions, URB is urbanization, and PSE is primary school enrolment. ε and t is the error term and the time series observation. β, γ, δ, η, and θ are parameters to be estimated and explain the impact of the respective independent variables on the dependent variable.

This study applies the autoregressive distributed lag (ARDL) to estimate equation 1. The technique is chosen based on its advantages for the present study. First, the method provides the short and long-run impact of independent series on the dependent variable, which is essential for policy variations in both periods. Furthermore, this approach resolves the endogeneity problem, which is usually encountered in environmental literature (Ahmed et al., 2019; Arnaut et al., 2023). Similarly, the method can be applied regardless of the variable's stationarity order so long as none of the series has stationarity properties greater than one. Thus, equation 1 is respecified using the ARDL format.

$$\begin{aligned} LCF_t = \alpha &+ \sum_{j=1}^{n} \kappa_j \Delta LCF_{t-j} + \sum_{j=0}^{n} \beta_j \Delta GDPP_{t-j} + \sum_{j=0}^{n} \gamma_j \Delta ENC_{t-j} + \sum_{j=0}^{n} \delta_j \Delta INS_{t-j} + \sum_{j=0}^{n} \eta_j \Delta URB_{t-j} \\ &+ \sum_{j=0}^{n} \theta_j \Delta PSE_{t-j} + \Gamma_1 LCF_{t-1} + \Gamma_2 GDPP_{t-1} + \Gamma_3 ENC_{t-1} + \Gamma_4 INS_{t-1} + \Gamma_5 URB_{t-1} \\ &+ \Gamma_6 PSE_{t-1} + \varepsilon_t \end{aligned} \tag{2}$$

Δ is the first difference symbol, and it represents the short-run movement. κ, β, γ, δ, η, and θ are the short-run parameters to be estimated. Γ_j $(j = 1,2, \dots ,6)$ is the long run parameter. n is the optimal lag to be chosen using the Schwarz information criteria. The bounds-testing approach is used to establish the long run cointegration, and it is based on the null hypothesis of no long-run cointegration ($\mathrm{H}_0\colon \Gamma_j = 0$) against the alternative hypothesis of cointegration ($\mathrm{H}_1\colon \Gamma_3 \neq 0$) The F-statistic is used to test the hypothesis.

To obtain the error correction term, which accounts for the speed of adjustment among the series, equation 2 is respecified as

$$\begin{aligned} LCF_t = \alpha + \textstyle\sum_{j=1}^{n} \kappa_j \Delta LCF_{t-j} + \sum_{j=0}^{n} \beta_j \Delta GDPP_{t-j} + \sum_{j=0}^{n} \gamma_j \Delta ENC_{t-j} + \sum_{j=0}^{n} \delta_j \Delta INS_{t-j} + \\ \textstyle\sum_{j=0}^{n} \eta_j \Delta URB_{t-j} + \sum_{j=0}^{n} \theta_j \Delta PSE_{t-j} + \Theta ECT_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

Θ is the error correction coefficient.

Apart from the ARDL technique, other long-run estimation techniques, such as FMOLS, DOLS, and CCR, are deployed. These long-run estimation techniques address the problems of endogeneity, serial correlation, and bias in the omitted variables in the environmental sustainability literature. These long-run techniques use parametric and non-parametric methods to resolve the above econometric pitfalls (Arnaut et al., 2023; Narayan & Smyth, 2007). The long-run estimation techniques' models have not been reported to save space.

Research results

This study starts the session by investigating the econometric characteristics of the data used. This sheds light on the stationarity or otherwise of the variables and helps choose appropriate estimation technique(s). The outcomes of the stationarity test are shown in Table 4. ADF and PP unit root tests are used to investigate the stationarity properties of the series. The result in Table 4 hints that the variable does not contain a unit root. Specifically, LCF, GDP per capita, energy consumption, and urbanization are stationary at first difference. Hence, they are the I(1) series. However, institutions and primary school enrolment are stationary at the level; thus, I(0) variables. In summary, the unit root test indicates the absence of the I(2) series; hence, cointegration and short and long-run links among the variables can be obtained.

Table 4. Stationarity Test (Source: Authors)

	ADF		PP	
	Level	1st Dif.	Level	1st Dif.
LCF	-0.620 (0.853)	-6.904[a] (0.000)	-0.584 (0.862)	-6.995[a] (0.000)
GDPP	0.616 (0.988)	-4.409[a] (0.001)	0.868 (0.993)	-4.424[a] (0.001)
ENC	-0.243 (0.923)	-5.819[a] (0.000)	0.937 (0.995)	-7.939[a] (0.000)
INS	-3.648[a] (0.009)	-4.805[a] (0.001)	-3.761[a] (0.007)	-11.816[a] (0.000)
URB	-1.280 (0.998)	-4.868[a] (0.003)	0.466 (0.981)	-4.018[a] (0.002)
PSE	-3.789[b] (0.029)	-4.731[a] (0.003)	-3.279[c] (0.086)	-4.731[a] (0.003)

[a], [b], and [c] represent 1%, 5%, and 10% significance levels, respectively

Given the conclusion of the stationarity test, the long-run cointegration among the variables is investigated using the Johansen cointegration test and the ARDL bounds testing approach. This is essential to understand the level of movement among the variables overall. Furthermore, establishing cointegration is a precursor to investigating long-term relationships. The Johansen cointegration and ARDL bounds testing results are presented in Tables 5 and 6. Table 5 (Johansen cointegration) reveals two cointegration equations, establishing evidence of a long-run relationship among the variables. In addition, the outcome of the ARDL bounds testing in Table 6 also confirms the existence of long-run relationships among the series. Precisely, the F-statistic (6.081) of the ARDL test is higher than the upper bounds at 1% significance level. These results hint that, although the variables drift apart in the short run, they tend to converge in the long run.

Table 5. Johansen Cointegration Test (Source: Authors)

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.
None[a]	0.671	110.710	95.754	0.003
At most 1[b]	0.572	71.828	69.819	0.034
At most 2	0.456	42.136	47.856	0.155
At most 3	0.324	20.841	29.797	0.368

[a] and [b] represent 1% and 5% significance levels

Table 6. ARDL Bound Test (Source: Authors)

Statistic	**Value**	**K**
F-statistic	6.081[a]	5
Level of significance	**Lower bound I(0)**	**Upper bound I(1)**
10%	2.26	3.35
5%	2.62	3.79
1%	3.41	4.68

[a] *represents 1% significance level*

Having established the level of cointegration through the use of Johansen cointegration and ARDL bounds testing, the result of the short- and long-run coefficients of the error correction term of ARDL (1,3,2,1,3,2) is shown in Table 7. The schematic representation of the results is reported in Figure 4. The error correction term ECT(-1) coefficient is significantly negative, indicating that the model corrects its short-run imbalance annually by 55.1% and returns to its long-run steady path. The substantial and negative value of the ECT(-1) also buttresses the long-run cointegration already established by the cointegration test. Furthermore, the diagnostic statistics to validate the consistency and robustness of the ARDL estimation are presented in the lower part of Table 7 and Figures 2 and 3. The findings from the diagnostic tests rejected the assumptions of serial correlation, heteroscedasticity, ARCH effect, model misspecification, and non-normality problems. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) in Figures 2 and 3 confirm the stability of the model's parameters. Consequently, the model is free from the above econometric pitfalls, and inference can be drawn.

The short-run effect of GDP per capita on LCF at lag zero is negative and non-significant. Nevertheless, GDP per capita at lags (1 and 2) significantly positively influences the LCF. Specifically, the coefficient of GDP per capita at lags (1 and 2) is 0.001, suggesting that it increases the LCF by 0.1%. These short-run results imply that per capita GDP strengthens the LCF and the environmental quality. The result hints at a time lag in the effect of per capita income on the environment in Nigeria. Similarly, the outcome discloses that the present income level is not environmentally disadvantageous. However, the long-run influence of per capita GDP on the LCF is insignificant. The insignificant influence in the long run hints that the growing per capita income is not environmentally sustainable.

Further, the insignificant nature in the long run points to the fact that Nigeria, as an emerging country, depends primarily on using extractive resources and traditional energy sources, which are highly carbon-intensive, to grow its economy, thereby worsening the long-run environmental sustainability. This variable's outcome on LCF has implications for sustainable development goals. The positive impact of per capita income on LCF in the short run implies that the increase in per capita income in Nigeria benefits the economy and strengthens the ecological asset in the short run, thus supporting SDG-8 (economic growth).

The outcome of the short-run positive impact of GDP per capita income aligns with the submissions of Yilanci and Pata (2020) and Ahmed et al. (2020), who used the LCF to gauge environmental sustainability. Furthermore, the finding aligns with the outcome of Dada et al. (2022b) for Malaysia using ecological footprint to proxy the environment. However, this result is inconsistent with the submissions of Pata & Isik (2021) for China and Liu et al. (2022) for Brazil.

Energy consumption significantly negatively influences the LCF in the short and long run. Specifically, the coefficients of energy consumption in the short run are -0.004 and -0.005 for lag zero and one, respectively, while the coefficient overall is -0.002. Thus, a percentage surge in energy consumption reduces the LCF by 0.4% on average in the short run and 0.2% in the long run. This shows that energy consumption abates the ecological quality through the LCF. In most developing countries like Nigeria, non-renewable energy takes a larger share of the energy mix. Nigeria uses more carbon-intensive energy resources for its economic growth. Fossil fuel dominates its energy composition, and it is used to drive her economic growth. The adverse impact of energy consumption on the environment stands in tandem with most of the empirical studies in the literature (Adebayo et al., 2021; Arnaut et al., 2023; Rafique et al., 2022). For instance, Udemba (2020) for Nigeria found that energy consumption intensifies the EF and adds to ecological squalor. Similarly, SDG-7 identifies access to clean and affordable modern energy as a determinant of sustainable development. Hence, it is expected that the country will shift its energy policy toward green energy sources, strengthening its ecological assets.

Having unfolded the effect of energy consumption, the result in Table 7 indicates that institutions have a significant positive influence on the LCF in the short run, while their impact is not significant in the long run. Precisely, the short-run coefficient of institutional quality on LCF is 0.061. Hence, a percentage increase in institutions in the short run strengthens the LCF by 6.1%. This result has vital implications for attaining a sustainable environment in Nigeria. For instance, the substantial nature of institutions only in the short run implies that the institutions are not strong enough to drive long-run environmental sustainability in Nigeria. Further, the result shows the importance of having strong institutions as a means of combating ecological degradation. Though insignificant, the long-run result suggests that weak institutional quality allows economic agents to produce non-environmentally friendly goods (Fredriksson & Mani, 2002). Studies (Dada et al., 2021; Huynh & Ho, 2020; Swain et al., 2020; Xie & Saltzman, 2000) have shown that strong institutions abate ecological degradation.

Urbanization, however, provides an interesting influence on the LCF in Nigeria. In the short run, the influence of urbanization is positive and significant, suggesting that urbanization strengthens the environmental quality by enhancing the LCF. The short-run coefficients of urbanization on LCF are 0.163 and 0.268 at lags 1 and 2, respectively. The long-run impact of urbanisation shows that it worsens the LCF and deteriorates the environment. Specifically, the long-run coefficient of urbanization is -0.001, suggesting that a percentage increase in urbanization reduces the LCF by 0.1%. This reveals that urbanization is not environmentally friendly in the long run. This result indicates that urbanization has a differential impact on the environment across time horizons. The beneficial effect of urbanization in the short run demonstrates that urbanization needs to be monitored by policymakers so that the long-run negative impact can be lessened. This can be achieved by developing other cities into urban centres to reduce overcrowding. Further, the long-run result implies that growth in urban population intensifies the demand for more energy, which is mainly met through fossil fuel consumption, increase in waste and sanitary production, and pollution (such as air, water, and land), among others, which have an adverse effect on the environmental quality.

Likewise, the growth of urbanization in Nigeria results from rural-urban migration, which threatens long-run environmental sustainability. As documented in SDG-11, cities (urban centres) need to be safe and conducive to represent the future of global living. However, most urban centres in Nigeria outpace the development of housing, infrastructure, and services, which deteriorates the environment. The conclusion of the short-run effect also receives support from the studies of Dada et al. (2022a), Danish et al. (2019) and Katircioglu and Katircioglu (2018), using ecological footprint to proxy the environment. For the long-run analysis, the inference supports the empirical output of Ali et al. (2022) and Dada et al. (2023).

Moreover, there is a negative link between primary school enrolment as a measure of human capital development and LCF. The 1% surge in primary school enrolment will reduce the LCF by 0.4% in the short run and 0.2% in the long run. This result implies that primary school education is insufficient to drive environmental sustainability. This result is unsurprising as a higher level of human capital development, in terms of higher quality education, will be able to adopt new environmental rules and regulations and eco-friendly equipment (Chankrajang & Muttarak, 2017; Lan & Munro, 2013). Furthermore, more educated individuals have better income and socioeconomic status, allowing them to adopt clean energy and be environmentally conscious. Similar studies (Ahmed et al., 2021; Nathaniel & Khan, 2020; Sarkodie et al., 2020) have also documented that the primary education level is insufficient for sustainable development.

Thus, for SDG-4 to transform into sustainable development, quality and higher education must be provided for all, while education financing must become a national investment priority.

Table 7. Estimate using ARDL (1, 3, 2, 1, 3, 2)

Dependent Variable: LCF

Variable	Coefficient	t-statistic	Probability
Short Run			
ΔGDPP	-0.001	-0.658	0.689
ΔGDPP(-1)	0.001[a]	3.257	0.005
ΔGDPP(-2)	0.001[b]	2.241	0.039
ΔENC	-0.004[b]	-2.245	0.039
ΔENC(-1)	-0.005[a]	-2.957	0.009
ΔINS	0.061[a]	5.400	0.003
ΔURB	0121[a]	3.315	0.004
ΔURB(-1)	0.163[a]	3.436	0.003
ΔURB(-2)	0.268[a]	5.817	0.003
ΔPSE	-0.004[a]	-5.166	0.005
ΔPSE(-1)	-0.002[a]	-4.171	0.007
Ect(-1)	-0.551[a]	-6.160	0.000
Long Run			
GDPP	0.001	1.405	0.179
ENC	-0.002[a]	-3.406	0.004
INS	-0.001	-0.016	0.987
URB	-0.032[a]	-7.228	0.000
PSE	-0.008[a]	-4.439	0.000
C	0.559[c]	1.780	0.094
Diagnostic Test			
J-B normality test	2.430		0.297
B-G serial correlation LM test	1.042		0.378
ARCH test	0.843		0.635
Ramsey	1.325		0.21

[a], [b], and [c] represent 1%, 5%, and 10% significance levels, respectively

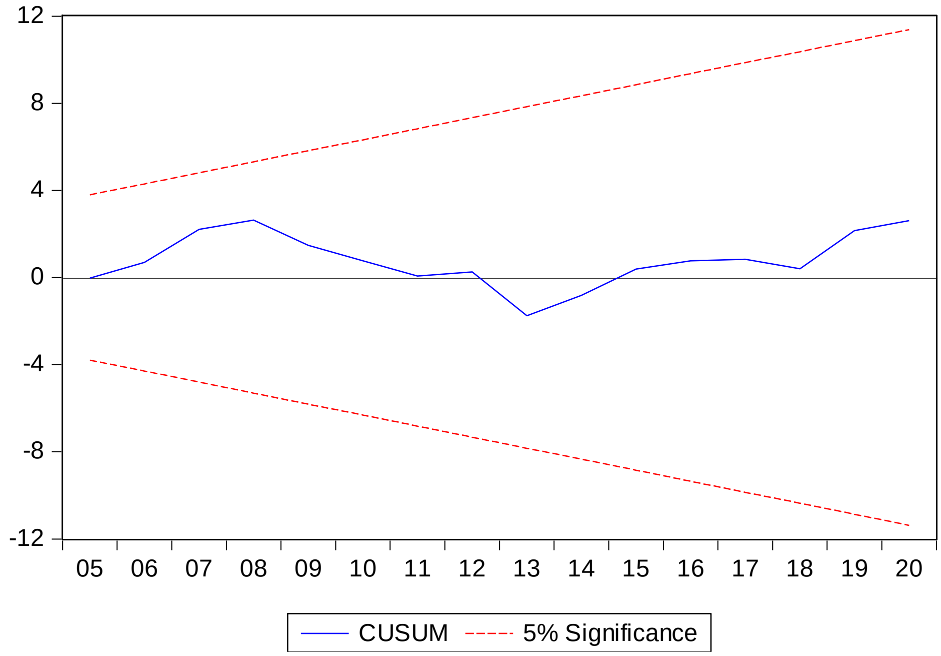

Figure 2: CUSUM

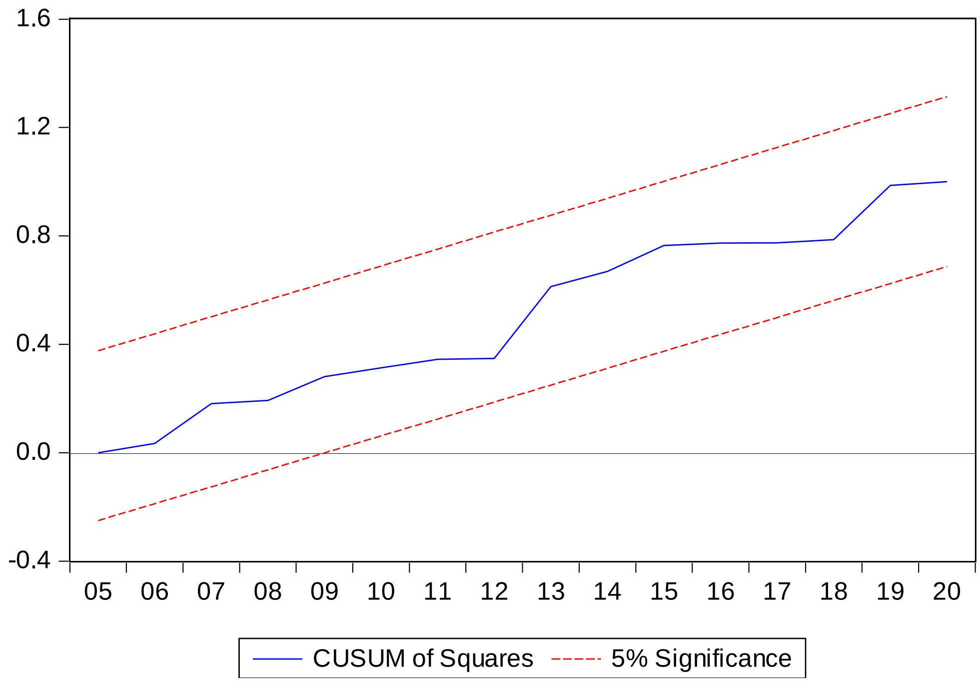

Figure 3: CUSUM of Squares

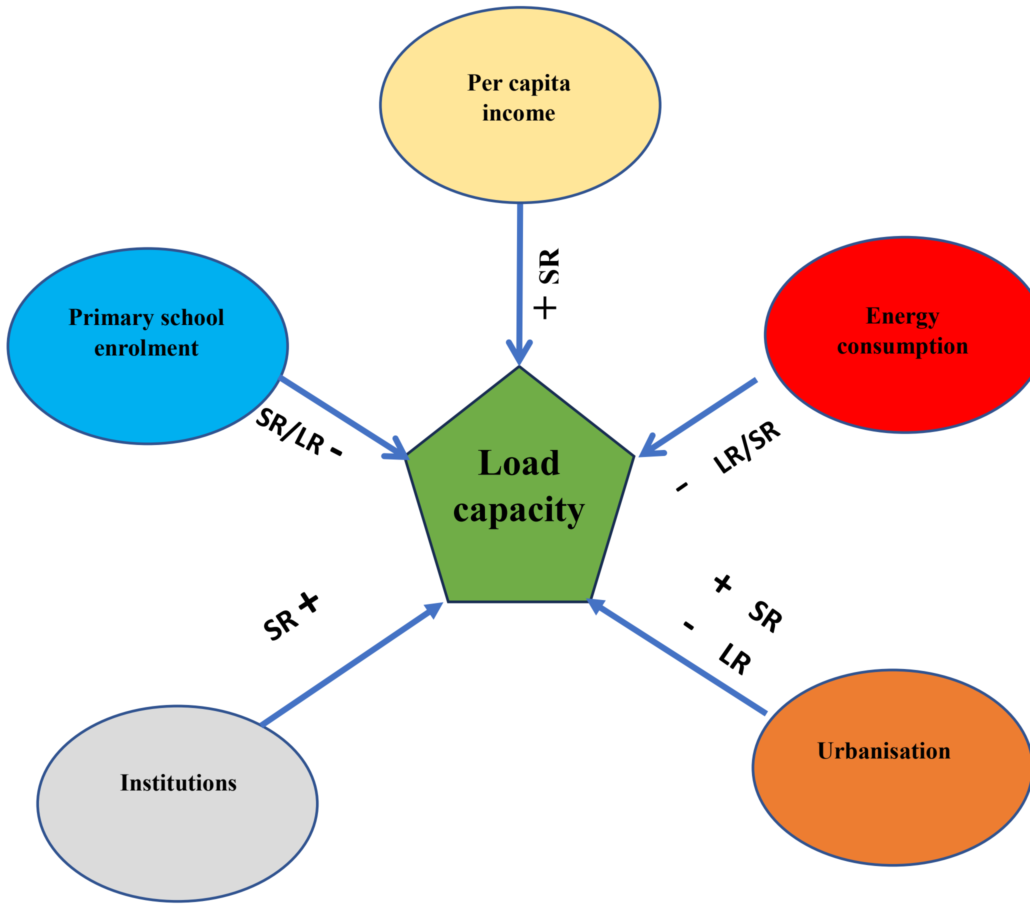

Fig. 5. Schematic representation of the result (Source: Authors)

Robustness Analysis

The robustness of the long-run relationship obtained through the ARDL in the earlier section is further validated using three other long-run cointegration regressions- FMOLS, DOLS, and CCR.

The outcomes of these alternative long-run estimates are provided in Table 8. The findings from these estimates show that per capita income reduces the LCF. However, its impact is marginally significant in the FMOLS model, while energy consumption, urbanization, and institutional quality significantly negatively influence the LCF. These outcomes are similar to the findings from the ARDL estimates, with slight variances in the magnitude of the coefficients and the significance level. Hence, the long-run estimate of ARDL is credible and consistent.

Table 8. Sensitivity analysis of the long-run estimates

Dependent Variable: LCF

Variable	**FMOLS**	**DOLS**	**CCR**
GDPP	-0.001^{c} (-1.980)	-0.001 (-0.708)	-0.001 (-1.437)
ENC	-0.001^{c} (-1.953)	-0.002^{b} (-2.385)	0.001 (1.628)

INS	-0.003 (-0.111)	-0.047 (-1.037)	-0.010 (-0.356)
URB	-0.024^{a} (-6.266)	-0.027^{a} (-4.545)	-0.024^{a} (-5.874)
PSE	-0.003^{a} (-2.871)	-0.007^{a} (-3.447)	-0.003^{a} (-3.159)
C	0.987^{a} (3.660)	0.832^{c} (1.816)	0.938^{a} (3.033)
Adj. R-sq	0.913	0.931	0.907
Long run variance	0.002	0.001	0.002
Mean dep. variance	0.599	0.597	0.598
SE of Reg.	0.032	0.029	0.035

^{a}, ^{b}, and ^{c} represent 1%, 5%, and 10% significance levels, respectively

Conclusions

This study investigates the determinants of LCF in Nigeria through the lens of SDGs. Specifically, the study scrutinizes the role of per capita income, energy consumption, institutions, urbanization, and primary school enrolment on LCF as a measure of environmental sustainability between 1984 and 2020. The ARDL bounds testing is used as the estimation technique, and the result confirms the presence of long-run cointegration among the series. FMOLS, DOLS, and CCR cointegration tests were utilized to check for robustness.

The results hint that in the short run, per capita income, institutions, and urbanization positively influence the LCF; hence, they contribute positively to environmental sustainability. Conversely, energy consumption and primary school enrolment negatively impact the LCF, reducing ecological quality. However, in the long run, the positive impact of per capita income and institutions on load capacity in the short run cannot be sustained, as the effect is not significant. The influence of urbanization changes from its positive impact in the short run to negative in the long run. The effect of energy consumption and primary school enrolment, as measures of human capital development, remains negative in the long run. The long-run result of the ARDL persists when other long-run cointegration methods are employed.

These results have important policy implications, especially in achieving the SDGs in developing countries like Nigeria. The outcomes from the study reveal that current economic growth is not environmentally sustainable. Hence, policymakers need to check the production and consumption patterns so that long-term ecological sustainability will not be eroded. Furthermore, production and consumption should completely shift from fossil fuel consumption, which accounts for more than 90% of the energy, to green and renewable energy. The consumption of fossil fuel energy can be phased out by subsidizing the cost of renewable energy and applying tax exemptions to firms ready to invest in the production and utilization of renewable energy. The carbon tax could also be introduced to discourage firms and households from using it, while the proceeds from the tax can be used for environmental clean-up.

Further, the urbanization policy needs to be strengthened. The urbanization policy should prioritize sustainable and smart cities to lessen the impact of urban congestion on the LCF. To reduce the rural-urban migration, which is the primary cause of urban overcrowding in Nigeria, policymakers should focus on developing the rural areas by providing functional social amenities that will make the teeming population, especially the youth, stay in the rural areas. Institutions, particularly those connected to environmental rules and regulations, should be reinforced to punish environmental offenders and serve as a deterrent to others.

Lastly, the study's outcome shows that primary school enrolment is inadequate to drive environmental sustainability. Thus, policymakers must focus on higher-quality education through massive investment in human capital. With this, well-educated individuals and society will be able to use natural resources sustainably and be conscious of the danger inherent in environmental squalor. Schools' curricula should include ecological awareness.

This study is not without limitations, which opens doors for future research. This study only centres on the implications of SDGs' measures on LCF in Nigeria, without considering other social, political, and macroeconomic variables that could affect the environment. Future studies could incorporate these important variables in determining a sustainable environment. Furthermore, variables such as technological innovation, sectoral dynamics, and comparative assessments of environmental governance can be included in the model. Lastly, this study can be replicated in other developing nations as a country-specific or cross-country study.

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