Mining and sustainable development in Sierra Leone: the role of institutional quality

Author(s) ORCID Identifier:
Ibrahim Massaquoi: 0009-0007-5749-8777

Mining and sustainable development in Sierra Leone: the role of institutional quality

Abstract

While mining can drive economic growth, create jobs, and promote infrastructural development, it also poses risks to the environment, human health, and social well-being. Therefore, to achieve sustainable development, responsible mining is crucial. This study empirically examines the role of institutional quality in the mining-sustainable development nexus in Sierra Leone. With the use of the planetary pressures-adjusted human development index (PHDI) as a comprehensive measure of sustainable development, the study is able to integrate economic, social, and environmental dimensions. The autoregressive distributed lag (ARDL) model confirms the existence of both short-run and long-run dynamics. The results of the study show that the contribution of mining to sustainable development depends on institutional quality, as framed by the resource curse hypothesis and institutional theory. The results indicate that weak institutions worsen the adverse effect of mining on sustainable development in Sierra Leone. Policy reforms that strengthen institutions and promote economic diversification will help regulate mining and transform mineral rents into sustainable development. This study is an advancement of the discourse on mining and sustainable development amidst weak institutions with insights from a resource-dependent economy.

Keywords

Mining, Resource dependence, Institutional quality, Sustainable development

Mining and sustainable development in Sierra Leone: The role of institutional quality

Ibrahim Massaquoi

Indonesia International Islamic University, Faculty of Economics and Business, Depok, Indonesia

Abstract

While mining can drive economic growth, create jobs, and promote infrastructural development, it also poses risks to the environment, human health, and social well-being. Therefore, to achieve sustainable development, responsible mining is crucial. This study empirically examines the role of institutional quality in the mining-sustainable development nexus in Sierra Leone. With the use of the planetary pressures-adjusted human development index (PHDI) as a comprehensive measure of sustainable development, the study is able to integrate economic, social, and environmental dimensions. The autoregressive distributed lag (ARDL) model confirms the existence of both short-run and long-run dynamics. The results of the study show that the contribution of mining to sustainable development depends on institutional quality, as framed by the resource curse hypothesis and institutional theory. The results indicate that weak institutions worsen the adverse effect of mining on sustainable development in Sierra Leone. Policy reforms that strengthen institutions and promote economic diversification will help regulate mining and transform mineral rents into sustainable development. This study is an advancement of the discourse on mining and sustainable development amidst weak institutions with insights from a resource-dependent economy.

Keywords: Mining, Resource dependence, Institutional quality, Sustainable development

1. Introduction

The relationship between mining and sustainable development has not been straightforward. While mining has often been viewed as essential for economic development, it can also lead to social and environmental issues [1]. Economically, mining accounts for shares of production and exports. Though mining can create employment and provide funds for social transfers, displacement and violent agitations are some of the known social vices [2]. Environmentally, mining revenues and material resources have been used to foster a healthy environment, but soil, water, and air pollution have been direct consequences of mining [3].

Previous empirical studies on mining and sustainable development have also had mixed results. On the one hand, studies [1,4,5] have found a positive relationship between mining and sustainable development. Researchers have provided several pieces of evidence and explanations for this relationship. In their study on Botswana, Lange, Wodon, and Carey [6] observed the positive role of diamond mining on sustainable development. They found out that effective management of mining revenue through policies ensured investment in education, healthcare, infrastructure, and the environment. Franks et al. [7] also observed a positive relationship between mining and sustainable development in Canada and Australia. They, however, noted that the implementation of corporate social responsibility (CRS) explains the positive relationship between mining and sustainable development. That is, transparency and community involvement foster sustainable development, which will outlast the mines.

Sierra Leone is a natural resource-dependent country. While mining is supposed to be a catalyst for economic growth and employment (SDG 8), creating more resilient infrastructure (SDG 9), and combating climate change and its impact (SDG 13), the case of most natural resource-dependent countries has not been straightforward. While Norway and Australia have been able to benefit

Received 18 January 2025; revised 19 August 2025; accepted 24 August 2025.
Available online 28 May 2026

E-mail address: ibrahim.massaquoi@uiii.ac.id.

https://doi.org/10.46873/2300-3960.1500

economically, socially, and also with better environmental standards from their mining, many natural resource-dependent countries in Africa, including Sierra Leone, continue to struggle with poverty, social upheavals, and poor environmental conditions. This study analyses the role of institutional quality given the hypothesis that poor institutions lead to corruption and misappropriation of mining revenues, resulting in poverty, social upheavals, and environmental degradation.

The contributions of this study are that most previous studies ignore the role of institutional quality in the relationship between mining and sustainable development, which might possibly account for the difference between those that have been able to develop out of mining and those that have been made poorer as a result of mining. Furthermore, sustainable development entails economic, social, and environmental considerations. Most previous studies have not been able to capture these three elements of sustainable development in one variable. Hence, estimating separate equations for economic, social, and environmental factors does not explain sustainable development as a whole. This study overcomes this challenge by using the Planetary pressures-adjusted Human Development Index (*PHDI*), which is more appropriate than the HDI because it goes beyond economic and social well-being to capture environmental and ecological well-being.

2. Stylised facts

The scatterplot in Figure 1 shows the relationship between mining in the form of natural resource rent and sustainable development measured by *PHDI* values. As shown in the figure, Norway and Australia have high *PHDI* values and lower reliance on natural resource rents. This illustrates the resource blessing hypothesis [8]. They argue that in countries with strong institutions, resource wealth is effectively managed and mostly invested in human capital, infrastructure, and social services, leading to sustainable development. On the other hand, Sierra Leone and Nigeria, as shown in the figure, have lower *PHDI* values and higher dependence on natural resource rents. This manifests the Resource Curse Hypothesis [9], where weak institutions result in resource mismanagement, corruption, and instability. As such, the interaction between resource rent and quality of governance is important. Acemoglu, Johnson, and Robinson [10] show that institutional quality limits the adverse effect of resource dependence. That is why Saudi Arabia, for example, has high resource rents and moderate *PHDI*, pointing out that though resources from mining provide economic growth, the constraints of weak institutions may limit the achievement of sustainable development.

The pictures in Figure 2 (published by the Sierra Leone Environmental Protection Agency and in the public domain) highlight the complex relationship

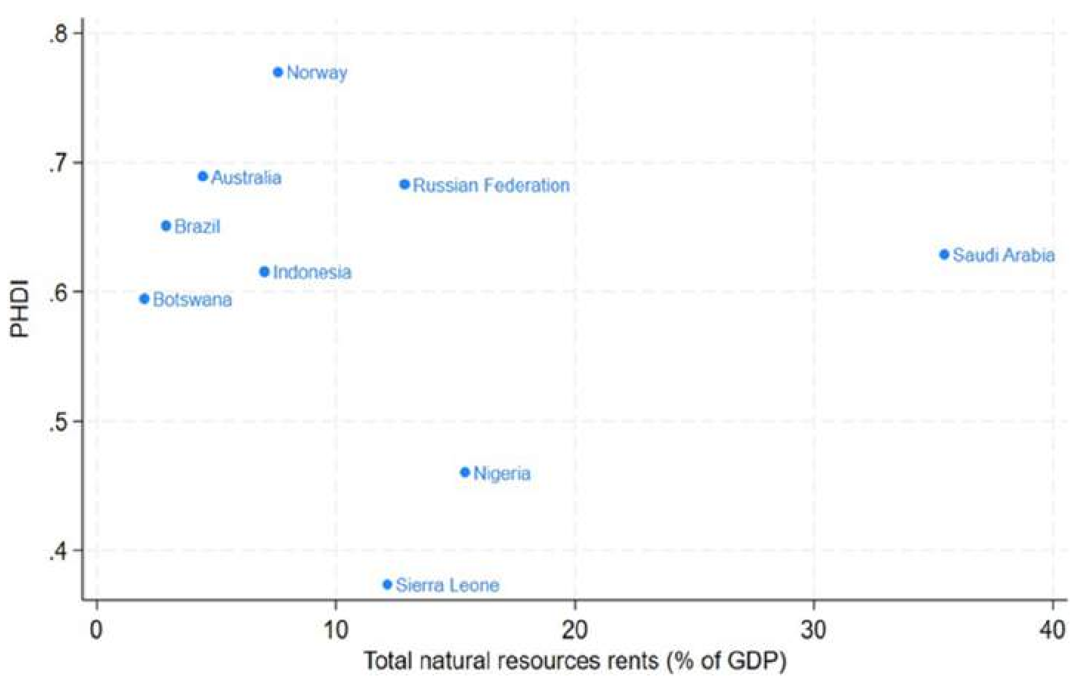

Fig. 1. Countries by resource rent and PHDI — 1990 to 2021 average. Source: Author's computation using UNDP and World Bank data.

Fig. 2. Pictures of mining in the Gola Forests of Sierra Leone (2020 images). Source: Sierra Leone Environmental Protection Agency 2020.

between mining and sustainable development in Sierra Leone. The figures show deforestation, land degradation, water pollution, and unsafe artisanal mining. While mining is an important contributor to the economy of Sierra Leone by providing foreign exchange earnings, employment, and revenue, its unsustainable practices undermine sustainable development. As depicted in the pictures, it destroys ecosystems, contaminates water sources, and threatens livelihoods dependent on agriculture and forests. Therefore, the pictures in Figure 2 highlight the necessity for strong institutions to establish effective environmental governance, which will promote sustainable mining practices and ensure that the country's mineral wealth contributes to sustainable development instead of leading to a resource curse.

3. Materials and methods

3.1. Model and data

The resource curse hypothesis suggests that resource dependence hinders sustainable development through corruption, rent-seeking, and economic volatility [11]. This negative impact of mining on sustainable development is expressed as:

$$PHDI = f(TNRR \quad -) \tag{1}$$

PHDI stands for the planetary pressures-adjusted human development index, which represents sustainable development, while *TNRR* refers to total natural resources rents as a percentage of *GDP*, indicating the role of mining. Institutionalists posit that institutional quality can mediate the impact of mining on sustainable development. They believe that strong institutions can help mitigate the negative effects of resource dependence by ensuring accountability, corporate social responsibility, and efficient and effective resource allocation [12]. This interaction is expressed as:

$$PHDI = f(TNRR \quad IQ \quad +) \tag{2}$$

The Kuznets curve (*EKC*) hypothesis proposes an inverted U-shaped relationship between environmental degradation and economic development. It suggests that as the income of people increases in a nation, environmental degradation initially increases and begins to decrease after a certain point.

That is: at a certain point, an increase in income or development will result in sustainability. Using per capita income for development (shortened as *GDP*) or increase in income, *PHDI* for sustainability (including the environment), and the *EKC*, expressed in equation (3) as:

$$PHDI = f \; GDP \;\; GDP^2 \tag{3}$$

Putting together equations (1)–(3) and including trade, the functional relationship becomes:

$$PHDI_t = {}_0 + {}_1TNRR_t + {}_2IQ_t + {}_3TNRR \;\; IQ_t + {}_4GDP_t + {}_5GDP^2 + {}_6Trade_t + e_t \tag{4}$$

The model derived in equation (4) integrates the effects of mining (resource rent), governance (institutional quality), the *EKC* effect, and trade. It is similar to Refs. [13–16]. The interaction term, *TNRR*IQ*, is based on the view that institutional quality is critical in determining whether mining fosters or hinders sustainable development. Table 1 contains variable definitions and data sources (see Table 1).

The *HDI* is a geometric mean of the three normalised indices – health index measured by life expectancy at birth, education index measured by mean years of schooling and expected years of schooling, and income index measured by gross national income (*GNI*) per capita and adjusted purchasing power parity (*PPP*).

$$HDI = (I_{\text{Health}} \times I_{\text{Education}} \times I_{\text{Income}})^{\frac{1}{3}} \tag{5}$$

The *PHDI* adjusts the *HDI* by a planetary pressure penalty *A*, which reduces the *HDI* based on CO_2 emissions per capita *C* and material footprint per capita *M*. The formula is:

$$PHDI = HDI \times (1 - A) \tag{6}$$

$$A = \frac{C + M}{2} \tag{7}$$

$$C = \frac{\ln(CO_{2\,\max}) - \ln \; CO_{2\text{country}}}{\ln(CO_{2\,\max}) - \ln(CO_{2\,\min})} \tag{8}$$

$$M = \frac{\ln(MF_{\max}) - \ln \; MF_{\text{country}}}{\ln(MF_{\max}) - \ln(MF_{\min})} \tag{9}$$

where:

$CO_{2\text{country}}$ is country's per capita CO_2 emissions,

MF_{country} is country's per capita material footprint,

max/min are UDNP benchmarks based on global distribution.

Table 1. Definition of variables and sources of data.

Variable	Code	Measurement	Source
Sustainable development	*PHDI*	Sustainable development is measured by the planetary pressures-adjusted human development index (*HDI*). It is measured as an index ranging from 0 (worst) to 1 (best)	UNDP
Mining	*TNRR*	Mining is measured by total natural resource rents as a percentage of *GDP*.	WDI
Institutional quality	*IQ*	Institutional quality is measured by the International country risk guide (ICRG) quality of government (QoG) index, which measures quality of government considering corruption, law and order, and bureaucratic quality. It ranges from 0 to 1, with higher values indicating better quality of government.	Political risk services (PRS) ICRG QoG data
Interaction term	*TNNR*IQ*	The interaction term is a product of the mining and institutional quality variables. It measures how much the effect of mining on sustainable development depends on quality of government.	Author's computation using PRS ICRG QoG and WDI data
Economic development	*GDP*	Economic development is measured by *GDP* per capita.	WDI
GDP square	*GDP²*	It is measured by the square of *GDP* per capita to capture any potential *EKC* effect.	Author's computation using WDI data
Trade openness	*Trade*	Trade openness is measured by trade, which is the sum of exports and imports of goods and services measured as a percentage of gross domestic product.	WDI

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
PHDI	33	0.375	0.058	0.299	0.459
TNRR	33	11.994	3.603	7.227	21.662
IQ	33	0.293	0.052	0.167	0.361
GDP	33	892.964	129.833	642.037	1146.82
TRADE	33	42.747	12.415	21.257	68.691

3.2. Econometric procedure

The first step undertaken is a summary of descriptive statistics of the variables. This enabled an understanding of the properties of the dataset, detection, and correction of anomalies [17]. Following this was the multicollinearity test using correlation coefficients. This is to detect highly correlated variables that might distort coefficient estimates and reduce the reliability of the model [18]. Important for a time series model like this is the stationarity test. This is done to ensure that the variables have a constant mean and variance over time, preventing spurious regression results and ensuring valid statistical inference. The Phillips-Perron test is used because it accounts for heteroscedasticity and serial correlation of the residuals [19]. Given that the variables have mixed order integration (I(0) and I(1)), the possibility of a long-run relationship is tested using the ARDL bound test [20].

ARDL has been proven to be efficient in estimating such variables (I(0) and I(1)). Secondly, sustainable development, which is the dependent variable, has been proven to be persistent [21]. Also, the independent variable, mining, normally has a lag effect on sustainable development given that the environmental effects are normally *ex-post* [13]. The general forms of the short- and long-run ARDL are expressed in equations (10) and (11).

$$y_t = a + \sum_{i=1}^{p} {}_i y_{t-i} + \sum_{j=0}^{q} \gamma_j x_{t-j} + e_t \tag{10}$$

$$y_t = \Theta_0 + \sum_{j=1}^{k} \Theta_i x_{j\,t} + u_t \tag{11}$$

where:

y is the dependent variable of sustainable development,

x is the vector of independent variables,

is the short-run constant,

and γ are the coefficients of the lag values of the dependent and independent variables, respectively,

p and q are the maximum lags for the dependent and independent variables, respectively.

Θ_0 and Θ_i are the long run constant or error correction term and the long run coefficient of the independent variables, respectively,

e_t and u_t are the residuals.

Diagnostic checks are done to assess the validity and reliability of the model estimates. The cumulative sum of squares recursive residuals (CUSUM squares) squared plot is used to test model stability to ensure there is no structural break or parameter instability [22]. The LM test for autocorrelation is performed to test whether the residuals are serially correlated, which could bias the estimates and invalidate statistical inference [23]. The White test is performed to establish whether the residuals are homoscedastic to make sure the model is well specified [24].

4. Results and discussion

4.1. Pre-estimation tests

As noted in the methodology, the empirical investigation begins with a summary of the descriptive statistics of the variables. Table 2 presents the results of the summary descriptive statistics.

The period covered in the study is 1990–2022, which provides an observation of 33. All the variables have 33 observations because their data is complete. There are no gaps or missing values. The mean *PHDI* and *IQ* are less than 0.4, indicating lower sustainable development and governance quality in Sierra Leone. Their standard deviations are low, showing less variability. The mean *TNRR* is 12.11, and the maximum is 21.66, showing a high mining contribution. The mean trade is 41.5%, and the maximum is 68.69%, indicating high trade openness and contribution of trade. Average *GDP* per capita is 892.964 United States Dollars (USD), which shows that Sierra Leone is a least developed country (LDC). The high standard deviation and the difference between the minimum and maximum values indicate high income inequality in the country and a possible rebound in economic growth after the civil wars between 1996 and 1998. Next is the test for multicollinearity. Table 3 shows the result of the multicollinearity test.

Table 3. Matrix of correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) *TNRR*	1.000					
(2) *IQ*	−0.737	1.000				
(3) *TNRR**IQ*	0.782	0.545	1.000			
(4) *GDP*	0.391	0.119	0.308	1.000		
(5) *GDP*^{2}	0.400	0.144	0.303	0.997	1.000	
(6) *Trade*	0.303	0.184	0.156	0.218	0.227	1.000

RESEARCH ARTICLE

The correlation coefficient for each set of predictors, except for *GDP* and *GDP*2, is much less than 1; this indicates no multicollinearity, which could distort the coefficient estimate [25]. The correlation coefficient of *GDP* and *GDP*2 is close to 1 because the latter is calculated based on the former. The high correlation between *GDP* and *GDP*2 is addressed by the dynamic structure of the ARDL model through the operation of their lagged values and the error correction formulation [26,27]. Unit roots of the variables are also examined, and the results are in Table 4.

The *PP* unit root test results in Table 4 show that the interaction term, *TNRR*IQ*, *GDP*, and *GDP*2 are stationary at the level. *PHDI*, *TNRR*, *IQ*, and Trade are stationary after first differencing. That is, the variables are I(0) and I(1). As such, the next step is to test the presence of a long-run relationship between the variables. Since the variables are of mixed order of integration, the ARDL bounds test for cointegration is applicable [22]. But before the cointegration test, the optimum lag order selection is done using the Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQIC), and Schwarz Bayesian Information Criterion (SBIC). The optimum lag is 3.

The results of the cointegration test in Table 5 show that the *F* value of 5.281 is higher than the upper bound value at 5%. As such, the null hypothesis of no cointegration is rejected. This indicates the presence of a long-run relationship. See Table 5.

Table 5. Pesaran, Shin and Smith (2001) ARDL bounds test for cointegration.

$F = 5.281$								
	[I_0] L_1	[I_1] L_1	[I_0] L_05	[I_1] L_05	[I_0] L_025	[I_1] L_025	[I_0] L_01	[I_1] L_01
k_6	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43

4.2. Long- and short-run effects of mining on sustainable development

Having confirmed through the stationarity and cointegration tests that the variables are integrated at levels and after first differencing and that they are cointegrated, the ARDL approach is used to estimate both the long-run and short-run effects of mining on sustainable development. The results are in Table 6.

The ARDL estimate in Table 5 provides insight into both the short-run and long-run relationship between sustainable development and mining and institutional quality measured by the Planetary-Adjusted Human Development Index (*PHDI*), Total Natural Resources Rents (*TNNR*) as a percentage of *GDP*, and institutional quality (*IQ*), respectively. The short-run estimated coefficient of *TNRR* indicates that mining has a significant negative effect on sustainable development. Mining (artisanal and large-scale diamond, iron ore, rutile, and bauxite mining in Sierra Leone) generates immediate environmental and social costs that outweigh its benefits. These include deforestation, land degradation, water pollution, displacement of people, and threats to livelihoods dependent on agriculture and forests. This finding is similar to Moshupya et al. [28], who also found that gold mining has a

Table 6. Results of short- and long-run ARDL estimates.

Variable	Long run		Short run	
	Coefficient	Std. err.	Coefficient	Std. err.
TNRR	−0.271***	0.083	−0.012***	0.002
IQ	0.0362**	0.014	−0.242	0.193
*TNRR*IQ*	−0.152**	0.072	−0.102**	0.054
GDP	0.032**	0.016	−0.115**	0.077
GDP^2	0.151	0.315	0.024	0.121
Trade	0.008	0.004	−0.011	0.43
ECT			−0.624**	0.201

Note: ***, **, and * denote no unit root at 1%, 5%, and 10% respectively.

Table 4. Phillips-Perron (PP) test for unit root.

Variable	Level				First difference			
	Random walk with drift		Random walk without drift		Random walk with drift		Random walk without drift	
	t-statistic	5% CV	t-statistic	5% CV	t-statistic	5% CV	t-statistic	5% CV
PHDI	2.46	−1.95	−2.15	−3.57	−3.47**	−1.95	−4.28**	−3.57
TNRR	−1.36	−1.95	−3.99**	−3.57	−7.52**	−1.95	−7.32**	−3.57
IQ	−1.03	−1.95	−4.15**	−3.57	−3.99**	−1.95	−3.58**	−3.57
*TNRR*IQ*	−2.17**	−1.95	−4.57**	−3.57		−1.95		−3.57
GDP	−2.21**	−1.95	−3.95**	−3.57		−1.95		−3.57
GDP^2	−2.32**	−1.95	−3.98**	−3.57		−1.95		−3.57
Trade	−0.12	−1.95	−3.29	−3.57	−6.55**	−1.95	−6.37**	−3.57

Note: ***, **, and * denote no unit root at 1%, 5%, and 10% respectively.

negative effect on sustainable development in the Wits area of South Africa.

Although the coefficient of institutional quality is negative, it is not significant in the short run. That is, governance quality does not affect sustainable development in the short term. This negates the institutional-sustainable development hypothesis in the short term. The hypothesis that the effect of mining on sustainable development depends on institutional quality is also true, as the coefficient of the interaction term (IT) is negative and significant. This shows that in the short term, weak institutions exacerbate the negative effect of mining on sustainable development. This supports evidence of previous studies that resource rents have come along with elite capture, corruption, and rent-seeking behaviour, which inhibit effective environmental impact assessment (EIA) tests and investment into production and social services [2,29,30].

In the short run, the estimated coefficient for trade is also negative and significant. This finding is inverse to that of Zmami et al. [13], who found that there is a positive relationship between trade and sustainable development in Saudi Arabia. Sierra Leone's enormous trade deficit puts strain on its fiscal balance, which does not augur well for sustainable development. Also, the "race to the bottom" effect of attracting foreign direct investment (FDI) has left the country compromising on its environmental and labour standards, undermining its ecological sustainability and the social well-being of its citizens. This is compounded by the country's narrow export and resource-intensive economy, which puts pressure on the environment. Similarly, the short-run coefficient of *GDP* is negative and significant. This indicates that in the short term, there might be a trade-off (growth first, environment later), which might result in environmental degradation. This also confirms that Sierra Leone's growth is resource-driven, unequal, volatile, and environmentally costly, and immediate increases do not translate into sustainable outcomes. There is no evidence of the *EKC* effect, as *GDP* squared is not significant. This is contrary to Zmami et al. [13], who in the short run observed a positive relationship between mining and environmental sustainability.

For the long-run estimates, the error correction term is significant and negative. The coefficient of −0.624 suggests that deviations from the long-run equilibrium are corrected at a speed of 62.4% per period. This indicates a strong adjustment process toward the long-run relationship. Furthermore, the long-run coefficient of total natural resource rents is significant and negative. This shows that in the long run, as in the short run, mining is associated with lower sustainable development. This agrees with the resource curse hypothesis that resource dependence undermines long-term development. In Sierra Leone, the mining sector is heavily resource-dependent, environmentally destructive, and not well integrated into the wider economy. The continuous extraction of mineral resources depletes non-renewable resources, causing ecological damage. Unlike the short run, the long-run estimate for institutional quality is significant and positive. This suggests that governance quality matters for sustainable development in the long run, emphasising the importance of strong institutions in mitigating negative outcomes. This agrees with institutionalists like Acemoglu and Robinson [31]; Nguyen et al. [12]; and Hoinaru et al. [32].

The interaction between institutional quality and total natural resources rent results in a significant and negative long-run coefficient. This indicates that in the long term, weak institutions can worsen the negative impact of mining on sustainable development. This agrees with Kumah [33], who observes that weak institutions worsened the negative impact of gold mining in developing countries. The long-run coefficient estimates for trade and *GDP* are significant and positive. This evidence shows that in the long run, increasing trade fosters sustainable development. This agrees with Zmami et al. [13], who with Saudi Arabia as a study area, found that in the long run trade contributes to sustainable development through diversification and access to the global market. For *GDP*, it is suggested that in the long term, rising income fosters sustainable development. This might be as a result of less pressure on the environment for agriculture, forest resources and mining due to an increase in education, a wider scope of economic activities, and government support for health and infrastructure [34–36].

4.3. Post-estimation tests

The CUSUM squared plot in Figure 3 is used to test model stability to ensure there is no structural break or parameter instability, as developed by Brown [37]. The result is shown in Figure 3. The CUSUM plot shows that the red CUSUM squared line stays within the green boundaries (the critical bound of 5% significance) throughout the sample period (1990–2022). This evidence shows that no structural break was detected in the data, and the model's estimated coefficients are stable over time

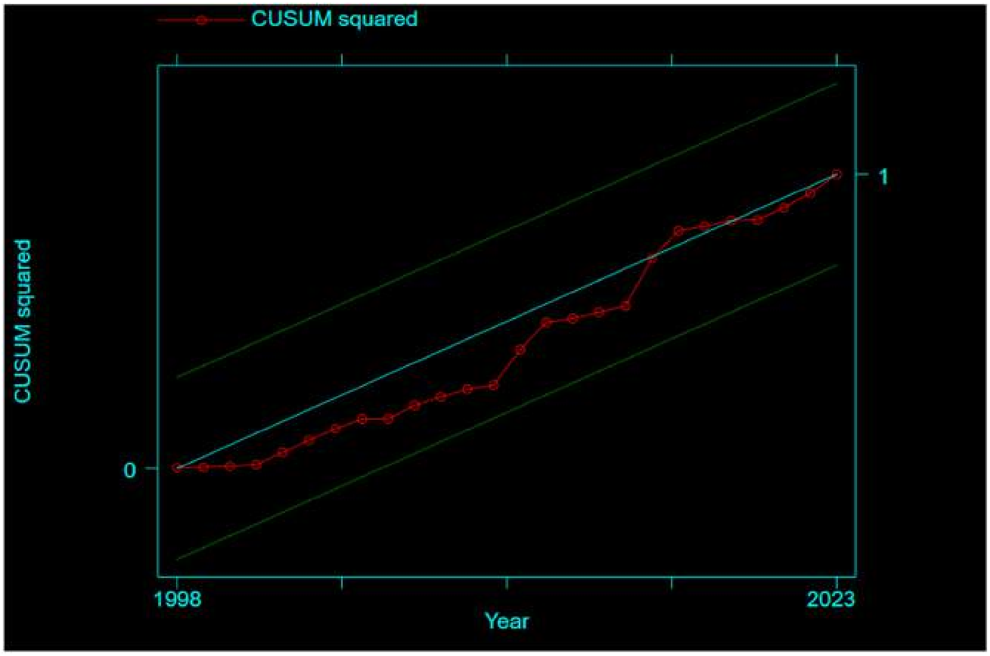

Fig. 3. Result of CUSUM test. Source: Author's computation using Stata 17.

[22]. Although Sierra Leone experienced a civil war from 1991 to 2000, using aggregated annual data may have reduced the impact of those shocks.

Furthermore, autocorrelation is also tested, and the result is in Table 7.

The result of the Breusch-Godfrey LM test for autocorrelation in Table 7 above shows that the *p*-value is greater than 0.05, and hence the null hypothesis that there is no autocorrelation is not rejected. This means that the residuals are not serially correlated, and hence the estimates are not biased, and any statistical inference made is valid [38]. In addition, homoscedasticity is also tested, and the result is in Table 8.

The result of the White's test in Table 8 shows that the *p*-value is greater than 0.05, and hence the null hypothesis of homoscedasticity is not rejected. Hence, the model is considered well-specified [24].

Given *p*-values of over 0.05, the results of Cameron and Trivedi's decomposition of the IM-test (Table 9) show that the model does not suffer from heteroskedasticity, skewness, and kurtosis individually and in total. This indicates that the model is well-specified and does not exhibit heteroskedasticity, skewness, or kurtosis in the residuals. Normality of the residuals is also tested using the Jarque-Bera test. Table 10 shows the results.

The results in Table 10 show that there is no skewness or kurtosis in the residuals, and the joint, which combines both kurtosis and skewness, also shows that the residuals are normally distributed. This is also confirmed by the histogram of fitted residual values of the estimated ARDL model overlaid with a probability density curve in Figure 4.

The histogram is approximately bell-shaped and symmetrical. Most of the fitted residual values,

Table 7. Result of Breusch-Godfrey LM test for autocorrelation.

Lags (p)	chi2	df	Prob > chi2
1	2.557	1	0.110

Table 8. Result of White's test.

chi2	Prob > chi2
32.00	0.4180

Table 9. Cameron & Trivedi's decomposition of IM-test.

Source	chi2	*df*	*p*
Heteroskedasticity	32.000	31	0.418
Skewness	12.330	13	0.501
Kurtosis	2.350	1	0.125
Total	46.680	45	0.404

Table 10. Result of Jarque Bera test for normality.

Variable	Obs.	Pr(skewness)	Pr(kurtosis)	Joint test	
				Adj	chi2(2)
Residual	32	0.612	0.623	0.520	0.773

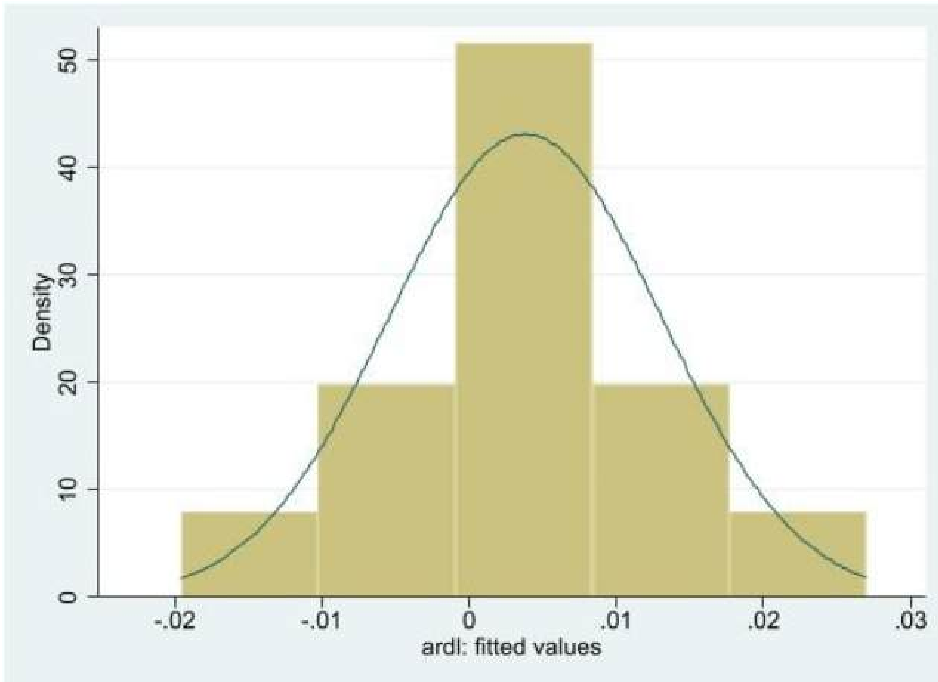

Fig. 4. Histogram of fitted residual values with normal density curve. Source: Author's computation using Stata 17.

cluster around the mean (0) and taper off toward both tails. There is no strong skewness and no obvious outlier.

5. Conclusions

The objectives of the study are twofold. Firstly, it examines the effect of mining on sustainable development in Sierra Leone. Secondly, the role of institutional quality in the effects of mining on sustainable development in Sierra Leone is investigated. The results of the econometric estimation show the negative impact of mining on sustainable development in both the short run and long run, indicating the prevalence of the resource curse. Sierra Leone's heavy reliance on mining faces challenges in translating resource wealth into sustainable development. However, strong institutions improve sustainable development in the long run. Sierra Leone's weak institutions exacerbate the negative effects of mining on sustainable development, suggesting governance reforms as critical in overcoming this resource curse. Also, in the short-run and long-run dynamics of the estimation is that the short-run negative effects of economic trade and economic growth on sustainable development reflect immediate trade-offs, including inequality and environmental degradation. Their long-term positive impacts emphasise the importance of policies that align short-term objectives with long-term sustainability. This strong adjustment toward the long-run equilibrium suggests that any deviations from sustainable development are corrected over time. This, however, requires strong institutions and policy reform.

Consequent to the findings, for mining to promote sustainable development, policymakers for Sierra Leone should consider establishing and enforcing a transparent mineral revenue management framework, including sovereign wealth funds, that allocates a substantial share of mining revenue to education, healthcare, land reclamation, and renewable energy. With regard to institutional quality, policy measures should aim to prioritise reforms such as clear extraction thresholds, accountability, transparency, and effective implementation of EIA. EPA should ensure that mining companies use energy-efficient equipment to reduce emissions and costs, as well as implement efficient technology that guarantees precision, reduces waste, and optimises extraction. Strong institutions are required to amplify the positive impact of mining on sustainable development. For economic development to foster sustainable development, policymakers should pursue inclusive growth and economic diversification policies, including agriculture, manufacturing, and services, that ensure rising GDP per capita translates into well-being. In terms of trade, policymakers must embark on export-oriented policies that encourage less resource-intensive and more value-added exports. This will enhance access to the global market while ensuring environmental sustainability.

Though the study provides valuable insights into the relationship between mining, institutional quality, and sustainable development, there are some limitations inherent in its design, data, and methodology that should be acknowledged and suggest possible areas for future research. Firstly, as noted by The India Forum, the PHDI is based on a relative scoring comparing countries to each other rather than against an absolute planetary boundary, which can be misleading. John Hickle also pointed out that the PHD adjustment factor places a high value on emission and material footprints more than other environmental factors like natural disasters, which makes ecologically unstable countries like Ireland and Switzerland rank high. While secondary data for mining (total natural resources rent), institutional quality (ICRG governance indicator), and sustainable development (PHDI) provide a broad measure, they might not fully capture the nuanced and dynamic aspects of mining and its impact on sustainable development. Future studies could benefit from primary data collection, which could include more granular measures of mining, governance, and the dimensions of sectoral, economic, social, and environmental impacts.

Ethical statement

The author states that the research was conducted according to ethical standards.

Funding body

This research received no external funding.

Conflicts of interest

The author declares no conflict of interest.

Acknowledgments

The author acknowledges the Environmental Protection Agency (EPA) of Sierra Leone for their extensive publications on the effects of mining on the environment. The author also acknowledges the supports of faculty members of the Faculty of Economics and Business of the Indonesian International Islamic University (UIII).

References

[1] Koitsiwe K, Adachi T. Australia mining boom and Dutch disease: analysis using VAR method. Procedia Econ Finance 2015;30:401−8. https://doi.org/10.1016/s2212-5671(15)01307-6.

[2] Voors M, Van Der Windt P, Papaioannou KJ, Bulte E. Resources and governance in sierra leone's civil war. J Dev Stud 2017;53(2):278−94. https://doi.org/10.1080/00220388.2016.1160068.

[3] Lima AT, Mitchell K, O'Connell DW, Verhoeven J, Van Cappellen P. The legacy of surface mining: remediation, restoration, reclamation and rehabilitation. Environ Sci Pol Dec. 2016;66:227−33. https://doi.org/10.1016/J.ENVSCI.2016.07.011.

[4] Maranon M, Kumral M. Empirical analysis of Chile's copper boom and the Dutch disease through causality and cointegration tests. Resour Policy 2021;70. https://doi.org/10.1016/j.resourpol.2020.101895.

[5] Gwebu TD. Botswana's mining path to urbanisation and poverty alleviation. J Contemp African Stud 2012;30(4):611−30. https://doi.org/10.1080/02589001.2012.724868.

[6] Lange G-M, Wodon Q, Carey K. The changing wealth of nations 2018: building a sustainable future. 2018. https://doi.org/10.1596/978-1-4648-1046-6.

[7] Franks DM, Davis R, Bebbington AJ, Ali SH, Kemp D, Scurrah M. Conflict translates environmental and social risk into business costs. Proc Natl Acad Sci USA 2014;111(21):7576−81. https://doi.org/10.1073/pnas.1405135111.

[8] Mehlum H, Moene KO, Torvik R, Mehlum H, Moene KO, Torvik R. Institutions and the resource curse. Econ J 2006;116(508):1−20 [Online]. Available: https://econpapers.repec.org/RePEc:ecj:econjl:v:116:y:2006:i:508:p:1-20. [Accessed 14 January 2025].

[9] Sachs J, Warner A. Natural reaource abundance and econmic growth. Natl Bur Econ Res 1995;3:54.

[10] Acemoglu D, Johnson S, Robinson JA. The colonial origins of comparative development: an empirical investigation. Am Econ Rev 2001;91(5):1369−401. https://doi.org/10.1257/AER.91.5.1369.

[11] Papyrakis E. The resource curse - what have we learned from two decades of intensive research: introduction to the special issue. J Dev Stud Feb. 2017;53(2):175−85. https://doi.org/10.1080/00220388.2016.1160070.

[12] Nguyen CP, Su TD, Nguyen TVH, Nguyen CP, Su TD, Nguyen TVH. Institutional quality and economic growth: the case of emerging economies. Theor Econ Lett Jul. 2018;8(11):1943−56. https://doi.org/10.4236/TEL.2018.811127.

[13] Zmami M, Ben-Salha O, Almarshad SO, Chekki H. The contribution of mining sector to sustainable development in Saudi Arabia. J Sustainable Min 2021;20(2):122−35. https://doi.org/10.46873/2300-3960.1056.

[14] Horowitz L. Section 2: mining and sustainable development. J Clean Prod 2006;14(3−4):307−8. https://doi.org/10.1016/j.jclepro.2005.03.005.

[15] Baninla Y, Wang C, Pu J, Gao X, Zhang Q. Evaluating the progress and identifying future improvement areas of mining's contribution to the sustainable development goals (SDGs). Extr Ind Soc Sep. 2025;23. https://doi.org/10.1016/J.EXIS.2025.101637.

[16] Mvile BN, Bishoge OK. Mining and sustainable development goals in Africa. Resour Policy Mar. 2024;90:104710. https://doi.org/10.1016/J.RESOURPOL.2024.104710.

[17] Mishra P, Pandey CM, Singh U, Gupta A, Sahu C, Keshri A. Descriptive statistics and normality tests for statistical data. Ann Card Anaesth Jan. 2019;22(1):67. https://doi.org/10.4103/ACA.ACA_157_18.

[18] Suleiman AA, Suleiman AA. Analysis of multicollinearity in multiple regressions. Int J Adv Technol Eng Sci April 2015; 2015 [Online]. Available: www.ijates.com.

[19] Phillips PCB, Perron P. Testing for a unit root in time series regression. Biometrika Jun. 1988;75(2):335. https://doi.org/10.2307/2336182.

[20] Kripfganz S, Schneider DC. ARDL: estimating autoregressive distributed lag and equilibrium correction models. London Stata Conf Sept 2018;7:1−44.

[21] Hernandez-Huerta A, Perez-Maqueo O, Zamora ME. Can development be sustainable, comprehensive and coherent? Reg Cohes Dec. 2018;8(3):1−14. https://doi.org/10.3167/RECO.2018.080302.

[22] Kripfganz S, Schneider DC, Kripfganz S, Schneider DC. Introduction ARDL model bounds testing stata syntax example conclusion ardl: Stata module to estimate autoregressive distributed lag models ARDL: autoregressive distributed lag model [Online]. Available: http://www.kripfganz.de/stata/. [Accessed 18 May 2023].
[23] Stock JH, Watson MW. Introduction to econometrics, Fourth Edition, 2nd Ed., Vol. 20, No. 1. Boston Massachusetts: Pearson Addison Wesley; 2020.
[24] White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica May 1980;48(4):817. https://doi.org/10.2307/1912934.
[25] Shrestha N. Detecting multicollinearity in regression analysis. Am J Appl Math Stat 2020;8(2):39–42. https://doi.org/10.12691/ajams-8-2-1.
[26] Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. J Appl Econom May 2001;16(3):289–326. https://doi.org/10.1002/jae.616.
[27] Pesaran MH, Pesaran MH, Shin Y, Smith RP. Pooled mean group estimation of dynamic heterogeneous panels. J Am Stat Assoc 1999;94(446):621–34. https://doi.org/10.1080/01621459.1999.10474156.
[28] Moshupya P, Abiye T, Mouri H, Levin M, Strauss M, Strydom R. Assessment of radon concentration and impact on human health in a region dominated by abandoned gold mine tailings dams: a case from the west rand region, South Africa. Geosci 2019;9(11). https://doi.org/10.3390/geosciences9110466.
[29] Stevens CMB, Bojang OA, Amara E, Msuya AS. Comprehensive overview of deforestation dynamics and sustainable forest management in Sierra Leone. Eur J Ecol Bio Agric Mar. 2025;2(2):18–29. https://doi.org/10.59324/EJEBA.2025.2(2).03.
[30] Mabey PT, Li W, Sundufu AJ, Lashari AH. Environmental impacts: local perspectives of selected mining edge communities in Sierra Leone. Sustainability Jul. 2020;12(14):5525. https://doi.org/10.3390/SU12145525.
[31] Acemoglu D, Robinson J. The role of institutions in growth and development. Rev Econ Inst Sep. 2010;1(2). https://doi.org/10.5202/rei.v1i2.1.
[32] Hoinaru R, Buda D, Borlea SN, Vaidean VL, Achim MV. The impact of corruption and shadow economy on the economic and sustainable development. Do they "sand the wheels" or "grease the wheels". Sustain Times Jan. 2020;12(2). https://doi.org/10.3390/su12020481.
[33] Kumah A. Sustainability and gold mining in the developing world. J Clean Prod Jan. 2006;14(3–4):315–23. https://doi.org/10.1016/J.JCLEPRO.2004.08.007.
[34] Mishra MK. The kuznets curve for the sustainable environment and economic growth. Leibniz Inf Cent Econ 2020; 29. 805–803.
[35] Abro AA, Alam N, Murshed M, Mahmood H, Musah M, Rahman AKMA. Drivers of green growth in the Kingdom of Saudi Arabia: can financial development promote environmentally sustainable economic growth? Environ Sci Pollut Res Feb. 2023;30(9):23764–80. https://doi.org/10.1007/S11356-022-23867-Z.
[36] Rashid Khan HU, Nassani AA, Aldakhil AM, Qazi Abro MM, Islam T, Zaman K. Pro-poor growth and sustainable development framework: evidence from two step GMM estimator. J Clean Prod Jan. 2019;206:767–84. https://doi.org/10.1016/j.jclepro.2018.09.195.
[37] Brown RL, Durbin J, Evans JM. Techniques for testing the constancy of regression relationships over time. J R Stat Soc, Ser B Stat Methodol Jan. 1975;37(2):149–63. https://doi.org/10.1111/J.2517-6161.1975.TB01532.X.
[38] Breusch TS, Godfrey L. A Review of recent work on testing for auto-correlation in dynamic simultaneous models. first ed. Routledge; 2015. https://doi.org/10.4324/9781315673943-4.