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Environmental Quality, Energy Consumption, and Economic Growth: Evidence from Selected African Countries

Olugbenga Olaoye[1,*]

[1]*Department of Economics, Covenant University, Nigeria*

Abstract: This study examines the nexus between environmental quality, energy consumption, and growth performance between 1981 and 2019 in selected African Countries. The study adopts the co-integration analytical technique based on the framework of fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) to analyze the panel data. The empirical finding shows that environmental quality (CO_2 emission) positively and significantly impacts economic growth in Africa. Similarly, energy consumption impacts economic growth positively and significantly. Also, the interaction of environmental quality and energy consumption positively and significantly propels economic growth. The FMOL evidence indicates that all the key variables are significant at 1% critical value. Therefore, the study recommends that African countries should be committed to sustainable measures toward sustainable economic growth and development based on Africa's aspiration by 2063 to attain growth and a quality environment.

Keywords: economic growth, energy consumption, environment, Africa

1. Introduction

Today, the environmental problem has attracted the attention of governments, international organizations, corporate bodies, and academia. This is because of the continuous fall in environmental quality globally. Akadiri et al. (2019) attributed environmental degradation to CO_2 emission. This implies that an increase in CO_2 emission through energy consumption depletes environmental quality. On the other hand, Mesagan and Vo (2023) posit that high-carbon emissions have often been traced to economic activities. This is the reason why the nexus between environmental quality and economic growth has attracted the attention of a wide range of researchers from multidimensional disciplines, but the empirical evidence provided is conflicting, perhaps due to the variation in the choice of methodology, data, and region of study.

For instance, Ahmad and Du (2017), Padhan et al. (2019), and Kahia et al. (2019) have argued that there is a direct nexus linking economic activities and environmental quality. This denotes that economic growth measures are accompanied by a corresponding increase in carbon emission which consequently affect environmental quality. In the quest to drive growth, economies consume energy sources like fossil fuel, gas, and coal that are considered cheaper to use but with high environmental repercussions. The essence is to maximize the gain from economic activities (see Mesagan & Ezeji, 2016; Olunkwa et al., 2021). This argument supports the first-order condition of the environmental Kuznet curve (EKC) that at the initial growth stage, carbon emission rises, affecting the environment negatively because the economy is not wealthy enough to employ less carbon-emitting technology to propel their needed growth (Olaoye & Dauda, 2022).

In the same vein, studies by Salahuddin and Gow (2019) raised a different line of argument that evidence of a direct or indirect link between the quality of the environment and economic growth is not robust enough upon which environmental policies aimed at abating environmental pollution and improving environmental quality are built on. More so, there is a need to unravel the influence of environmental quality and economic growth on each other. In this respect, Abdouli and Hammami (2017) provided evidence of one-way causality of environmental quality and growth and the causal implication flow from growth toward the environment. The evidence implies that as economic activities such as production, distribution, and consumption rise, they harm the quality of the environment because the economic activities are accompanied by biodiversity destruction, deforestation in the quest to build industries and production plants, and carbon emission arising from the consumption of thick energy. Again, the evidence of a causal relationship provided by Danish and Wang (2018), Saud et al. (2019), and Akadiri et al. (2019) deviate from the former as they found a two-way influence between environmental quality and economic performance. It means that economic performance threatens the natural environment, while, on the other hand, environmental quality can also limit the economy's performance. This shows that tightened environmental policies geared toward environmental quality promotion can restrict the free operation of economic activities, consequently hamper growth.

*Corresponding author: Olugbenga Olaoye, Department of Economics, Covenant University, Nigeria. Email: olaoyeolugbenga1@yahoo.com

Some African countries, especially Nigeria, Angola, Algeria, Tunisia, Egypt, and South Africa, are naturally endowed with both conventional and unconventional energy resources such as coal, crude oil, gas, solar, hydro, biogas, and wind (Mesagan & Vo, 2023). The abundance of these energy resources, especially oil in African countries, not only serves as a source of revenue to the economies but also constitutes the primary source of energy use in the region to propel economic growth. However, most countries, especially Nigeria, encourage fossil fuel energy consumption through excessive subsidy support (Adejumo, 2020; Mesagan & Vo, 2023). While the consumption of energy can promote economic growth, its environmental repercussion is well established in the literature, and also the fact that African countries are fast gaining prominence in an environmental quality campaign has triggered about 33 African countries representing about 60%, to append their signature on the Paris Agreement in 2015 to abate greenhouse gas (GHG) emission below 2%. Again, in line with the environmental quality campaign, African Union (AU) aspires to attain sustainable growth and development by utilizing clean energy by 2063 based on the framework of Agenda 2063.

Owing to these moves by African economies to improve energy consumption that enhances environmental quality even in the midst of an abundance of thick energy resources that is mostly consumed to expedite economic activities in these nations, it becomes pertinent to investigate specifically the impact that environmental quality has on Africa's economic performance, the impact of energy consumption on growth performance of Africa, and the interactive effect of environmental quality and energy consumption on Africa's growth performance. The interaction effect enables the study to understand whether emission abatement through energy consumption with corresponding environmental quality significantly affects the performance of African economies. And this is the main deviation from related studies in the literature. Additionally, this study is significant for governments and policymakers in African countries as the empirical findings of this study will guide the environmental-economic policy trade-off toward achieving sustainable growth and development through responsible energy consumption. Similarly, the empirical output of this study is significant for African countries as it will provide policy suggestions for balancing economic growth, environmental protection, and sustainable energy consumption. Concerning methodological significance, this study employs the novel co-integration regression based on the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) framework. This method is robust to generate consistent and efficient estimates to guide policy inferences to support sustainable growth policies in Africa. Therefore, the remaining parts of the paper follow: 2. Review of literature, 3. Method of analysis, 4. Presentation of findings, and 5. Conclusion and policy recommendation.

2. Literature Review

A plethora of evidence exists in the literature on energy consumption, environmental quality, and economic growth. This study reviews the most relevant evidence. Gangopadhyay et al. (2023) focused on the USA and examined the connection between renewable energy (RE), trade, globalization, and CO_2 using the novel nonparametric quintile autoregressive distributed lag model (ARDL). The study revealed that between 1970 and 2019, across quintile RE lowered CO_2, globalization increased CO_2, and gross domestic product (GDP) increased CO_2 in all the quintiles except in the lower quintile. Das et al. (2023) assessed the link between industrialization and carbonization in India using the quintile-on-quintile regression (QQR). The evidence suggested that industrialization does not drive carbonization. Das et al. (2022) combined the conventional ARDL and QR ARDL to establish the connection between RE, foreign trade, and CO_2. The conventional ARDL showed that RE lowered CO_2, and trade and GDP exacerbated CO_2. The QR ARDL evidence consolidated the evidence of the conventional ARDL except that trade was insignificant. Utilizing the same methodology and similar sample, Ibekilo and Emmanuel (2022) established that natural resources rent lowered growth in Africa, but technology and resource rent interaction increased growth between 1985 and 2019.

More so, Baz et al. (2020), between 1971 and 2014, adopted the nonlinear and asymmetric regression approach for Pakistan. Evidence of the asymmetric effect shows a causal relationship between environmental quality and energy consumption. Adejumo (2020) employed ARDL methodology to verify the EKC preposition for Nigeria from 1970 to 2014. The study validates the EKC preposition for Nigeria. Meaning that environmental quality is a function of income in the long run. Salahuddin and Gow (2019) focused on Qatar employing the Toda Yamamoto (TY) and ARDL techniques of investigations from 1980 to 2016. The study revealed that GDP per capita (GDPPC) and energy use worsen the environment. Again, the study found a two-way influence among energy use, economic growth, and environmental quality.

Akadiri et al. (2019) employed the same methodology for Iraq between 1972 and 2012. The study found a unidirectional link flowing from economic performance to energy consumption. And again, a one-way influence was found running from CO_2 emission to energy consumption. Kahia et al. (2019) extended the study to 12 Middle East and North Africa (MENA) economies between 1980 and 2012. The study used the panel vector autoregressive (VAR) approach to analyze the panel data for the 12 countries. The study found that economic growth worsens environmental quality. It also revealed that international trade, RE, and foreign direct investment (FDI) enhance environmental quality by reducing CO_2 emission. Padhan et al. (2019) focused on the N-11 between 1971 and 2013 using the first and second generations of co-integration. The study revealed that income inequalities, per capita energy use, and growth engender environmental pollution. Bekun et al. (2019) focused on 16 EU countries between the period of 1996 and 2014. The study used the pooled mean group (PMG)-ARDL approach and upheld the U-shaped proposition of EKC between growth and ecological footprint. Again, the study also found two causal effects between economic output and environmental quality.

Charfeddine et al. (2018) utilized periodic data between 1970 and 2014 for Qatar, and the data were analyzed with ARDL analytical technique. The study found that energy use positively and significantly affected economic output in the long- and short-run periods. Saud et al. (2019) examined a similar situation for Belt and Road Initiative (BRI) economies between 1980 and 2016. They adopted the DSUR method of estimation, and the result revealed that electricity use and economic performance degrade the quality of the environment, while trade, FDI, and financial development propagate environmental quality. For the period of 1960 and 2014, Rahman and Kashem (2017) analyzed panel series for 11 South Asia economies using the FMOLS and DOLS estimations techniques, and the evidence shows that population density, export, and energy consumption adversely affect environmental quality. Abid (2017) covered a wider panel consisting of 41 EU and 58 MEA countries between 1990 and 2011. The system generalized moment method (GMM) approach was adopted, and the finding showed that economic growth worsens CO_2 emissions.

Abdouli & Hammami (2017) employed the VAR technique to analyze 17 MENA countries in the period of 1990 to 2012. They found a one-way causality from economic growth to CO_2

emission. Baloch (2018) used the ARDL approach for Pakistan to estimate the series running from 1971 to 2017. The study found that transportation infrastructure and urbanization kill the environmental quality. Twerefou et al. (2017) investigated a similar study for 36 African economies between the period of 1990 and 2013 using the system GMM technique. The study found the EKC preposition to be valid and satisfactory for sub-Saharan economies. Ahmad and Du (2017) utilized the FMOLS and DOLS to investigate Iran's situation between 1971 and 2011. The study found that CO_2 emission positively impacts growth.

Padhan et al. (2019), Akadiri et al. (2019), Ahmad and Du (2017), and Abdouli and Hammami (2017) studies are closely related to this study. Still, the point of deviation is that these studies focus on the direction of influence among environmental quality, energy consumption, and economic growth. Still, this present study extended the methodology by using the co-integration regression, as suggested by Pedroni (2001). Again, the study interacts with environmental quality and energy consumption to understand whether emission abatement through energy consumption with corresponding environmental quality significantly affects the African economy's performance. To the researcher's knowledge, no study related to this study has interacted with environmental quality and energy consumption on Africa's growth. This is the main innovation of the study.

3. Methodology

The study adopts FMOLS and DOLS analytical techniques based on the framework of co-integration regression suggested by Pedroni (2001). This estimation technique possesses several advantages that make it robust for use in studies like ours. First, comparing FMOLS and DOLS to other approaches like the Engle–Granger two-step method or the Johansen process, they are more resistant to serial correlation and heteroscedasticity (Akadiri et al., 2019). This is because, throughout the estimating phase, FMOLS and DOLS correct for these problems. Also, Pedroni (2001) pointed that even if the co-integrating relationship of a model is not well stated, the FMOLS and DOLS approaches nevertheless produce reliable estimates. This is because they employ a more open-ended model definition that takes into account potential nonlinearities and omitted variables biasedness. Moreover, since the DOLS has an in-built mechanism that corrects for serial correlation and endogeneity through the selection of the appropriate lags and leads, the study uses the DOLS to confirm the robustness of the FMOLS. Another reason for this is hinged on the fact that it accounts for potential nonlinearities in the estimated model. Also, since unobserved heterogeneity and omitted variables biasedness can affect the robustness of the fixed effect model, the DOLS is preferable. The uniqueness of the techniques makes them useful and relevant for this study. In this regard, the model follows the studies of Akadiri et al. (2019), Abdouli and Hammami (2017), and Ahmad and Du (2017). Following the objectives of the study, the model becomes

$$GDPPC_{it} = \alpha_0 + \beta_1 ENV_{it} + \beta_2 CI_{it} + \beta_3 LF_{it} + \beta_4 FDI_{it} + \beta_5 TO_{it} + \mu_{it} \quad (1)$$

Equation (1) captured the impact of environmental quality on African growth. The core variables in the model are environmental quality proxied with CO_2 emission (ENV) and GDPPC, while control variables include gross investment (CI), the labor force (LF), trade (TO), and FDI:

$$GDPPC_{it} = \alpha_0 + \beta_1 EC_{it} + \beta_2 CI_{it} + \beta_3 LF_{it} + \beta_4 FDI_{it} + \beta_5 TO_{it} + \mu_{it} \quad (2)$$

Equation (2) captured energy consumption and African economic performance:

$$GDPPC_{it} = \alpha_0 + \beta_1 ENVEC_{it} + \beta_2 CI_{it} + \beta_3 LF_{it} + \beta_4 FDI_{it} + \beta_5 TO_{it} + \mu_{it} \quad (3)$$

Equation (3) captured the interactive effect of environmental quality and energy consumption on Africa's growth performance. The justification for testing for the interaction of energy consumption and environmental quality is that energy resources significantly impact the environment, and both variables can affect economic productivity. However, as countries rely on fossil energy consumption, it deteriorates the environment, leading to unsustainable growth. The interaction variable will help the study show how the combination of energy and environmental quality affects sustainable growth in Africa. This will guide policy on the optimal energy mix for Africa to drive sustainable growth.

In equation (2), (3), α_0 is the intercept term, while β_1, β_2, β_3, β_4, and β_5 are the parameters of the regressors. Environmental quality proxied with carbon emission (CO_2), LF, GDPPC, gross capital (CI), and environmental quality and energy consumption interaction (ENVEC) are log-transformed to prevent bias estimate since some other variables are in their natural form. Again, panel data from selected African countries spanning from 1981 to 2019 are collected for analysis. The selected African countries of analysis are Nigeria, South Africa, Algeria, Angola, Tunisia, and Egypt. These selected countries are critical for analysis because they constitute the largest economies in Africa in terms of GDP size and the level of CO_2 emissions. For instance, Nigeria has the largest nominal GDP in Africa, about $441 billion; South Africa is the second largest, with about $419 billion (Trading Economics, 2022). Regarding CO_2 emission, South Africa emits 436 million metric tons of $C0_2$, the highest in Africa, followed by Egypt emitting 205 million metric tons of $C0_2$ (Statista, 2022). Nigeria, Algeria, and Tunisia are also high emitters in Africa (Statista, 2022). Therefore, analysis of these countries can give insight into Africa's environment, energy, and growth nexus. Table 1 explains the definition of the key variables, their measurements, and the sources of our data.

4. Empirical Result

4.1. Homogeneous and heterogeneous unit root

Panel homogeneous and heterogeneous unit root is used to check the stationarity of the panel series, and the result is presented in Table 2.

Looking at Table 2, evidence of panel homogenous unit root is mixed at the level since some variables are stationary while others are not. In contrast, at the first difference, homogenous unit root revealed that the variables are stationary at 1% and 5% significance. Similarly, the evidence of heterogeneous panel unit root only FDI is stationary, while other variables are not. But at the first difference, all the variables are stationary. At the first difference, the homogeneous and heterogeneous unit root evidence revealed that the variables are stationary. Hence, there is the rejection of the hypothesis in the presence of unit root. Therefore, the study proceeds for further estimation.

Table 1
Source and data measurement

Variables	Definition	Measurement	Source
ENV	Environmental quality	Environmental quality is captured with carbon emissions (CO_2) measured in kilo tons	World Development Indicators (2020)
EC	Energy consumption	Captured with energy use per capita	World Development Indicators (2020)
GDPPC	Economic growth	Captured with GDP per capital	World Development Indicators (2020)
CI	Gross capital investment	Proxied with gross capital formation	World Development Indicators (2020)
FDI	Foreign direct investment	Captured with foreign direct investment net inflows	World Development Indicators (2020)
TO	Trade	Captured with trade in % of GDP	World Development Indicators (2020)
ENVEC	Environmental quality and energy consumption	Captured with environmental quality and energy consumption interaction	Derived

Table 2
Homogeneous and heterogeneous unit root

	Homogeneous criteria				Heterogeneous criteria			
	Level		First difference		Level		First difference	
Variables	Levin et al. (2002)	Breitung (2001)	Levin et al. (2002)	Breitung (2001)	Im et al. (2003)	ADF–Fisher	Im et al. (2003)	ADF–Fisher
GDPPC	0.1579	4.6404	−3.9248***	−3.5602***	3.2098	−2.0049	−5.9343***	16.087***
ENV	35.771	−3.3293***	28.406**	−1.1487***	−0.3576	−0.3696	−4.3533***	−2.1056**
EC	3.0940	−1.7979**	−6.4478***	−9.7113***	1.8337	−1.8278	−8.7306***	36.911***
ENVEC	3.9086	−0.6321	−6.8978***	−10.391***	3.0667	−2.1910	−8.7269***	36.758***
CI	1.5008	1.6660	−4.5752***	−4.9881***	2.1394	−0.8020	−7.9271***	36.758***
LF	−2.7030***	0.1190	−6.9489***	−10.382***	−0.9576	0.0080	−8.7365***	36.875***
FDI	−3.4415***	−5.3685***	−8.6099***	−8.1617***	−4.5978	9.7884***	−10.185***	66.771***
TO	−1.6270**	−2.2521***	−8.7968***	−6.9703***	−1.2809	0.7654	−8.3864***	34.609***

Note: *** and ** represents 1% and 5% significant levels, respectively.

4.2. Panel co-integration

This shows the long-run relationship among panel vectors. That is how the variables are related in the long-term period. The study used the Kao residual panel co-integration test. The evidence of the test guides the study in refuting or agreeing with the null hypothesis in the absence of long-run relationship. In Table 3, Kao residual co-integration result is presented.

Table 3 presents the Kao co-integration result for the respective models based on the objectives discussed above (environmental quality and economic performance (ENV and GDPPC), energy consumption and economic performance (EC and GDPPC), and interactive effect of environmental quality and energy consumption on economic performance (ENVEC and GDPPC)). Based on the evidence of Kao residual co-integration, co-integration exists among the panel series for each model, which is significant at 1%. This denotes rejecting the false hypothesis and validating the true hypothesis that co-integration exists among the panel series. Therefore, the study proceeds to the estimation proper.

Table 3
Kao residual co-integration

	Null: co-integration does not exist		
	ENV and GDPPC Statistic	EC and GDPPC Statistic	ENV and GDPPC Statistic
ADF	−2.0306***	−3.2460***	−2.0749***
Residual variance	0.6740	11.496	11.526
HAC variance	0.6695	11.290	6.9088

Note: *** means 1% significant level.

4.3. Presentation of panel regression result and discussion

The research adopts the co-integration regression technique of panel regression using the FMOLS and DOLS estimation methods. The co-integrating vectors of DMOLs and FMOLS are presented in Tables 4 and 5.

FMOLS estimates for the panel are presented in Table 4. Showing the impact of environmental quality and economic performance in Africa, the estimated coefficient of environmental quality (CO_2) is 0.0110. This means that environmental quality proxied with CO_2 emission positively and significantly impacts economic growth by about 1.1%, if the environment deteriorates by at least 1%. This indicates that the African economy shows higher growth rates when emissions increase, which intuitively means that African economies perform well at the environment's expense. The evidence is not surprising because African economies are rich in traditional energy sources such as crude oil and coal and utilize them for accelerating economic activities. Ahmad and Du (2017) findings are similar to this evidence. To ascertain whether energy consumption affects economic performance, the FMOLS estimate revealed that energy consumption positively and significantly impacts African economic performance. Energy is a prerequisite in

Table 4
FMOLS estimate

Regressors	ENV and GDPPC	EC and GDPPC	ENVEC and GDPPC
ENV	0.0110*** (0.0046)	–	–
EC	–	0.0002*** (0.00009)	–
ENVEC	–	–	0.0057*** (0.0018)
CI	0.0058* (0.0035)	0.0053 (0.0035)	0.0049 (0.0035)
LF	−0.0137*** (0.0018)	−0.0140*** (0.0018)	−0.0150*** (0.0019)
TO	0.000482** (0.0002)	0.0004** (0.0002)	0.0003* (0.0002)
FDI	−0.004105*** (0.0009)	−0.0040*** (0.0009)	−0.0041*** (0.0009)
R^2	0.9972	0.9973	0.9972
Adj R^2	0.9969	0.9970	0.9971

Note: *** and ** represents 1% and 5% significant levels, respectively.

Table 5
DOLS estimate

Regressors	ENV and GDPPC	EC and GDPPC	ENVEC and GDPPC
ENV	0.2727** (0.1176)	–	–
EC	–	0.0002* (0.0001)	–
ENVEC	–	–	0.0061** (0.0027)
CI	0.0061 (0.0046)	0.0050 (0.0047)	0.0046 (0.0046)
LF	−0.0130*** (0.0025)	−0.0151*** (0.0024)	−0.0161*** (0.0025)
TO	0.0009** (0.0004)	0.0012*** (0.0005)	0.0009** (0.0005)
FDI	−0.0056*** (0.0015)	−0.0070*** (0.0017)	−0.0068*** (0.0016)
R^2	0.9989	0.9987	0.9988
Adj R^2	0.9980	0.9975	0.9976

Note: *** and ** represents 1% and 5% significant levels, respectively.

driving economic activities. The evidence only confirms that as firms and industries consume more energy, output tends to increase and thus results in economic growth. Also, Charfeddine et al. (2018) found similar evidence.

Again, there is the interactive effect of environmental quality and energy consumption on the economic performance of African countries. FMOLS estimate in Table 4 reveals that the interactive variable coefficient is thus 0.0057. It positively and significantly affects growth. This means that as the variable changes by at least 1%, the African economy grows by about 0.5%. The implication of these findings is that interacting environmental quality and energy consumption still accelerate growth. This implies that African countries depend more on carbon-emitting energy sources to accelerate economic activities even amid the carbon consumption abatement campaign, thus putting the environment in danger.

Table 5 presents the DOLS estimates for the panels. Ascertaining the impact of environmental quality on economic performance in Africa, the DOLS estimate shows that the coefficient of environmental quality, which is proxied with CO_2 emission, is 0.2727. This implies that environmental quality positively and significantly relates to African growth. The evidence confirms the fact that African countries are abundantly rich in energy resources, especially carbon-emitting energy that is cheap to use. In this respect, they utilize such energy in driving economic activities, thereby accelerating growth but with strong repercussions on the environment. The evidence is related to the evidence of Ahmad and Du (2017). For whether energy consumption affects African growth performance, evidence of positive and significant impact is revealed by DOLS estimate as presented in Table 5. The evidence shows that energy is a prerequisite to enhance production in driving economic activities. The more the energy is consumed, the more the economic activities tend to grow.

In the same vein, there is the interactive effect of environmental quality and energy consumption on African growth performance. DOLS estimate presented in Table 5 shows that the interactive variable has a positive and significant coefficient as thus 0.0061. This implies that as the variable changes by 1%, economic growth in African countries increases by 0.6%. The consequence of this result is that interacting environmental quality and energy consumption still contribute to African growth. African countries depend more on carbon-emitting energy sources to accelerate economic activities even amid carbon consumption abetment campaigns, thereby putting the environment in danger. Again, the evidence revealed that the African agenda of economic sustainability and development by 2063 and abating carbon emission and improving environmental quality are yet to yield result as economic activities are still much driven by carbon-emitting energy in the region. However, the FMOLS and DOLS estimates presented in Tables 4 and 5 are similar. This confirms the estimate's robustness and reliability in formulating environmental policy.

4.4. Panel causality

In this section, the study presents causal analysis to ascertain the flow of influence among the variables environmental quality (CO_2 emission), economic growth, and energy consumption. This is to verify the argument of Salahuddin and Gow (2019); that in a study like this, the direction of influence is necessary to check how robust the estimates are. Therefore, the study presents panel causality in Table 6.

Panel causality presented in Table 6 revealed a prediction between growth and environmental quality (CO_2 emission) with the flow of influence flowing from environmental quality to growth. Again, energy consumption causes economic growth to vary with a direction of influence flowing from energy consumption to growth. It denotes that energy consumption drives economic activities. Also, the panel causality revealed that energy consumption causes environmental quality to change. This means that changes in energy

Table 6
Panel causality result

F-statistic	GDPPC	ENV	EC
GDPPC	–	0.4663	0.057
ENV	2.6458**	–	0.1275
EC	0.3753*	114.87***	–

Note: ***, **, and * denotes 1%, 5%, and 10% significant levels, respectively, for refuting the nonexistence of causality.

consumption can account for a worsening environment. The panel causality result supports the argument of Salahuddin and Gow (2019).

4.5. Normality test

The study checks whether the residuals of the estimated vectors are normally distributed. This is because nonnormally distributed residuals are a pointer to the true robustness of the regression estimates. Hence, this study uses a histogram and the Jarque–Bera normality test to check whether the residuals are normally distributed as shown in Figures 1, 2, and 3.

In Figures 1, 2, and 3, the study presents the histogram and JB statistic, among others. The histograms suggest that the residuals are normally distributed, and JB probability confirms the normality of

Figure 1
Environmental quality and economic growth (ENV and GDPPC)

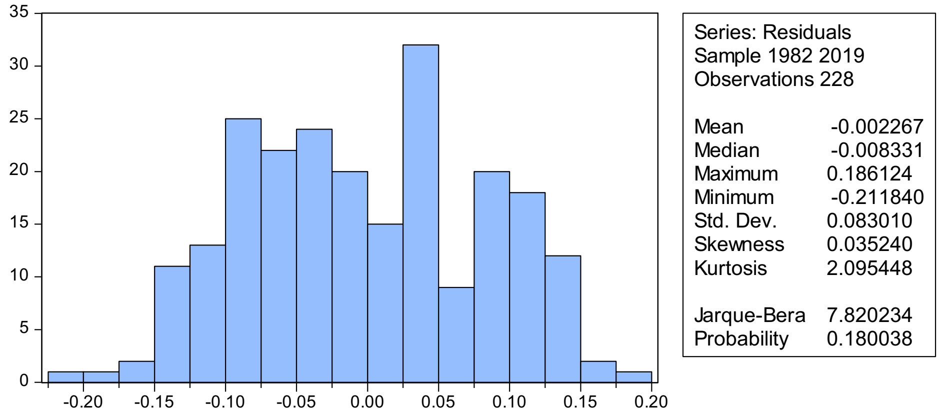

Figure 2
Energy consumption and economic growth (EC and GDPPC)

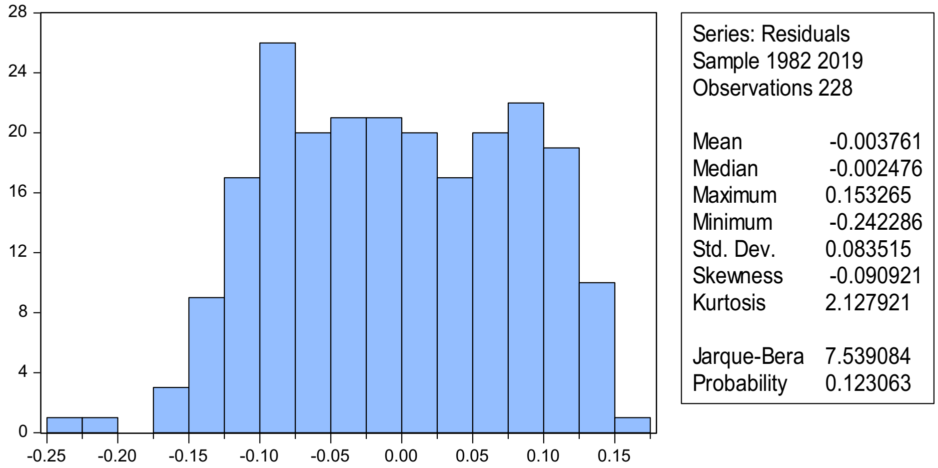

Figure 3
Environmental quality and energy consumption on economic growth (ENVEC and GDPPC)

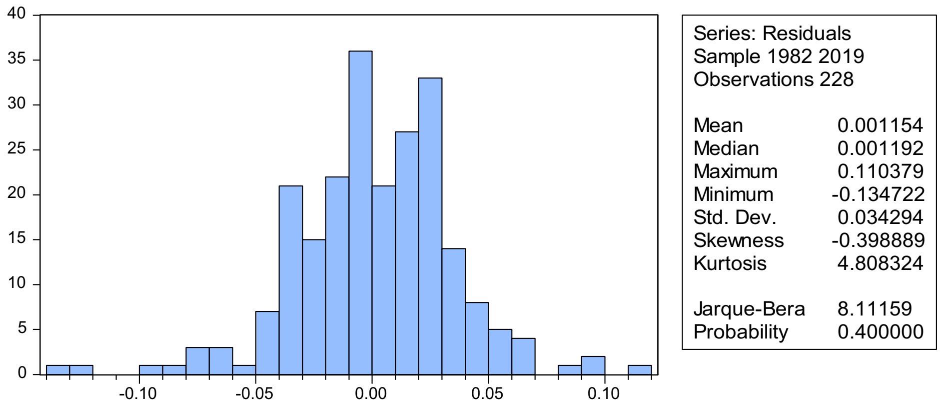

Table 7
List of abbreviations

Abbreviation	Meaning
ARDL	Autoregressive distributed lag model
BRI	Belt and Road Initiative
CO_2	Carbon dioxide emission
DOLS	Dynamic ordinary least squares
FMOLS	Fully modified ordinary least squares
FDI	Foreign direct investment
EKC	Environmental Kuznet curve
EU	European Union
GDP	Gross domestic product
GMM	Generalized moment method
MENA	Middle East and North Africa
NARDL	Nonlinear autoregressive distributed lag model
N-11	Next 11 countries
PMG	Pooled mean group
RE	Renewable energy
TY	Toda Yamamoto
VAR	Vector autoregressive
QR ARDL	Quintile regression autoregressive distributed lag model
QQR	Quintile-on-quintile regression

the histogram. In this respect, since the JB probability is greater than 5% as presented in Figures 1, 2, and 3, the study accepts the null hypothesis that the series follows the normal distribution. This means that there is no unequal spread problem in the panel series since the residuals follow a normal distribution.

5. Conclusion, Theoretical, and Managerial Implication

The present research examines Africa's environmental quality, energy consumption, and economic performance between 1981 and 2019. The study adopts the co-integration analytical technique based on the framework of FMOLS and DOLS to analyze the panel data sets. Both FMOLS and DOLS revealed that environmental quality proxied with CO_2 emission positively and significantly impacted Africa's growth. It means that the African economy prospers with higher emissions, which intuitively means that African economies perform well at the expense of the environment. The finding also pointed to the fact that African countries utilized their endowment to drive growth because African economies are rich in coal, gas, and oil, which are energy sources and also primary sources of CO_2 emission. Again, energy consumption positively and significantly affects growth for both estimation techniques. This revealed that energy consumption propels economic activities and consequently engenders high output and growth. In order to ascertain the interaction effect of environmental quality and energy consumption on African growth, the estimates for both DOLS and FMOLS revealed that the interaction is positive on African growth performance. The meaning is that African countries depend more on carbon-emitting energy sources for the continuous operation of economic activities with less attention to carbon consumption abetment campaigns which undermine environmental quality for the pursuit of economic wealth.

More so, panel causality revealed a unidirectional link between environmental quality and growth performance in Africa, with the direction of influence flowing from environmental quality to growth. This means that environmental quality (carbon emission) affects economic growth in Africa because African countries are energy-dependent. In the same vein, energy consumption has a causal link with growth in Africa, with the direction of influence running from energy consumption to growth. It shows that energy is important in facilitating economic activities (production, distribution, and consumption). Again, energy consumption also has a causal link with environmental quality with the direction of influence flowing from energy consumption. This denotes that the level of energy consumption affects the environment.

The finding of this study is novel, with theoretical and managerial implications. Concerning the theoretical implication, this study is novel by considering energy consumption and environmental quality as the drivers of economic growth. Theoretically, our study deviates from existing theoretical literature because we did not consider growth as a driver of environmental quality but in the reverse order. The intuition is that the quality of the environment necessitates improvement in economic productivity. For instance, as the environment degrades, it can reduce economic growth by lowering the availability of natural resources, affecting public health, and increasing the cost of doing business. On the other hand, as environmental quality improves, it increases sustainable economic growth and development. This theoretical argument presented in this strongly deviates from existing literature as most evidence seeks to test the validity of the environmental Kuznets hypothesis. Hence, the finding of our study presents a theoretical innovation.

The empirical findings of the study present managerial implications. The study's key finding is that energy and environmental quality (CO_2) increased economic growth in Africa. The implication is that as energy use and CO_2 continued to rise, the economic output increased, suggesting a positive linkage among the variables. The evidence favors African countries because they pursue growth to catch up with emerging economies. However, African countries must ensure that they do not harm the ecology at this stage that energy and CO_2 contribute toward growth. As a result, governments of African countries should begin to invest the receipt from current growth toward sustainable energy resources such as solar energy, wind turbines, hydropower, and biomass to begin a gradual energy substitution from crude oil and coal toward renewable to lower emissions and sustain economic growth in a sustainable manner. Again, African countries should be tentative in domesticating and implementing the Paris Agreement that most of the countries signed in 2015 and committed to the region's aspiration by 2063, which is to drive sustainable growth through balancing energy, environment, and growth.

Lastly, the theoretical and managerial is novel; however, the study is not without a gap to be filled by future research. As such, future research should consider expanding the scope of this current study to a wide range of samples. Also, African countries are heterogeneous, which sometimes can be difficult to draw inferences or suggest a one-size-fits-all policy for the region. As such, another gap future research may consider replicating this study for specific African countries to ascertain the impact of energy use and environmental quality on growth.

Table 7 clearly defines in full the list of abbreviations used throughout this article.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

Data sharing not applicable – no new data generated.

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Appendix

Appendix 1. List of selected African countries

List of selected countries
Nigeria
South Africa
Algeria
Angola
Tunisia
Egypt