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Energy supply, institutional quality and environmental quality in West Africa

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Abstract

The study investigated energy supply, institutional quality and environmental quality in West Africa. This study used secondary data collected from World Development Indicator and World Governance Indicator between 2015 and 2024. Different estimation methods were used in analyzing the obtained data. This study considered static panel, panel autoregressive distributed lag model (Panel ARDL), generalized method of moment and panel quantile regression. These set of estimation techniques were used to check the consistencies in the results obtained. The findings from the Panel ARDL model revealed that, energy supply has a positive statistically significant effect on environmental quality with a coefficient value of 0.0016 and at 5% significance level suggesting that, improved electricity which can resuscitate the production activity of a country which in turn improves the quality of the environment. Moreover, the study findings showed that the institutional quality and environmental quality were significantly positively correlated at 5% level of significance with coefficient value of 0.0567. The result also showed that gross domestic product has positive and significant relationship with environmental quality with coefficient value of 0.2311 and at 5% level of significance supporting the Environmental Kuznets Curve (EKC) hypothesis which assumes that economic indicators influence the level of the environment. The study revealed that energy supply and institutional quality are factors that affect the quality of environment in West Africa. Thus, the study recommends that the governments should develop and enact policies to support sustainable economic growth. Governments need to invest in green infrastructure, renewable energy and environmentally friendly technologies to enhance environmental quality while promoting economic growth.

1. Introduction

With the worsening environmental degradation affecting the climate, the enhancement of environmental quality has become a major issue on the international agenda. Environmental quality improves a region's resilience to climate-related hazards such as bush fires, hurricanes, floods and sea level rise. Pham et al. (2024) claim that lowering CO2 emissions protects ecosystems and fights climate change. It promotes natural carbon absorption processes and aids in the prevention of extreme weather events. According to Hoa et al. (2024), environmental quality is crucial for many economies since it reduces emissions such severe storms, floods, and droughts, which are frequently produced by climatic imbalance brought on by high CO2. Additionally, reducing CO2 emissions creates opportunities for investments in clean energy technologies, job creation in the green economy, and sustainable economic development (Boyle et al., 2024). Improving energy efficiency, and lowering pollution are all part of improving environmental quality.

Energy supply plays a critical role in enhancing the economy situation of developing countries most especially in West African Countries by ensuring adequate distribution of electricity supply which leads to improved industrializationimprove people's quality of life and boost the economy's output of products and services (Chaurey & Kampala, 2020). A sufficient energy supply is essential for businesses and households to increase production, attract foreign investment and reduce production costs (UNCTAD, 2023). The energy sector is at the forefront of successfully reducing CO2 emissions and tackling climate change challenges in developed countries. However, despite regional governments' promises to increase power generating capacity, Africa's electrical subsector has been static for more than ten years (Oyedun, et al., 2025). Even if the energy production in the West African countries is increased, the distribution of electrical supplies in the area is still a problem and the problem has not been solved (Oyaromade, Mathew & Abalaba, 2021). Dada, et al., (2021); Kolawole (2026) posited in their work that strong institutional quality is important in fostering economic growth, reducing the dilemma of energy generation and distribution, as well as promoting sustainable development.

Building a secure and predictable climate that promotes investment requires an effective institutional structure that includes regulatory quality, corruption control, government effectiveness, voice, and responsibility. According to Acemoglu et al., (2005), nations with robust institutions that support private property and free entrepreneurship have witnessed economic growth, whereas those with weak institutions have endured decades of poverty and unproductivity. In order for nations to maintain energy infrastructure that can affect CO2 emission reduction, institutional quality is essential (Bhattacharya et al., 2017). For example, political stability and the lack of violence, government efficacy, control over corruption, the quality of regulations, the rule of law, and voice and accountability are all seen to be crucial components in reducing CO2 emissions. According to

Kolawole et al. (2020), an inadequate institutional framework causes distortions in the social, economic, and political structure, which impedes the region's economic and environmental development. Studies in the recent past shows conflicting results as to the connection between energy supply and environmental quality. al., (2020) and Onyeneke (2024) reported that energy supply is negatively related to environmental quality in Africa.Studies such as Ahmed et al., (2022), Onyeneke (2024) and Gueye (2025) showed that there is a statistically significant positive relationship between energy supply and environmental quality in Africa, while studies like Nasreen et al., (2020) and Onyeneke (2024) showed that energy supply is negatively related to environmental quality in Africa.

al., 2017; Adams et al., 2020; and Nasreen et al., 2020 reported a negative relationship. The conflicting results need further research to establish whether energy availability has a positive or negative effect on environmental quality as the area is still one of the poorest in the world in terms of energy availability. Previous studies (Kirikkaleli and Adebayo, 2021; Musibau 2021; Qudrat-Ullah and Nevo, 2021; Jinapor 2023) examined the impact of electricity supply on environmental quality, but did not consider the role of institutional quality. The need to examine institutional quality as a mediator in the relationship between energy supply and environmental quality was driven by the bias that was not addressed in these previous studies. This study used principal component analysis (PCA) to create an institutional quality index, in contrast to the few studies that considered institutional quality measurements of six variables independently: political stability and absence of violence, voice and accountability, government effectiveness, rule of law, regulatory quality, and control of corruption. This study also considered a number of estimating approaches to obtain a reliable comparison of the outcomes. Unlike previous studies which focused on a single methodology, the studies investigated the use of static panel, panel autoregressive distributed lag model (Panel ARDL), extended method of moment and panel quantile regression in analyzing the acquired data.

The study examines the impact of institutional quality, environmental quality and energy supply in West Africa on the basis of the above. The rest of the paper is organized as follows: section two reviews the previous studies and formulates the hypotheses; section three presents the data and methodology of the study; section four interprets the data and presents the results; and section five concludes the paper.

2. Literature Review

Theory of Institutional Economics

The theory of institutional economics is the theory that can be used to support this research, it can be connected with the research of Shleifer and Vishny (1993) and Myrdal and Sitohang (1957). Institutional economics theory (Shleifer & Vishny, 1993) suggests that the rule of law has a significant impact on growth. The performance of a country is directly influenced by the structure, trend and proper foundation of the country. In most emerging countries, the institutional system is flawed, corruption is a serious issue, and inefficient institutions severely limit the scope for economic growth. Another advantage that can significantly boost the economic growth and the efficiency of resource utilization in a country or region. However, the influence of the institution on countries varied depending on the level of development of the countries (Qiang & Jian 2020).

The core of the theory is that institutions are very relevant to the growth and development of countries because they have a significant influence on human behaviour. Although there is no universal definition of institutions, there is a general agreement in the studies about what institutions are, as well as their main functions and effects. There are many who think that institutions play a key role in shaping economic welfare or economic success. The novel analytical methods provided by institutional theory have been extremely beneficial to research in the areas of growth and domestic finance (Scott, 2008). The neoclassical economics' concept of equilibrium as a state of permanent balance is a natural step away from institutional economics in the face of the complexity and dynamism of the economy.

The institutional economic theory suggests that organizations can shape organizational behavior, especially if they provide monetary rewards. Most scholars and researchers think that institutions are essential to increasing domestic investment and improving the economy as a whole. The theory of institutional economics has been used in studies such as Salman et al. (2019) to explain the effect of the rule of law on a few selected variables of interest.

Environmental Kuznets Curve (EKC) hypothesis

In 1991, Gene Grossman and Alan Krueger presented the EKC theory, suggesting a relationship between macroeconomic variables and the environment. The theory is based on the assumption that the initial phase of economic activities is associated with environmental degradation and that the continuous improvement of the economic activities of an economy is associated with environmental quality. This assumption propelled a U-curve event in the association that existed in environmental issues and economic indicators (Budi & Syaifu, 2022).

Stern (2004) suggested that there are some proximate factors that can explain EKC. Increasing production is one of the factors affecting environmental quality; another factor is the different pollution intensities of several industries. The third aspect is changes in the input mix, which include substituting more ecologically harmful inputs with less harmful ones and vice versa. Finally, the use of technology in manufacturing will improve environmental quality. Based on this, EKC proposes that environmental quality rises at first as income rises, but then falls after a certain income threshold (Grossman & Krueger, 1991).

2.3 Empirical Evidence

2.3.1. *Energy supply and Environmental Quality*

It is well recognized that energy supply has a major role in reducing CO2 emissions in all of Africa's regions. Positive findings on the connection between environmental quality and energy availability have been reported in the literature. have, nonetheless, been inconsistent. Energy efficiency reduces environmental pollution both directly and indirectly, according to a paper by Jinapor et al. (2023). The study notably discovers that energy efficiency and energy consumption combine to reduce the emissions of greenhouse gas when compared to carbon and nitrous emissions. According to Adamasi (2023), the majority of developing nations, especially those in West Africa, have seen a decline in their energy infrastructure as a result of the neglect of environmental and energy-related issues. Mesagan (2022) found carbon emissions and a unidirectional causality between carbon emission pollution and energy consumption in emerging countries, supports the ecological modernization hypothesis. Ahmed et al. (2022), Musibau (2021), Qudrat-Ullah and Nevo (2021), Jinapor et al. (2023), Onyeneke (2024), and Gueye (2025) investigated the relationship between energy supply and environmental quality in developing economies in Africa. Nonetheless, the aforementioned research' findings demonstrated a positive and significant relations between Africa's environmental quality and energy supplies. In a similar vein, Aderinto (2023) investigated the impact of economic activity, energy consumption, and greenhouse gas emissions on health risks for developing Asian countries. They stated that the region's loss of natural resources, fossil fuel usage, and greenhouse gas emissions are the main causes of the growing health risks. According to Jinapor, et al. (2023), and Farhani et al., (2021), having an adequate supply of energy is crucial for reducing environmental issues related to energy use. In the backdrop of Africa's growing urbanization, Seraj et al. (2025), Onifade (2023), Achuo (2022), and Radoine et al, (2022) revealed favorable correlations between energy consumption and environmental quality.

However, research by Nasreen et al. (2017), Adams et al. (2020), and Nasreen et al. (2020) found that energy consumption increases CO2 emissions, supporting the EKC concept that short-term economic activity lowers environmental quality. Similarly, Wada et al. (2021) found that Brazil's CO2 emissions are increasing as energy consumption increases. This was corroborated in South Asia, where Munir and Riaz (2019) found that although lower electricity usage eventually enhances the quality of the environment, higher electrical consumption leads to environmental degradation. Ali et al. (2021) also noted that pollution emissions are strongly impacted by the energy used for economic activity.

2.3.2. Institutional Quality and Environmental Quality

Sah (2021) claims that institutional quality plays significant role in enhancing environmental protection. Mignamissi et al. (2024) investigates the relationship between African institutional quality and CO2 emissions. The study found that institutional quality significantly reduced CO2 emissions in Africa. Ibrahim et al. (2023), Bambi (2024), and Saboori et al. (2024) discovered that institutional quality characteristics were considerably and favorably favorable in decreasing CO2 emissions. According to Biala and Aromasodun (2024), maintaining both economic growth and environmental quality requires a solid institutional

framework and colonial history. Sah (2021) in his study shows institutional quality plays significant impact in enhancing environmental protection. Mignamissi (2024) investigates the relationship between African institutional quality and CO2 emissions. The study found that institutional quality significantly reduced CO2 emissions in Africa. The report also highlights the significance of the energy sector in reducing the impact of CO2 emissions in Africa. Ibrahim et al. (2023), Bambi (2024), and Saboori et al. (2024) in their studies revealed favorable impact of institutional quality on CO2 emissions. According to Biala and Aromasodun (2024), maintaining both economic growth and environmental quality requires a solid institutional framework and colonial history. Huyen & Ha (2026) contend that institutional quality influences CO2 emissions either directly or indirectly, making it a significant factor in lowering CO2 emissions. Additionally, Shabir et al. (2023) investigates the impact of institutional quality and environmental technology innovation on lowering greenhouse gas emissions. Lastly, Eberechukwu et al. (2024) discovered that an institutional quality framework may considerably reduce CO2 emissions in Africa.

However, Mignamissi, Ekoula, and Thioune (2024) found that improved institutions significantly and negatively impact pollution in Africa, supporting the environmental Kuznets curve concept. Bambi, Batatana, Appiah, and Tetteh (2024) revealed an increasing interaction between institutions and governance causes the ecological footprint to diminish beyond a certain point. Furthermore, better governance helps to mitigate the deterioration in institutional performance, and high institutional quality (IQ) is linked to a reduced environmental effect. There is a one-way causative link between ecological footprint, governance, infrastructure development, and energy usage, according to panel causality tests between the variables and control components.

Furthermore, better governance helps to mitigate the deterioration in institutional performance, and high institutional quality (IQ) is linked to a reduced environmental effect. There is a one-way causative link between ecological footprint, governance, infrastructure development, and energy usage, according to panel causality tests between the variables and control components.

3. Methodology

Secondary data from the World Development Indicator from 2015 to 2024 was used in the study. The sixteen West African nations included by the statistics are Burkina Faso, Benin, Côte d'Ivoire, Cabo Verde, The Gambia, Guinea, Ghana, Guinea-Bissau, Niger, Liberia, Nigeria, Mali, Sierra Leone, Mauritania, and Togo. This area was picked since it is among the world's poorest. Static panel regression, panel autoregressive distributed model, generalized method of moment (GMM), C-S ARDL, and panel quantile regression were all used in the study. Since the panel is small, C-S ARDL was selected as the main method for analyzing the data, and quantile was used to determine how institutional quality and energy availability affect energy supply over time. Nonetheless, GMM and static panel were used as a reliable check for the outcomes from both CSARD and Quantile regression.

Model Specification

Considering the reviewed literature, the model of the study was stated as:

ENVQ = *f* (ENE, FSD, INSQ, EXR, INF, LGDP) (1)

This model was further stated econometrically as:

$$ENVQ_{it} = \beta_0 + \beta_1 ENE_{it1} + \beta_2 FSD_{it2} + \beta_3 INSQ_{it3} + \beta_4 EXR_{it4} + \beta_5 INF_{it5} + \beta_6 LGDP_{it6} + \mu_t \quad (2)$$

Due to the dynamic nature of this study, a model was developed to reflect the nature of the study which is stated as

$$ENVQ_{it} = \beta_0 + \beta_1 ENVQ_{it1} + \beta_2 ENE_{it2} + \beta_3 FSD_{it3} + \beta_4 INSQ_{it4} + \beta_5 EXR_{it5} + \beta_6 INF_{it6} + \beta_7 LGDP_{it7} + \mu_t \quad (2)$$

Where:

ENVQ = Environmental Quality (Proxy with Carbon dioxide (CO2) emission per capital)

ENE = Energy supply (Proxy with the ratio of e to GDP)

DS = Debt Servicing (Proxy with the ratio of debt service to GDP)

INT = Interest Rate

TE = Technology progress (Proxy with the ratio research and development to GDP)

CAP= Capital (Proxy with the ratio of capital formation to GDP)

LAB = Labour (Proxy with the ratio of employment generation to GDP)

μ = Error term

Using Pesaran and Shin (1996)' model, ARDL was stated:

$$Yit = \sum_{j=1}^{p} \backslash\text{upvarphi}\ \text{ijYi, t} - \text{j} + \backslash\text{upvartheta}\ \text{i} + \epsilon\text{it}$$

4

N represents the number of countries considered; T represents time; j is the number of lags; and #i represents the fixed effect of each countries. Eq. (2) is reparametrized to take the modification coefficient and long-term dynamics:

$$\Delta\, Yit = \text{ø}i\left(Yi, t - 1 - \square iXi, t\right) + \sum_{j=1}^{p-1} \backslash\text{upvarphi}\ \text{ij}\Delta\ \text{Yi, t} - \text{j} + \sum_{j=0}^{q-1} \delta\ \text{ij}\Delta\ \text{Xi, t} - \text{j} + \backslash\text{upvartheta}\ \text{i} + \epsilon\text{it}$$

5

The term 1_i represents coefficient that was used to address the dynamics of long-term. While U_i represents equilibrium at the long-term from Y_{it} and X_{it}, 0 serves with short-term coefficients represents to environmental quality in its past values with the independent variables.

4. Data Presentation and Interpretation

Table 1
Descriptive Statistics of the Study Variables

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
ENVQ	0.467	0.284	0.404	0.093	1.995
ENE	47.583	47.250	22.182	9.400	98.600
FSD	54.439	50.402	23.693	17.541	149.063
INSQ	0.000	−0.049	1.000	−2.048	2.956
EXR	681.749	413.566	1730.537	0.000	9565.082
INF	6.274	3.677	7.644	−3.233	47.643
LGDP	10.077	10.073	0.626	9.055	11.759

Source

Author's computation (2026).

Table 4.1 displays the research variables' summary statistics. ENVQ, ENE, FSD, INSQ, EXR, INF, and LGDP have average values of 0.467, 47.583, 54.439, 0.000, 681.749, 6.274, and 10.077, respectively; the corresponding standard deviations are 0.404,

22.182, 23.693, 1.000, 1730.537, 7.644, and 0.626. ENVQ has a minimum of 0.093 and a maximum of 1.995, respectively. ENE ranges from 9.400 to 98.600, while FSD ranges from 17.541 to 149.063. INSQ has minimum and maximum values of − 2.048 and 2.956, respectively. Similarly, EXR ranges from 0.000 to 9565.082, INF ranges from − 3.233 to 47.643, and LGDP ranges from 9.055 to 11.759. The wide differences between the minimum and maximum values indicate substantial variations in the study variables, thereby warranting further empirical investigation.

Table 2
Pearson Correlation Matrix of the Study Variables

Variable	ENE	FSD	INSQ	EXR	INF	LGDP	VIF
ENE	1.000						1.418
FSD	0.615	1.000					1.418
INSQ	0.651	0.561	1.000				2.136
EXR	−0.096	−0.143	−0.329	1.000			1.335
INF	0.071	−0.017	−0.102	0.025	1.000		1.771
LGDP	0.223	−0.471	0.031	0.013	0.215	1.000	1.480

Source

Author's computation (2026).

Table 2 displayed the research variables' variance inflation factor (VIF) and Pearson correlation matrix. Determining if multicollinearity exists between the independent variables is crucial. This study used VIF and Pearson correlation to assess if multicollinearity was present or absent. The highest correlation among the explanatory variables is between ENE and INSQ (0.651), which is below the conventional multicollinearity threshold of 0.80. In addition, the VIF values range from 1.335 to 2.136, suggesting that multicollinearity is not severe among most variables. Hence, the absence of multicollinearity among the variables.

Table 3
Summary of Panel Unit Root Test Results

Variable	Levin-Lin-Chu (LLC) Statistic	LLC *p*-value	Im-Pesaran-Shin (IPS) Statistics	Im-Pesaran-Shin (IPS) *p*-value	LLC	IPS
ENVQ	-4.5377	0.0000	-2.1202	0.0170	I(1)	I(1)
ENE	-3.8878	0.0001	-1.7746	0.0446	I(0)	I(1)
FSD	-6.4332	0.0000	-2.6202	0.0044	I(1)	I(1)
INSQ	-6.8890	0.0000	-2.6231	0.0044	I(0)	I(0)
EXR	-3.0357	0.0012	-1.6899	0.0455	I(1)	I(I)
INF	-1.7312	0.0417	-0.7746	0.0044	I(1)	I(1)
LGDP	-9.2620	0.0000	-5.5474	0.0000	I(1)	I(1)

Source

Author's computation (2026).

Table 3 displays the panel unit root test results.The stationarity properties of the variables were examined using the Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS). The LLC test indicates that some energy supply and institutional quality are significant at levels. This is corroborated by IPS that supports that institutional quality is significant at level while energy supply

is significant at first difference I(1). LLC and IPS that all variables were significant at first difference. Overall, the results indicate that ENVQ, ENE, FSD, INSQ, EXR, INF, and LGDP are stationary, making them suitable for subsequent panel regression analysis.

Table 4
Random Effect Regression Results

Variable	Coefficient	Std. Error	t-Statistic	p-value
Dependent Variable: ENVQ				
ENE	0.0063	0.0027	2.338	0.0207**
FSD	0.0039	0.0033	1.178	0.2407
INSQ	0.1337	0.0573	2.333	0.0209**
EXR	0.000008	0.000015	0.556	0.5791
INF	−0.0051	0.0043	−1.188	0.2368
LGDP	−0.0021	0.0151	−0.138	0.8902
Diagnostic Test	Statistics		P-Value	
Breusch Pagan LM Test	48.9869		0.0000	
Hausman Test	0.7078		0.9943	

Source

Author's computation (2026).

Notes

ENVQ (Environmental Quality) is the dependent variable. Robust standard errors clustered by country are reported. Significant at 5% level is denoted by **. The model is statistically significant ($F = 134.90$, $p < 0.001$) and accounts for about 84.0% of the variation in environmental quality ($R^2 = 0.8401$).

Table 4 shows the random effect regression results. The Breusch Pagan test is used to evaluate the most preferred results between pooled OLS and random effect and the result indicates that the most preferred result is random result due to the significance of the P-value, whereas the Hausman test is used to determine the appropriate static panel estimator. The insignificant Hausman test statistic ($p = 0.9943$) suggests that the Random Effects estimator is preferred to the Fixed Effects estimator. The dependent variable is environmental quality and the explanatory variables are inflation, energy supply, institutional quality, exchange rates, and GDP. The results show that energy supply (ENE) has a positive and statistically significant effect on environmental quality (ENVQ) at the 5% level ($\beta = 0.0063$, $p = 0.0207$). This means that for every unit increase in energy supply, there will be an improvement in environmental quality of 0.0063. In the same way, institutional quality (INSQ) has a positive and significant effect on environmental quality ($\beta = 0.1337$, $p = 0.0209$). This therefore means that a unit increase in institutional quality will lead result in positive change of 0.1337 in environmental quality. The findings indicate that under the pooled regression model, only energy supply and institutional quality are significant in explaining the differences in environmental quality.

Table 5
ARDL Panel and GMM Regression

Dependent Variable: ENVQ				
Independent Variables	**Mean Group (MG)**	**Pooled Mean Group**	**Dynamic CCE (CS-ARDL)**	**GMM**
ENVQ_1	-	-	-	0.8218(0.3920)**
ENE	0.0041(0.0012)**	0.0016(0.0002)**	0.0080(0.0023)***	0.0229(0.0023)**
FSD	0.0005 (0.0014)	0.0010(0.0007)	−0.0046 (0.0047)	0.0100(0.0038)***
INSQ	−0.0658 (0.0545)	0.0567(0.0244)**	0.0652 (0.1240)	0.1190(0.0420)***
EXR	-0.0047(0.0007)**	−0.0120(0.0198)	−0.0052(0.0199)	−0.0144(0.0670)
INF	0.0030(0.0017)*	−0.0000(0.0011)	−0.0077(0.0057)	−0.0101(0.0050)**
LGDP	0.3654 (0.2693)	0.2311(0.1060)**	−2.0524(0.9312)**	0.1608(0.1019)
ECT	-1.3063(0.1400)***	−1.3513 (0.1445)***	0.9218(0.3920)***	
Hausman Test	1.73(0.8856) 2.63(0.7565)			
Wald chi2 Statistic	11.91(0.000)			
Sargan test	60.89(0.137)			
Hansen test	8.42(1.00)			
Arellano-Bond test for AR(2)	1.50(0.133)			

Source

Author's computation (2026).

The findings of this investigation, which employed the GMM and panel ARDL, are shown in Table 5. The error correlation's (ECT) 1% p-value indicates a significant value. However, the coefficient value of 1.3513 suggests that environmental quality is sensitive to the shocks of LGDP, INF, ENE, INSQ and EXE. The rate of change of environmental quality from a short term state of disequilibrium to a long term state of equilibrium is 1.3513. A Hausman test between MG and PMG and another Hausman test between PMG and DFE must be performed in order to determine which of the panel ARDL models (MG, PMG, and DFE) is most appropriate. The Hausman test results between MG and PMG suggest that PMG is the best method as the p-value is 0.8856. This is due to the p-value's insignificance. Likewise, the Hausman test result for PMG and DFE is 0.7565 which is insignificant. As a consequence, PMG was determined to be the best method. The ARDL model has environmental quality as the dependent variable and inflation, energy supply, institutional quality, exchange rate, and gross domestic product as explanatory variables. The results of the ARDL showed that environmental quality is positively statistically significantly impacted by energy supply (ENE) (β = 0.0016). Thus, an increase of one unit in ENE will result in an increase of 0.0016 in environmental quality. This implies that the environmental issues, such as CO2 emissions, are mainly caused by industrial activities, such as fossil fuel combustion, dam construction to satisfy energy needs, and production of methane and other greenhouse gasses. These gasses can be reduced by improving the distribution of energy supplies through technological innovation and renewable energy practices that combine economic performance and environmental quality (Razzaq et al. 2023).

With a correlation value of 0.0567, institutional quality and environmental quality are likewise positively correlated. As a result, this lends credence to the notion that institutions are essential in creating environmental regulations, keeping an eye on and enforcing compliance, and offering accountability and transparency to increase public awareness of pollution and its effects (Karakara & Osabuohien, 2021). The outcome also showed that, with a correlation value of 0.2311, GDP and environmental

quality had a positive and substantial link. This shows that an increase in GDP of one unit will result in an increase in environmental quality of 0.2311.

Environmental quality is still the dependent variable for the GMM conclusion, and the explanatory factors are the lag of environmental quality, energy supply, institutional quality, exchange rate, gross domestic product, and inflation. With a coefficient value of 0.8218, it was shown that environmental quality is positively and significantly impacted by lag. Therefore, an improvement of 1 unit in the past will lead to an improvement of 0.8218 in environmental quality. Furthermore, the results indicated that at 5% level, energy supply (ENE) has positive and statistically significant relationship with environmental quality (ENVQ) with coefficient value of 0.0229. Therefore, for each unit increase in energy supply, there will be a positive gain in environmental quality of 0.0229. Likewise, financial sector development (FSD) has a significant and positive relationship with environmental quality with a coefficient value of 0.0100. Therefore, an increase of 1 unit of FSD will lead to an increase of 0.0100 in environmental quality.

The study also showed that, with a coefficient value of 0.1190, institutional quality (INSQ) significantly and favorably affects environmental quality. This implies that an increase of 0.1190 in environmental quality will follow a unit improvement in institutional quality. Lastly, with a coefficient value of − 0.0101, inflation significantly and negatively affects environmental quality. This implies that a unit drop in inflation will result in a 0.0101 improvement in environmental quality and vise versa.

Table 6
Panel Quantile Regression Results

Variable	Q10	Q25	Q50	Q75	Q90
Dependent Variable: ENVQ					
ENE	0.0052***	0.0036***	0.0050***	0.0135***	0.0160***
FSD	−0.0000	0.0021**	0.0028*	0.0020	0.0009
INSQ	0.0313**	0.0248*	0.0890***	0.1127***	0.0618**
EXR	0.0000	0.0000	0.0000	−0.0000	−0.0000
INF	0.0001	−0.0009	−0.0028	−0.0037	−0.0067**
LGDP	0.1342***	0.1873***	0.0515	−0.0623	−0.1257*

Source

Author's computation (2026).

Notes

ENVQ (Environmental Quality) is the dependent variable. Q10, Q25, Q50, Q75, and Q90 are the 10th, 25th, 50th (median), 75th, and 90th conditional quantiles of the environmental quality distribution, respectively. The explanatory factors' marginal effects at each quantile are represented by coefficients. The symbols ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. The findings show that Energy Supply (ENE) has a statistically significant and beneficial impact on all quantiles, with larger impacts shown at the top quantiles. Moreover, the majority of quantiles have positive significance for Institutional Quality (INSQ). Financial Sector Development (FSD) and Gross Domestic Product (LGDP) are significant only at certain quantiles, suggesting different impacts across the distribution of environmental quality, while Inflation (INF) is significant and negative only at the 90th quantile. The results of the Panel Quantile Regression are presented in Table 8. The findings show that the effects of the explanatory factors on environmental quality (ENVQ) were different across quantiles. The energy supply (ENE) has a positive and statistically significant effect on all quantiles, ranging from 0.0052 at Q10 to 0.0160 at Q90. The majority of quantiles are positively and significantly impacted by institutional quality (INSQ), with Q75 showing the biggest effect (β = 0.1127). The exchange rate (EXR) is not significant at any quantile, while the financial sector development (FSD) is only significant at the lower and intermediate quantiles (Q25 and Q50). While economic growth (LGDP) has a positive

and significant effect at the lower quantiles (Q10 and Q25) but turns negative at higher quantiles (β = −0.1257), inflation (INF) is only significant at the upper quantile (Q90), where it has a negative effect (β = −0.0067). These results show that the effects of the explanatory factors on environmental quality vary throughout the conditional distribution of environmental quality.

According to the study's findings, energy consumption has a beneficial influence on environmental quality across all estimating approaches. This is in line with other researches, including Dées, 2020; Musibau, 2021; Qudrat-Ullah, 2021; Jinapor, 2023; Onyeneke (2024); and Gueye (2025). Additionally, this analysis supports the EKC theory, which has been empirically validated to show that the growth of energy infrastructure has a significant impact on the environment. The idea that energy supply has no discernible impact on environmental quality is rejected since this study contradicts it.

Additionally, the study found institutional quality having positive impact on environmental quality across all estimation techniques. This is consistent with other studies that highlight the significance of institutions in promoting environmental development, such as Karakara & Osabuohien, 2021; Karim et al., 2022. The hypothesis, which claims that institutional quality has little bearing on environmental quality, is rejected since this study does not support it. According to Aljadani 2022 and Konuk et al. 2023, the growth of the financial industry is also predicted to have a major influence on environmental quality. Lastly, the study found that GDP had a major influence on environmental quality in West Africa, but inflation and currency rates had no effect.

The aforementioned figure illustrates the marginal effects of energy supply, financial sector development, institutional quality, exchange rate, inflation, and economic growth across all quantiles of the environmental quality distribution. The plots show that the effects of the explanatory variables are not constant across the different quantiles of the environmental quality distribution, suggesting that the effects of the explanatory variables are not linear. Specifically, the impact of institutional quality and energy supply is more pronounced at the higher quantiles, whereas the impact of financial sector development, exchange rate, inflation and economic growth varies across the conditional distribution, indicating that the impact of these variables is heterogeneous and depends on the level of environmental quality considered.

5. CONCLUSION AND RECOMMENDATIONS

The study's conclusion highlights the significance of using multiple panel estimation techniques to obtain solid and trustworthy empirical evidence: economic growth continues to be the most consistent determinant of environmental quality, while the influence of the other variables depends on the estimation method and the time horizon taken into consideration. Hence, the study recommends the development and implementation of policies that promote sustainable economic growth, while ensuring that economic growth is accompanied by investments in renewable energy, green infrastructure, and eco-friendly technologies to improve environmental quality. To foster environmental governance and sustainability, environmental institutions need to be strengthened by effective use of environmental rules, better monitoring and greater transparency. To reduce environmental deterioration and promote long-term environmental quality, policies that encourages energy efficiency should be strengthened. Financial institutions may also expand their green financing activities by providing incentives and affordable loan facilities for investments in clean technology, low-carbon industries and environmentally friendly projects. To create an atmosphere that supports sustained economic growth and environmental preservation, the government should continue to implement stable macroeconomic policies, especially with regard to inflation and currency rate control. Future research should employ additional environmental indicators, longer time spans, and larger panel data sets, as well as different estimation methods, to further explore the determinants of environmental quality and to validate the findings for different countries and regions.

Declarations

During the preparation of this work, the author(s) did not employ the aid of any AI tools. The work is an original work from the authors

1. Ethics approval and consent to participate: Not applicable

2. Consent for publication: Not applicable.

3. Availability of data and materials: Data will be made available upon request

4. Competing interests: The authors declare no conflicts of interest.

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Writing—original draft, K.D.K., B. O. O. and S.O.A.; data curation, K.D.K. and F. A.; writing—review and K.D.K and A. I. I.; supervision, A. I. I. and F. A. All authors have read and agreed to the published version of the editing, manuscript.

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Figures

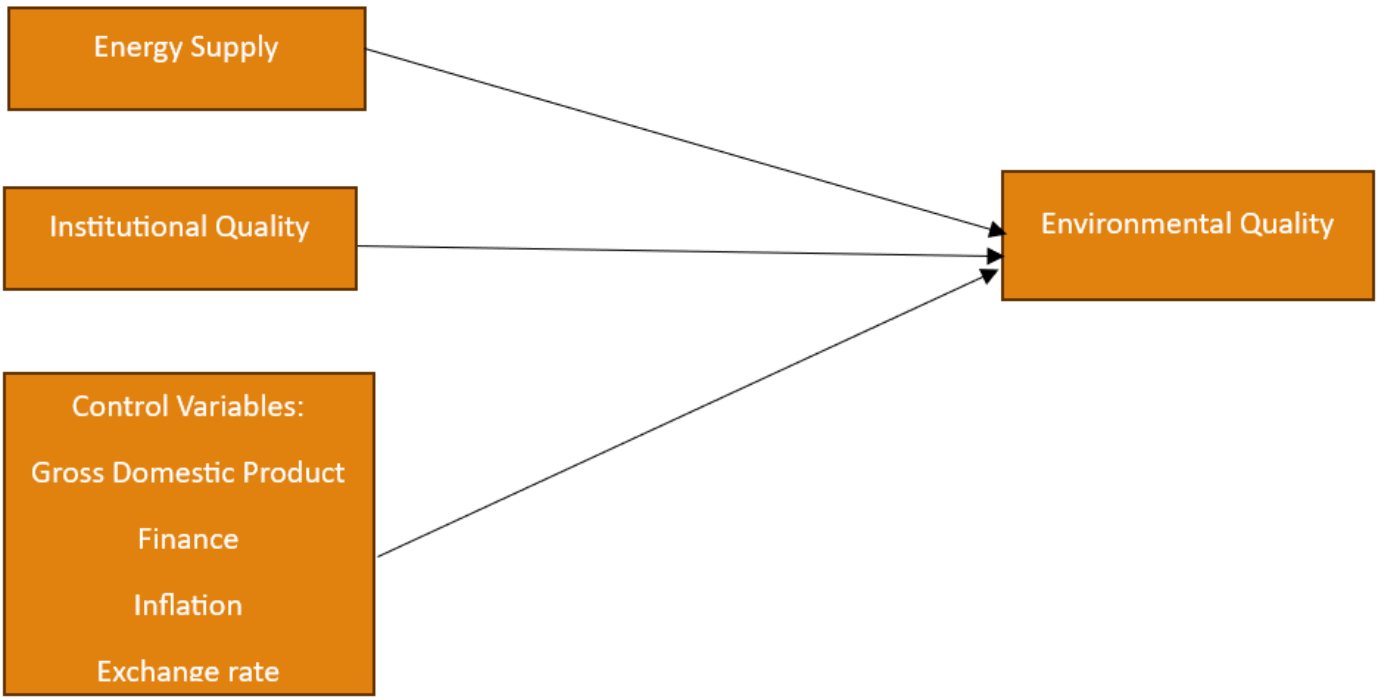

Figure 1

Conceptual Framework on Environmental Quality

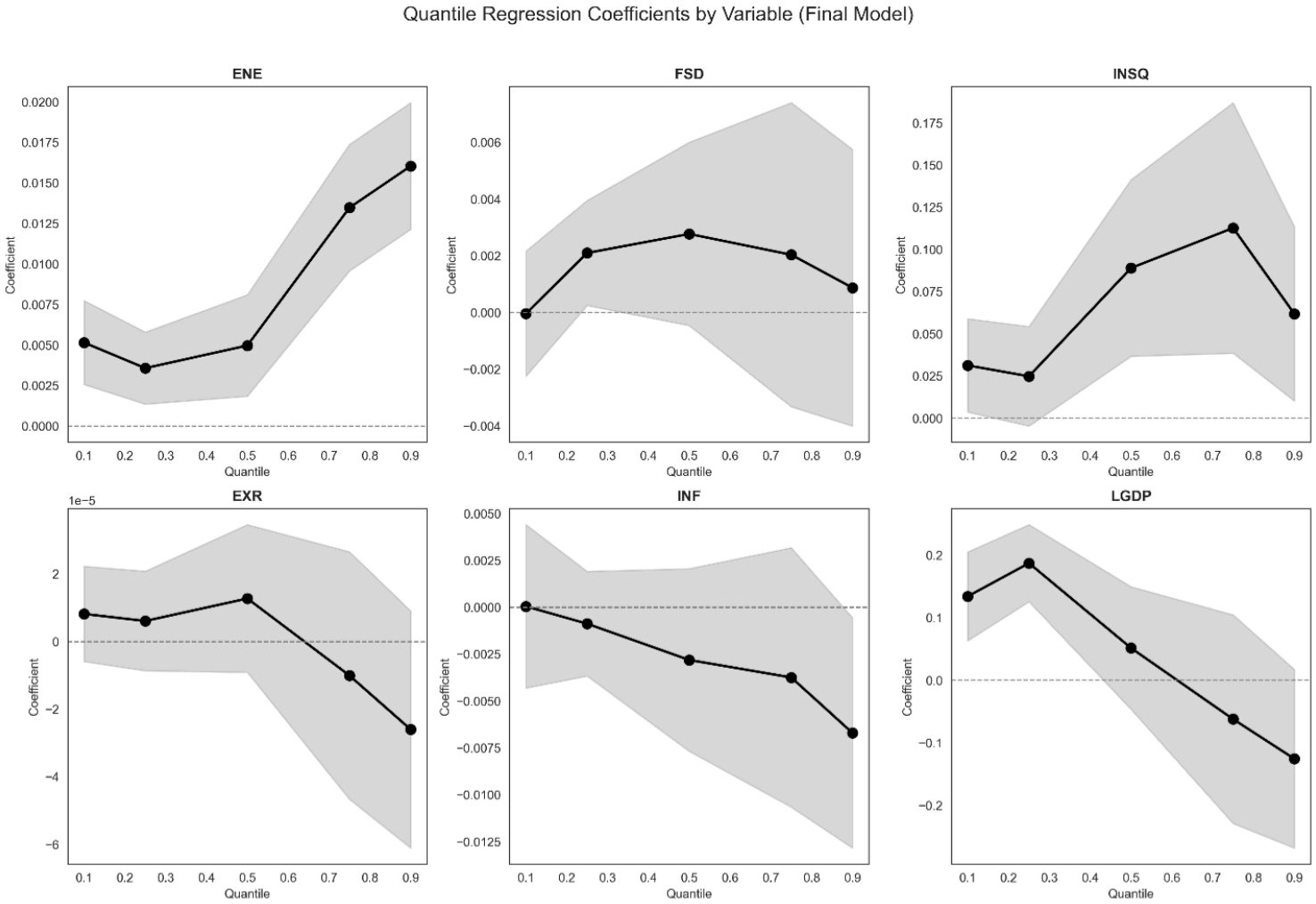

Figure 2

Marginal Effects of the Explanatory Variables across the Quantiles of Environmental Quality