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RESEARCH

The Impact of Electricity Production on Environmental Quality: The Role of Institutional Quality in Ghana

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Abstract

The study investigated the impact of electricity production on environmental quality by specifically considering the role of institutional quality. The study used secondary data spanning from 1995 to 2021 and the autoregressive distributive lag model (ARDL) as a method of estimation. The findings revealed that electricity production, both in the short and long run, negatively affects environmental quality. Similarly, foreign direct investment and environmental quality were found negative both in the short and long run whereas economic growth and environmental quality had a positive relation in the short and long run. Furthermore, the findings showed that fossil fuel consumption in the long run has a negative impact on environmental quality. The study thus recommends that policymakers strengthen the various institutions to ensure that electricity production improves environmental quality. Thus, future studies should be geared toward the disaggregation of electricity production into different components and examine the effects of each component on environmental quality.

Keywords Electricity production · Environmental quality · Institutional quality · Autoregressive distributive lag model · Granger causality

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1 Introduction

Climate change has become a topical issue of concern around the globe due to its adverse effects on the environment, economy, and livelihoods. Khan et al. [1] affirmed that the greatest threat to sustainable development in the world is the deteriorating quality of the environment, which results from emissions of greenhouse gases (GHG). In all likelihood, the most challenging environmental problem facing humanity in this century will be global climate change. There is sound evidence that burning fossil fuels like coal, oil, and natural gas is changing Earth's climate by increasing the amount of CO_2 in the atmosphere [1]. Undeniably, energy is a major input for production and economic growth [2]. Luni and Majeed [3] asserted that energy demand is a catalyst for social and economic welfare and for fulfilling basic human needs.

Notwithstanding the great contribution of energy, especially electricity, to production, economic growth, and societal welfare, nations are formulating policies and industrial practices to create sustainable living conditions. Thus, tackling climate change is one of the major challenges from a policy perspective in both developed and developing countries among the sustainable development goals [4, 5]. In resolving the menace of the adverse effects of energy without compromising the quality of the environment, Luni and Majeed [3] and the World Bank [6] admitted that renewable technologies such as solar, wind, hydropower, geothermal, tidal, biomass, and biogas are key technologies for environmental conservation.

Climate change brought on by a decline in environmental quality in Africa is comparable to the situation worldwide. Under all climate scenarios with rising temperatures above 1.5 °C, Africa is the continent that is most affected by climate change. Despite having the lowest emissions and the least amount of greenhouse gas emissions, Africa faces exponential collateral damage that poses systemic risks to its economy, infrastructure investments, water and food systems, public health, agriculture, and livelihoods, threatening to undo its modest development gains and regress into higher levels of abject poverty [7].

The most frequently used kind of energy in Ghana is electricity, which was produced mostly by hydropower in the 1960s and supplemented by thermal power generation in the 1980s due to harsh and drought-prone weather changes that oscillated production. Ghana's power production has gone through several stages, beginning with diesel generators and independent electricity supply systems owned by industrial mines and factories, moving on to the hydro phase after the construction of the Akosombo dam, and now concentrating on a thermal complement phase powered by natural gas and/or crude oil derivatives. As a primary source of electricity, thermal power generation has gradually displaced hydroelectric power [8].

However, the production or consumption of electricity results in the emissions of greenhouse gases (GHG) into the environment, resulting in a deterioration of the quality of the environment. For instance, data shows that electricity generation of 4.01 trillion kilowatt-hours (kWh) results in CO_2 emissions ranging from 1.55

billion metric tonnes to 1.71 billion short metric tonnes from all energy sources, equating to around 0.85 pounds of CO_2 emissions per kWh, according to the Energy Commission [9]. Evidence suggests that electricity is Ghana's primary source of modern energy, which is increasing and is primarily used for industrial and service purposes (53%) and residential purposes (47%) [9]. Owning to the adverse effect of electricity production on the quality of the environment, the study examines the effect of electricity production on environmental quality in Ghana. This study contributes to the empirical literature in three strands.

The first strand is that studies on energy and environmental quality use different proxies. For example, Khan et al. [10], Omri et al. [11], and Aye and Edoja [12] used CO_2 emissions as proxies for environmental hazards. CO_2 emissions, however, are not always a reliable indicator of environmental deterioration. For example, Hassan et al. [13] and Ulucak and Apergis [14] argued that CO_2 emissions may not be a conclusive indicator of environmental deterioration in such areas as mining, oil, soil, and forests. Another indicator used in measuring environmental hazards is ecological footprint (EFP) as an aggregated indicator [1, 15]. The ecological footprint disregards the use of non-renewable resources, biodiversity, pollution, toxicity, and 78% of the Earth's surface which is considered non-biologically productive, among many other restrictions [16]. To address sustainable development and environmental quality issues, an aggregated indicator is therefore required. Different from previous studies, this one uses the environmental performance index as a measure of environmental quality. Environmental performance broadly measures climate change performance, environmental health, and ecosystem vitality.

The second strand in the environment and energy literature is that the role of institutional quality in regulating electricity production, especially in Ghana, has remained unexplored. Thus, making mitigation policies for environmental hazards ineffective. This study establishes empirically the impact of institutional quality on electricity production and environmental quality relationships. This information will be useful for future research.

The third strand is that there is a paucity of studies on electricity production and environmental-related hazards. Asumadu-Sarkodie and Owusu [17] tested the relationship between electricity production and consumption and carbon emissions in Ghana using disaggregated data. This study adds to the empirical literature by establishing the empirical relationship between electricity production and environmental quality by using aggregated data. By analysing aggregate data, policymakers and stakeholders will be able to analyse current energy policies, identify trends and patterns, gather relevant insights, and review current measures for strategic planning. The remainder of the study is organised as follows: The next section explains the review of related literature, followed by the methodology that describes the analytical techniques used in the data analysis as well as the data sources and descriptions. The results, presentation, and discussion are presented in the next section. The final section contains the results conclusions and implications.

2 Literature Review

Sustainable development entails meeting the needs of the current generation without jeopardising future generations' ability to meet their own. Global economies are concerned about climate change caused by deteriorated environmental quality caused by anthropogenic activities. The environment's role in promoting development and raising living standards is critical. Because an ecosystem provides the majority of the services that support and sustain life, its sustainability depends on a clean environment [18]. The sustainability of life on Earth is jeopardised by deteriorating environmental quality. Energy consumption is viewed as the primary cause of deteriorating environmental quality. Several studies have examined environmental-related challenges and energy production or consumption that cannot be overlooked. This study reviews the literature on the effect of electricity production on environmental quality.

The empirical research has primarily focused on the following: First, the study examines the environmental Kuznets curve (EKC) to see if it can link economic growth and pollution. According to the EKC hypothesis, economic growth causes environmental degradation in its early phases, but after a certain degree of growth, the growth processes contribute to improvements in environmental quality. The majority of these studies found evidence to support the existence of this hypothesis. Harbaugh et al. [19], Coondoo and Dinda [20], Omisakin [21], Dogan and Seker [22], Kang et al. [23], Adu and Denkyirah [24], Gill [25], and Pata and Samour [26] are some of these studies that include both panel and single-country analysis.

The second line of research looks at the relationship between CO_2 emissions, economic growth, and energy consumption. These studies essentially show that there is a long-term link between energy consumption and CO_2. Oteng-Abayie et al. [27], Shahbaz et al. [28], Anwar et al. [29], Asumadu-Sarkodie and Owusu [17], Kartal [30], Bekun et al. [31], Nan et al. [32], Majeed et al. [33], and many others are among the studies in this dimension.

Studies on energy consumption, economic growth, and financial sector development were examined in the third strand of literature on the energy-CO_2 relationship. The majority of these studies found that financial sector development leads to the use of more energy-efficient approaches, which improve environmental quality, particularly in developing economies (see, for example, [22, 34–37]). Other studies, on the other hand, argue that financial development leads to economic growth and subsequent pollution, and thus financial development leads to CO_2 emissions.

The four strands of the literature examine renewable energy and environmental quality. The majority of the findings showed a negative relationship between renewable energy and CO_2 emissions [38–41], and the findings of other studies were inconclusive [42, 43].

Lastly, the literature on energy and the environment has used various proxies and methodologies to measure environmental quality. Baloch [44] and Ben-Youssef et al. [45], for instance, used sulphur dioxide (SO_2), whereas Cole et al. [46] and Yahaya et al. [47] used nitrous oxide (NO_2). Conversely, Ansari [48] used the ecological and material footprint to assess environmental quality. Ahmad et al. [49], Chen et al. [50], Li et al. [51], and Mrabet et al. [52] used CO_2 emissions to measure environmental degradation, whereas Ahmed et al. [53, 54], Al-Mulali et al. [55], and Dogan et al. [56] used EFP as a proxy to measure environmental degradation. Altntaş and Kassouri [57] investigated the utility of the ecological footprint as a tool for measuring environmental quality. Sharif et al. [58] asserted that renewable energy improves environmental quality over time, whereas Alola et al. [59] discovered that non-renewable energy depletes environmental quality. According to Van-Tran et al. [60] and Destek and Sinha [61], renewable energy reduces ecological footprints, while non-renewable energy degrades the environment. Natural resources improve environmental quality, according to Balsalobre-Lorente et al. [62]. Danish et al. [63] discovered that natural resource rent contributes to a lower ecological footprint, whereas Danish et al. [13, 64] demonstrated that it reduces CO_2 emissions. Natural resources have a positive relationship with environmental quality.

In the case of Ghana, there are few studies. Asumadu-Sarkodie and Owusu [17] used an autoregressive distributed lag model. This study looked at the relationship between carbon dioxide, electricity production, and consumption in Ghana from 1971 to 2012. (ARDL). The study's main findings indicated that total energy production has long-run positive effects on carbon dioxide emissions, while hydroelectric and carbon dioxide had opposite results. This study, on the other hand, used disaggregated data from electricity production, which makes it impossible to identify the patterns of electricity production.

In conclusion, based on the empirical review, few studies have examined electricity production and environmental quality. It can also be ascertained that the findings from the energy and environmental quality relationship are inconclusive. Thus, the need for further research to establish the empirical relationship, especially in the case of Ghana, for policy purposes. Noticeably from the literature, the majority of studies used different measures to proxy for environmental quality and the findings from these studies are inclusive, thus a broad measure of environmental quality is required to establish a clear relationship between electricity production in Ghana and environmental quality. Furthermore, no empirical study has examined the role of institutional quality on electricity production and the environmental quality relationship, especially in the case of Ghana. Therefore, this study fills these gaps in the literature.

3 Methodology

The study examines the relationship between electricity production and environmental quality in Ghana by specifically examining the role of institutional quality using the autoregressive distributive lag model (ARDL).

3.1 Data Source

The study employed time series data extracted from the World Development Indicator [65], Environmental Performance Index [66], and Energy Commission Statistics

Table 1 Variable source and measurement

Variable	Measurement	Source
EPI	Environmental performance index	Environmental performance index
REELC	Electricity production (renewable electricity output(% of total electricity output)	WDI
Fuel	Fossil fuel (Ktoe)	Energy statistics report
GDP	Economic growth (current LCU)	WDI
IQ	Institutional quality index	World governance indicators
FDI	Foreign direct investment inflows, net (BoP, current US$)	WDI

[67]. The data for the variables span from 1995 to 2021 because the data available for the environmental performance index begins in the above range. The data set used for the study includes the environmental performance index (EPI), electricity production (REELC), fossil fuels, and institutional quality. An index was constructed for the institutional quality of the indicators (rule of law, control of corruption, regulatory quality, government effectiveness, political stability, absence of violence or terrorism, and voice and accountability) using principal component analysis. Achia et al. [68] attest that principal component analysis is a multivariate statistical technique that helps reduce the number of variables without losing too much information in the process. The principal component analysis helps in identifying the dimensions that are relevant in measuring institutional quality in developing countries such as Ghana. The principal components retained, that is, those with eigenvalues above one (1) for the creation of the institutional quality index, were

Table 2 Descriptive statistics

	LNEPI	LNREELC	LNIQ	LNFUEL	LNGDP	LNFDI	IQREELC
Mean	3.996	3.735	−0.295	8.724	23.936	20.381	−0.451
Median	3.953	4.212	−0.206	8.687	24.130	21.200	0.174
Maximum	4.605	4.605	0.560	9.133	26.853	22.079	6.964
Minimum	3.148	−0.481	−2.382	8.489	20.469	17.892	−9.745
Std. dev	0.565	1.314	0.670	0.182	2.063	1.586	5.490
Skewness	−0.287	−2.134	−1.178	0.602	−0.136	−0.269	−0.321
Kurtosis	1.632	6.420	4.534	2.329	1.659	1.270	1.892
Jarque-Bera	2.476	33.648	8.893	2.138	2.105	3.557	1.844
Probability	0.290	0.000	0.012	0.343	0.349	0.169	0.398
Correlation							
LNEPI	1						
LNREELC	0.040	1					
LNIQ	0.585	0.279	1				
LNFUEL	−0.481	−0.744	−0.606	1			
LNGDP	0.202	−0.668	−0.306	0.681	1		
LNFDI	0.127	−0.461	−0.236	0.600	0.903	1	
LNIQREELC	0.489	−0.148	0.230	0.119	0.616	0.750	1

control of corruption, government effectiveness, and regulatory quality. These indicators captured 78% of the variation. Table 1 shows the sources and measurements of the selected variables for the study.

3.2 Descriptive Statistics and Correlation Analysis

The descriptive statistical analysis of the variables for the study is shown in Table 2. The mean lnEPI, InREELC, InIQ, InFUEL, InGDP, InFDI, and IQREELC are 4.0%, 3.74%, −2.95%, 8.72 Ktoe, GHC23.94 billion, US$20.38 billion, and 4.51%. The results showed that lnEPI, InREELC, InIQ, InGDP, InFDI, and IQREELC are negatively skewed, whereas InFUEL is positively skewed. In terms of distribution, except for LNREELC and LNIQ, the jarque bera shows that the individual variables are normally distributed at a 5% level of significance. Overall, the variables were normally distributed at a 5% level of statistical significance. Testing the correlation that exists between InEPI and the other variables, the results show a negative relationship between InEPI and InFUEL and a positive relationship between InEPI and mean InEPI, InREELC, InIQ, InGDP, InFDI, and IQREELC.

3.3 Empirical Econometric Specification

In examining the effect of electricity production on environmental quality in Ghana, the study follows Asumadu-Sarkodie and Owusu [17] and Rahman and Vu [2] and expresses a linear function between the variables as given below.

$$EPI_t = f(REELC_t, IQ_t, FUEL_t, GDP_t, FDI_t, IQREELC_t) \quad (1)$$

The model variables are log-transformed for empirical estimation, which reduces the sharpness of the data and improves the distributional properties of the variables. Data issues related to autocorrelation and heteroskedasticity can be eliminated using natural logarithmic transformation. Results from log-transformed models are more reliable and effective than the results from the linear transformation [69]. Empirically, the environmental quality model can be expressed as given in Eq. 2.

$$lnEPI_t = \theta_0 + \theta_1 lnREELC_t + \theta_2 lnIQ_t + \theta_3 lnFUEL_t + \theta_4 lnGDP_t + \theta_5 lnFDI_t + \theta_6 lnIQREELC_t + \epsilon_t \quad (2)$$

where EPI_t is the dependent variables whereas the explanatory variables in years include $REELC_t$, IQ_t, $FUEL_t$, GDP_t, FDI_t, and $IQREELC_t$ and θ_0, θ_1, θ_2, θ_3, θ_4, θ_5, θ_6, and ϵ_t denote the error term and elasticities to be estimated.

3.4 Estimation Technique

The autoregressive distributive lag (ARDL) model was utilised to estimate the empirical model. The ARDL model estimate technique developed by Pesaran and Shin was used because the data sample size was small and because it does not require variable pretesting [17], hence avoiding uncertainty. According to Asumadu-Sarkodie and Owusu [70], the study used the ARDL cointegration approach to estimate the short- and long-term equilibrium connection between the dependent and independent variables, as described in Eq. (3).

$$\begin{aligned}\Delta lnEPI_t &= \theta_0 + \theta_1 lnEPI_{t-1} + \theta_2 lnREELC_{t-1} + \theta_3 lnIQ_{t-1} + \theta_4 lnFUEL_{t-1} + \theta_5 lnGDP_{t-1} \\ &+ \theta_6 lnFDI_{t-1} + \theta_7 lnIQREELC_{t-1} + \sum\nolimits_{i=1}^{p} \gamma_1 \Delta lnEPI_{t-i} + \sum\nolimits_{i=0}^{p} \gamma_2 \Delta lnREELC_{t-i} \\ &+ \sum\nolimits_{i=0}^{p} \gamma_3 \Delta lnIQ_{t-i} + \sum\nolimits_{i=0}^{p} \gamma_4 \Delta lnFUEL_{t-i} + \sum\nolimits_{i=0}^{p} \gamma_5 \Delta lnGDP_{t-i} \\ &+ \sum\nolimits_{i=0}^{p} \gamma_6 \Delta lnFDI_{t-i} + \sum\nolimits_{i=0}^{p} \gamma_1 \Delta lnIQREELC_{t-i} + \varepsilon_t\end{aligned} \tag{3}$$

where $p, \Delta, \theta_0, \gamma_1$, and ε_t are the lag orders of the variables the white noise, intercept, and the error term, respectively. In contrast to the alternative hypothesis of cointegration, the null hypothesis suggests that there is no cointegration among the series. The computed F-test corresponds to both the first and second critical values (lower and upper bounds) [71]. The null hypothesis of no cointegration between the variables is rejected if the estimated F-statistic exceeds the upper bound, and vice versa.

4 Results and Discussion

The empirical findings and discussions such as trends of energy type and environmental quality, unit root test, model selection and cointegration test, ARDL estimates, Granger causality, and diagnostics checks for results reliability are presented below.

4.1 Trends of Energy Types and Environmental Quality

Figure 1 depicts the trends of energy types and environmental quality in Ghana over the study period. The energy type was broadly categorised into electricity production or consumption and fossil fuel based on usage. The findings show that fossil fuel consumption has been increasing steadily throughout the study period, whereas electricity production or consumption fluctuates but decreases steadily over the

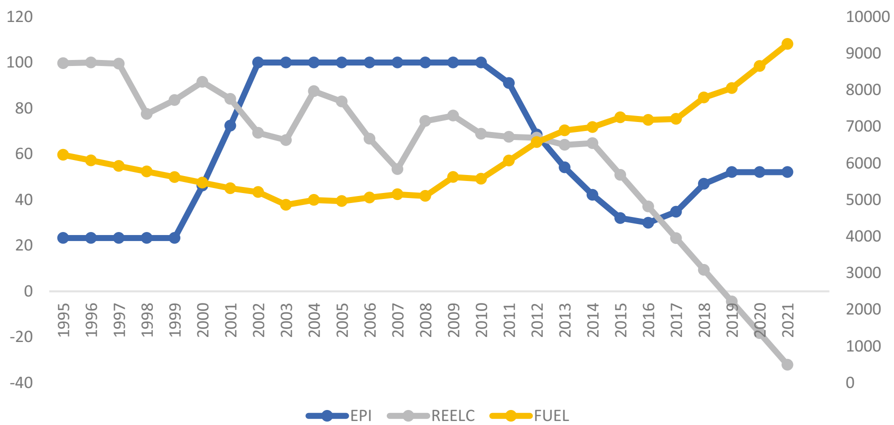


Fig. 1 Trends of energy type and environmental quality

study period. This implies that more fossil fuel-related energy is consumed more than that electricity production or consumption. This confirms the empirical findings of Acheampong et al. [8] that electricity production has been displaced recently. As a result of prolonged and recurring electricity supply crises, consumers have naturally turned to alternative energy sources. As a result, electricity consumption continues to fall. Contrarily, environmental quality over the study period fluctuates. The findings indicate that environmental quality showed stable (1995–1999 and 2002–2010), sharp rise (1999–2002), gradual decline (2010–2016), and rises steadily recently (2016–2021). This fluctuation in the quality of the environment maybe as a result of the various regulatory policies for protecting environment and the quest for economic growth leading to improvement and deterioration of the environment.

Overall, the fluctuation of the quality of the environment couples to a decline in electricity production or consumption over the study period. Energy and environmental issues are inextricably linked. Energy cannot be produced, transported, or consumed without having a significant environmental impact. Air pollution, climate change, water pollution, thermal pollution, and solid waste disposal are all environmental issues directly related to energy production and consumption. Contrary to the empirical findings that electricity consumption or production as a form of renewable improves the quality of the environment [72], the empirical findings in this study deviate from that conclusion. The effect of electricity production is further established in this study by the estimates of ARDL model in this study.

4.2 Unit Root Test

Unit root pretesting is frequently required for cointegration analysis. For most cointegration techniques, it is presumed that the economic variables are non-stationary at level 1 and stationary at level 2. The augmented Dickey-Fuller (ADF) and Philips-Perron unit root tests are used in the study, as shown in Table 3. At the 5% significance level, the null hypothesis of a unit root at this level cannot be rejected. Thus,

Table 3 Unit root test

Variables	Series	Augmented Dickey-Fuller test		Phillips-Perron test	
		$I(0)$	$I(1)$	$I(0)$	$I(1)$
Environmental quality	lnEPI	– 2.407	– 3.564**	– 2.407	– 2.605**
Renewable energy	lnREELC	4.865	– 6.682***	4.864	– 15.572**
Fossil fuel	lnFUEL	1.767	– 3.215**	0.862	– 3.188**
Institutional quality	lnIQ	– 2.091	– 4.465***	– 1.964	– 4.818***
Foreign direct investment	lnFDI	– 1.252	– 3.599**	– 1.114	– 3.562**
Economic growth	lnGDP	– 1.746	– 4.646***	– 1.761	– 4.647***
Institutional Quality*RENEWABLE ENERGY	REC*IQ	1.653	– 6.302***	2.694	– 6.302

**$p < 0.05$; ***$p < 0.01$

Table 4 Bounds test for cointegration

Test statistic	Null hypothesis: no long-run relationships exist	
	Value	*K*
Critical value bounds	4.118	6
Significance	*I*(0) bound	*I*(1) bound
10%	2.12	3.23
5%	2.45	3.61
2.5%	2.75	3.99
1%	3.15	4.43

at the 5% significance level, the alternative hypothesis of no unit root of the first difference cannot be rejected. The results of the stationary Phillips-Perron test reveal the same conclusions as the results of the augmented Dickey-Fuller test.

4.3 Model Selection and Cointegration

Following confirmation that lnEPI, InREELC, InIQ, InFUEL, InGDP, InFDI, and IQREELC are integrated into (1), the study utilised the Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ) to select the optimal lag before testing for cointegration. The study estimates the ARDL cointegration analysis using the optimal lag.

The study employed a bounded test for cointegration. The findings indicate that the *F*-statistic is above I(1) bounds at a 5% level of significance, indicating that there is cointegration among the variables as presented in Table 4. This implies that the null hypothesis of no long-run relationship among the variables at the 5% level of significance cannot be accepted, indicating that there is a long-run relationship among the series. Johasssen cointegration was also estimated to validate the results of the bounds, and the results are presented in Table 8 in the Appendix. The results conclude that there is a long-term relationship among the series. Thus, the ARDL model is estimated using the optimal lag as selected using the Akaike information criterion (AIC), as shown in Fig. 3 in the Appendix.

4.4 Short- and Long-Run ARDL Estimates

The empirical investigations of the effect of renewable energy on environmental quality results are presented in Table 5 below. Evidence from the model shows that the model is fit ($R - squared = 0.9791$, $Adjusted\ R - squared = 0.9666$, and $F - Statistic = 78.247(p - value = 0.0000)$) and can be used for making inferences.

In the short run, electricity production (LNREELC) has a negative effect on environmental quality at a 1% level of significance, indicating that an increase in the production of electricity in the short run leads to a 0.16% reduction in environmental

Table 5 ARDL estimates

Dependent variable: environmental quality selected model: ARDL(1, 0, 0, 1, 0, 0, 1)				
Variable	Coefficient	Std. error	*t*-statistic	Prob.
Short-run coefficients				
D(LNREELC)	−0.162	0.040	−4.002	0.0012
D(LNIQ)	0.005	0.058	0.090	0.9294
D(LNFUEL)	−0.688	0.709	−0.970	0.3476
D(LNGDP)	0.135	0.048	2.804	0.0134
D(LNFDI)	−0.201	0.045	−4.505	0.0004
D(IQREELC)	0.016	0.009	1.722	0.1057
ECM	−0.543	0.102	−5.305	0.0001
Long-run coefficients				
LNREELC	−0.298	0.087	−3.412	0.0039
LNIQ	0.010	0.105	0.091	0.9289
LNFUEL	−4.061	0.566	−7.176	0.0000
LNGDP	0.249	0.067	3.694	0.0022
LNFDI	−0.370	0.106	−3.507	0.0032
IQREELC	0.076	0.022	3.360	0.0043
C	42.169	5.102	8.265	0.0000
R-squared	0.9791			
Adjusted *R*-squared	0.9666			
F-statistic	78.247			
Prob(*F*-statistic)	0.0000			

quality. This finding confirms the empirical findings that electricity production negatively impacts the environment [72]. This is because electricity production results in the release of greenhouse gases and other air pollutants, the generation of solid waste, and discharges that pollute water bodies, thus reducing the quality of the environment. Similarly, lnFDI has a negative connection with InEPI, indicating that an improvement in the flow of foreign direct investment in the short run reduces environmental quality by 0.20% at a 1% level of significance. This is in line with the findings of Shahbaz et al. [73], who found that, while it is true for high-income countries, foreign direct investment does not reduce CO_2 emissions in low-income countries at all stages. This suggests that foreign direct investment regulations in developing nations encourage environmental pollution and deteriorate the quality of the environment. The increase in foreign direct investment, particularly in the industrial and production sectors, will pollute the environment in low-income countries over time, making the environment significantly unsustainable. Contrary to the above short-run findings, economic growth in the short run has a positive relationship with environmental quality. The empirical evidence indicates that improving economic growth by percentage results in a 0.14% improvement in environmental quality at a 5% level of statistical significance. These findings concur with those of Radoine et al. [74]. These findings concur with those of Radoine et al. [74]. The results demonstrate that GDP negatively affects CO_2 emissions, demonstrating the critical role that West Africa's economic development has in enhancing environmental quality. The results demonstrate that GDP negatively affects CO_2 emissions, demonstrating the critical role that West Africa's economic development has in enhancing environmental quality. The study finds no significant effect between institutional quality and the interaction of electricity production, fossil fuel, and institutional quality with environmental quality, even though the relationship is positive and negative for fossil fuel. In line with expectations, at the 5% level, the error correction term, which shows the speed of adjustment in correcting deviations to equilibrium, is negative and significant.

In analysing the long-run empirical results, the findings indicate a negative relationship between electricity production and environmental quality. This implies that a percentage increase in electricity production lowers environmental quality by 0.30% at a 1% level of significance. Consistent with empirical studies by Rashedi et al. [75] and Bond [76] that fossil fuel and electricity production have a negative effect on environmental quality. The climate crisis is centred on energy, and energy is essential to finding a solution. Burning fossil fuels, such as coal, oil, or gas, to produce electricity and heat is a major contributor to the greenhouse gases that cover the Earth, thus affecting the quality of the environment negatively. Similar to the short-run results, foreign direct investment lowers environmental quality by 0.37% at the 1% level of significance. Furthermore, at 1% significance level, fossil fuel consumption reduces environmental quality by 4.06%.

Similar to the short-run findings, economic growth and environmental quality in the long run have a positive relationship. The empirical findings indicate that economic growth improves environmental quality by 0.25% at a 1% level of significance. In line with expectation, the interactive effect of institutional quality and renewable energy improves environmental quality by 0.76% at the 1% level of significance. Consistent with the empirical results from Ali et al. [77], it shows that institutional quality lowers carbon dioxide emissions and, as a result, lowers the degree of environmental degradation in the countries that were studied. As a result of this finding, the level of environmental quality is increased by better and higher-quality institutional regulation of electricity production.

4.5 Granger-Causality Results

To determine the direction of causality among the series, the study estimated the Granger causality test, and the results are presented in Table 6. The empirical evidence indicates a bidirectional causal relationship from EPI to REELC, EPI to IQ, and EPI to IQREELC. Asumadu-Sarkodie and Owusu [17] used carbon emissions as an environmental factor. This finding backs up their previous research that found bidirectional causality between electricity production and environmental quality. One of the environmental effects of electricity generation is greenhouse gas emissions. Although hydropower, biomass, geothermal, and ocean power are generally low-carbon sources of energy, some power plants may have higher emissions due to poor design or other factors. Thus, higher institutional quality may lead to better regulation of electricity production, thus improving the quality of the environment.

Table 6 Granger-causality results

Null hypothesis:	*F*-statistic	Prob.
LNREELC does not Granger Cause LNEPI	0.82304	0.4534
LNEPI does not Granger Cause LNREELC	1.33878	0.2847
LNIQ does not Granger Cause LNEPI	0.66367	0.5259
LNEPI does not Granger Cause LNIQ	1.21548	0.3176
LNFUEL does not Granger Cause LNEPI	1.19781	0.3226
LNEPI does not Granger Cause LNFUEL	5.61438	0.0116
LNGDP does not Granger Cause LNEPI	0.50798	0.6093
LNEPI does not Granger Cause LNGDP	1.89166	0.1768
LNFDI does not Granger Cause LNEPI	0.72454	0.4975
LNEPI does not Granger Cause LNFDI	2.52039	0.1069
IQLNREELC does not Granger Cause LNEPI	2.48557	0.1086
LNEPI does not Granger Cause IQREELC	2.16066	0.1414

Evidences from Table 6 also indicate a bidirectional causality from EPI to GDP, EPI to FDI, and a unidirectional causality from EPI to FUEL. The unidirectional causality implies that fossil fuel consumption causes environmental quality, but the reverse does not hold. Ghana's overreliance on hydropower as a source of electricity generation resulted in an energy crisis that crippled its economy due to reduced rainfall inflow into the Akosombo dam (Ghana's main source of hydropower), which resulted in a transition to a thermal power plant (fuel: oil and gas) to support the hydropower during reduced rainfall.

4.6 Diagnostic Test

To prevent inaccurate results, model validation and verification are indispensable. The diagnostic and stability checks are used in the study to check the residuals' independence from the fitted model. If the residuals exhibit the necessary independence, diagnostic and stability checks can be performed; otherwise, a model modification is necessary before performing additional diagnostic and stability checks. This makes the model robust and unbiased for drawing appropriate statistical conclusions. Table 7 provides evidence that the ARDL model has no heteroskedasticity issues, no serial correlation issues at the appropriate lag orders, and residuals that are normally distributed (Jarque–Bera test).

Table 7 Diagnostic test

Variable	Coefficient	Prob.
Breusch-Godfrey serial correlation LM test	0.1610	0.8529
Heteroskedasticity test: Breusch-Pagan-Godfrey	1.3229	0.3035
Normality test: Jarque Bera	0.6306	0.7296

Stability Test

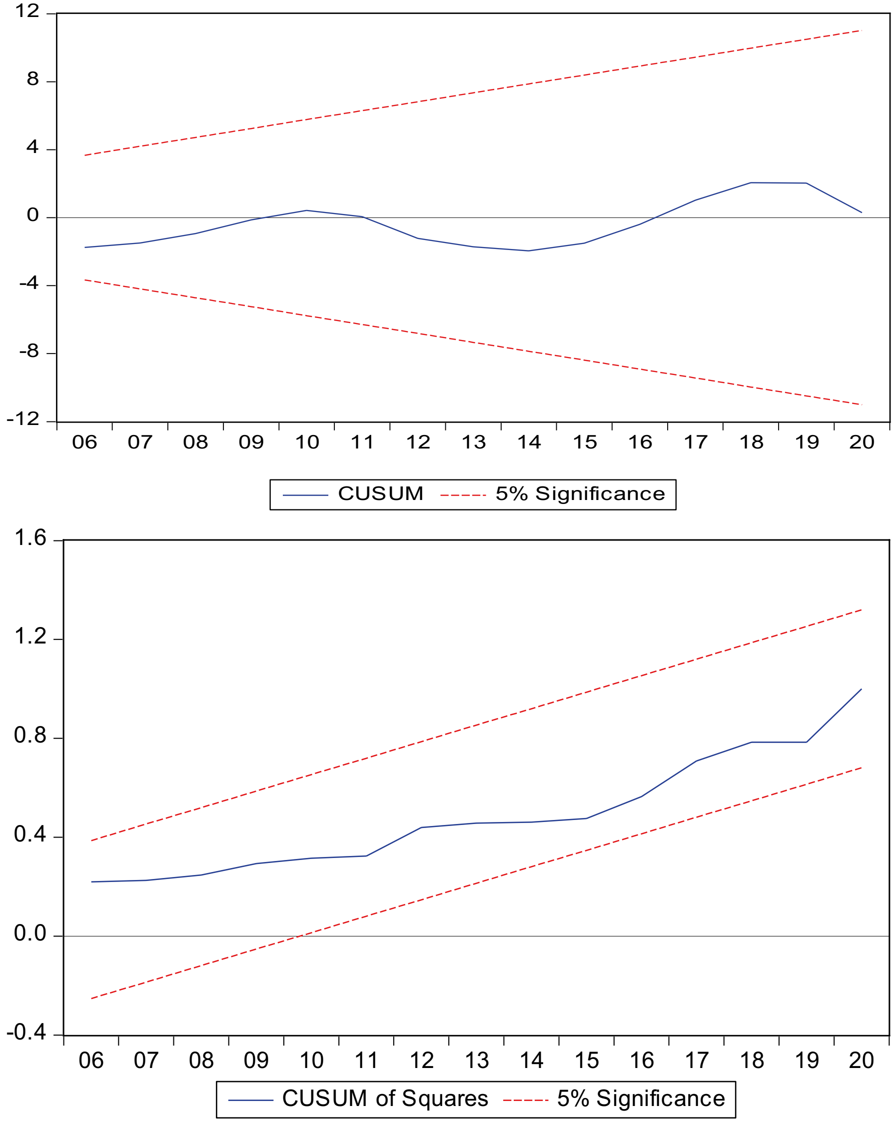


Fig. 2 The CUSUM of squares and the CUSUM test

To determine the ARDL model's structural stability, the study uses the CUSUM of squares and the CUSUM test. Figure 2 provides evidence that all plots in the CUSUM and CUSUM of Squares tests are within 5% of significance, or 2 standard errors (SE). The ARDL model's validity is supported by the fact that the equation's parameters are stable and constant.

5 Conclusions

The study examines the effect of renewable energy on environmental quality. The study's main goals were to assess the trends in energy consumption types and environmental quality, as well as the role of institutional quality in the relationship between renewable energy consumption and environmental quality in Ghana from 1995 to 2021, using secondary data. The study employed the autoregressive distributive lag model (ARDL) as the method of analysis for the data.

1. The study showed that both renewable energy consumption and fossil fuel energy consumption are asymmetrically related, while environmental quality fluctuates over the study period. However, environmental quality in recent years (2016–2021) was found to be increasing while renewable energy consumption declined.
2. Moreover, the results further indicated that renewable energy consumption and foreign direct investment, both in the short and long run, lower environmental quality in Ghana. The empirical evidence also concluded that economic growth improves environmental quality in both the short and long run. The results revealed that the interactive effect of institutional quality and renewable energy improves environmental quality.
3. The study further examined the causality among the variables. Evidence indicates two directions of causality. First, there is bidirectional causality between EPI and REELC, EPI and IQ, EPI and IQREELC, EPI and GDP, EPI and FDI, and unidirectional causality between EPI and FUEL.
4. The study thus recommends that policymakers strengthen various institutions to ensure that renewable energy consumption improves environmental quality. Thus, future studies should be geared toward the disaggregation of electricity production into different components and examine the effects of each component on improving environmental quality.

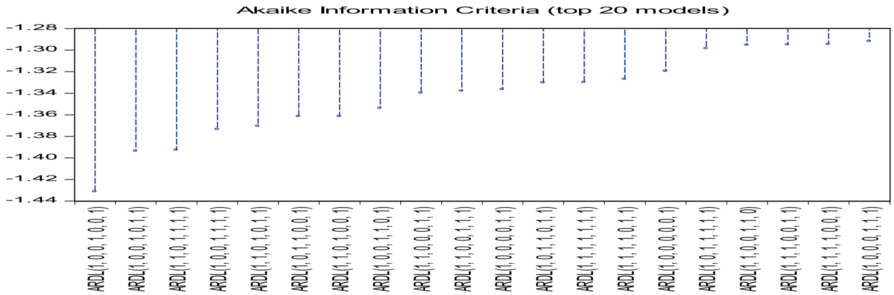
Appendix

Table 8 Unrestricted cointegration rank test (trace)

Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None*	0.980354	238.2730	125.6154	0.0000
At most 1*	0.889336	143.9554	95.75366	0.0000
At most 2*	0.813143	91.12532	69.81889	0.0004
At most 3*	0.703280	50.86747	47.85613	0.0254
At most 4	0.420840	21.70828	29.79707	0.3150
At most 5	0.284889	8.600067	15.49471	0.4037
At most 6	0.022755	0.552431	3.841466	0.4573

The * are showing the significance level

Fig. 3



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Author Contribution All authors worked on conceptualization. All authors worked on methodology/study design. All authors worked on software. All authors worked on validation. All authors worked on formal analysis. All authors worked on investigation. All authors worked on resources. All authors worked on data curation. All authors worked on writing original draft. All authors worked on writing review and editing. All authors worked on visualization. All authors worked on supervision. All authors worked on project administration. All authors reviewed the manuscript.

Data Availability The datasets generated and or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors declare no competing interests.

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