frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 01 May 2024
DOI 10.3389/fenvs.2024.1352344

OPEN ACCESS

EDITED BY
Nils Ekelund,
Malmö University, Sweden

REVIEWED BY
Bright Akwasi Gyamfi,
Istanbul Commerce University, Türkiye
Mahmood Ahmad,
Shandong University of Technology, China

*CORRESPONDENCE
Derrick Tetteh,
dorscon2017@gmail.com

RECEIVED 11 December 2023
ACCEPTED 12 April 2024
PUBLISHED 01 May 2024

CITATION
Bambi PDR, Batatana MLD, Appiah M and Tetteh D (2024), Governance, institutions, and climate change resilience in Sub-Saharan Africa: assessing the threshold effects.
Front. Environ. Sci. 12:1352344.
doi: 10.3389/fenvs.2024.1352344

Governance, institutions, and climate change resilience in Sub-Saharan Africa: assessing the threshold effects

Prince Dorian Rivel Bambi[1], Marly Loria Diabakanga Batatana[2], Michael Appiah[3] and Derrick Tetteh[4]*

[1]Faculty of Economics, Marien Ngouabi University, Brazzaville, Republic of Congo, [2]School of Public Administration, Xi'an University of Architecture and Technology, Beilin, China, [3]School of Management, Jiangsu University, Zhenjiang, Jiangsu, China, [4]School of Business, University of Cape Coast, Cape Coast, Ghana

The concerns about institutional weakness in Sub-Saharan Africa (SSA) are central to the discussion on environmental degradation in the region. This study employs a robust dynamic panel data estimator to explore the relationships between institutions, governance, and environmental quality, focusing on the ecological footprint of 25 SSA nations from 1990 to 2020. The results reveal the threshold effects of the interaction between institutions and governance, following an inverted U-shape pattern. This suggests that beyond a certain ecological footprint, increased interaction between institutions and governance leads to a decrease in ecological footprint. Additionally, high institutional quality (IQ) is associated with a lower environmental impact, while improved governance contributes to mitigating the decline in institutional performance. The panel causality tests among the variables and control components indicate a one-way causal relationship from ecological footprint to governance, infrastructural development, and energy use. Conversely, a feedback causal relationship exists between IQ, industrialization, and ecological footprints. Policymakers should prioritize investments in energy consumption that align with environmental quality, ensuring efficient use of energy budgets through coordinated planning, execution, and transfer of sound energy practices to prevent duplication of efforts.

KEYWORDS

environmental outcomes, governance, institutions, emerging markets, dynamic panel method

1 Introduction

The ecological footprint, a measure of human demand on Earth's ecosystems, is a pivotal factor in understanding environmental sustainability. In regions such as Sub-Saharan Africa (SSA), the interplay between governance, institutions, and the ecological footprint reveals a complex dynamic crucial for addressing environmental degradation (Masron and Subramaniam, 2019). Effective governance and robust institutions are fundamental in mitigating the ecological footprint by enforcing environmental legislation, integrating environmental considerations into development strategies, and promoting sustainable practices (Omri, Omri, Slimani and Belaid, 2022). However, SSA faces challenges in governance that exacerbate environmental degradation, impacting its vulnerability to climate change effects such as floods and droughts (O'Neill et al., 2018). This degradation not only threatens biodiversity and disrupts critical Earth system processes, including climate regulation and the nitrogen cycle but also poses significant risks to human populations dependent on natural resources for their livelihoods (Ölund et al., 2012; Schaltegger et al., 2018). Addressing these challenges requires a multifaceted approach that encompasses strengthening governance and institutional frameworks, promoting environmental sustainability, and engaging in global efforts such as multilateral environmental agreements (MEAs) (Kassouri and Altıntaş, 2020). These measures are vital for reducing the ecological footprint, ensuring long-term economic growth, and enhancing resilience to climate change, particularly in vulnerable regions (Manimekalai and Sindhuja, 2019).

Sustainable development is influenced by environmental policy, institutional, and legal frameworks, as well as implementation capacity. Although there is a need for improvement, in developing and transition nations, the basic legal and policy framework is frequently in place. The biggest obstacles are related to the framework's effective execution (Robertua, 2018; Robertua and Bainus, 2018). The implementation gap is the difference between what is agreed upon and what is done to enhance environmental results. At the subnational level, the implementation gap is particularly noticeable (OECD, 2019; Appiah et al., 2020). Traditionally, the lack of technical and financial capacity among environmental authorities, combined with the low political priority assigned to environmental issues, has been blamed for the implementation gap in developing nations (OECD, 2019; Appiah et al., 2020). Thus, the identification of the driving mechanisms that raise or mitigate environmental pressures, as well as measures to reduce negative environmental impacts, have received assistance. However, interventions have frequently been limited to the environmental sector, with varying degrees of success. Institutions and governance are becoming increasingly important for implementation (Bank, 2018; Sarker and Blomquist, 2019). There is now a widespread agreement that governance and institutions have a significant impact on environmental activities and outcomes. The rule of law, individuals' rights to information and participation, and equal access to justice are all essential for poverty reduction and long-term development (Fernández and Malwé, 2019). Weak governance has been linked to negative environmental results as well as societal issues like corruption, social isolation, and a lack of faith in the authority (Arminen and Menegaki, 2019; Asongu and Odhiambo, 2020). Good governance, on the other hand, has the ability to regulate and enforce environmentally sound policies, guiding individuals and communities toward productive outcomes and long-term environmental sustainability. Improved governance, when combined with strong institutional legal frameworks and processes, could be significant tools for achieving long-term growth (Adekunle, 2021; Bahizire, Fanglin, Appiah and Xicang, 2022).

The literature on the relationship between a specific aspect of pollution and governance is separated into two important groups. According to (Appiah et al., 2020), the first is based on the environmental impact of institutions. Institutional variables have a significant impact on the environment because they relate to the rules and standards of behaviour that structure recurring human interactions. Corruption, political stability, government regulation, the rule of law, and government efficacy, among other institutional variables, are said to have a significant impact on environmental policies and plans to reduce carbon emissions (Fredriksson and Svensson, 2003; Abid, 2016; Fredriksson and Neumayer, 2016; Abid, 2017; Bae et al., 2017). According to Bhattacharya et al. (2017), institutions that support property rights protection and voluntary exchange enable the government to enact desired environmental policies. In other words, if institutions are not effective and efficient, environmental measures to cut carbon emissions may be compromised. While institutions are indicators and forerunners to many development outcomes, understanding their impact on carbon emissions is more crucial.

The impact of governance signals on the development and deployment of environmental instruments is the emphasis of the second category of studies, rather than concrete actions. The impact of good governance on environmental degradation is investigated by Bahizire et al. (2022), and they confirmed that good governance increases environmental quality. Kassouri and Altıntaş (2020) also investigate the impact of good governance on environmental quality, finding that regulatory frameworks and the power of green parties have significant beneficial effects on improving environmental quality (Adekunle, 2021). has also investigated the importance of excellent governance in understanding the relationship between CO_2 emissions and foreign direct investment. The findings imply that foreign investment (FDI), political, and institutional governance work together to prevent environmental degradation. Asongu and Odhiambo (2020) also looked at the function of governance indicators in reducing environmental degradation, and they find that government efficacy and regulation quality help to cut carbon emissions (Omri, Kahia and Kahouli, 2021; Omri et al., 2022). investigate the function of good governance in dampening the positive impact of financial development carbon emissions. Their data also demonstrate that governance has both direct and indirect benefits in lowering emissions. There has been an increase in a study on the role of governance and institutions on environmental degradation, but there has been little or no research on the specific consequences of institutional quality and governance individually especially for the category of the poor developing countries. Generally, there is an interchangeable usage of governance and institutional quality. This is the first study to look at the direct role of governance and institutional quality in a single approach and the first of its kind on the SSA nations.

This study marks a significant contribution in understanding the intricate dynamics between institutional quality, governance, and environmental sustainability by leveraging a robust methodological framework that addresses key econometric challenges and employs a panel causality technique to uncover causal relationships. It broadens the scope of environmental analysis by using the ecological footprint as a comprehensive pollution index and employs the Country Policy and Institutional Assessment (CPIA) index for a nuanced assessment of institutional quality, recognizing its multifaceted nature. The research highlights governance as a pivotal mediating factor in the institutional quality-environmental degradation nexus, offering deep insights into how governance structures can influence environmental outcomes. Furthermore, it explores the threshold effects of institutional quality and governance

TABLE 1 Variable description.

Factors	Abbreviation	Unit	Source
Ecological footprint	ECO	Hectares	GFN
Country Policy and Institutional Assessment	CPIA	Index	AfDB
Governance efficiency	GE	Index	World Bank
Infrastructure	AIDI	Index	World Bank
Industrialization	IND	Index	World Bank
Energy Consumption	ENE	Kilotonne	World Bank

interactions, providing valuable guidance for targeted policy interventions. This study's nuanced analysis and methodological innovations offer critical implications for policymakers, emphasizing the integration of governance in environmental strategies and contributing significantly to the literature on sustainable development and environmental economics. The subsequent sections of this study follow this sequence: Section 2 reviews the literature, while Section 3 presents the data, model, and methodology. Section 4 delineates the empirical results and their interpretation, and Section 5 provides concluding remarks along with policy recommendations.

2 Literature review

Based on the review of extant studies, the justifications for the testable hypotheses on governance, institutions, and environmental deterioration are developed in this section. According to Asongu and Odhiambo (2021), governance concerns in Africa are linked to a growing variety of crises, including food insecurity, unequally distributed economic resources, water scarcity, the loss of arable land, poverty, and environmental degradation. Some other studies have also corroborated these challenges in Africa (Erdoğan et al., 2020; Çevik et al., 2020; Onifade et al., 2020). The governance challenges surrounding environmental mismanagement are evident since many African countries are severely strained by the underlying concerns, which include a lack of competence to implement reforms arising from enhanced worldwide community norms, among other things. Environmental governance rules in Africa, according to (Asongu and Odhiambo, 2020; 2021), need to be significantly reformed in light of mainstream environmental protection norms. While the author has made a case for Western countries assisting African countries in strengthening environmental governance, this study expands on the idea by examining how enhancing governance norms affects environmental deterioration in SSA.

Effective environmental legislation and policy frameworks that ensure compliance and enforcement, according to Gök and Sodhi (2021), generate good governance. As a result, when the rule of law and effective governance is in place, compliance is more likely. According to a study by (Liu, Latif, Latif and Li, 2020; Omri et al., 2021), governance quality has a beneficial impact on environmental quality, and efforts to improve governance indicators are recommended since they harm environmental deterioration. However, governments' role in environmental protection extends beyond the formulation of good environmental policies, as ineffective and corrupt governments face popular opposition to increasing government spending on such policies (Kulin and Johansson Sevä, 2019; Gyamfi, 2022).

The impact of governance indicators on environmental quality was explored by Wuijts, Driessen, and Van Rijswick (2018) and (Bahizire et al., 2022). Wuijts et al. (2018) found that the rule of law and government efficacy increase air quality, whereas regulatory quality, rule of law, and voice and accountability improve water quality. The six governance variables, on the other hand, were shown to be negatively connected with wilderness, with no indication of governance's impact on biodiversity. (Bekun et al., 2021; Bahizire et al., 2022), on the other hand, emphasizes the need for good governance in achieving improved environmental results. They demonstrated that effective and efficient environmental outcomes require public participation, government responsiveness, rule of law, and consensus.

According to research, each aspect of governance has a substantial impact on environmental consequences. Purcel (2019) and (Olaoye, 2024) makes the key point that environmental damage is a significant cost of corruption, and he proposes increased openness as a treatment for corruption and poor governance. "Environmental sustainability requires good governance, which includes a wide commitment to the rule of law." Iwińska et al. (2019) discovered that democracy and the environment have a favourable and statistically significant relationship. Purcel (2019) and (Ma, 2023) examines the impact of political stability and finds that both political and social systems must be stable to reduce CO2 emissions. Studies on the influence of corruption on the environment have revealed a negative association between the two, as corruption undermines the rule of law and policy compliance (Arminen and Menegaki, 2019; Ridzuan, 2019; Ssekibaala et al., 2021).

On the policy front, they advocate for more transparent legislation and harsher penalties for corrupt officials and entrepreneurs whose illegal activities contribute to increased environmental degradation. Li et al. (2020) generated an interesting U-shaped income curve, indicating an initial fall in *per capita* income rises, followed by a gain after an income turning point. According to their findings, changes in political stability and corruption cause the forest-income curve to shift up or down. The CO_2 emissions–income curve flattens as political stability increases, resulting in lower variations in CO_2 emissions per unit change in wealth. Environmental results are also influenced by regulatory and institutional quality. Using panel vector

TABLE 2 Descriptive & correlation analysis.

	EFP	AIDI	CPIA	IND	ENE	GE
Mean	1.319307	12.78592	3.161103	21.05636	74.73917	−.7699548
Std. Dev	.5,578,305	5.825209	.7,011,706	7.780858	18.20034	.4,380,906
Min	.61	.37	1.5	3.38941	26.37392	−1.745683
Max	4.18	28.16	4.5	44.1079	97.29142	.2,668,521
Correlation Analysis						
EFP	1.0000					
AIDI	0.0152	1.0000				
CPIA	−0.2588	0.0273	1.0000			
IND	0.1349	0.2476	0.0365	1.0000		
ENE	−0.2838	−0.1800	0.0887	−0.3152	1.0000	
GE	−0.2269	0.1845	0.4537	−0.2953	0.0337	1.0000

autoregressive approaches, Grochová (2014) shows that more efficient institutional settings help enhance environmental quality with economic development for 166 nations. Environmentally friendly policies and low-carbon growth strategies could help to escape a "pollution trap" and prevent environmental degradation.

According to the studies above, environmental challenges can be addressed if countries improve their environmental governance standards. As a result, addressing apparent flaws and limits in the continent's environmental institutions is a policy priority in the post-2015 development agenda. Effective regulation, better transparency, security and peace, political stability, and rigorous environmental management systems are all necessary for Africa's CO_2 emissions to be reduced sustainably. Improved institutional, economic, and political channels or instruments can be used to address the issue. This current research can then be hypothesized that: *H1*: Improved Governance helps to increase environmental quality, against the alternantive (*H2*) that Quality Institutional Efficiency reduces environmental degradation.

3 Methodology, model, and data

3.1 Data

This study utilizes a balanced panel dataset comprising 25 Sub-Saharan African (SSA) nations spanning from 1990 to 2020. The selection of this time frame and these specific countries was strategically made to encompass a significant period that allows for the observation of long-term trends and impacts within the region. The choice was also influenced by the comprehensive availability of data for our critical variables of interest—ecological footprint (ECO), Country Policy and Institutional Assessment (CPIA), and governance efficiency (GE)—ensuring a robust analysis. The ecological footprint, employed as a measure of environmental quality, encapsulates the demand placed on nature by human activities, with a larger footprint indicating greater environmental stress. This measure, derived from the Global Footprint Network (GFN), encompasses six categories of productive surfaces, providing a holistic view of the environmental impact. The study's period and geographical focus were chosen not merely due to data availability but also to align with the objectives of assessing environmental trends and policy impacts in SSA countries, offering valuable insights into sustainable development and governance practices. We employed the CPIA (Country Policy and Institutional Assessment) for institutional quality (IQ), and GE stands for governance. This metric has also been mentioned in recent research ((Appiah, Karim, Naeem and Lucey, 2022; Appiah, Onifade and Gyamfi, 2022). We add critical control factors Z) such as infrastructure (AIDI), energy consumption (ENE), and industrialization (IND) to current studies. Table 1 shows descriptive and correlation statistics for all of the variables. Table 1 below give a description to the variables employed in the study.

3.2 Specifications of models

Given that the goal of this study is to see how IQ and GE affect ecological footprint, we create a start point model with ecological footprint as the dependent variable, IQ and GE as independent variables, and other factors as control variables Z). This is represented by the following model:

$$ECO_{it} = \beta_0 + \beta_1 IQ_{it} + \beta_2 GE_{it} + \beta_3 Z_{it} + \varepsilon_{it} \quad (1)$$

Where β_0 denotes an unobserved time-invariant individual effect; β_1 and β_3 capture the influence of IQ and GE indicators on ECO with certain control factors, respectively. ε_{it} denotes the probability term. The stochastic term is distributed with a zero mean and constant variance assumption, and the time (t = 1, 2, 3., T) is superscripted. Thus, IQ and GE diminish degradation if their respective coefficients (β_1, β_2) are adverse and substantial at conservative values, according to Equation 1. In combination with these direct effects, we look into whether the standard of GE in a country influences the impact of IQ on ecological

TABLE 3 Pre-diagnostic tests.

Test		P. Value
CSD of Pesaran	2.042	0.0411**
Testing for SH	5.179	0.000***
Testing for SH (ADJ)	7.091	0.000***

NB:***,**,* signifies1,5,10% significance level.

footprint. In significance, we present an interacting term of IQ_{it} and GE_{it}, resulting in the following equation:

$$ECO_{it} = a_0 + \beta_0 + \beta_1 IQ_{it} + \beta_2 GE_{it} + \beta_3 Z_{it} + (\beta_4 IQ_{it} {}^* GE_{it}) + \varepsilon_{it} \quad (2)$$

All variables stay the same when β_4 is the interacting term of IQ_{it} and GEit. We introduce a square term of the interacting term of IQ_{it} and GE_{it}, to explore the threshold effects of the interacting term on degradation, as illustrated in Equation 3 below:

$$ECO_{it} = a_0 + \beta_0 + \beta_1 IQ_{it} + \beta_2 GE_{it} + \beta_3 Z_{it} + (\beta_4 IQ_{it} {}^* GE_{it})(\beta_5 IQ_{it} {}^* GE_{it})^2 + \varepsilon_{it} \quad (3)$$

Using the signs of β_4 and β_5, we can deduce the nature of the threshold from Equation 3. Explicitly, if $\beta_4 > 0$ and $\beta_5 < 0$, we draw the inference that the IQ–pollution link has an inverted U–shaped bond.

3.3 Methodology

3.3.1 Cross-sectional dependence (CSD), slope homogeneity (SH) and unit root

This study uses econometric approaches that are compatible with the characteristics of the data. A bad technique will result in inaccurate and inconsistent results (Dodoo et al., 2020). This study uses the (H. Pesaran, 2004; M. H; Pesaran, 2015; M. H; Pesaran, Ullah and Yamagata, 2008) CD (M. H. Pesaran and Yamagata, 2008), SH, and (H. M. Pesaran, 2007) unit root tests to avoid such consequences. If CD is neglected, as previously stated, findings may be skewed. Earlier studies ignored the possibility of CD in their empirical study, although the world has become a global community with countries tied to one another. Because of the spillover effect of micro and macroeconomic variables, the CD has become popular. Aside from the CD and SH tests, the data integration qualities are also required. The existence of CD and SH will influence the unit root test selection. In the vicinity of CD and SH, second-generation tests are preferred. As a result (H. M. Pesaran, 2007), CIPS and CADF were used in this investigation. Both tests take CD and heterogeneity into account.

3.3.2 Cointegration

When variables share the same integration order, such as I 1), it is required to determine whether they have a long-run agreement. The (Westerlund and Edgerton, 2007) test is used to look into the potential of a cointegrating link between the variables. The test accounts for CD and endogeneity-related annoyance. When compared to dynamic cointegration tests, it has a higher explanatory power. Westerlund and Edgerton (2007) created four different statistics. The group mean statistics, which test the cointegration of the entire panel, and the panel mean tests, which look for cointegration in at least one of the units, are two of the four statistics. To account for CD and non-strictly exogenous regressors, the test uses a bootstrap technique.

3.3.3 Coefficient estimation and causality

Because the AMG estimator of Bond and Eberhardt (2013) is congruent with the properties of our data, it was used in this analysis. It also takes into consideration heterogeneity and CD, two key panel data difficulties (Gyamfi et al., 2021). The AMG estimator has the drawback of not providing information on causality. The Dumitrescu and Hurlin (2012) test is used to check the direction of causation, which is important for policy direction.

4 Results discussion

Table 2 shows that ENE has a very high mean value of 74.73917 and ranges from a minimum value of 26.37392 to a maximum value of 97.29142. It reveals that energy contributed significantly to the SSA's ecological footprint over the study period. In 1990, the ecological footprint (ECO) was 0.61, and by 2020, it had risen to 4.18, indicating tremendous environmental degradation. Infrastructure (AIDI) grew from.37 percent in 1990 to 28.16 percent in 2020, demonstrating increasing trends due to rapid industrialization. The governance (GE) has an average value of −0.7699548, with a minimum of −1.745683 and a maximum of 0.2,668,521. In 2020, institutional quality (CPIA) is more than 0.2668521of GE, suggesting a significant improvement in institutional quality. Between 1990 and 2020, the CPIA (GE) grew from 1.5 to 4.5. The correlation between the constituent series is established in the lower panel of Table 1. Except for infrastructural development (AIDI) and industrialization IND, EFP has a negative association with all variables. Furthermore, the relationship between EFP, AIDI, and IND is unfavourable. The significant association between EFP and IND suggests that the SSA countries' environmental deterioration has accelerated as a result of their industrial expansion.

The cross-section dependence tests were used to start the empirical analysis. The null hypothesis of "no cross-section dependency" is highly accepted for the model, according to Table 3, but the null hypothesis of "no cross-section dependence" is rejected for all variables, according to the majority of CD test findings. The results on slope homogeneity reject the null hypothesis of homogeneous variables and accept the alternative hypothesis. As a result, for cointegration tests and estimations, panel data estimation methods that operate under the postulation of cross-

TABLE 4 Panel unit root outcomes.

Panel unit root	EFP	AIDI	CPIA	IND	ENE	GE
CIPS Level	−2.492***	−2.467***	−1.953	1.636	0.606	−2.014***
CIPS 1st Diff	−3.607***	−4.067***	−3.051***	−3.647***	−3.068***	−3.962***
CADF Level	−0.690	−2.438***	−3.429***	2.041	0.306	0.197
CADF 1st Diff	−3.461***	−6.012***	−1.705**	−3.711***	0.276	−2.445***

NB:***,**,* signifies1,5,10% significance level.

TABLE 5 Panel cointegration outcomes.

Panel coint	AIDI	CPIA	IND	ENE	GE
G_t	−10.072***	−8.096***	−5.347***	−10.150***	−8.364***
G_a	−0.327	−0.057	−0.514	−3.477***	−1.959**
P_t	−6.257***	−9.083	−11.005***	−7.139***	−9.915***
P_a	−5.072***	−6.373***	−7.972***	−8.436***	−8.884***

NB:***,**,* signifies1,5,10% significance level.

TABLE 6 Long term Coefficients Outcomes.

	Model 1 (direct effects)	Model 2 (moderating effects)	Model 3 (threshold effects)
AIDI	.0011722 (1.95)*	.0010936 (1.77)*	.0025172 (1.93)*
CPIA	.0261656 (1.66)*	−.014662 (−1.79)*	−.0171773 (−3.67)***
IND	.0008974 (0.25)	−.0038447 (−1.10)	−.0004036 (−0.12)
ENE	−.0001359 (−0.04)	.0034067 (0.76)	−.0483465 (−0.08)
GE	−.0171426 (−3.72)***	−.0399993 (−3.92)***	−.0050653 (−2.08)**
CPIA*GE	-	−.0667845 (−1.83)*	−.0043482 (−2.18)**
CPIA*GE^2	-	-	−.0066866 (−3.89)***
Cons	.7,648,618 (2.18)**	1.989932 (2.89)**	1.295871 (1.38)

NB:***,**,* signifies1,5,10% significance level, Values in parenthesis are theZ stats.

section independence can be used, whereas unit root-stationarity methods that operate under the assumption of cross-section dependence can be used to determine the stationarity level of the variables (Hurlin, 2010; H; Pesaran, 2004; Westerlund and Edgerton, 2007).

We used robust-based panel unit root tests (H. Pesaran, 2004) to account for cross-section dependence and report the results in Table 4. The results reveal that in the CIPS model, CPIA, IND, and ENE variables have a non-stationary process at the level, but variables at the first difference have a stationarity process although at varied significance levels. EFP, IND, ENE, and GE are non-stationary variables in the CADF test, while the other variables are stable. After utilizing the first difference estimation, all of the variables were stationary, indicating that the variables under consideration have an I 0) and I 1) integration order. This result paves the way for long-distance association using the Westerlund and Edgerton (2007) technique.

The findings of the Westerlund and Edgerton (2007) cointegration test are shown in Table 5. The test's null hypothesis indicates that there is no cointegration. Alternatively, the presence of long-run connections for all panel members is supported by the alternate hypothesis. The *p*-values of Gt and Ga, as well as Pt and Pa, are substantial, indicating that the unit and panel are cointegrated, indicating that the null hypothesis was rejected and the long-run association between EFP, AIDI, CPIA, IND, ENE, and GE were confirmed.

Beginning with the effects of institutional quality and governance on ecological footprint, it is observed that governance exerts a negative impact on ecological footprint, indicating that a 1% increase in institutional quality reduces the ecological footprint by −0.0171 *per capita* (Model 1, Table 6). The assertion that enhanced governance positively impacts environmental quality is both plausible and supported by evidence. Governance that prioritizes cleaner, more environmentally friendly processes facilitates sustainable development and the protection of our natural surroundings. It serves as an essential mechanism for alleviating tensions within and between nations over the utilization of natural resources, thereby fostering the development of trust and confidence at all levels, which, in turn, contributes to increased security. Generally, higher governance standards are conducive to the effective implementation of

TABLE 7 Causality test results.

Hypothesis	W bar	W Bar tilde	P. Value	Direction
EFP≠AIDI	4.3901	7.6670	0.0000***	Single-Track
AIDI≠EFP	1.9505	1.7626	0.1051	
EFP≠CPIA	3.6583	7.7780	0.0000***	Dual-Course
CPIA≠EFP	2.3391	3.7985	0.0001***	
EFP≠IND	2.3894	2.8248	0.0047***	Double-Course
IND≠EFP	2.4358	2.9371	0.0033***	
EFP≠ENE	4.2889	7.4219	0.0000***	Single- Course
ENE≠EFP	1.7656	1.3150	0.1885	
EFP≠GE	2.0022	1.8876	0.0591**	Single- Course
GE≠EFP	1.2452	0.0555	0.9557	

Note: ***, **, *implies 1,5,10%.

environmental regulations and initiatives, leading to improved environmental outcomes (Omri et al., 2021; Appiah et al., 2024). The study by (Asongu and Odhiambo, 2020; Kousar et al., 2020) shows that GE has a dampening effect on environmental degradation.

Table 5 reveals that institutional quality has a positive and marginally significant effect on the ecological footprint, with a coefficient of 0.0261656, suggesting that an increase in institutional quality can, counterintuitively, lead to an increase in ecological footprint. This finding implies that, within our sample, enhanced institutional quality does not necessarily promote environmental quality. While governance contributes to environmental improvement by reducing the ecological footprint, higher institutional quality appears to undermine environmental values. The degradation of environmental quality due to increased institutional quality occurs through several mechanisms, including poor implementation strategies, and weak systems and structures. Although governments and administrations strive to establish robust institutional frameworks, the efficacy of these efforts is often compromised by corruption and a lack of transparency among employees, collaborators, and agents, leading to suboptimal institutional performance. To some extent, higher institutional quality does contribute to improved environmental quality, but this is offset by significant challenges in implementation and governance (Asongu and Odhiambo, 2020; Agussani, 2021; Sah, 2021). According to (Bahizire et al., 2022), vibrant institutions can impact economic growth and environmental degradation by ensuring that dirty companies are located in areas where pollution can be controlled. Furthermore, institutional action can stimulate rapid economic expansion (Huynh and Ho, 2020), which can lead to increased environmental damage, which can be controlled by institutions through appropriate regulation, which is not the case in SSA nations (Dada, Ajide and Sharimakin, 2021). As a result, increasing IQ hurts the environment. Furthermore, a high IQ attracts both domestic and international investment, which comes at a cost to the environment in the form of higher carbon emissions (Dada et al., 2021).

We examine the role of governance in the relationship between institutional quality and ecological footprint, noting that improved institutional quality leads to an increase in ecological footprint. Specifically, we aim to determine whether higher governance levels mitigate or exacerbate the positive effect of institutional quality on ecological footprint, as suggested in model 2). The results from model two reveal that the coefficients for governance and institutional quality exhibit opposite signs—negative for governance and positive for institutional quality—although the magnitude of their impacts varies. Interestingly, while the governance coefficient decreases, indicating an enhancement in environmental quality, the coefficient for institutional quality also declines. Compared to the findings from model 1, our analysis suggests that governance has a more significant positive effect on environmental quality than the negative impact of institutional quality. The analysis identifies a negative and significant coefficient for the interaction term between governance and institutional quality, highlighting governance's mediating role in the institutional quality–ecological footprint relationship. Given the positive effect of institutional quality and the negative coefficient of the interaction term, we deduce that while higher governance levels lessen the detrimental unconditional impact of institutional quality on environmental quality, improved institutional quality still leads to a higher ecological footprint. Moreover, our findings indicate that in contexts of effective governance, the anticipated negative link between institutional quality and environmental degradation becomes stronger. Good governance plays a crucial role in tackling environmental issues, particularly those related to climate change, which have been associated with gains in institutional quality (Adekunle, 2021; Bahizire et al., 2022). Low institutional quality levels can contribute to environmental damage. Good governance is recognized as a significant factor in reducing the negative effects of institutional quality (Dutt, 2009).

By incorporating a square term of the interaction variable into the equation for ecological quality, we explore the potential threshold level. The results, displayed in Model 3, show that the coefficient of the direct impact of the interactive variable maintains its negative and significant effect, reinforcing previous observations on the relationship between the interactive variable and environmental quality. Additionally, the coefficient for the square term of the interaction variable is negative. Consequently, both the direct and threshold effects exhibit the same sign, indicating an inverted U-shaped relationship between the interactive variables and ecological footprint. This suggests that while interactive variables may reduce environmental pollution at lower levels, exceeding a certain threshold of the interaction variable could diminish pollution reduction benefits. By isolating the coefficient of the interactive variable and its square on institutional quality, we calculate the turning point of the relationship, which is set at zero. In this analysis, we identify a threshold coefficient of −0.0066866 percent, below zero, demonstrating that enhanced governance efforts improve the relationship between institutional quality and pollution.

The investigation reveals that the effects of AIDI are positive and marginally significant at the 10% level compared to our control variables. This influence remains consistent across the regressions (refer to models one–3), indicating that a higher AIDI exacerbates environmental impact. A critical takeaway is that substantial AIDI leads to environmental degradation and resource depletion, adversely affecting the ecosystem. In most cases, increased resource consumption and the deterioration of the natural environment are associated with environmental degradation. This finding aligns closely with several previous studies (see (Shilling et al., 2007; Laurance et al., 2015; Teo et al., 2019). While the exact impact of IND and ENE is unknown, a large body of research implies a favourable correlation with environmental damage (Ozcan et al., 2020; Appiah et al., 2021; Destek, 2021; Appiah et al., 2022). Teo et al. (2019), for example, claims that rising AIDI and IND reduce environmental quality because they are linked to larger economies of scale, a well–advanced service division, enhanced waste administration practices, and the employment of green technologies. Given the insignificance of the coefficients, however, our research does not support this claim. In the same way, energy consumption has little impact on the environment.

The results of the Dumitrescu and Hurlin (2012) panel causality test are presented in Table 7. The data indicate a bidirectional relationship between industrialization and environmental footprint, as well as between ecological footprint and institutional quality. Thus, the utilization of institutional quality (IQ) enhances environmental quality, while the shift from dirty to cleaner energy resources is influenced by improvements in the institutions and industrialization processes of SSA nations. Additionally, unidirectional causalities from ecological footprint to CPIA*GE, ENE, and GE have been identified. These causal relationships highlight the importance of reducing the environmental footprint to enhance institutional quality, governance, and energy use in SSA countries.

4.1 Conclusion and policy recommendation

This study investigates the interactions between institutional quality (IQ), governance effectiveness (GE), and environmental sustainability through the lens of the ecological footprint in 25 Sub-Saharan Africa (SSA) nations. Our analysis reveals an inverted U-shaped relationship between the interaction of IQ and GE and the ecological footprint, indicating that beyond a specific threshold, enhanced levels of IQ and GE interaction lead to a reduction in the ecological footprint. This finding underscores the critical role of governance and institutional frameworks in mitigating environmental degradation and supports the necessity for policies aimed at strengthening these aspects. Moreover, our results suggest that high IQ is associated with a smaller environmental impact, while improved governance mitigates the decline in the effectiveness of IQ, highlighting the potential for targeted interventions to significantly impact environmental quality.

Acknowledging the limitations of our study, the reliance on data from 1990 to 2020 from 25 SSA nations, while insightful, restricts the generalizability of our findings and points to the need for broader datasets to enhance the applicability of our conclusions. Additionally, the application of a fixed threshold in analyzing the interaction effects between IQ and GE may not fully capture the complex dynamics involved, suggesting that future research could use a sample-splitting approach for a more nuanced understanding. Furthermore, while the Dumitrescu and Hurlin causality test provides valuable insights into the directionality of relationships, it may not adequately address endogeneity issues or capture the dynamic interplay over time, highlighting the need for advanced methodologies that can offer a more detailed causal analysis. These considerations emphasize the importance of ongoing research to refine our comprehension of the governance-environment nexus and its implications for policy formulation in SSA.

To mitigate environmental degradation effectively, policies must prioritize investments in energy consumption aligned with environmental quality, encourage green production, and facilitate low-emission projects. The nuanced relationship between IQ, GE, and the ecological footprint revealed by our study provides critical insights for policymakers, suggesting the need for strengthening governance and institutional quality, promoting energy efficiency, and fostering the development of green technologies. Despite the limitations highlighted, our findings contribute to the discourse on environmental sustainability in SSA, offering a foundation for future research aimed at further unraveling the governance-environment nexus and guiding policy formulation in the region.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

PB: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Writing–original draft. MB: Data curation, Formal Analysis, Investigation, Project administration, Writing–original draft. MA: Conceptualization, Formal Analysis, Methodology, Resources, Writing–review and editing. DT: Data curation, Methodology, Software, Writing–original draft.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO2 emissions: evidence from Sub-Saharan Africa economies. *Util. Policy* 41, 85–94. doi:10.1016/j.jup.2016.06.009

Abid, M. (2017). Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries. *J. Environ. Manag.* 188, 183–194. doi:10.1016/j.jenvman.2016.12.007

Adekunle, I. A. (2021). On the search for environmental sustainability in Africa: the role of governance. *Environ. Sci. Pollut. Res.* 28 (12), 14607–14620. doi:10.1007/s11356-020-11432-5

Agussani, A. (2021). Do social and institutional factors improve the quality of environment? Evidence from 5 ASEAN economies. *J. Studi Pemerintah.* 12 (1), 21–34. doi:10.18196/jgp.121126

Appiah, M., Frowne, D. Y. I., and Tetteh, D. (2020). Capital market and financial development on growth: a panel ardl analysis. *Indones. Cap. Mark. Rev.* 12 (3), 28–41. doi:10.21002/icmr.v12i1.12050

Appiah, M., Karim, S., Naeem, M. A., and Lucey, B. M. (2022). Do institutional affiliation affect the renewable energy-growth nexus in the Sub-Saharan Africa: evidence from a multi-quantitative approach. *Renew. Energy* 191, 785–795. doi:10.1016/j.renene.2022.04.045

Appiah, M., Li, F., and Frowne, D. I. (2020). Financial development, institutional quality and economic growth: evidence from ECOWAS countries. *Organ. Mark. Emerg. Econ.* 11 (1), 6–17. doi:10.15388/omee.2020.11.20

Appiah, M., Li, F., and Korankye, B. (2021). Modeling the linkages among CO2 emission, energy consumption, and industrialization in sub-Saharan African (SSA) countries. *Environ. Sci. Pollut. Res.* 28, 38506–38521. doi:10.1007/s11356-021-12412-z

Appiah, M., Li, M., Taden, J., Ashraf, S., Tiwari, A. K., and Laari, P. B. (2024). Enhancing natural resource rents through industrialization, technological innovation, and foreign capital in the OECD countries: does financial development matter? *Resour. Policy* 89, 1–12. doi:10.1016/j.resourpol.2023.104520

Appiah, M., Onifade, S. T., and Gyamfi, B. A. (2022). Building critical infrastructures: evaluating the roles of governance and institutions in infrastructural developments in sub-sahara african countries. *Eval. Rev.* 0 (0), 391–415. doi:10.1177/0193841x221100370

Arminen, H., and Menegaki, A. N. (2019). Corruption, climate and the energy-environment-growth nexus. *Energy Econ.* 80, 621–634. doi:10.1016/j.eneco.2019.02.009

Asongu, S. A., and Odhiambo, N. M. (2020). Governance, CO2 emissions and inclusive human development in sub-Saharan Africa. *Energy Explor. Exploitation* 38 (1), 18–36. doi:10.1177/0144598719835594

Asongu, S. A., and Odhiambo, N. M. (2021). Enhancing governance for environmental sustainability in sub-Saharan Africa. *Energy Explor. Exploitation* 39 (1), 444–463. doi:10.1177/0144598719900657

Bae, J. H., Li, D. D., and Rishi, M. (2017). Determinants of CO2 emission for post-Soviet Union independent countries. *Clim. Policy* 17 (5), 591–615. doi:10.1080/14693062.2015.1124751

Bahizire, G. M., Fanglin, L., Appiah, M., and Xicang, Z. (2022). Research on the advance role of institutional quality on achieving environmental efficiency in sub sahara Africa. *Front. Environ. Sci.* 10. doi:10.3389/fenvs.2022.845433

Bank, W. (2018). *Ghana financial sector development Project (P161787).* Available at: http://documents.worldbank.org/curated/en/768071536096255699/Ghana-Financial-Sector-Development-Project.

Bekun, F. V., Gyamfi, B. A., Onifade, S. T., and Agboola, M. O. (2021). Beyond the environmental Kuznets Curve in E7 economies: accounting for the combined impacts of institutional quality and renewables. *J. Clean. Prod.* 314, 1–10. doi:10.1016/j.jclepro.2021.127924

Bhattacharya, M., Churchill, S. A., and Paramati, S. R. (2017). The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions. *Renew. Energy* 111, 157–167. doi:10.1016/j.renene.2017.03.102

Bond, S., and Eberhardt, M. (2013). Accounting for unobserved heterogeneity in panel time series models. in *Working paper, nuffield college* (Oxford, United Kingdom: University of Oxford).

Dada, J. T., Ajide, F. M., and Adeiza, A. (2021). Shadow economy and environmental pollution in West African countries: the role of institutions. *Glob. J. Emerg. Mark. Econ.* 14 (3), 366–389. doi:10.1177/09749101211049038

Dada, J. T., Ajide, F. M., and Sharimakin, A. (2021). Shadow economy, institutions and environmental pollution: insights from Africa. *World J. Sci. Technol. Sustain. Dev.* 18, 153–171. doi:10.1108/wjstsd-12-2020-0105

Destek, M. A. (2021). Deindustrialization, reindustrialization and environmental degradation: evidence from ecological footprint of Turkey. *J. Clean. Prod.* 296, 126612. doi:10.1016/j.jclepro.2021.126612

Dodoo, R. N. A., Appiah, M., and Donkoh, D. T. (2020). Examining the factors that influence firm performance in Ghana: a GMM and OLS approach. *Natl. Account. Rev.* 2 (3), 309–323. doi:10.3934/nar.2020018

Dumitrescu, E.-I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* 29 (4), 1450–1460. doi:10.1016/j.econmod.2012.02.014

Dutt, K. (2009). Governance, institutions and the environment-income relationship: a cross-country study. *Environ. Dev. Sustain.* 11 (4), 705–723. doi:10.1007/s10668-007-9138-8

Fernández, E. F., and Malwé, C. (2019). The emergence of the 'planetary boundaries' concept in international environmental law: a proposal for a framework convention. *Rev. Eur. Comp. Int. Environ. Law* 28 (1), 48–56. doi:10.1111/reel.12256

Fredriksson, P. G., and Neumayer, E. (2016). Corruption and climate change policies: do the bad old days matter? *Environ. Resour. Econ.* 63 (2), 451–469. doi:10.1007/s10640-014-9869-6

Fredriksson, P. G., and Svensson, J. (2003). Political instability, corruption and policy formation: the case of environmental policy. *J. Public Econ.* 87 (7-8), 1383–1405. doi:10.1016/s0047-2727(02)00036-1

Gök, A., and Sodhi, N. (2021). The environmental impact of governance: a system-generalized method of moments analysis. *Environ. Sci. Pollut. Res.* 28 (25), 32995–33008. doi:10.1007/s11356-021-12903-z

Grochová, L. I. (2014). Regulatory quality and sustainable economic development. *Acta Univ. Agric. Silvic. Mendelianae Brunensis* 62 (1301–1308). doi:10.11118/actaun201462061301

Gyamfi, B. A. (2022). Consumption-based carbon emission and foreign direct investment in oil-producing Sub-Sahara African countries: the role of natural resources and urbanization. *Environ. Sci. Pollut. Res.* 29 (9), 13154–13166. doi:10.1007/s11356-021-16509-3

Gyamfi, B. A., Adedoyin, F. F., Bein, M. A., and Bekun, F. V. (2021). Environmental implications of N-shaped environmental Kuznets curve for E7 countries. *Environ. Sci. Pollut. Res.* 28 (25), 33072–33082. doi:10.1007/s11356-021-12967-x

Hurlin, C. (2010). What would Nelson and Plosser find had they used panel unit root tests? *Appl. Econ.* 42 (12), 1515–1531. doi:10.1080/00036840701721539

Huynh, C. M., and Ho, T. X. (2020). Institutional quality, shadow economy and air pollution: empirical insights from developing countries. *Empir. Econ. Lett.* 19 (1), 75–82.

Iwińska, K., Kampas, A., and Longhurst, K. (2019). Interactions between democracy and environmental quality: toward a more nuanced understanding. *Sustainability* 11 (6), 1728. doi:10.3390/su11061728

Kassouri, Y., and Altıntaş, H. (2020). Human well-being versus ecological footprint in MENA countries: a trade-off? *J. Environ. Manag.* 263, 110405. doi:10.1016/j.jenvman.2020.110405

Kousar, S., Ahmed, F., López García, M. d. l. N., and Ashraf, N. (2020). Renewable energy consumption, water crises, and environmental degradation with moderating role of governance: dynamic panel analysis under cross-sectional dependence. *Sustainability* 12 (24), 10308. doi:10.3390/su122410308

Kulin, J., and Johansson Sevä, I. (2019). The role of government in protecting the environment: quality of government and the translation of normative views about government responsibility into spending preferences. *Int. J. Sociol.* 49 (2), 110–129. doi:10.1080/00207659.2019.1582964

Laurance, W. F., Peletier-Jellema, A., Geenen, B., Koster, H., Verweij, P., Van Dijck, P., et al. (2015). Reducing the global environmental impacts of rapid infrastructure expansion. *Curr. Biol.* 25 (7), R259–R262. doi:10.1016/j.cub.2015.02.050

Li, F., Appiah, M., and Dodoo, R. N. A. (2020). A Co-integration approach to the study of economic growth and environmental impact in Ghana. *NMIMS Manegement Rev.* 38 (2), 31–47.

Liu, X., Latif, K., Latif, Z., and Li, N. (2020). Relationship between economic growth and CO2 emissions: does governance matter? *Environ. Sci. Pollut. Res.* 27 (14), 17221–17228. doi:10.1007/s11356-020-08142-3

Ma, X. (2023). Environmental regulation and public environmental concerns in China: a new insight from the difference in difference approach. *Green Low-Carbon Econ.* 1 (2), 60–67. doi:10.47852/bonviewglce3202868

Manimekalai, K., and Sindhuja, P. (2019). *Mainstreaming gender in environment: a path for sustainable development* (India: NEW INDIA), 25.

Masron, T. A., and Subramaniam, Y. (2019). Does poverty cause environmental degradation? Evidence from developing countries. *J. poverty* 23 (1), 44–64. doi:10.1080/10875549.2018.1500969

OECD. (2019). *Infrastructure investment: links to growth and the role of public policy in economic policy reforms: going for growth*. Paris: Organisation for Economic Cooperation and Development.

Olaoye, O. (2024). Environmental quality, energy consumption and economic growth: evidence from selected African countries. *Green Low-Carbon Econ.* 2 (1), 28–36. doi:10.47852/bonviewglce3202802

Ölund Wingqvist, G., Drakenberg, O., Slunge, D., Sjöstedt, M., and Ekbom, A. (2012). "The role of governance for improved environmental outcomes," in *Swedish environmental protection agency*, 6514.

Omri, A., Kahia, M., and Kahouli, B. (2021). Does good governance moderate the financial development-CO2 emissions relationship? *Environ. Sci. Pollut. Res.* 28 (34), 47503–47516. doi:10.1007/s11356-021-14014-1

Omri, A., Omri, H., Slimani, S., and Belaid, F. (2022). Environmental degradation and life satisfaction: do governance and renewable energy matter? *Technol. Forecast. Soc. Change* 175, 121375. doi:10.1016/j.techfore.2021.121375

O'Neill, D. W., Fanning, A. L., Lamb, W. F., and Steinberger, J. K. (2018). A good life for all within planetary boundaries. *Nat. Sustain.* 1 (2), 88–95. doi:10.1038/s41893-018-0021-4

Ozcan, B., Tzeremes, P. G., and Tzeremes, N. G. (2020). Energy consumption, economic growth and environmental degradation in OECD countries. *Econ. Model.* 84, 203–213. doi:10.1016/j.econmod.2019.04.010

Pesaran, H. (2004). *General diagnostic tests for cross-sectional dependence in panels*. Cambridge: University of Cambridge. *Working Papers in Economics No. 0435*.

Pesaran, H. M. (2007). A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econ.* 22, 265–312. doi:10.1002/jae.951

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econ. Rev.* 34 (6-10), 1089–1117. doi:10.1080/07474938.2014.956623

Pesaran, M. H., Ullah, A., and Yamagata, T. (2008). A bias-adjusted LM test of error cross-section independence. *Econ. J.* 11 (1), 105–127. doi:10.1111/j.1368-423x.2007.00227.x

Pesaran, M. H., and Yamagata, T. (2008). Testing slope homogeneity in large panels. *J. Econ.* 142 (1), 50–93. doi:10.1016/j.jeconom.2007.05.010

Purcel, A.-A. (2019). Does political stability hinder pollution? Evidence from developing states. *Econ. Res. Guard.* 9 (2), 75–98.

Ridzuan, A. R. (2019). *The impact of corruption on environmental quality in the developing countries of ASEAN-3: the application of the bound test.* 670216917.

Robertua, V. (2018). The deconstruction and reconstruction of global environmental governance: case study of peat restoration agency. *J. Asia Pac. Stud.* 2 (2), 180–196. doi:10.33541/japs.v2i2.789

Robertua, V., and Bainus, A. (2018). From Stockholm to rio: critical reading of global environmental governance. *AEGIS J. Int. Relat.* 2 (2). doi:10.33021/aegis.v2i2.429

Sah, M. R. (2021). Effects of institutional quality on environmental protection in CEMAC countries. *Mod. Econ.* 12 (5), 903–918. doi:10.4236/me.2021.125045

Sarker, A., and Blomquist, W. (2019). Addressing misperceptions of governing the commons. *J. Institutional Econ.* 15 (2), 281–301. doi:10.1017/s1744137418000103

Schaltegger, S., Beckmann, M., and Hockerts, K. (2018). Sustainable entrepreneurship: creating environmental solutions in light of planetary boundaries. *Int. J. Entrepreneurial Ventur.* 10 (1), 1–16. doi:10.1504/ijev.2018.090990

Shilling, J. D., Chomitz, K., and Flanagan, A. E. (2007). The nexus between infrastructure and environment: from the evaluation cooperation group of the international financial institutions. Accessed

Ssekibaala, D. S., Ariffin, M. I., and Duasa, J. (2021). Transmission channels and indirect effects in the relationship between institutions and environmental degradation in Sub-Saharan Africa. *Int. J. Green Econ.* 15 (4), 335–358. doi:10.1504/ijge.2021.122651

Teo, H. C., Lechner, A. M., Walton, G. W., Chan, F. K. S., Cheshmehzangi, A., Tan-Mullins, M., et al. (2019). Environmental impacts of infrastructure development under the belt and road initiative. *Environments* 6 (6), 72. doi:10.3390/environments6060072

Westerlund, J., and Edgerton, D. L. (2007). A panel bootstrap cointegration test. *Econ. Lett.* 97 (3), 185–190. doi:10.1016/j.econlet.2007.03.003

Wuijts, S., Driessen, P. P., and Van Rijswick, H. F. (2018). Towards more effective water quality governance: a review of social-economic, legal and ecological perspectives and their interactions. *Sustainability* 10 (4), 914. doi:10.3390/su10040914