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Research article

The role of environmental regulatory quality in the relationship between natural resources and environmental sustainability in sub-Saharan Africa

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HIGHLIGHTS

- Environmental regulatory quality improves environmental sustainability.
- Natural resources degrade environmental sustainability.
- NR complemented ERQ quality to reduce environmental sustainability.
- We appeal for effective and rigorous implementation of ERQ.

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ABSTRACT

Natural resources benefit economies through economic growth and development. However, continuing unsustainable exploitation of these resources tend to harm the sustainability of the environment. Therefore, this paper explores the role of environmental regulatory quality (ERQ) in the relationship between natural resources (NR) and environmental sustainability (ES). The study covered 28 sub-Saharan African countries (SSA) from 2005-2017. Regarding the estimations, we utilized cross-sectional dependence, first-and second-generation unit root, and cointegration tests for preliminary checks. Finally, we used the system-GMM estimation for the analysis. We found that environmental regulatory quality improves environmental sustainability in SSA. We also observed that natural resources degrade environmental sustainability. Furthermore, we noticed that natural resources complemented environmental regulatory quality to reduce environmental sustainability in SSA. Therefore, we establish that ERQ in SSA does not complement NR to induce environmental sustainability. Based on the findings, we appeal for effective and rigorous implementation of environmental policies and regulations in SSA.

1. Introduction

The economic effects of the COVID-19 pandemic have shifted global policies and public dialogues to deal with high levels of macroeconomic uncertainties with disproportionate attention to sustainable environmental quality. As such, the COP26[1] climate summit, for example, aimed to ensure environmental quality by initiating policies to mitigate greenhouse gas (GHG) emissions and ensuring that global warming is below 1.5 degrees. The Sustainable Development Goals (SDGs) also place climate change mitigation as a relevant action to achieve development goals (Griggs et al., 2013). Despite these efforts, the global environment has been plagued by pollutants due to a high enthusiasm for economic development, which harms environmental sustainability. For example, Global CO2 and Total Greenhouse Gas Emissions 2020 Report[2] documents that global GHG emissions in 2019 reached 57.4 GtCO2 eq, with CO2 emissions accounting for 73%, while the remaining 27% was attributed to methane (19%), fluorinated gases (3%), and nitrous oxide (5%). Undoubtedly, the GHG emissions have health implications and, therefore, are alarming. Watts et al. (2019) states that 20% and 26% of global health challenges emanate from primary minerals extraction and carbon emissions, respectively. Furthermore, the adverse effect of higher GHG emissions increases the level of poverty, especially

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[1] 2021 United Nations climate change conference (COP26).

[2] https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gas-emissions-2020-report.

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in the sub-Saharan Africa (SSA) region. This is because climate change due to the increase in emissions negatively affects the agriculture activities of the region, leading to low income in SSA. Consequently, most people in SSA lived on less than $1.90 a day, as noted by Khan (2021). Thus, poor environmental sustainability (ES) poses a tremendous threat to the welfare of the citizenry. The hazardous effect of a poor environment on humans and ecology has called for the implementation of international instruments[3] to manage pollution, including land, water, and air pollution. Despite the numerous agreements, there has been no real success in reducing global pollution (CO2 emissions). Therefore, it is always urgent to investigate the possible causes of pollution to protect the sustainability of the environment.

Scholars have identified natural resources (NR) among the variables that explain low environmental quality globally, particularly in SSA (Adedoyin et al., 2020; Erdoğan et al., 2021). SSA is notably a region endowed with growth-enhancing resources such as diamonds, bauxite, crude oil, arable land, and oil. However, the growing population in SSA, coupled with the guarantee of sustainable development and industrialization, has intensified the need to extract more natural resources to accommodate present demands. This is because natural resources account for the region's key export commodities. Most SSA economies depend on the earnings from these resources for development projects such as roads, schools, health centres, and others. Despite the benefits derived from natural resources, their untenable exploitation degrades the quality of the environment and, therefore, threatens its sustainability. For example, the processes involved in extracting these resources often lead to the disposal of waste products, which, in effect, affects the sustainability of the environment (Oteng-Abayie et al., 2022). Due to the environmental impact of the extraction of natural resources, the central question is whether the SSA economies should continue to depend on their abundant resources for survival (growth and development) at the expense of environmental sustainability. Given this concern, this study explores the empirical connection between natural resources and environmental sustainability (or quality) in SSA while considering the complementary role of environmental regulatory quality. In doing so, we incorporate various measures of environmental sustainability such as ecological footprint[4] (EFP), material footprint[5] (MFP), and sustainable development index[6] (SDI) to ensure how natural resources broadly affect the environment. In assessing the effect of natural resources on environmental sustainability, this study makes three significant contributions to the existing literature, particularly SSA.

First, this study considers the significance of environmental regulatory quality (ERQ) and its complementary role between natural resources and environmental sustainability. Studies (Bokpin, 2017; Adams et al., 2020; Duodu et al., 2021) have shown that regulatory quality and institutions are one sure way to prevent environmental deterioration. Therefore, effective environmental regulatory quality could complement natural resource extraction to ensure a sustainable environment. For example, Abid (2017) indicated that effective and efficient laws minimize CO2 emissions since polluted companies could be enforced to comply with environmental quality regulations. Despite the vital role of environmental regulatory quality in ensuring a good environment, as highlighted above, previous studies related to natural resources and environmental sustainability (or quality) in SSA have neglected the role of environmental regulatory quality in their investigations (see, for example, Adedoyin et al., 2020; Ansari et al., 2020; Ahmad et al., 2021. Therefore, this study includes environmental regulatory quality in the analysis to assess its complementary effect between natural resources and environmental sustainability. The study uses policies and institutions for environmental sustainability to measure environmental regulatory quality. This variable assesses how environmental policies and institutions promote natural resource conservation, sustainable use, and pollution management. Hence, it is appropriate to use policies and institutions for environmental sustainability as a measure of environmental regulatory quality. Second, this study deviates from existing literature (Bruckner et al., 2012; Ansari et al., 2020; Ahmad et al., 2021; Nathaniel et al., 2021a) by using different measures of environmental sustainability. Thus, we used ecological footprint (EFP), material footprint (MFP), and sustainable development index (SDI) to comprehensively examine how natural resources influence environmental sustainability. For example, the MFP captures mostly production-based emissions, EFP captures consumption-based emissions, and SDI captures both MFP and EFP, in addition to the human capital dimensions.[7] Therefore, SDI gives a complete view of how natural resources influence environmental sustainability. However, previous studies mentioned above used EFP or MFP to measure environmental sustainability. Hence, this study contributes by considering a broad view of environmental sustainability. Furthermore, using different measures (EFP, MFP, and SDI) provides a more robust analysis of the environmental effect of natural resources than using a single measure of environmental sustainability. Finally, this study provides the true effect of natural resources on environmental sustainability by generating a marginal effect of natural resources when it is interacted with environmental regulatory quality. Studies, for instance, Ahmed et al. (2020) used the interaction parameter to assess the complementary effect on the outcome variable. However, such an approach fails to estimate an accurate effect in a model with interaction, as argued by Brambor et al. (2006). As a result, we followed Brambor et al. (2006) to generate the marginal effect of natural resources on environmental sustainability. This helps to accurately examine natural resources' actual effect when it complements environmental regulatory quality.

The rest of the paper is outlined as follows. The following section presents a review of pertinent literature. Section three focuses on the methodological framework employed. The fourth section discusses the empirical findings, and the final section concludes the paper with implications.

2. Literature review

This section reviews relevant literature related to the subject matter in SSA and beyond.

2.1. Natural resources and environmental sustainability

Studies on the effect of natural resources on environmental sustainability point to the view that unsustainable exploitation of natural resources harms the sustainability of the environment. For example, Ahmed et al. (2020) explored the causal effect of natural resource rent on the ecological footprint in China. They found that natural resource rent moves in tandem with the ecological footprint. This suggests that the extraction of natural resources adversely affects environmental sustainability in China. Also, Ahmed et al. (2020) found that by introducing an interaction term between urbanization and human capital in the study, the interaction term has a bidirectional causal link with ecological footprint in China. Many studies have supported the finding that natural resources adversely affect the environment in China and other countries. For example, Hassan et al. (2020), Zafar et al. (2019), Bekun et al. (2019), Nathaniel et al. (2021a) and

[3] See the Clean Development Mechanism-under Kyoto Protocol, the European Green Deal, Paris Agreement, and others.

[4] It tracks the use of productive surface areas-such as cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land.

[5] It covers the sum of material footprint for biomass, fossil fuels, metal ores and non-metal ores.

[6] It comprises both the EFP and MFP in addition to the human capital dimensions.

[7] Life expectancy, expected years of schooling, and income per capita.

Nathaniel et al. (2021b) have used CO2 emissions and ecological footprint as a measure of environmental quality. They found that natural resources impede environmental sustainability because their extraction causes pollution.

Furthermore, Ibrahim and Ajide (2021) noticed that overdependence on natural resources had a long-term environmental impact on the BRICS economies when they tested the heterogeneous effect of total natural resource rent on environmental quality from 1996 to 2018. The detrimental effect of natural resources on the ecological footprint has also been revealed in SSA, where natural resources seem abundant. For example, Adedoyin et al. (2020) and Erdoğan et al. (2021) reported that natural resources deteriorate the sustainability of the environment since the processes involved in extracting these resources tend to degrade the quality of the environment. Moreover, studies with material footprint as a measure of environmental sustainability have also proved that natural resources deteriorate environmental quality. One can relate to the empirical analysis by Ansari et al. (2020) and Sahoo et al. (2021), demonstrating that natural resources degrade the material footprint in BRICS countries. Muhammad et al. (2021) and Zia et al. (2021) have supported the adverse effect of natural resources on the environment in BRICS and China, respectively. However, studies (Zafar et al., 2019; Altinoz and Dogan, 2021; Xiaoman et al., 2021) in the United States and other resource-rich economies argue that natural resources enhance environmental quality. Recently, the evidence that natural resources improve environmental quality has been supported by Muhammad and Khan (2021) and Dagar et al. (2022). These studies have shown contradictory evidence, suggesting that natural resources improve environmental sustainability by reducing CO2 emissions and ecological footprint. Their findings suggest that adopting mindful environmental practices, such as green technologies, to extract these resources could mitigate the adverse environmental impact.

From the reviewed studies, it is evident that the significance of environmental regulatory quality, and its complementary role, in the relationship between natural resources and environmental sustainability is virtually missing, especially in SSA. However, many existing studies have shown evidence of how institutional quality or governance promotes environmental quality in MENA and Africa (Abid, 2017; Bokpin, 2017; Adams et al., 2020; Ulucak et al., 2020). Others, such as Duodu et al. (2021), also narrowed down to the specific role of environmental policies and institutions and found that environmental policies and institutions sustain the environment. These studies have shown the importance of environmental regulatory quality in ensuring environmental sustainability. Therefore, assessing its complementary role in the natural resources and environmental sustainability nexus becomes essential. However, this has been ignored in the relationship, in particular SSA. Therefore, this study incorporates in the analysis the complementary role of environmental regulatory quality in the effect of natural resources on environmental sustainability.

2.2. Other determinants of environmental sustainability

In addition to natural resources and environmental regulations, researchers have identified many critical factors that determine environmental sustainability. These include, but are not limited to, FDI, trade openness, energy or electricity consumption, urbanization, and others (see Shahbaz et al., 2014; Jiang and Guan, 2016; Ansari et al., 2019; Duodu et al., 2022). For example, Ansari et al. (2019) applied Fully Modified Ordinary Least Squares to investigate the impact of foreign direct investment on environmental quality in 29 Asian countries. The study shows that FDI reduces environmental quality, thus validating the pollution haven hypothesis in Asian countries. Furthermore, Antweiler et al. (2001) explored the impact of trade openness on pollution concentrations in developed countries and found that international trade benefits the environment.

Furthermore, Al-Mulali and Ozturk (2016) studied the effect of energy prices on environmental pollution from 1990 to 2012, and the result shows that energy prices reduce environmental pollution in 27 advanced economies. In the United Arab Emirates (UAE), Shahbaz et al. (2014) found that electricity consumption reduces CO2 emissions while urbanization worsens CO2 emissions. Again, their study established the existence of the environmental Kuznets hypothesis (an inverted U-shaped relationship between economic growth and CO2 emissions) in the UAE. Lastly, Jiang and Guan (2016) examined the determinants of global CO2 emissions growth in developed and developing countries from 1995 to 2009. They revealed that, among the three fossil fuels (coal, oil, or gas), CO2 emissions from coal and natural gas grew rapidly in developing and developed countries. Recently, Hassan et al. (2020) analyzed the extent to which institutions corrects environmental pollution in Pakistan from 1984-2016. Using the autoregressive distributed lag model, they found that institutions in Pakistan due to corruption results in higher CO2 emissions. Furthermore, they found that energy consumption from fossil energies leads to an increase in CO2 emissions. The indication is that green sustainable development will be a mirage if the use of sustainable energy such as renewable energies are not considered.

From the reviews, we find that extant studies have only focused on the ecological footprint (EFP), material footprint (MFP), or CO2 emissions as a measure of environmental sustainability. Again, it is observed that no study has considered the sustainable development index (SDI) in addition to EFP and MFP as a measure of environmental sustainability. SDI gives a complete or broad view of sustainability. Therefore, in addition to EFP and MFP, we used SDI to comprehensively analyze how natural resources influence environmental sustainability. Finally, we observed that studies (see Ahmed et al., 2020) with interaction terms in this analysis had neglected the marginal effects, which adequately assesses the actual impact of an interaction term on environmental sustainability (see Brambor et al., 2006). As a result, this study implemented the marginal effects of natural resources on environmental sustainability to accurately assessed the true impact of natural resources on the environment.

3. Methodology and data

This section presents the methodological framework adopted to analyze the data set used in this study.

3.1. Model specification

Following previous studies (Bekun et al., 2019; Ahmed et al., 2020; Nathaniel et al., 2021a) specifying environmental quality as a function of natural resources and other control variables such as urbanization and others, this study specifies a simple linear model with environmental sustainability as a function of natural resources and some relevant controls. However, the present study modifies the model to incorporate environmental regulatory quality and its interaction with natural resources. The modified model is expressed in its functional form in equation (1).

$$ES = f(NR, ERQ, NR * ERQ, DI, FDI, URB, TO) \tag{1}$$

where ES, NR, ERQ, DI, FDI, URB, and TO are environmental sustainability (proxied by ecological footprint, material footprint, and sustainable development index), natural resources, environmental regulatory quality, domestic investment, foreign direct investment, urbanization, and trade openness, respectively. $NR * ERQ$ captures the interaction between natural resources and environmental regulatory quality. We transform equation (1) into an estimable panel model specified in equation (2).

$$lnES_{it} = \theta_0 + \gamma_1 NR_{it} + \gamma_2 ERQ_{it} + \gamma_3 (NR * ERQ)_{it} + \gamma_4 DI_{it} + \gamma_5 lnFDI_{it} + \gamma_6 lnURB_{it} + \gamma_7 lnTO_{it} + \delta_i + \varepsilon_{it} \tag{2}$$

where θ_0 and $\gamma' s$ (1, 2, 3, … 7) denotes the constant term and the unknown parameters to be estimated. ε is the stochastic error term assumed to be normally distributed with zero mean and constant variance [$\varepsilon_{it} \sim N(0,1)$]. Also, δ_i, t and i indicate the unobserved country-specific heterogeneity, time trend and cross-sectional units, respectively. We estimated equation (2) using ecological footprint (EFP), material footprint (MFP), and SDI as dependent variables and reported them as models 1, 2, and 3, respectively. It must be noted that the coefficient of interest in this study is $\gamma_1 + \gamma_3 ERQ$, which provides the true effect of natural resources on environmental sustainability through the marginal effects when environmental regulatory quality is at its mean or is improved.

3.2. Sources of data

We selected data from a balanced panel of twenty-eight (28) countries[8] in SSA from 2005 to 2017. The 28 SSAs and the time frame used for the study were based on the availability of data on some important variables[9] and the importance of the subject to the context of the countries selected. Data for this study is sourced from Global Footprint Network (GFN, 2021), World Development Indicators (WDI, 2021), and Global Indicator Framework (GIF, 2021). Specifically, data on ecological footprint, material footprint, and sustainable development index are gleaned from Global Footprint Network and Global Indicator Framework, respectively. Data on environmental regulation quality, domestic investment, foreign direct investment, urbanization, and trade openness were extracted from the World Development indicators. The choice of sample variables is based on the STIRPAT[10] model and previous literature (Altinoz and Dogan, 2021; Duodu et al., 2021; Erdoğan et al., 2021). We report the description of the variables used for this analysis in Table A.1 (see the Appendix).

3.3. Estimation strategy

We used Blundell and Bond's (1998) two-step system generalized method of moments (system-GMM) to examine the impact of natural resources, environmental regulatory quality, and its mediating role between natural resources and environmental sustainability in SSA. The system-GMM estimation technique is chosen over other panel estimators such as fixed effect, random effect, and panel-corrected standard error due to some advantages of the system-GMM. The system-GMM estimator can handle panel data with small time (T) and large cross-sectional units (N), such as $T = 13$ and $N = 28$ in this case. Furthermore, it employs the lags of the endogenous regressor as internal instruments to mitigate any potential endogeneity issues that may develop because of the introduction of the lagged dependent variable as part of the regressors. Therefore, the system-GMM specification of equation (2) is expressed in equation (3).

$$lnES_{it} - lnES_{it-1} = \rho_0 \left(lnES_{it-1} - lnES_{it-2} \right) + \boldsymbol{\rho'} \left(\boldsymbol{lnZ}_{it} - \boldsymbol{lnZ}_{it-1} \right) + \left(\varepsilon_{it} - \varepsilon_{t-1} \right) \quad (3)$$

where all the variables are already explained in the previous equations. $\boldsymbol{Z}$ represents a vector of variables included in the previous equations. Arellano and Bond's (1991) AR(2) test and Hansen and Singleton (1982) J-test are employed to check for the absence of second-order serial correlation and validity of the instruments, respectively. The null hypothesis of the AR(2) and the J-test suggests no second-order serial correlation and validity of instruments, respectively. Therefore, this study concludes the absence of serial correlation and instruments validity if we reject the null hypothesis of both tests at the 5% significance level.

Following Brambor et al. (2006) and Duodu et al. (2021), we further generate the marginal effects of the interaction between natural resources and environmental regulatory quality in equation (2). This is because the marginal effects of the interaction term clearly show the true impact of a unit change in the natural resources on environmental sustainability than the coefficient of the interaction term. Therefore, the marginal effect of the interaction term is computed as given by equation (4).

$$\frac{\partial \boldsymbol{lnES}_{it}}{\partial NR_{it}} = \rho_1 + \rho_3 ERQ \quad (4)$$

From equation (4), it is important to interpret the marginal effect of the interaction term $\rho_1 + \rho_3 ERQ$ but not ρ_3.

Furthermore, to ensure that the estimates generated from equation (3) are robust and not spurious, we employed Pesaran's (2004) cross-sectional dependence (CD) test to check for cross-sectional dependency. In contrast, Im et al. (2003) and Pesaran (2007) cross-sectional augmented IPS (CIPS) tests were also employed for stationarity properties. Moreover, we used Pedroni's (2004) cointegration test to check for the long-run relationship among the variables employed in this study. The null hypothesis for these tests is cross-sectional independence, unit root (nonstationary series), and no cointegration between the variables. Hence, rejection of the null hypothesis shows cross-sectional dependence (correlation among countries), no unit root (stationarity of the series), and a long-run relationship.

4. Analysis of empirical estimates

In this section, we report and discuss descriptive statistics, cross-sectional dependence tests, unit root tests, and cointegration tests. Finally, we analyze the empirical findings from the system-GMM short- and long-run estimates and marginal effects.

4.1. Descriptive statistic

The descriptive statistics of the variables are reported in Table 1.

Table 1. Descriptive statistics.

Variables	Mean	Standard deviation	Minimum	Maximum
EFP	16.3519	1.2417	13.5213	19.1058
MFP	17.1395	1.2396	14.1630	20.0621
SDI	0.5010	0.0776	0.3160	0.7050
NR	13.5687	10.5452	0.4492	58.6501
ERQ	3.1236	0.5478	0.000	4.000
FDI	5.6195	10.4896	-6.0572	103.3374
DI	4.7139	1.2914	0.000	5.8636
URB	15.2746	1.2121	12.4955	18.3643
TO	4.1621	0.4449	3.0312	5.7409

Note: EFP, MFP, SDI, NR, ERQ, FDI, DI, URB and TO indicate ecological footprint, material footprint, sustainable development index, natural resources, environmental regulation quality, foreign direct investment, domestic investment, urbanization, and trade openness, respectively.

In Table 1, we observe that the ecological footprint, the material footprint, and the sustainable development index have mean values of approximately 16.35, 17.14, and 0.50, respectively. Accordingly, the maximum values of these indicators were revealed to be 19.11, 20.06, and 0.71. Regarding natural resources and environmental regulatory quality, we observed an average value of approximately 13.57 percent of GDP and a score of 3.12, respectively. It can be construed that, on average, the quality of environmental regulation in SSA is strong. However, its effectiveness in ensuring sustainable use of the environment

[8] Angola, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Ethiopia, Gambia, The, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, and Uganda.

[9] Ecological footprint, natural resources, and environmental regulation quality.

[10] Stochastic impact regression on population, affluence, and technology model.

Table 2. Cross-Sectional Dependence Test Results.

Model	CD test	P-value
Model 1	-0.89	0.374
Model 2	-1.76	0.078
Model 3	-1.67	0.096

Note: The Pesaran CD test has the null hypothesis of cross-sectional independence.

Table 3. Unit Root Test Results.

Variable	IPS		CIPS		Decision
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	
EFP	-1.396	-2.850***	-2.779***	-4.014***	Stationary
MFP	-1.836**	-3.315***	-2.552***	-3.447***	Stationary
SDI	-1.584	-2.429***	-2.156*	-3.431***	Stationary
NR	-1.475	-2.514***	-1.696	-3.615***	Stationary
ERQ	-1.691*	-2.454***	-1.673	-2.870***	Stationary
FDI	-1.950***	-2.303***	-2.646***	-3.929	Stationary
DI	-2.812***	-3.150***	-2.277**	-3.200***	Stationary
URB	-0.847	-3.139***	-1.815	-2.872	Stationary
TO	-1.294	-2.283***	-1.310	-2.979***	Stationary

Note: IPS, CIPS, $I(0)$ and $I(1)$ denote Im-Pesaran-Shin, cross-sectionally augmented IPS, levels, and first difference, respectively. *** indicate the 1% significance level. -2.07, -2.17, and -2.34 are the critical values for CIPS at 10%, 5%, and 1% error level, respectively.

is weak, given the higher average means of ecological footprint, material footprint, and SDI. Furthermore, we observed that foreign direct investment and domestic investment have an average value of approximately 5.62% and 4.71 percent of GDP, respectively. Urbanization was also shown to have a mean value of 15.27%. Again, trade openness is also indicated to have a mean value of 4.16 percent of GDP. Generally, we noticed that the deviations from the respective means are relatively lower, except for natural resources and foreign direct investment.

4.2. Cross-sectional dependence and unit root test

Given the assertion that cross-country correlation could lead to bias and inconsistency in estimates, we used the Pesaran (2004) CD test for cross-sectional dependence. The results are reported in Table 2.

In Table 2, we observe the absence of cross-sectional dependence in all models (1, 2 and 3) for the analysis. The existence of no cross-sectional correlation (or dependence) is based on the nonrejection of the null hypothesis that errors are cross-sectional independent at a 5% significant level. Thus, all models exhibit no cross-sectional correlation. Hence estimates from these models are reliable.

Turning to the unit root test, we report both Im, Pesaran, and Shin (2003) (IPS) and cross-sectional augmented IPS (CIPS) unit root test results in Table 3. We noticed that only four variables were stationary at the levels using the IPS test. In addition, the ecological footprint, the sustainability index, natural resources, urbanization, and trade openness were stationary at the first difference. Regarding the Pesaran (2007) CIPS test, all variables were stationary at the first difference, except urbanization. After confirming the stationarity of the variables, we continued to establish a long-run relationship among the variables.

4.3. Cointegration test results

The long-run relationship results are reported in Table 4.

It is shown in Table 4 that except for panel augmented Dickey-Fuller statistic, all the tests statistic suggests the existence of a long-run relationship (cointegration) among the variables for the analysis. This is because the null hypothesis of no cointegration is rejected in all test statistics at the 1% significance level. We conclude the existence of a long-run relationship in this study. Hence, we estimated the long-run and short-run relationships and the marginal effects, respectively.

Table 4. Cointegration Test.

Test	Test Statistic	Model 1	Model 2	Model 3
	Panel v	-3.972***	-4.520***	-3.956***
Pedroni	Panel rho	6.425***	6.624***	7.133***
	Panel P-P	-9.944***	-10.970***	-3.623***
	Panel ADF	-1.243	1.434	0.6522
	Group rho	8.747***	9.012***	9.283***
	Group P-P	-13.140***	-13.060***	-4.163***
	Group ADF	-1.189	2.803***	0.7577

Note: In this test, the null hypothesis of no cointegration is tested against the alternative hypothesis of cointegration. *** indicate the significance level at 1%.

Table 5. Short-Run Effect of NR on ES.

System-GMM			
Variable	Model 1	Model 2	Model 3
	Coefficient	Coefficient	Coefficient
$lnEFP_{t-1}$	0.4679***		
	(0.0548)		
$lnMFP_{t-1}$		0.9581***	
		(0.0205)	
SDI_{t-1}			0.9073***
			(0.0296)
NR	0.0629**	-0.1373***	0.0039**
	(0.0282)	(0.0444)	(0.0015)
ERQ	-0.2469***	-0.2327***	-0.0035*
	(0.0589)	(0.0649)	(0.0018)
NR*ERQ	-0.1286**	0.4831***	-0.0067*
	(0.0571)	(0.1044)	(0.0038)
FDI	-0.0027	0.0053*	-0.0001*
	(0.0053)	(0.0027)	(0.0001)
lnDI	-0.0636**	-0.0679**	-0.0002
	(0.02303)	(0.0252)	(0.0006)
lnURB	0.6929***	0.3943***	0.0.0074
	(0.0790)	(0.0606)	(0.0049)
lnTO	0.1245*	0.5404***	0.0040
	(0.0407)	(0.0909)	(0.0032)
Constant	-2.0576*	-7.1879***	-0.0777
	(1.2100)	(1.0457)	(0.0713)
AR(2) P-value	0.494	0.577	0.808
Hansen P-value	0.651	0.781	0.576
No. Groups	28	28	28
No. Instruments	23	22	26
No. observations	336	336	336

Note: In Model 1, 2, and 3, the dependent variable is ecological footprint, material footprint and sustainable development index, respectively. *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. Standard errors are in parentheses.

4.4. The effect of natural resources on environmental sustainability

This section reports three different estimation results on the effect of natural resources (NR) on environmental sustainability (ES) in SSA. In models 1, 2, and 3 of Table 5, we used the ecological footprint (EFP), the material footprint (MFP), and the sustainable development index (SDI) as a measure of environmental sustainability, respectively. This analysis must emphasize that a negative sign implies an improvement in environmental sustainability (decreasing EFP and MFP and increasing SDI score). On the contrary, a positive sign indicates a reduction in environmental sustainability (increasing EFP and MFP and decreasing SDI score).

Beginning with the short-run analysis, we observed that the previous values of ecological footprint, material footprint, and sustainable development index have a significant positive effect on EFP, MFP, and SDI, respectively. The coefficients of these indicators[11] imply that en-

[11] Ecological footprint, material footprint and sustainable development index.

vironmental sustainability in SSA does not converge since a percentage increase in the past values of ecological footprint, material footprint, and sustainable development index causes environmental unsustainability in SSA by approximately 0.468%, 0.958%, and 0.907%, respectively. Muhammad et al. (2021) provided similar evidence of no convergence in BRICS, developed, and developing countries, and Duodu et al. (2021) in SSA.

Regarding the variable of interest (natural resources), it is revealed in Table 5 that natural resources (without the interaction or unconditional effect) have a positive and significant effect on ecological footprint and the sustainable development index. However, the effect was negative (improving) on the material footprint. Intuitively, the results suggest that a percentage increase in natural resources in SSA will decrease environmental sustainability on average by about 0.063% and 0.003% in the EFP and SDI models, respectively. However, a percentage increase in natural resources improves environmental sustainability by about 0.137% in the MFP model. Muhammad et al. (2021) reported similar findings that the total natural resource degrades the environment, but the fuel resources improve the environment.

The negative impact of natural resources on the material footprint can be explained by the fact that most natural resources in SSA are not considered material footprints. As a result, natural resources tend to have a less significant impact on MFE. This is because MFP captures the extraction of domestic materials from the environment and the raw materials equivalent of imports and exports. According to the International Resource Panel (IRP) (2018), for a natural resource to be counted as a domestic extraction, it must be processed and transformed in the domestic country. However, most of the natural resources extracted in SSA are not processed, and their effect on the environment could be marginal. The positive effect of natural resources on environmental sustainability (EFP and SDI) accords with the study by Adedoyin et al. (2020), Erdoğan et al. (2021), and Nathaniel et al. (2021a). The negative outcome of natural resources on environmental sustainability also supports Zafar et al. (2019) and Xiaoman et al. (2021).

Furthermore, the results reveal that the environmental regulatory quality in all models has a significant negative effect on environmental sustainability. The indication is that quality environmental regulations improve environmental sustainability. The coefficients indicate that an improvement in environmental regulation will enhance environmental sustainability in SSA by about 0.247%, 0.233%, and 0.004%, respectively, in models (EFP, MFP, and SDI). These findings establish beyond a shadow of a doubt that better environmental regulations will ensure sustainable exploitation of natural resources, which tends to reduce the harmful environmental impact of natural resources in SSA. The results support the empirical findings of Abid (2017), Adams et al. (2020), and Duodu et al. (2021), arguing that the quality of environmental institutions and policies enhances environmental quality. With the control variables, we found in Table 5 that FDI harms environmental sustainability in the EFP and SDI models, but FDI degrades environmental sustainability in the MFP model. The positive effect of FDI on the environment is in line with Muhammad et al. (2021) reporting that FDI causes environmental degradation in BRICS and developing countries but improves the environment in developed economies. Similarly, domestic investment (DI) enhances environmental sustainability in all models. This outcome is also consistent with Duodu et al.'s (2021) argument that domestic investment is among the factors that enhance environmental quality. On the contrary, urbanization and trade openness degrade environmental sustainability in all models. Duodu et al. (2022) reported similar results in SSA that trade openness degrades the environment.

Moving to the long-run analysis (Table 6), we noticed that the long-run estimates reported in Table 6 are not significantly different from the short-run estimates. However, the emphasis here has to do with the magnitude of the impact in the long run. As revealed in Table 6, natural resources degrade environmental sustainability (ecological footprint and sustainable development index). The coefficients in the EFP and SDI models suggest that if natural resources increase by 1%, environmental sustainability will dwindle by about 0.118% and 0.042%, respectively. Adedoyin et al. (2020), Erdoğan et al. (2021), and Nathaniel et al. (2021a) reported similar findings. However, the impact of natural resources on the material footprint was negative and significant (thereby improving ES in the case of the short run). One observation is that the impact of natural resources on environmental sustainability, in the long run, tends to have a higher magnitude than in the short-run case. This suggests that the adverse long-run effects of natural resources on the environment are more crucial than the short-run. This is true since excessive exploitation of natural resources without conscious control will further deteriorate the quality of the environment in the long run more than in the short run. These results align with the studies by Zafar et al. (2019) and Bekun et al. (2019).

Table 6. Long-Run Effect of NR on ES.

System-GMM			
Variable	Model 1	Model 2	Model 3
	Coefficient	Coefficient	Coefficient
NR	0.1183**	-3.2764*	0.0420*
	(0.0589)	(1.7316)	(0.0241)
ERQ	-0.4639***	-5.5547**	-0.0377
	(0.1462)	(2.7726)	(0.0261)
NR*ERQ	-0.2417**	1.5308*	-0.0741*
	(0.1002)	(0.7765)	(0.0398)
FDI	-0.0051	0.1273**	-0.0015
	(0.0103)	(0.0498)	(0.0010)
lnDI	-0.1196**	-1.6213**	-0.0024
	(0.4720)	(1.0087)	(0.0064)
lnURB	1.3022***	1.4107***	0.0803
	(0.1435)	(0.6201)	(0.0393)
lnTO	0.2333***	2.8975***	0.0432
	(0.0728)	(0.5110)	(0.0415)
Constant	-3.8671*	-1.553***	-0.8383
	(2.3910)	(0.1025)	(0.6738)

Note: In Model 1, 2, and 3, the dependent variable is ecological footprint, material footprint and sustainable development index, respectively. *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. Standard errors are in parentheses.

Furthermore, Table 6 shows that improving environmental regulations in SSA has a more significant long-run impact on environmental sustainability than in the short run. Models (EFP, MFP and SDI) suggest that better environmental regulations enhance environmental sustainability in SSA by approximately 0.464%, 5.555%, and 0.038%, respectively. The higher magnitudes of environmental regulation indicate that if proper environmental regulations are well implemented in SSA, the negative repercussion emanating from excessive exploitation of natural resources on the environment would be curtailed in the long run. Abid (2017), Bokpin (2017), Adams et al. (2020), and Duodu et al. (2021) also reported that effective environmental policies and institutions improved environmental quality.

4.5. Marginal impact of NR on ES

It has been established from the unconditional impact that natural resources cause an unsustainable environment (in the EFP and SDI models) while improving the environment in the MFP model. However, to determine the actual effect of natural resources (NR) on environmental sustainability (ES), it is necessary to provide the marginal effect (conditional impact) (see Brambor et al., 2006). Given equation (2), the actual impact of NR on ES can be realized through the marginal effect ($\frac{\partial lnES_{it}}{\partial NR_{it}} = \rho_1 + \rho_3 ERQ$) due to the interaction term (NR*ERQ) but not the coefficient of NRE. As a result, we report the results of the marginal effects in Table 7.

From Table 7, it is revealed that if the environmental regulatory quality is improved or is at its mean, environmental sustainability wors-

Table 7. The Marginal Effect of NRE on ES.

Percentile	Percentile value	System-GMM		
		Model 1	Model 2	Model 3
		Coefficient	Coefficient	Coefficient
25%	-0.5119	0.1288**	-0.3845***	0.0074***
		(0.0411)	(0.0849)	(0.0025)
50%	-0.0119	0.0645**	-0.14302***	0.0039**
		(0.0282)	(0.0450)	(0.0014)
75%	0.4881	0.0002	0.0985*	0.0005
		(0.0392)	(0.0479)	(0.0023)

Note: In Model 1, 2, and 3, the dependent variable is ecological footprint, material footprint and sustainable development index, respectively. *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. Standard errors are in parentheses.

ens (or reduces) for every 1% increase in natural resources in the EFP and SDI models. Interestingly the conditional impacts are not different from the unconditional effects. The coefficients at the 25th to 75th percentiles in the EFP model imply that natural resources significantly reduce environmental sustainability by about 0.129%, 0.065%, and 0.0002% and by 0.007%, 0.004%, and 0.001% in the SDI model when environmental regulation quality is at its mean or improved. These results suggest that the quality of environmental regulations is necessary to ensure a reduction in the adverse environmental impact. However, its effective implementation in the case of SSA is questionable since an improvement in these regulations rather complements natural resources to induce an unsustainable environment. This outcome could be due to the high levels of corruption prevalent in SSA regions. As a result, improvements in environmental regulations to prevent unsustainable exploitation of resources are unlikely to materialize. Although the effect of natural resources reduces environmental sustainability, the impact seen in EFP and SDI models continues to diminish from the 25th to the 75th percentile. The indication is that with effective implementation of environmental regulations and rigorous enforcement, the negative effect of natural resources on environmental sustainability could gradually be reduced and improve the environment. The findings of the EFP and SDI models support the results of Adedoyin et al. (2020), Erdoğan et al. (2021), and Nathaniel et al. (2021a) that NR worsens ES.

In contrast to the findings in the EFP and SDI models, the MFP model indicates that if the environmental regulatory quality is improved at the 25th and 50th percentile levels, natural resources will be associated with an improvement of about 0.385% and 0.143% in environmental sustainability, respectively. Notwithstanding the effect at the 25th and 50th percentiles, it is shown that at a high percentile (75th), natural resources tend to worsen environmental sustainability by about 0.10%. This outcome could be attributed to the fact that as time progresses, the accumulation of material footprint through resource extraction can undoubtedly harm the environment. The result of the MFP model confirms the findings of Zafar et al. (2019), Bekun et al. (2019), and Xiaoman et al. (2021). However, these studies do not condition their findings on environmental regulatory quality as in this study.

The AR(2) and Hansen tests from Table 5 show that the estimates are accurate and efficient. This is because the p-values of AR(2) in all models, 0.494, 0.577, and 0.808, indicate nonrejection of the null hypothesis of no second-order serial correlation. Furthermore, the Hansen test also shows that the instruments are valid since the p-values of 0.651, 0.781, and 0.576 in models (1, 2, and 3), respectively, indicate nonrejection of the null hypothesis of instrument validity.

5. Concluding remarks

The exploitation of natural resources has been argued to degrade the quality of the environment in SSA. However, stringent environmental regulations are considered to prevent unsafe environmental practices. In line with this, the current study employed the system-GMM estimation technique to examine the connection between natural resources and environmental sustainability (proxied ecological footprint, material footprint, and sustainable development index) in SSA while considering the role of environmental regulatory quality for the period 2005-2017. Using 28 selected countries in SSA, we observed the following outcomes.

- Natural resources degrade the quality of the environment in both EFP and SDI models in both the short and long run.
- Environmental regulatory quality, on the other hand, improves environmental sustainability in SSA in both the short- and-long run.
- The unrelated view identified in this study is that as environmental regulatory quality improves, natural resources dampen environmental sustainability (Models 1 and 3).
- Based on the results, the study concludes that environmental regulatory quality does not complement natural resources to improve environmental sustainability in the case of selected SSA economies.

The implications of the above findings indicate that continuous or over dependence of natural resources in SSA would lead to future environmental unsustainability. As a result, this study suggests that governments, policy makers, and environmental regulators must ensure a considerable reduction in the unnecessary or excessive extraction (or consumption) of natural resources. This will ensure a maximum reduction of resources extraction and hence a clean environment. Additionally, we suggest that governments initiate policies that help provide advanced green equipment for extraction of natural resources, as this will ensure less adverse impact of natural resources on the environment. Furthermore, since natural resources dampen environmental sustainability despite environmental regulations in SSA, this study suggests that policymakers and governments should intensify implementation of environmental regulation policies to mitigate unsafe environmental practices (in particular, illegal extraction of resources) in SSA. This could be achieved if environmental regulation institutions are free from corruption and ensured effective and rigorous enforcement of clean environmental policies. One way is to force companies in natural resources extraction to adopt low carbon technologies, which have little or no environmental consequences. In all, ensuring the above suggestions and paying the greatest attention to inappropriate extraction of natural resources in SSA could have a greater positive influence on environmental sustainability, as the United Nations desired in the 2030 SDGs.

Declarations

Author contribution statement

Eric Fosu Oteng-Abayie; Gideon Mensah; Emmanuel Duodu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

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The authors declare no competing interests.

Additional information

No additional information is available for this paper.

Appendix A

Table A.1. Variable description.

Variable (Notation)	Measurement/Proxy	Source
Environmental Sustainability (ES)	Total ecological footprint, Material footprint and Sustainable Development Index.	GFN (2021) and GIF (2021)
Natural Resources (NR)	Total natural resources rents (% of GDP).	WDI (2021)
Environmental Regulatory Quality (ERQ)	Policy and institutions for environmental sustainability rating (1 = low to 6 = high).	WDI (2021)
Foreign Direct Investment (FDI)	Net inflows of foreign direct investment (% of GDP).	WDI (2021)
Domestic Investment (DI)	Gross fixed capital formation (% of GDP)	WDI (2021)
Urbanization (URB)	Urban population as a percentage of the total population	WDI (2021)
Trade Openness (TO)	Trade (% of GDP)	WDI (2021)

Note: GFN, GIF, and WDI represent global footprint network, global indicators framework, and World Development Indicators, respectively.

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