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Policy Measures for Advancing Environmental Sustainability: Assessing the Impact of Governance Efficiency and Fiscal Approach in Sub-Saharan Africa

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ABSTRACT

This study navigates the complex intersection of fiscal policy, governance quality, and environmental sustainability within Sub-Saharan Africa (SSA). Utilizing a dataset from 2005 to 2020 encompassing 33 SSA countries, the study employs the environmental load capacity factor (LCF) to assess environmental sustainability within the STIRPAT framework as well as unravel the nexus between fiscal strategy and governance quality. Key findings reveal that the impact of government expenditure on LCF varies across quantiles. The positive impact of the interaction between governance quality and government expenditure on LCF accentuates the significance of effective governance in bolstering sustainability efforts. These findings offer pertinent implications for SSA policymakers.

1 | Introduction

The environment continues to suffer habitat destruction, acidification of the oceans, air pollution, and soil erosion owing to unsustainable human activities. It has also led to a severe lack of natural resources and long-term trends toward quickly increasing environmental deterioration, posing significant future challenges (Dibeh et al. 2021; Dimnwobi et al. 2023a). Consequently, the advent of the UN Sustainable Development Goals (SDGs), specifically SDG7, SDG12, and SDG13, signaled a global initiative to avert the impending ecological crisis. Despite growing recognition of the necessity of tackling climate change and its consequences, the degradation of global ecosystems has not been given enough attention. Nearly 99% of people on the planet are estimated to be exposed to environmental pollution, higher than the WHO's recommended threshold (WHO 2022). Due to this persistent ecological overshoot, the human resource demands across countries have surpassed the earth's ability to replenish itself, and more biodiversity has been lost than the planet can repopulate (Dimnwobi et al. 2023b).

Scholars have deployed several metrics to evaluate environmental deterioration, concentrating on CO_2 emissions and the variables linked to them. However, focusing on CO_2 emissions alone offers little understanding of other types of pollution, such as contaminated water and land (Ezenekwe et al. 2023). To overcome this constraint, current research on environmental sustainability is shifting from CO_2 emissions to ecological footprint (EF), a more all-encompassing indicator of environmental damage (Dimnwobi et al. 2021). EF has gained popularity among scholars as a useful indicator for evaluating ecological harm. According to Dimnwobi et al. (2022), the EF offers a thorough framework that permits the comparison of natural resource use rates with the bioproductive forest, land, clean water, and air capacity that are currently available. The EF shows the demand for and environmental restrictions associated with ecosystem goods and services, whereas biocapacity indicates the productivity that is available for resource use (Okere et al. 2023). However, the supply side of ecological circumstances is not taken into account in the EF analysis. In these situations, Pata and Isik (2021) and Pata and Balsalobre-Lorente (2022) recommend evaluating the contributing elements to environmental quality using a load capacity factor (LCF). According to Pata and Isik (2021), the LCF, which is derived by dividing biocapacity by the EF, can be used to assess whether the ecological quality of a nation is sustainable when its value is greater than one or unsustainable when it is less than one, making it a growing environmental evaluation tool (Nwani et al. 2024, Okere et al. 2024a).

There are four key reasons why this research primarily looks at Sub-Saharan Africa (SSA). First, SSA has an abundance of natural resources, and global demand for her resources will only increase at a rapid pace with detrimental ecological consequences, especially for nations without substantial natural resources (Okere et al. 2024b). Second, with an ecological deficit of more than 35 million global hectares (NFBA 2023), SSA countries are currently exceeding the ecological resources and services their ecosystems can sustainably provide. This consequently threatens economic stability and the general well-being of people in the region. Third, as noted by the International Energy Agency (2020), the region contributes less than three percent of the world's energy-related CO_2 emissions, and its per capita emissions are the lowest of any continent, but the continued reliance on fossil fuels poses a serious environmental threat. As such, it is now imperative to explore and pursue viable avenues for mitigating climate change on the African continent. Lastly, concerns exist over many SSA nations' inadequate ability to adjust to climate change and the corresponding changes that frequently coincide with environmental deterioration. These worries coincide with the region's population growth, which is expected to double by 2050 according to forecasts (Dimnwobi et al. 2021). While environmental degradation is gaining a lot of research attention, this study addresses environmental research in African countries that are frequently overlooked, perhaps because the continent produces comparatively less greenhouse gas (GHG) emissions than other regions.

The effect of fiscal policy on the LCF in SSA and the interaction between governance quality and fiscal policy on the LCF in SSA are not taken into account in the current empirical literature. By examining the impact and interaction, this study seeks to close this gap. Fiscal policy can have both positive and negative effects on the ecological LCF. On the plus side, government funding for sustainable development, biodiversity preservation, and environmental conservation helps preserve ecosystems and raises the ecological LCF (Adebayo and Samour 2023). The favorable effects of fiscal policy on the LCF can be amplified when governance quality is good, as evidenced by effective institutions, accountability, and openness. A higher ecological load capacity results from the efficient execution of fiscal policies that place a high priority on renewable energy, sustainable development, and environmental preservation. Conversely, ecological damage and a lower LCF may arise from fiscal policies that place a higher priority on short-term economic rewards than on environmental factors, such as allowing unchecked resource extraction. Fiscal measures that have a favorable impact on the ecological LCF may potentially be hampered by inadequate financing for environmental management and lax enforcement of regulations (Kwakwa 2022). Poor governance, which is characterized by corruption, a lack of transparency, and shoddy institutions, can obstruct fiscal policy's beneficial effects. Under such circumstances, funds designated for sustainable development and environmental preservation may be misapplied or misappropriated, which would have a detrimental effect on the ecological LCF (Hashmi et al. 2023).

Consequently, there are multiple ways in which this research adds to the body of existing literature. As far as we are aware, no previous empirical study has assessed how fiscal policy affects SSA's ecological LCF. Because of its comprehensiveness and completeness, the LCF is utilized as a proxy for capturing environmental quality. The LCF is a superior proxy for gauging environmental quality since it simultaneously captures the supply and demand sides of the environment. It compares biocapacity (the ability of an ecosystem to regenerate resources) with the ecological footprint (the demand placed on these resources by human activities) (Pata and Isik 2021). Second, the study analysis centers on the impact that the interaction of governance quality and fiscal policy has on the ecological LCF. Comprehending the dynamics of this relationship is crucial because it makes it possible to evaluate how SSA's sustainable natural resource management might be supported by governance infrastructure. Third, the research provides useful recommendations to encourage coordinated actions to safeguard the climate, taking into account the requirement for sustainable progress in SSA nations, and to achieve SDGs 8, 11, and 13 in particular. Lastly, the empirical technique used in the study also aids in addressing possible weaknesses in the body of previous research.

This study's ensuing sections are arranged as follows. Section 2 provides the literature, while Section 3 contains the methodology. The empirical outcomes are reported in Section 4. Finally, concluding remarks are offered in Section 5.

2 | Literature Review

The opinions of scholars on the impact of fiscal policy on the environment remain divided. Some studies find that fiscal policy protects the environment. For example, Lau et al. (2023) report that public spending promotes ecological sustainability in BRICS economies. This is also related to the observations of Ya et al. (2024) in BRICS concluding that fiscal policy enhances ecological quality. Additionally, Katircioglu and Katircioglu (2017) confirm that fiscal policy considerably improved the environment in Turkey. Halkos and Paizanos (2016) and Kwakwa (2022) affirm that government spending reduces emissions levels in the United States and Ghana, respectively. Conversely, some other scholars contend that fiscal policy damages the ecosystem. For instance, Zeraibi et al. (2022) find that government spending increases carbon emissions in China. Le and Ozturk (2020) confirm in 47 emerging nations that public spending escalates ecological damage. However, some studies report that the environment responds differently to the various components of fiscal policy. For example, Li et al. (2023) report that government spending triggers ecological damage while tax revenue improves the environment in BRICS. Habeşoğlu et al. (2022) document that government spending and tax revenues improve and undermine Turkey's ecological quality, respectively. Zahra et al. (2022) highlight in Pakistan that public development spending expands ecological decline while tax revenue reduces it.

Another group of studies evaluates the environmental effect of governance quality, mostly showing that environmental quality is enhanced by governance infrastructure. For instance, Ali et al. (2023) confirm that governance infrastructure improves environmental quality in the European Union. The same outcome is obtained by Akpan and Kama (2023) in 163 nations as well as by Xaisongkham and Liu (2022) and Hashmi et al. (2023) in emerging nations. In a similar study of African nations, Mesagan and Olunkwa (2022) affirm that a regulatory framework has a negative influence on pollution, thereby promoting Africa's environment from 1996 to 2017. The outcome of Farooq (2022) is not different, revealing that strong governance minimizes environmental degradation in Asian nations. Shehzad et al. (2022) disclose that governance infrastructure contributes to environmental preservation by lowering carbon emissions in Pakistan between 1990 and 2018.

In contrast, there is some evidence that contradicts the enhancing environmental effect of governance quality. For instance, Bildirici (2022) reveals that governance quality increases environmental degradation in selected Middle Eastern and SSA countries. Yang et al. (2022) report that institutional quality escalates CO_2 emissions in developing nations. In a group of 35 African nations from 1991 to 2015, Dada et al. (2021) document that African environmental contamination is largely triggered by institutional quality. Hassan et al. (2020) conclude that environmental pollution was escalated by institutional quality in Pakistan between 1984 and 2016.

3 | Methodology and Data

3.1 | Model

The model formulation is rooted in the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) framework, which was initially introduced by Dietz and Rosa (1994). The STIRPAT equation, employed for studying the factors influencing environmental impact, can be represented as follows:

$$I_t = \beta_0 \, .P_t^{\beta_1} .A_t^{\beta_2} . \, T_t^{\beta_3} \tag{1}$$

Equation (1) integrates key parameters to evaluate human impact on the environment. Here, the impact (I) is defined via the ecological LCF. The constants β_0, β_1, β_2, and β_3 represent the scaling factor and elasticities for population (P), affluence (A), and technology (T), respectively, with 't' accounting for time. This study uniquely examines technology's influence through government fiscal strategies—specifically, government expenditure—and governance quality, focusing on regulatory quality (REQ) and government effectiveness (GVT). This leads to an empirical model based on the extended STIRPAT equation:

$$ln\text{LCF}_{it} = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\text{GE}_{it} + \beta_4 ln\text{GVT}_{it} + \varepsilon_{it} \tag{2}$$

$$ln\text{LCF}_{it} = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\text{GE}_{it} + \beta_4 ln\text{REQ}_{it} + \varepsilon_{it} \tag{3}$$

Equations (2) and (3) use logarithmic forms (denoted by "ln"). Subscripts i and t represent country i in year t, with ε as the error term. The ecological load capacity factor is LCF, while GE, GVT, and REQ indicate government fiscal strategies, GVT, and REQ, respectively. P represents urban population, and A denotes GDP per capita. Onuoha et al. (2023a) show that the interaction between governance quality and government expenditure separately affects environmental quality. This approach captures the relationship's complexity, evaluates various scenarios, addresses subcategory differences, offers policy insights, and enhances model predictive accuracy. They can be reformulated as thus:

$$\begin{aligned} ln\text{LCF}_{it} = {} & \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\text{GE}_{it} + \beta_4 ln\text{GVT}_{it} \\ & + \beta_5 \left(ln\text{GE}_{it} * ln\text{GVT}_{it}\right) + \varepsilon_{it} \end{aligned} \tag{4}$$

$$\begin{aligned} ln\text{LCF}_{it} = {} & \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\text{GE}_{it} + \beta_4 ln\text{REQ}_{it} \\ & + \beta_5 \left(ln\text{GE}_{it} * ln\text{REQ}_{it}\right) + \varepsilon_{it} \end{aligned} \tag{5}$$

In this context, $i = 1 \dots N$ indicates the number of cross-sections. It is noteworthy that the expectations are as follows: When $\beta_1 < 0$ and $\beta_3 < 0$, this suggests that GDP contributes to environmental degradation. Additionally, β_3 and β_4 are anticipated to have either a detrimental or beneficial impact on the LCF. The sign of the coefficient for the interaction term, β_5, measures whether the interaction between governance quality and government expenditure enhances or modifies the influence of fiscal strategy on the LCF. A positive (negative) sign for the interaction coefficient implies that governance quality improves (distorts) the performance of government expenditure concerning the LCF. Consequently, the overall effect of government expenditure on the LCF, given governance quality, can be calculated as follows:

$$\frac{\partial ln\text{LCF}}{\partial ln\text{GE}} = \beta_3 + \beta_5 ln\text{GVT} \tag{6}$$

$$\frac{\partial ln\text{LCF}}{\partial ln\text{GE}} = \beta_3 + \beta_5 ln\text{REQ} \tag{7}$$

Hence, when $\beta_5 > 0$, it indicates that governance quality facilitates government expenditure in influencing the LCF. Conversely, if $\beta_5 < 0$, the overall effect of government expenditure on the LCF relies on the extent of the negative value. If the negative value of β_5 outweighs the positive value of β_3, governance quality distorts the impact of government expenditure on the LCF. However, if the negative value of β_5 is less than the positive value of β_3, it suggests that the distorting effect of governance quality is not potent enough to counter the positive effect of government expenditure on the LCF. Finally, if $\beta_5 = 0$, it signifies that the interaction between governance quality and government expenditure holds no significant influence on the LCF.

3.2 | Data

The data for this study comes from 33 Sub-Saharan African countries (see Appendix 1) and spans 2005–2020. The selection of this period is based on data availability. Urbanization and economic growth are included as control variables, following similar studies (Kwakwa 2022; Onuoha et al. 2023b, Adebayo and Samour 2023). Appendix 2 contains detailed descriptions of all variables.

3.3 | Estimation Approach

1. Cross-sectional dependency (CSD): Evaluated using Pesaran and Yamagata's (2008) testing approach.
2. Stationarity: Assessed with two tests: CIPS test, a modified Dickey-Fuller test for detecting unit roots, especially with structural breaks or data variance changes. Cross-Sectionally Augmented Dickey-Fuller (CADF) test.
3. Cointegration: Assessed using the Westerlund (2007) cointegration test, designed for panels with heterogeneity and cross-sectional dependence. The null hypothesis of no cointegration is rejected if cointegration is found in all or part of the panels.

If both CSD and cointegration are observed, method of moments-quantile regression (MM-QR) estimates are used.

3.4 | MM-QR Estimates

This study utilizes the method of moments quantile regression[5] (MMQR), which was developed by Machado and Silva (2019). MMQR efficiently addresses the issue of fixed effects in panel quantile models, enabling the estimate of distinct components of the conditional distribution at various quantiles of the dependent variable. More precisely, we estimate the 25th, 50th, and 75th conditional quantiles of LCF by utilizing the conditional quantile Q_y(τ | X_it) of the location-scale variant model. This is obtained by altering Equations (6) and (7) using the approaches suggested by Machado and Silva (2019). We employ a thorough specification to modify the equations accordingly.

$$Q_y\ (\tau|X_{it}) = (\beta_i + \delta_i qi) + X'_{it}\beta + Z'_{it}\gamma q\,(\tau) \tag{8}$$

where $Q_y(\tau|X_{it})$ depicts the quantile distribution of the dependent variable $lnLCF_{it}$, conditional on the location and scale of the explanatory variable (X'_{it}). X'_{it} is a vector of explanatory variables (see Appendix 1). $\alpha_i\ (\tau) = \alpha_i + \delta_i q(\tau)$ represents the distributional effect at τ or the scalar coefficient of the quantile - τ fixed effect for individual i. $q(\tau)$ is the τ-th quantile estimated through optimization function:

$$\min_q \sum_i \sum_t \rho_\tau(\hat{R}_{it} - (\hat{\delta}_i + Z'_{it}\hat{\gamma})q) \tag{9}$$

where $\min_q$ → The function minimizes the sum of quantile loss functions.

$\sum_i \sum_t$ → Summation over all individuals (i) and time periods (t), indicating a panel data setting.

ρ_τ-quantile loss function (also called the check function), which assigns asymmetric weights to residuals depending on whether they are above or below the quantile of interest

Accordingly, this threshold $\rho_\tau\ (A) = (\tau - 1)\ AI\{A \le 0\} + \tau AI\{A > 0\}$ offers a check-function. Drawing from Equation (9), we present the final modified baseline model stated in Equations (2–5) for panel quantile calculation as thus

$$Q_{lnLCF_{it}},\ (\tau|\beta_i, \varepsilon_{it}, X_{it}) = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\mathrm{GE}_{it} + \beta_4 ln\mathrm{GVT}_{it} + \varepsilon_{it} \tag{10}$$

$$Q_{lnLCF_{it}},\ (\tau|\beta_i, \varepsilon_{it}, X_{it}) = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\mathrm{GE}_{it} + \beta_4 ln\mathrm{REQ}_{it} + \varepsilon_{it} \tag{11}$$

$$Q_{lnLCF_{it}},\ \left(\tau|\beta_{i_i}, \varepsilon_{it}, X_{it}\right) = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\mathrm{GE}_{it} + \beta_4 ln\mathrm{GVT}_{it} + \beta_5\,(ln\mathrm{GE}_{it} * ln\mathrm{GVT}_{it}) + \varepsilon_{it} \tag{12}$$

$$Q_{lnLCF_{it}},\ \left(\tau|\beta_{i_i}, \varepsilon_{it}, X_{it}\right) = \beta_0 + \beta_1 lnP_{it} + \beta_3 lnA_{it} + \beta_3 + ln\mathrm{GE}_{it} + \beta_4 ln\mathrm{GVT}_{it} + \beta_5\,(ln\mathrm{GE}_{it} * ln\mathrm{REQ}_{it}) + \varepsilon_{it} \tag{13}$$

The quartile model in Equation (10) takes into account the distributional effects of P, A, GE, and GVT on LCF. In the specifications in Equations (11)—(13), the impact of GE on the LCF is adjusted to account for the role of REQ and GVT in the composition of governance quality in the SSA region.

4 | Empirical Results and Discussion

4.1 | Correlation Graph

Exhibit 1 presents the distributional plots of the variables, visually illustrating a positive correlation between load capacity, government expenditure, GVT, and the interaction between government expenditure and its effectiveness. Simultaneously, a negative correlation is evident between load capacity, REQ, and their interaction.

4.2 | CSD and Slope Homogeneity Tests

The results presented in **Exhibit 2** showed that the Pesaran (2015) LM, Pesaran (2007) CDs, and Breusch-Pagan (1980) LM tests exhibited cross-sectional dependence, suggesting that all the variables are interrelated with each other throughout the study period and the assumption of slope heterogeneity was correct.

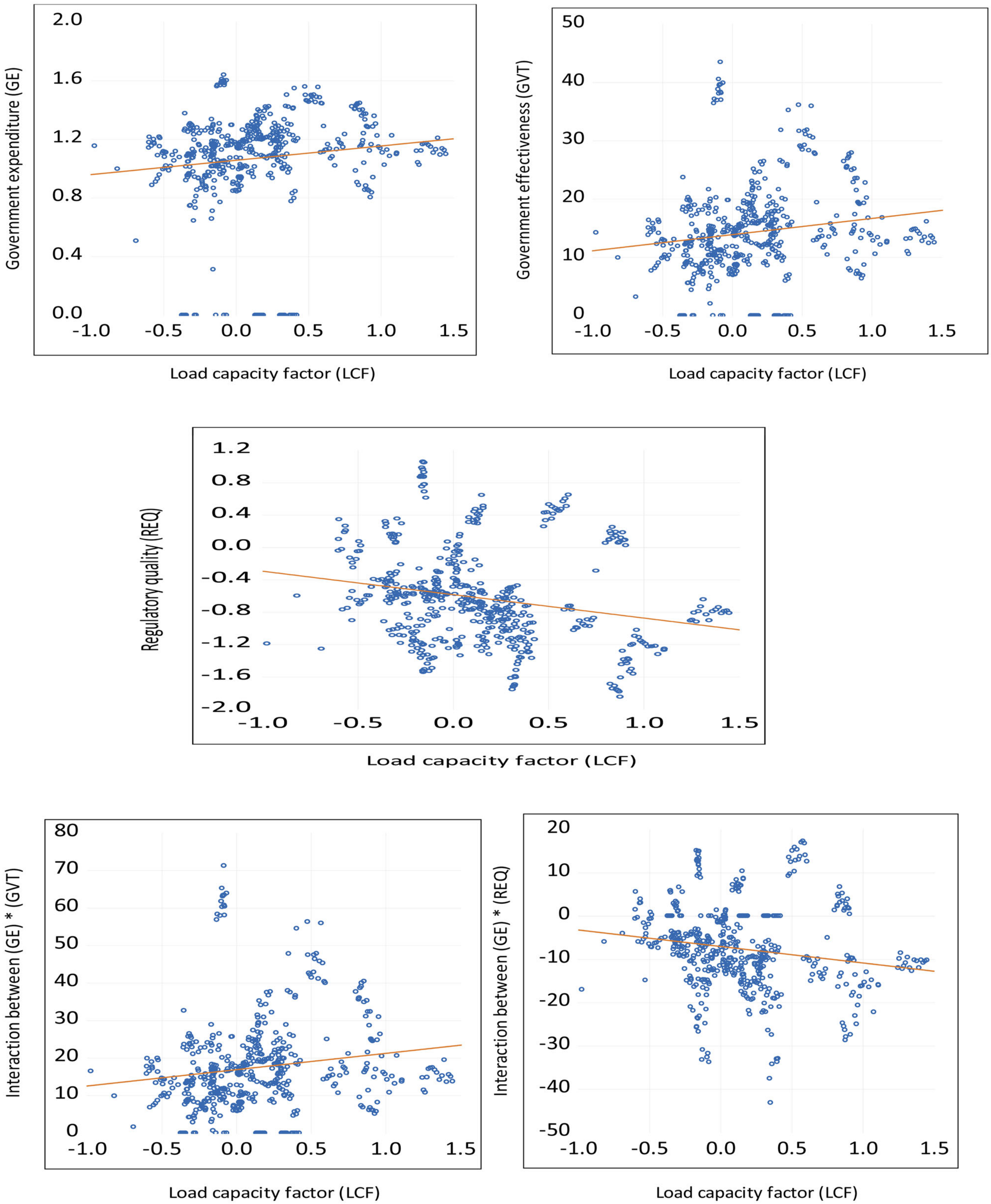

EXHIBIT 1 | Scatter plots of load capacity, urban population, GDP per capita, government expenditure, and governance quality indicators. *Source:* Authors' computation. [Color figures can be viewed at wileyonlinelibrary.com.]

4.3 | Unit Root

Exhibit 3 reveals that all variables except GE are integrated of order one order that is, parameters are non-stationary at levels but become stationary after differencing once. GE is stationary at levels in CIPS estimation.

4.4 | Cointegration Test

Given the presence of CD and heterogeneous attributes, the Westerlund (2007) panel cointegration procedure is employed to assess the potential existence of a long-run relationship among the variables. The results in **Exhibit 4** confirm that the

EXHIBIT 2 | Cross-sectional dependency and slope homogeneity analysis.

Model	Pesaran (2007) CD test	Pesaran (2015) LM test	Breusch-Pagan (1980) LM test	Slope homogeneity test		*p* value
LCF = f (GE, *A*, *P*, GVT, REQ)	35.282	51.323	2195.797	Delta_tilde	6.054	0.000
p value	0.000	0.000	0.000	Adj. Delta_tilde	8.561	0.000

EXHIBIT 3 | Second generation unit root tests.

	CIPS		CADF	
Variables	*I*(0)	*I*(1)	*I*(0)	*I*(1)
LCF	−1.988	−4.279***	−1.361	−2.849***
GE	−2.152**	−3.888***	−1.949	−3.355***
A	−1.461	−2.8***	−1.588	−2.186***
P	−0.022	−3.615***	−0.978	−3.554***
GVT	−2.117	−4.015***	−1.866	−3.233***
REQ	−1.828	−4.097	−1.29	−2.924***

Note: *** = $p < 1\%$, ** = $p < 5\%$, * = $p < 10\%$ indicate significance level. Authors computation.

EXHIBIT 4 | Westerlund cointegration test.

Statistic	Value	*Z* value	*p* value
Gt	−2.44**	−0.079	0.046
Ga	−0.849**	8.958	0.099
Pt	−8.590**	3.033	0.0199
Pa	−0.463	6.262	1.000

Source: Authors computation.

variables under investigation are indeed cointegrated in the long run.

4.5 | Presentation and Discussion of Regression Results

Exhibits 5 and **6** provide parameter estimates for the location and scale functions, with z-statistics in parentheses, using a robust variance estimator (see also **Exhibit 7**). The scale function is assumed linear to maintain quantile linearity. Panel A of Exhibit 6 shows a significant decline in the ecological carrying capacity factor due to changes in urban population size. Specifically, a 1% change in urban population size decreases the ecological LCF by 2.063%, 1.524%, and 1.160% at the 10th, 50th, and 90th quantiles, respectively. This indicates that urban population growth in SSA hinders environmental sustainability, consistent with studies by Jian et al. (2022) and Kwakwa (2023). Policymakers should prioritize awareness campaigns on the negative effects of poor environmental quality and adopt birth control strategies to mitigate ecological deficiencies.

Similarly, there is a negative relationship between GDP and the LCF in SSA. Panel A shows that a 1% increase in per capita GDP decreases the LCF by 0.367%, 0.138%, and 0.0346% at the 10th, 50th, and 90th quantiles, respectively. Higher quantiles show a less significant negative effect of GDP on LCF, indicated by the 0.0346 coefficient. This finding aligns with previous research (Jian et al. 2022; Kwakwa 2023) highlighting the negative environmental impacts of economic growth in emerging economies. SSA countries must adopt measures that mitigate environmental damage while enhancing biodiversity support.

The study reveals a significant negative impact of government expenditure on the LCF at lower quantiles (10th and 25th), indicating a deterioration of ecological sustainability. However, at the median and upper quantiles, the coefficient turns positive. At lower quantiles, increased government expenditure expands the EF beyond the earth's biocapacity. In contrast, countries at median and upper quantiles exhibit a different trend, highlighting the nuanced effects of fiscal policy on LCF. This suggests that growth reliant on government expenditure, along with economic vulnerabilities such as corruption and political interference, may hinder resource allocation and threaten ecological sustainability in SSA.

The study shows that GVT has a significantly negative impact on the LCF in SSA across all quantiles. A 1% increase in GVT leads to a substantial decrease in LCF, and this aligns with previous studies (Bildirici 2022; Yang et al. 2022), indicating that weak institutions hinder environmental sustainability in SSA. Additionally, in Panel B, the interaction between GVT and government expenditure has a statistically significant positive effect on LCF, improving environmental sustainability.

Our findings indicate that while GVT is lacking in SSA, hindering environmental progress, government expenditure enhances it, particularly at the upper quantiles. The key question is whether GVT can moderate the negative impact of government expenditure on environmental sustainability and further reinforce it at the upper quantiles in SSA. To explore this, we evaluate the overall

EXHIBIT 5 | Quantile-based distributional effects with robust variance estimator.

	PANEL A							PANEL B						
	Lower median upper							**Lower median upper**						
Variables	Location	Scale	qtile_10	qtile_25	qtile_50	qtile_75	qtile_90	Location	Scale	qtile_10	qtile_25	qtile_50	qtile_75	qtile_90
P	−1.362***	0.1700	−1.639***	−1.486***	−1.333***	−1.236***	−1.101***	−1.376***	0.184	−1.695***	−1.517***	−1.355***	−1.240***	−1.118***
	(0.1560)	(0.1340)	(0.3260)	(0.2180)	(0.1410)	(0.1290)	(0.1710)	(0.1540)	(0.1300)	(0.3250)	(0.2120)	(0.1440)	(0.1340)	(0.1670)
A	0.160**	−0.127*	0.367**	0.253**	0.138*	0.0663	−0.0346	0.155*	−0.139**	0.396**	0.262**	0.139*	0.0519	−0.0405
	(0.0816)	(0.0692)	(0.1790)	(0.1200)	(0.0717)	(0.0541)	(0.0645)	(0.0835)	(0.0694)	(0.1870)	(0.1230)	(0.0761)	(0.0563)	(0.0610)
GE	−0.00559	0.0354	−0.0633*	−0.0316*	0.0005**	0.0207**	0.0489**	0.2020**	0.1430**	−0.0446**	−0.0932**	0.2190**	0.308**	0.403***
	(0.0288)	(0.0239)	(0.0627)	(0.0424)	(0.0257)	(0.0198)	(0.0246)	(0.1620)	(0.1380)	(0.3660)	(0.2440)	(0.1530)	(0.1250)	(0.1520)
GVT	0.0004**	0.0023*	−0.0042*	−0.0021*	−0.0009*	−0.0013*	−0.0032**	−0.0411	0.0245	−0.0012**	−0.0224**	−0.044**	−0.0593**	−0.0755**
	(0.0016)	(0.0013)	(0.0034)	(0.0023)	(0.0014)	(0.0011)	(0.0013)	(0.0312)	(0.0263)	(0.0696)	(0.0464)	(0.0295)	(0.0247)	(0.0303)
GE*GVT								0.0213**	0.0116**	0.0011**	0.0124**	0.0226**	0.0299**	0.0376**
								(0.0156)	(0.0132)	(0.0346)	(0.0231)	(0.0148)	(0.0126)	(0.0155)
Net effect								0.1892	0.1361	−0.0453	−0.1006	0.2055	0.2901	0.3805
Constant	1.789***	0.161	1.527***	1.671***	1.817***	1.909***	2.037***	1.827***	0.176	1.523***	1.693***	1.848***	1.958***	2.074***
	(0.2640)	(0.2180)	(0.5140)	(0.3550)	(0.2530)	(0.2550)	(0.3440)	(0.2690)	(0.2220)	(0.5430)	(0.3670)	(0.2610)	(0.2590)	(0.3280)

Note: Standard errors are in (); *** indicates p value < 0.1.

EXHIBIT 6 | Quantile-based distributional effects with robust variance estimator.

	Panel A							Panel B						
	Lower median upper							Lower median upper						
Variables	Location	Scale	qtile_10	qtile_25	qtile_50	qtile_75	qtile_90	Location	Scale	qtile_10	qtile_25	qtile_50	qtile_75	qtile_90
P	−1.563***	0.282	−2.063***	−1.768***	−1.524***	−1.339***	−1.160***	−1.586***	0.276	−2.048***	−1.762***	−1.540***	−1.371***	−1.182***
	(0.2100)	(0.1820)	(0.5020)	(0.3110)	(0.1870)	(0.1380)	(0.1730)	(0.2110)	(0.1860)	(0.4890)	(0.3000)	(0.1840)	(0.1370)	(0.1730)
A	0.291**	0.201**	−0.648**	−0.437***	−0.263***	−0.131*	−0.0030**	0.290**	0.202**	−0.628**	−0.418***	−0.256***	−0.132*	−0.0063**
	(0.1140)	(0.0979)	(0.2720)	(0.1670)	(0.1010)	(0.0735)	(0.0919)	(0.1140)	(0.1000)	(0.2670)	(0.1620)	(0.0985)	(0.0703)	(0.0862)
GE	0.0075**	−0.0089	0.0234**	0.014**	0.006**	0.0003**	0.0053**	0.0308**	0.0053**	0.0218**	0.0274**	0.0317**	0.0350**	0.0386*
	(0.0094)	(0.0080)	(0.0204)	(0.0130)	(0.0090)	(0.0087)	(0.0113)	(0.0146)	(0.0134)	(0.0306)	(0.0193)	(0.0141)	(0.0148)	(0.0201)
REQ	−0.0999**	0.0595	−0.205**	−0.143**	−0.0916**	−0.0527	−0.0149	−0.121**	0.0469	−0.199**	−0.151**	−0.113***	−0.0841**	−0.0521**
	(0.0430)	(0.0371)	(0.0991)	(0.0614)	(0.0387)	(0.0325)	(0.0437)	(0.0443)	(0.0389)	(0.0979)	(0.0607)	(0.0398)	(0.0353)	(0.0468)
GE*REQ								0.0014*	0.0009**	−0.00067*	0.0008**	0.0016**	0.0022***	0.0028***
								(0.0008)	(0.0008)	(0.0019)	(0.0012)	(0.0007)	(0.0006)	(0.0008)
Net effect								0.0300	0.0049	0.0218	0.0269	0.0308	0.0338	0.0371
Constant	1.625***	0.27	1.147**	1.429***	1.663***	1.840***	2.012***	1.639***	0.266	1.194**	1.469***	1.683***	1.846***	2.028***
	(0.2640)	(0.2150)	(0.5120)	(0.3350)	(0.2590)	(0.2800)	(0.3580)	(0.2680)	(0.2200)	(0.5150)	(0.3350)	(0.2600)	(0.2740)	(0.3550)

Note: Standard errors are in (); *** indicates p value < 0.1, ** indicates p value <0.5, * indicates p value < 0.10.

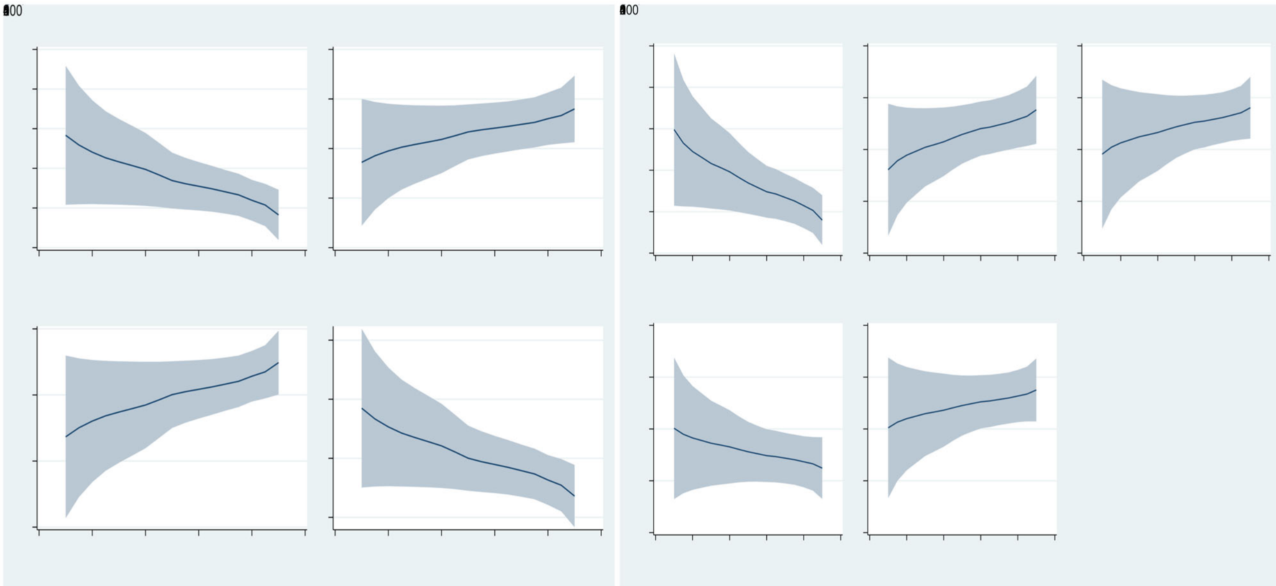

EXHIBIT 7 | Quantile plot. *Note:* govtex = government expenditure (GE), govef = government effectiveness (GVT), gdp = gross domestic product per capita [A], urb = urbanization [P], inter1 = interaction between government expenditure and government effectiveness GE*GVT. [Color figures can be viewed at wileyonlinelibrary.com.]

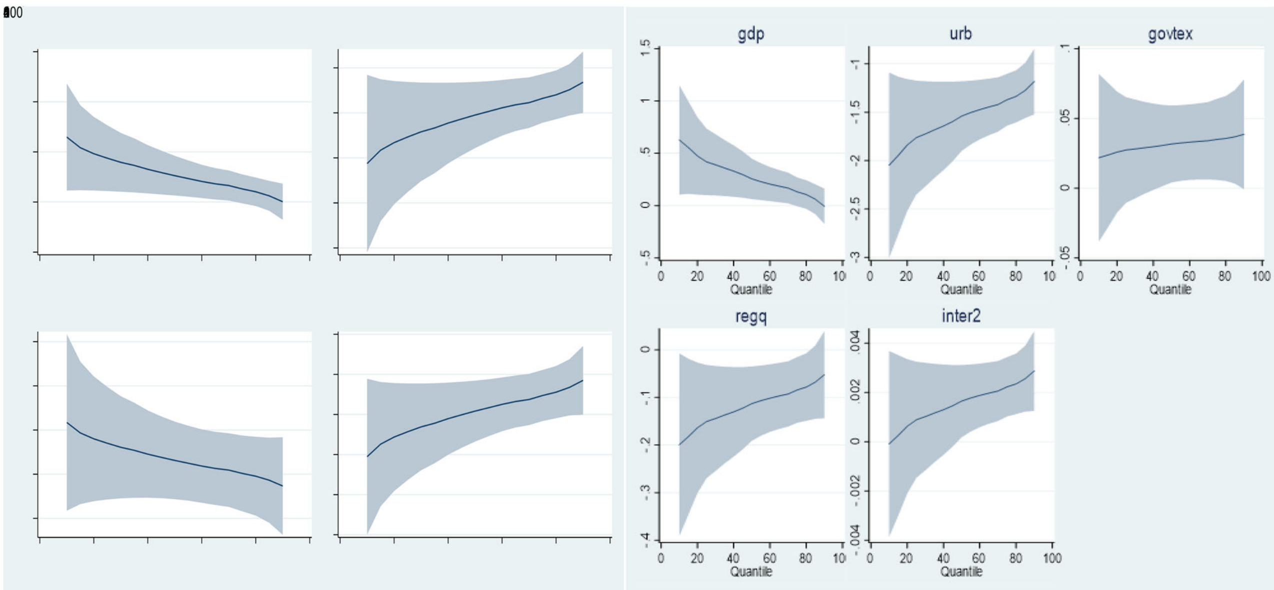

EXHIBIT 8 | Quantile plot. *Note:* govtex = government expenditure (GE), regq = regulatory quality (REQ), gdp = gross domestic product per capita [A], urb = urbanization [P], inter2 = interaction between government expenditure and regulatory quality (GE*REQ). [Color figures can be viewed at wileyonlinelibrary.com.]

effect of leveraging GVT to influence government expenditure for promoting environmental sustainability. This involves solving Equation (6) using various approaches, including the unconditional effect and the conditional effect through the interaction term, and considering the average level of GVT (−0.599). For example, at the 10th quantile in Panel B of Exhibit 6, we compute the net effect of government expenditure using Equation (6).

$$\frac{\partial ln\text{LCF}}{\partial ln\text{GE}} = -0.0446 + 0.0011\ (-0.599) = -0.0453 \qquad (14)$$

Our examination of net effects reveals varied outcomes:

1. Lower quantiles: There is a detrimental net impact ranging from 0.0453 to 0.1006, indicating that GVT is insufficient to mitigate the environmental deterioration caused by government spending.
2. Middle and higher quantiles: There is a positive overall impact ranging from 0.2055 to 0.3805, suggesting that the combination of GVT and government expenditure pro-

EXHIBIT 9 | Robust analysis using JKS multivariate non-causality test.

	1	2	3	4	5	6	7	8	9	10	11	12
Variables	**LCF**	***A***	***P***	**GE**	**GE**	**GE*GVT**	**LCF**	***A***	***P***	**GE**	**REQ**	**GE*REQ**
	Panel A: Non-causality test											
HPJ Wald test	81.456	18.261	6.339	79.719	208.59	333.493	113.479	27.0971	0.849	32.118	4.7823	3.739
p value	0.0000	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2321	0.0000	0.4430	0.5875
	Panel B-panel Jackknife estimates of selected covariate											
LA	−0.099											
	(0.1000)											
L.P	−2.426***											
	(0.4490)											
L.GE	0.0219*											
	(0.2610)											
L.GVT	−0.0029**											
	(0.0500)											
L. GE*GVT	0.00137**											
	(0.0249)											
L. GE*REQ							0.00163**	0.00201***	−0.00481*	−0.0062	−0.00229	
							(0.0011)	(0.0007)	(0.0000)	(0.0118)	(0.0035)	
L.LCF		0.016	0.00043	0.120*	0.743	0.531		0.0215	0.000395	0.156**	−0.0775	−0.0145
		(0.0210)	(0.0008)	(0.0671)	(0.7280)	(1.0550)		(0.0206)	(0.0008)	(0.0686)	(0.0536)	(0.8820)
Observations	33	33	33	33	33	33	33	33	33	33	33	33

*H*0: Selected covariates do not Granger-cause; *H*1: H0 is violated. Standard errors in (). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

motes environmental advancement, enhancing the beneficial impacts on environmental sustainability.

The analysis extends to REQ to assess its policy implications in SSA. Panel B of Exhibit 6 and **Exhibit 8** show that the interaction between REQ and government expenditure has a positive and statistically significant impact on the LCF, significant at the 1%–10% level except at the 10th quantile. Net effects computed from this interaction indicate that combining REQ with government expenditure promotes environmental progress, enhancing the positive impact of government spending on environmental sustainability.

The key takeaways from the findings are (i). Urban population size: Significantly reduces ecological carrying capacity, highlighting environmental challenges in SSA. (ii). Per capita GDP: Negatively affects the LCF across quantiles. (iii) Government expenditure: Deteriorates the environment at lower quantiles but improves it at median and upper quantiles. Urbanization and economic expansion interacting might worsen environmental damage. For example, the combined effect of urbanization and GDP growth has been demonstrated to raise the EF of rising economies (see Danish, and Wang 2019). (iv) GVT: Weakness in effectiveness reduces environmental sustainability across all quantiles. (v) Interaction of GVT and expenditure: Positively influences LCF, showing the importance of governance quality. Enhanced governance, encompassing corruption mitigation and regulatory excellence, is associated with improved green growth, highlighting the significance of effective governance frameworks for environmental sustainability. (vi) REQ: Further enhances the positive impact of government expenditure on LCF, emphasizing the role of governance quality in environmental progress.

4.6 | Robustness Test

To enhance the reliability of our results, we use the Juodis et al. (2021) Half-Panel Jackknife (HPJ) Wald-type test, noted for its superior size and power. This method, capable of handling multivariate and heterogeneous panel data, uses bootstrap variance to address cross-sectional dependence and performs a Wald test for Granger causality. Results are detailed in **Exhibit 9**. Columns (1) to (12) examine the Granger causality between parameters (*P*, *A*, GE, GEGVT, GEREGQ) and the LCF in SSA. The Half-Panel Jackknife (HPJ) Wald statistic confirms significant Granger causality, rejecting the null hypothesis. The regression results show that government expenditure, GVT, regulatory effectiveness, and their interactions significantly impact LCF. A notable bidirectional positive relationship between government expenditure and LCF is observed, indicating a mutually reinforcing connection.

5 | Conclusion and Policy Recommendations

5.1 | Conclusion

> “*This research investigates the intricate dynamics between governance quality, fiscal strategy, and environmental sustainability in SSA from 2005 to 2020. The empirical results, analyzed through the MMQR, reveal multifaceted relationships with insightful policy implications.*”

This research investigates the intricate dynamics between governance quality, fiscal strategy, and environmental sustainability in SSA from 2005 to 2020. The empirical results, analyzed through the MMQR, reveal multifaceted relationships with insightful policy implications. To begin with, government expenditure exhibits a mixed effect, causing environmental deterioration at lower quantiles but contributing positively at median and upper quantiles. Weak GVT is linked to reduced environmental sustainability, underlining the adverse ecological consequences of governance inadequacies. Importantly, the interaction between GVT and government expenditure exerts a statistically significant positive impact on the LCF, emphasizing the pivotal role of governance quality in promoting environmental sustainability. Further inclusion of REQ strengthens the positive impact, emphasizing the importance of governance quality in enhancing environmental progress.

5.2 | Policy Suggestions

From the findings, it is evident that enhancing governance quality should be a top priority for governments in SSA. This should involve a concerted effort to strengthen institutions, reduce corruption, and improve REQ and GVT. A move towards the realization of a more robust and effective governance policy framework in the region can commence by deepening continental and national efforts. By doing so, respective national governments in the region can create a conducive environment for effective environmental governance. Our findings also highlight that policymakers in the region need to integrate considerations of governance quality into fiscal policies. This entails aligning government expenditure with effective governance practices and ensuring that financial resources are directed towards projects and initiatives that are environmentally sustainable. By integrating governance quality into fiscal decisions, governments can amplify the positive impact of expenditures on environmental outcomes.

5.3 | Agenda for Future Research

In terms of scope, the study covers the period from 2005 to 2020. Future research could consider more recent data and explore longer time frames to capture more extended trends and assess the long-term impact of policy interventions. Also, exploring regional or country-specific analyses within SSA could reveal insightful variations in the relationships studied, contributing to a more tailored and effective policy approach.

Conflicts of Interest

All authors have read and consent to the manuscript

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Endnotes

[1] Average level of government effectiveness that is −0.599 (see the computation in Table 1).

[2] Average level of regulatory quality that is −0.525 (see the computation in Table 1).

[3] Marginal effect (conditional effect through the interaction term between governance quality indicators and government fiscal strategies-government expenditure).

[4] Unconditional effect of government expenditure on ecological load capacity.

[5] Quantile regression techniques, such as the method of moments quantile regression (MMQR), are effective in capturing the asymmetric and non-linear relationships between fiscal policies and environmental outcomes.

References

Adebayo, T. S., and A. Samour. 2023. "Renewable Energy, Fiscal Policy and Load Capacity Factor in BRICS Countries: Novel Findings From Panel Nonlinear ARDL Model." *Environment, Development and Sustainability* 26: 4365–4389. https://doi.org/10.1007/s10668-022-02888-1.

Akpan, U., and U. Kama. 2023. "Does Institutional Quality Really Matter for Environmental Quality?" *Energy & Environment* 35, no. 8: 4361–4385. https://doi.org/10.1177/0958305x231180702.

Ali, E. B., R. Radmehr, S. Shayanmehr, B. A. Gyamfi, and V. P. Anufrieva. 2023. "The Role of Technology Innovation, R&D, and Quality Governance in Pollution Mitigation for EU Economies: Fresh Evidence From Method of Moment Quantile Regression." *International Journal of Sustainable Development & World Ecology* 30, no. 3: 244–261. https://doi.org/10.1080/13504509.2022.2134939.

Bildirici, M. 2022. "The Impacts of Governance on Environmental Pollution in Some Countries of Middle East and sub-Saharan Africa: The Evidence From Panel Quantile Regression and Causality." *Environmental Science and Pollution Research* 29: 17382–17393. https://doi.org/10.1007/s11356-021-15716-2.

Breusch, T. S., and A. R. Pagan. 1980. "The Lagrange Multiplier Test and Its Application to Model Specification in Econometrics." *Review of Economic Studies* 47: 239253. https://doi.org/10.2307/2297111.

Dada, J. T., F. M. Ajide, and A. Sharimakin. 2021. "Shadow Economy, Institutions and Environmental Pollution: Insights From Africa." *World Journal of Science, Technology and Sustainable Development* 18, no. 2: 153–171. https://doi.org/10.1108/WJSTSD-12-2020-0105.

Danish, and Z. Wang. 2019. "Investigation of the Ecological Footprint's Driving Factors: What We Learn From the Experience of Emerging Economies." *Sustainable Cities and Society* 49: 101626.

Dibeh, G., A. Fakih, W. Marrouch, and G. Matar. 2021. "Who Cares About Environmental Quality in the MENA Region?." *Social Indicators Research* 157: 603–629. https://doi.org/10.1007/s11205-021-02667-x.

Dietz, T., and E. A. Rosa. 1994. "Rethinking the Environmental Impacts of Population, Affluence and Technology." *Human Ecology Review* 1, no. 2: 277–300.

Dimnwobi, S. K., C. Ekesiobi, C. V. Madichie, and S. A. Asongu. 2021. "Population Dynamics and Environmental Quality in Africa." *Science of The Total Environment* 797: 1–11. https://doi.org/10.1016/j.scitotenv.2021.149172.

Dimnwobi, S. K., K. I. Okere, F. C. Onuoha, and C. Ekesiobi. 2022. "Energy Poverty, Environmental Degradation and Agricultural Productivity in Sub-Saharan Africa." *International Journal of Sustainable Development & World Ecology* 30, no. 4: 428–444. https://doi.org/10.1080/13504509.2022.2158957.

Dimnwobi, S. K., K. I. Okere, F. C. Onuoha, B. I. Uzoechina, C. Ekesiobi, and E. S. Nwokoye. 2023a. "Energizing Environmental Sustainability in Sub-Saharan Africa: The Role of Governance Quality in Mitigating the Environmental Impact of Energy Poverty." *Environmental Science and Pollution Research* 30: 101761–101781. https://doi.org/10.1007/s11356-023-29541-2.

Dimnwobi, S. K., K. I. Okere, C. B. Azolibe, and K. C. Onyenwife. 2023b. "Towards a Green Future for Sub-Saharan Africa: Do Electricity Access and Public Debt Drive Environmental Progress?" *Environmental Science and Pollution Research* 30: 94960–94975. https://doi.org/10.1007/s11356-023-29058-8.

Ezenekwe, U. R., K. I. Okere, S. K. Dimnwobi, and C. Ekesiobi. 2023. "Balancing the Scales: Does Public Debt and Energy Poverty Mitigate or Exacerbate Ecological Distortions in Nigeria?" *International Social Science Journal* 74, no. 252: 451–475. https://doi.org/10.1111/issj.12465.

Farooq, U. 2022. "Foreign Direct Investment, Foreign Aid, and CO2 Emissions in Asian Economies: Does Governance Matter?" *Environmental Science and Pollution Research* 29, no. 2022: 7532–7547. https://doi.org/10.1007/s11356-021-16115-3.

Habeşoğlu, O., A. Samour, T. Tursoy, M. Ahmadi, L. Abdullah, and M. Othman. 2022. "A Study of Environmental Degradation in Turkey and its Relationship to Oil Prices and Financial Strategies: Novel Findings in Context of Energy Transition." *Frontiers in Environmental Science*, April 12. https://doi.org/10.3389/fenvs.2022.876809.

Halkos, G. E., and E. A. Paizanos. 2016. "The Effects of Fiscal Policy on CO_2 Emissions: Evidence From the U.S.A." *Energy Policy* 88: 317–328. https://doi.org/10.1016/j.enpol.2015.10.035.

Hashmi, N. I., N. Alam, A. Jahanger, I. Yasin, M. Murshed, and K. Khudoykulov. 2023. "Can Financial Globalization and Good Governance Help Turning Emerging Economies Carbon Neutral?" *Evidence from Members of the BRICS-T. Environmental Science and Pollution Research* 30: 39826–39841. https://doi.org/10.1007/s11356-022-25060-8.

Hassan, S. T., K. Danish, U. D. S. Khan, E. Xia, and H. Fatima. 2020. "Role of Institutions in Correcting Environmental Pollution: An Empirical Investigation." *Sustainable Cities and Society* 53: 101901. https://doi.org/10.1016/j.scs.2019.101901.

International Energy Agency (IEA). 2020. "Digitalization and Energy." https://www.iea.org/reports/digitalization-and-energy.

Jian, L., K. Chuimin, Z. Jijian, K. Yusheng, and A. H. Ntarmah. 2022. "The Relationship Between Economic Growth and Environmental Degradation: Could West African Countries Benefit From EKC Hypothesis?" *Environmental Science and Pollution Research* 29: 73052–73070. https://doi.org/10.1007/s11356-022-21043-x.

Juodis, A., Y. Karavias, and V. Sarafidis. 2021. "A Homogeneous Approach to Testing for Granger Non-Causality in Heterogeneous Panels." *Empirical Economics* 60, no. 1: 93–112.

Katircioglu, S., and S. Katircioglu. 2017. "Testing the Role of Fiscal Policy in the Environmental Degradation: The Case of Turkey." *Environmental Science and Pollution Research* 25, no. 6: 5616–5630. https://doi.org/10.1007/s11356-017-0906-1.

Kwakwa, P. A. 2022. "The Effect of Industrialization, Militarization, and Government Expenditure on Carbon Dioxide Emissions in Ghana." *Environmental Science and Pollution Research* 29: 85229–85242. https://doi.org/10.1007/s11356-022-21187-w.

Kwakwa, P. A. 2023. "Sectoral Growth and Carbon Dioxide Emission in Africa: Can Renewable Energy Mitigate the Effect?" *Research in Globalization* 6: 100130. https://doi.org/10.1016/j.resglo.2023.100130.

Lau, C. K., G. Patel, M. K. Mahalik, B. K. Sahoo, and G. Gozgor. 2023. "Effectiveness of Fiscal and Monetary Policies in Promoting Environmental Quality: Evidence From Five Large Emerging Economies." *Emerging*

Markets Finance and Trade 60, no. 1: 203–215. https://doi.org/10.1080/1540496X.2023.2210716.

Le, H. P., and I. Ozturk. 2020. "The Impacts of Globalization, Financial Development, Government Expenditures, and Institutional Quality on CO_2 Emissions in the Presence of Environmental Kuznets Curve." *Environmental Science and Pollution Research* 27: 22680–22697. https://doi.org/10.1007/s11356-020-08812-2.

Li, S., A. Samour, M. Irfan, and M. Ali. 2023. "Role of Renewable Energy and Fiscal Policy on Trade Adjusted Carbon Emissions: Evaluating the Role of Environmental Policy Stringency." *Renewable Energy* 205: 156165. https://doi.org/10.1016/j.renene.2023.01.047.

Machado, J. A., and J. S. Silva. 2019. "Quantiles via Moments." *Journal of Econometrics* 213, no. 1: 145–173.

Mesagan, E. P., and C. N. Olunkwa. 2022. "Heterogeneous Analysis of Energy Consumption, Financial Development, and Pollution in Africa: The Relevance of Regulatory Quality." *Utilities Policy* 74: 101328. https://doi.org/10.1016/j.jup.2021.101328.

National Footprint and Biocapacity Accounts (NFBA). 2023. National Footprint and Biocapacity Accounts, 2023 edition, Global Footprint Network. https://data.footprintnetwork.org/?_ga=2.143546428.849031653.16779374362147145951.1637574805#/countryTrends?cn=5001&type=BCtot,EFCtot.

Nwani, C., K. I. Okere, S. K. Dimnwobi, E. Uche, and P. T. Iorember. 2024. "From Non-Renewables to Renewables and High-Tech Production: The Impact of Natural Wealth and Technology on Ecological Load Capacity in Sub-Saharan Africa." *Review of Development Economics* 29, no. 2: 1170–1194. https://doi.org/10.1111/rode.13161.

Okere, K. I., S. K. Dimnwobi, C. Ekesiobi, and F. C. Onuoha. 2023. "Pollution, Governance, and Women's Work: Examining African Female Labour Force Participation in the Face of Environmental Pollution and Governance Quality Puzzles." *Women's Studies International Forum* 102: 102851. https://doi.org/10.1016/j.wsif.2023.102851.

Okere, K. I., S. K. Dimnwobi, and I. O. Fasanya. 2024a. "Do Fintech, Natural Resources and Globalization Matter During Ecological Crises? A Step towards Ecological Sustainability." *Journal of Open Innovation: Technology, Market, and Complexity* 10, no. 3: 100371. https://doi.org/10.1016/j.joitmc.2024.100371.

Okere, K. I., S. K. Dimnwobi, and I. O. Fasanya. 2024b. "Striding Towards a Greener Future: Unlocking the Potential of Natural Resources and Employment Dynamics in Green Energy Transition in Sub-Saharan Africa." *Managerial and Decision Economics* 46, no. 1: 329–346. https://doi.org/10.1002/mde.4377.

Onuoha, F. C., S. K. Dimnwobi, K. I. Okere, and C. Ekesiobi. 2023a. "Funding the Green Transition: Governance Quality, Public Debt, and Renewable Energy Consumption in Sub-Saharan Africa." *Utilities Policy* 82: 101574. https://doi.org/10.1016/j.jup.2023.101574.

Onuoha, F. C., S. K. Dimnwobi, K. I. Okere, and C. Ekesiobi. 2023b. "Sustainability Burden or Boost? Examining the Effect of Public Debt on Renewable Energy Consumption in Sub-Saharan Africa." *Energy Sources, Part B: Economics, Planning, and Policy* 18, no. 1: 115. https://doi.org/10.1080/15567249.2023.2214917.

Pata, U. K., and C. Isik. 2021. "Determinants of the Load Capacity Factor in China: A Novel Dynamic ARDL Approach for Ecological Footprint Accounting." *Resources Policy* 74: 102313. https://doi.org/10.1016/j.resourpol.2021.102313.

Pata, U. K., and D. Balsalobre-Lorente. 2022. "Exploring the Impact of Tourism and Energy Consumption on the Load Capacity Factor in Turkey: A Novel Dynamic ARDL Approach." *Environmental Science and Pollution Research* 29: 13491–13503. https://doi.org/10.1007/s11356-021-16675-4.

Pesaran, M. H. 2007. "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence." *Journal of Applied Econometrics* 22, no. 2: 265–312. https://doi.org/10.1002/jae.951.

Pesaran, M. H. 2015. "Testing Weak Cross-Sectional Dependence in Large Panels." *Econometric Reviews* 34, no. 6–10: 1089–1117. https://doi.org/10.1080/07474938.2014.956623.

Pesaran, M. H., and T. Yamagata. 2008. "Testing Slope Homogeneity in Large Panels." *Journal of Econometrics* 142, no. 1: 50–93. https://doi.org/10.1016/j.jeconom.2007.05.010.

Shehzad, K., U. Zaman, M. Ahmad, and E. Kocak. 2022. "Governance, Financial Development, and Environmental Degradation: Evidence From Symmetric and Asymmetric ARDL." *Environment, Development and Sustainability* 25: 14643–14660. https://doi.org/10.1007/s10668-022-02682-z.

Xaisongkham, S., and X. Liu. 2022. "Institutional Quality, Employment, FDI and Environmental Degradation in Developing Countries: Evidence From the Balanced Panel GMM Estimator." *International Journal of Emerging Markets* 19, no. 7: 1920–1939. https://doi.org/10.1108/IJOEM-10-2021-1583.

Westerlund, J. 2007. "Testing for Error Correction in Panel Data." *Oxford Bulletin of Economics and Statistics* 69, no. 6: 709–748.

World Health Organization. 2022. "Ambient (outdoor) Air Pollution." October 24, 2024. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

Ya, D., A. Quddus, M. Feng, E. Ullah, and W. Ameer. 2024. "Assessing the Impact of Fiscal Policy and Natural Resources on Environmental Degradation in BRICS Countries: A Resource Management Perspective." *Resources Policy* 90: 104792. https://doi.org/10.1016/j.resourpol.2024.104792.

Yang, B., M. Ali, S. H. Hashmi, and A. Jahanger. 2022. "Do Income Inequality and Institutional Quality Affect CO_2 Emissions in Developing Economies?" *Environmental Science and Pollution Research* 29: 42720–42741. https://doi.org/10.1007/s11356-021-18278-5.

Zahra, S., D. Khan, and M. Nouman. 2022. "Fiscal Policy and Environment: a Long-run Multivariate Empirical Analysis of Ecological Footprint in Pakistan." *Environmental Science and Pollution Research* 29: 2523–2538. https://doi.org/10.1007/s11356-021-15665-w.

Zeraibi, A., Z. Ahmed, K. Shehzad, M. Murshed, S. P. Nathaniel, and H. Mahmood. 2022. "Revisiting the EKC Hypothesis by Assessing the Complementarities Between Fiscal, Monetary, and Environmental Development Policies in China." *Environmental Science and Pollution Research* 29: 23545–23560. https://doi.org/10.1007/s11356-021-17288-7.

Appendix 1: List of Countries

Angola, Benin, Botswana, Burkina Faso, Cabo Verde, Cameroon, Central Africa Republic, Congo Republic, Cote d'Ivoire, Eritrea, Eswatini, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Appendix 2: Data Summary

Definition	Variables	Measurements	Sources
Ecological Load Capacity Factor	(LCF)	Biocapacity divided by ecological footprint	Global Footprint Network Database
Government expenditure	(GE)	General government final consumption expenditure (% of GDP)	World Bank Database
Regulatory quality	(REQ)	Ranges from −2.5 to 2.5	World Governance Indicator Database
Government effectiveness	(GVT)	Ranges from −2.5 to 2.5	World Governance Indicator Database
Gross Domestic Product Per Capita	$[A]$	Constant 2010 US$	World Bank Database
Urbanization	$[P]$	% overall population	World Bank Database

Source: Authors computation.