



Assessing the moderating effect of institutional quality on economic growth—carbon emission nexus in Nigeria

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Abstract

This study explores the relationship between economic growth and carbon dioxide and the moderating effect of institutional quality in Nigeria from 1990 to 2020, by employing long-run and short-run dynamic ARDL regression, quartile regression and Granger causality test for the estimation. Utilizing CO₂ per capita emissions; GDP per capita, a proxy for economic growth; capital stock (CAPSTK), proxy for capital investment in Nigeria and control of corruption and regulatory quality (COC and RGQ) which represent the effective environmental regulations and laws put in place for the control and prevention of environmental degradation, the study found a significant cointegration between CO₂ emissions and economic growth (lnGDP) in Nigeria. Furthermore, an N-shaped nexus exists between CO₂ emissions and economic growth in the long-run and short-run instead of the inverted U-shape curve postulated by the EKC hypothesis. This was confirmed by both ARDL and quartile regression results. Similarly, lnCAPSTK contributed significantly to the growth of CO₂ emissions in Nigeria both in the long run and short run; although, the short run did so at 10% significant level. Contrary to expectations, control of corruption (COC) contributes significantly to CO₂ emissions in the long run, but when it interacts with income (lnGDP × COC), it significantly contributes to the reduction of CO₂ emissions. More so, regulatory quality (RGQ) had no significant impact on CO₂ emissions in Nigeria either in the long run or short run, even when it interacts with lnGDP. This finding is further supported by the quartile regression outcomes and Granger causality. The study therefore concludes that CO₂ emissions–economic growth nexus in Nigeria assumes an N-shape both in the long run and short run. Based on the results, the study recommends that Government should pursue industrialisation policy with sophisticated method of production that will bring about rapid economic progress and at the same time support environmental sustainability.

Keywords Regulatory quality · Control of corruption · Carbon emission · Economic growth · Quartile regression · Environmental sustainability

JEL Classification O44 · Q5 · C5

Introduction

The threat posed by climate change has intensified interest in the study of economic growth and carbon emissions (CO₂). While hydrocarbon fuel reliance and continued

carbon emissions have significant effects on the ecosystem and global rising temperatures, sustainable development guarantees the existence of humanity (Ouédraogo et al. 2021). According to Mesagan and Ekundayo (2015), a precondition for the attainment of sustainable development as contained in the 2030 global development agenda is for countries to transit to eco-friendly growth and engender an emission-free environment. Polluting growth activities directly affect humans, causing illnesses such as cancer, inflammation and heart disease (Pope and Dockery 2006), and environmental quality (Ben Amar 2021). The writings by Kuznets (1955) and Grossman and Krueger (1991) fostered the creation of the environmental Kuznets curve (EKC) concept, an inverted U-shaped association between

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environmental pollution and economic growth, providing an interesting examination within emerging economic research. Correspondingly, a large body of studies on the subject matter has accumulated in recent decades, emphasizing the importance of a country's degree of economic growth with environmental quality. The EKC hypothesis also suggests that environmental quality initially deteriorates when the economy expands, but after reaching a specific income threshold, it improves as income rises.

The influence of economic growth on environmental degradation cannot be overstated (Mobosi et al. 2017), as increased production leads to swelled pollution. Changes in climate conditions have greater effects on Africa (Dimnwobi et al. 2021), placing the continent as the most vulnerable to global warming. Recent studies have proved that most of the environmental degradation witnessed in African countries have been debilitating, emanating from the production and consumption of energy commodities and a general increase in economic activity (Ogwu 2021). Among the countries in Sub-Saharan Africa, Nigeria is of significant interest. The country has the highest economy in Africa, is the largest black nation on earth with over 200 million persons and the largest producer of crude oil in Africa, as well as the world's 25th largest economy by nominal GDP and PPP (Whiting 2019). With abundant oil resources serving as the major economic backbone, the Nigerian economy has experienced considerable petrodollar revenues and economic prosperity since its independence. From 2011 to 2021, Nigeria grew her GDP annually at an average rate of 2.63 percent, with a peak of 6.88 percent in Q1 of 2011, recording strong figures through the 2008/2009 global economic turmoil in the process and a low of -6.10 percent in Q2 of 2020 partly due to the COVID-19-induced economic recession. Interestingly, the National Bureau of Statistics GDP report of 2021 states that the Nigerian economy increased by 3.4 percent in 2021 (N72.39 trillion in real value), the strongest rate of GDP growth in 7 years.

However, Nigeria's environmental pollution levels have been alarming on the heels of a rise in 'dirty growth' (Maduka et al. 2021). A World Bank (2021) report states that, although Nigeria alongside six other countries contributes 40 percent of global oil supply, these countries are equally responsible for about two-thirds (65%) of gas flaring in the world for the past 9 years successively. This makes the country one of the single largest sources of emissions in the world (Maduka et al. 2021; Kankara 2013), and puts at risk, the attainment of the Zero Routine Flaring by 2030 initiative inaugurated by the World Bank and the United Nations in 2015 and backed by several energy corporations, governments and organizations (U. S. IEA 2021). As a result, according to the WHO (2018) and Dada and Ajide (2021), 94 percent of Nigerians are vulnerable to high levels of pollution. The amount of pollution in the country surpasses the

SSA average of 72%, while the cost of air pollution impairment is roughly 1% of post-GNP.

Recent economic literature opines that sustainable development is tractable to economic growth accompanied by structural and institutional improvements. As an economy grows, adjustments in output structure from primary production to processing and manufacturing under eco-friendly circumstances become more necessary to ensure sustainable development (Adewuyi and Adeleke, 2016). In a natural resource-dependent economy like Nigeria, good governance and quality institutions are also required to support the fair, transparent and equal allocation of resources and opportunities. Surprisingly, despite commitments to the global sustainability agenda, the Paris accord and local environmental efforts like the Ogoni oil spill clean-up and the national policy to end gas flaring, there has been little action with hazardous consequences for the economy and environment (Mobosi et al. 2017). This scenario is largely due to weak institutions, as no tangible abatement measures have been implemented despite the increasing environmental degradation (Alege and Ogundipe 2013; Adewuyi and Adeleke 2016). Quality institutions are however critical to attaining sustainable economic prosperity, especially for a resource-rich country like Nigeria, which is plagued by bad governance, including corruption and abuse of power, as well as a disregard for the rule of law (Okoye, et al. 2018; Mobosi et al. 2017; Adewuyi and Adeleke 2016).

In the light of the background information, the contributions of this study are fivefold. First, the study makes a modest contribution to the EKC discourse that is largely mixed, while some studies back the EKC's existence (Lv and Li 2021; Le and Ozturk 2020; Le and Nguyen 2020; Elsalih et al. 2020; Godil et al. 2020) other findings do not (Adams et al. 2020; Acheampong et al. 2020; Olubusoye and Musa 2020). Our research further contributes to the extant literature by reassessing and reinterpreting the EKC hypothesis because Nigeria is still on the road to sustainable development since the EKC professes that environmental degradation is high at the inception of development. Second, we contend and present empirical evidence that rises in economic growth alone does not contribute to environmental quality improvement, but rather the institutional factors that facilitate economic growth. This improves on the inconsistent findings of existing studies on the link between economic growth and environmental pollution. The goal of this research is to investigate the moderating influence of institutional quality on the impact of economic expansion on ecological pollution. This study varies from previous studies on institutional quality and CO₂ emissions (Danish and Ulucak 2020; Wawrzyniak and Doryń, 2020; Sarkodie and Adams 2018) given the adoption of regulatory quality and corruption control as indicators of institutional quality. Third, given the prevalence of pervasive corruption,

weak institutions and regulatory fragility that have become synonymous with Nigeria (Okoye et al. 2018; Mobosi et al. 2017; Adewuyi and Adeleke 2016), this study is particularly pertinent and timely. As a result, neglecting these two factors may result in an understatement of the real environmental damage attributable to emissions, threatening to put Nigeria's initiatives and strategies for safeguarding the environment off course. Fourth, Nigeria is a developing nation with a fast-rising population and a continuously growing economy. Economic development is expected to continue along the same path into the future, with repercussions for the ecology. The results of the study will present pragmatic and evidence-based solutions to enable the country to achieve the Sustainable Development Goals (SDGs), the Paris Accord pact and the Zero Routine Flaring by 2030 goal. Five, apart from adopting the ARDL dynamic regression by Pesaran et al. (2001) as observed in the literature, the quantile regression model proposed by Koenker and Basset (1978) will be employed to validate the outcome of the ARDL model, alongside the Granger causality technique and other supporting tests.

Thus, the goal of this study is to verify the EKC validity for Nigeria and determine whether the level of institutional quality moderates the influence of economic growth on environmental pollution. The subsequent sections of this paper are arranged as follows: “[Empirical evidence](#)” is the empirical evidence, “[Methodology and data sources](#)” is the methodology, “[Result presentation and discussions](#)” is the result presentation and discussion, while “[Conclusion and recommendations](#)” is the conclusion and recommendation.

Empirical evidence

Many studies have examined the relationship between economic growth and carbon dioxide emissions. This empirical exploration reviews and elicits information on the EKC along with the growth–CO₂ nexus on the one hand, and the role of institutional quality on the other. Following the first strand under the EKC, Le and Ozturk (2020) studied the influence of economic growth on carbon emissions for 47 Emerging Markets and Developing Economies (EMDEs), confirming the existence of the EKC. Similarly, Le and Nguyen (2020) examined the effect of economic prosperity on environmental pollution for 95 nations using the panel corrected standard errors (PSCE) and discovered the presence of the EKC. This result agrees with Elsalih et al. (2020) that employed a dynamic two-step SYS-GMM estimator to evaluate the impact of economic expansion on environmental deterioration in 28 oil-producing nations. In addition, Godil et al. (2020) applied a quartile autoregressive distributive lag method for Pakistan and discovered the occurrence of the EKC. For 39 developing nations, Halidar

and Sethi (2021) studied the impact of economic expansion on environmental pollution and established identical conclusions. Sarkodie and Adams (2018) validated the presence of the environmental Kuznets curve in the instance of South Africa, while Lv and Li (2021) employed the spatial econometric framework to examine the impact of economic development on environmental pollution for 97 nations and concluded that the EKC exists. Egbetokun et al. (2020) evaluated the impact of economic growth on CO₂ emissions in Nigeria and confirmed the validity of the EKC.

Additional research, contrary to the ones described previously, reported no evidence of the presence of the EKC. Lise (2006), for instance, looked at the relationship between carbon dioxide and income in Turkey. The study found a linear relationship between the variables, rather than a quadratic relationship, concluding that the relationship does not support the EKC hypothesis. Omojolaibi (2010) conducted a study on environmental quality and economic growth in some selected West African countries, including Nigeria, assessing the existence of an EKC in those countries. The pooled OLS results showed a consonance with EKC, while the fixed effects results were at variance with the applicability of EKC in West Africa. Akpan and Chuku (2011) examined economic growth and environmental degradation in Nigeria, using the Autoregressive Distributed Lag (ARDL) from 1960 to 2008. The outcome did not back the existence of the EKC hypothesis. Equally, Akpan and Abang (2014) found that the relationship between economic growth and environmental quality has an N-shaped curve instead of a U-shaped curve from panel data from 47 countries. Adams et al. (2020) analysed the effect of economic expansion on environmental contamination in 19 Sub-Saharan African nations. The EKC was shown to be invalid. Likewise, in a study of 83 economies, Acheampong et al. (2020) investigated the impact of economic growth on environmental pollution and established the absence of the EKC. Olubusoye and Musa (2020) investigated the relationship between carbon emissions and economic growth in Africa. The EKC hypothesis was investigated using the ARDL model, mean group (MG) and pooled mean group (PMG) models for 43 African countries divided into three income groups from 1980 to 2016. Only 21% of the nations in the sample accepted the EKC hypothesis, whereas 70% of the countries in the whole sample rejected it. According to the study, increased economic expansion will result in higher emissions in the majority of African countries.

Likewise, in terms of the relationship dynamics between CO₂ emission and economic growth, Coondoo and Dinda (2002) studied the causal relationship between carbon dioxide (CO₂) and growth of income in a panel study representing 88 countries in America, Europe, Asia and Africa using Granger causality tests. The findings reveal that causality goes from emissions to income in industrialized countries in

North America, Eastern Europe and Western Europe. But for the group of countries like Japan, Oceania and Central and South America, causation runs from income to emission. However, for the country groups of Asia and Africa, the causality is found to be bidirectional. Similarly, Richmond and Kaufmann (2006) applied a panel study to determine the existence of a turning point in the relationship between economic development and carbon emissions in OECD and non-OECD countries, using variables like a ratio of fuel mix supplied by energy suppliers, income and CO₂ emission. The results showed a negative nexus between economic development and carbon emissions for OECD countries and a positive relationship for non-OECD countries. In another development, Soytaş and Sarı (2009) used the Granger causality test to study energy consumption, economic growth and carbon emissions for Turkey, controlling for gross fixed capital formation and labour. The results showed that unidirectional causality runs from carbon emission to energy consumption without feedback. Also, Kasperowicz (2015) studied the economic growth impact of carbon emissions in Poland using the ECM technique for the period 1995 to 2012. Employing variables like gross domestic product (GDP), carbon dioxide emissions (CO₂), energy consumption, capital stock and total employment, the results found that there is a significant relationship between economic growth and CO₂ emissions. The results differ from that of Richmond and Kaufmann (2006) which were not significant. Menyah and Wolde-Rufael (2010) studied the long-run and causal relationship between energy consumption, pollutant emissions and economic growth in South Africa from 1965 to 2006. Adopting the ARDL bound test for long-run relationships and the ECM technique for short-run dynamics, the result found unidirectional causality running from emissions to economic growth. Furthermore, in another related study, Menyah and Wolde-Rufael (2010) identified a unidirectional causality going from nuclear energy to CO₂ without feedback in a work examining the relationship between CO₂ emissions, nuclear energy, renewable energy and economic growth in the USA from 1960 to 2007. The findings also revealed no link between renewable energy and CO₂. For the period 2002–2012, Zaidi and Ferhi (2019) investigated the causal link between energy consumption, economic growth and CO₂ emissions in a dynamic simultaneous equation model. Using variables of the study including GDP, a proxy for energy use and CO₂ emissions, they found a bidirectional nexus between energy use and electricity use.

In Nigeria, some studies have focused on the relationship between economic growth and CO₂ emissions. Mesagan (2015) used the ECM technique to determine the relationship between economic growth and carbon emission. Findings reveal that economic growth has a favourable influence on carbon emissions in the initial period, but a negative impact in the lagged period; also, capital investment and

trade openness have a positive effect on carbon emissions. Ayadi (2014) discovered that economic expansion and foreign direct investment in Nigeria contributed significantly to pollution, although trade is helpful in both the long and short term. Olubusoye and Musa (2020) applied data spanning to 2016 and conducted a panel study which at most could only produce a short-run country-specific result.

Concerning works involving institutional quality and the environment, the following studies are reviewed. According to Teng et al. (2021), academics, policymakers and administrators devote little consideration to the effects of institutional quality on environmental contamination. However, there have been several noteworthy instances. For instance, Danish and Ulucak (2020) employed the FMOLS, DOLS and DK regression approaches to assess the association between both institutional quality and environmental pollution in 18 Asia–Pacific nations. The study discovered that institutional quality does help the environment. Sarkodie and Adams (2018) employed different evaluation approaches for South African data, including the ARDL methodology, to explore the impact of institutional quality on CO₂ emissions. They observed that institutional quality could aid in lessening CO₂ emissions. Joshi and Beck (2018) examined the association between democracy (political freedom and economic freedom) and carbon dioxide emissions in a sample of OECD and non-OECD countries using the Arellano-Bover/Blundell-Bond Generalized Method of Moments (GMM) technique. Findings reveal the relationship of both political and economic freedoms have a positive and significant relationship with emissions in OECD and non-OECD countries. Examining a group of 93 developing and emerging economies, Wawrzyniak and Doryń (2020) applied a GMM estimation to analyse how institutional quality modifies the nexus between economic growth and CO₂ emission. Although the study found that government efficacy influences the economic growth–emissions link, it did not establish that corruption control has a moderating function in influencing the economic growth–carbon emission nexus.

Methodology and data sources

The study tests the nexus between carbon dioxide emissions and economic growth and the moderating effect of institutional quality in Nigeria. The autoregressive distributed lag (ARDL) and the quantile regression are adopted for the analysis; thereafter, the causality tests will be conducted to further support the regression results. Annual data on GDP per capita (GDP), CO₂ emissions per capita (CO₂), gross fixed capital formation (CAPSTK), control of corruption (COC) and regulatory quality (RGQ) which are measures of institutional quality were sourced from the World Bank Development Indicator (WDI).

Theoretical framework

In the long run, the link between economic growth and carbon dioxide, according to the EKC hypothesis, takes the shape of an inverted U. It claims that once per capita income reaches a particular level, economic growth will be accompanied by improvements in environmental quality. This suggests that after a certain threshold of economic growth, the resulting environmental degradation following the increased economic activities will begin to decrease. Three effects emanate from such a relationship, namely;

1. **Scale effect:** according to the scale effect, as production increases, more inputs are required, resulting in higher emissions of pollutants such as carbon dioxide, gas and methane, among others. As a result, economic growth has a negative relationship with the environment in the short run, according to the hypothesis (Jardón et al. 2017).
2. **Composition effect:** the composition effect, according to Jardón et al. (2017), implies that as the economy grows, its structure may alter as more people participate in cleaner or dirtier activities. The composition effect, on the other hand, is thought to have an uncertain impact on environmental standards.
3. **Technique effect:** this implies that variations in income per head can lead to shifts in civic environmental priorities. Such an increase, for example, may lead to a desire for more stringent environmental rules, which in turn can impact production methods, leading them toward the adoption of less polluting technologies (Grossman and Krueger 1995; Panayotou 1997).

The EKC hypothesis claims that economic expansion is the solution to environmental concerns based on these effects. In other words, economic expansion leads to environmental betterment. As economic growth is sustained, environmental degradation fizzles away. Higher-income growth will lead to a more advanced production process that is less harmful to the environment (Roca et al. 2001; Perman and Stern 2003). To put it another way, as a country grows wealthier, current environmental issues will be handled through legislative changes that both protect the environment and support economic development (Roca et al. 2001, Perman and Stern 2003).

Since the EKC illustrates the nexus between income and the environment, this study can then express the conventional functional hypothesis to be:

$$E_t = F(Y, Y^2, Y^3) \quad (1)$$

where E_t is the environmental factor is at a time (t) and Y is the measure of income (GDP). By extension,

$$E_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \beta_4 Z_t \omega_t \quad (2)$$

In Eq. (2), E_t is the amount of carbon emission in the country, Y_t is the income (GDP) used to measure economic growth in the early stage of growth (pre-industrial stage), Y_t^2 indicating advancement in economic growth (industrial economy or turning point in growth), it is at this point that emissions stop increasing, and then Y_t^3 is the stage of economic growth where emissions begin to decline (service-oriented economy) and Z_t represents other variables that influence emission (Mishra 2020). β_1 , β_2 and β_3 are coefficients of the different levels of income, β_4 is the coefficient of the other variable (s) that impact emission and ω_t measures the error in the model. The differences in functional forms are expressed by the different values of coefficients of the income terms. According to Alvarez-Herranz and Lorente (2016) cited in Allard et al. (2018), the EKC can adopt any shape based on the sign of the parameters of the different levels of income. Firstly, $\beta_1 = \beta_2 = \beta_3 = 0$ indicates that there is either a flat pattern or absence of any form of relationship between environmental degradation and income. But if $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, then a monotonically positive relationship exists between environmental degradations and income, indicating that environmental degradations rise with an increase in income. Similarly, if $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, then a negative monotonic relationship exists between environmental degradation and income such that increasing income will lead to a decline in environmental degradation. However, if $\beta_1 > 0$ and $\beta_2 < 0$ and $\beta_3 = 0$, then the classical inverted U-shaped EKC exists. But a U-shaped relationship exists between environmental degradations and income if $\beta_1 < 0$ and $\beta_2 > 0$ and $\beta_3 = 0$. Furthermore, if $\beta_1 > 0$ (positive) and $\beta_2 < 0$ (negative) and $\beta_3 > 0$ (positive), then an N-shaped nexus exists between environmental degradation and income. Contrarily, the relationship will assume that of an opposite N-shaped if $\beta_1 < 0$ and $\beta_2 > 0$ and $\beta_3 < 0$.

Zhang (2021) among others, who found the existence of an N-shaped nexus between pollution and income in China, identified three stages in the growth of income that gave birth to the N-shaped nexus. They are the scale effect, where the government pays attention to the growth of income, employment and production while neglecting the environmental and conservation policies; the compositional and technical effects, where the government now focuses on reducing the pollution level; and the technological obsolescence effects, where the technological effects that take the form of innovations have reached its maximum limit, thereby leading to scale effects outweighing the technical effects, and bringing about further deteriorations in the environment with the increase in income.

Estimation technique

ARDL regression

The use of the ARDL model is possible if a long-run relationship exists among the variables. It is justified since it

removes the constraint in the event of variables being stationary at both I(0) and I(1). Similarly, the ARDL model is a potent solution to spurious regression resulting from missing or omitted variables (Engle and Granger 1987; Yule 1926; Simon 1954). Its application in this study is to account for both the long-run and short-run relationships between economic growth and carbon emission. To ascertain the existence of cointegration in our model that will guarantee the use of the ARDL, the bound *F*-statistic test proposed by Pesaran et al. (1991) will be used. All the variables for the study are changed to their log form in order to reduce skewness. The ARDL model is thus stated as:

$$\begin{aligned} \Delta CO_{2t} = & \beta_0 + \beta_1 CO_{2t-1} + \beta_2 \ln GDP_{t-1} + \beta_3 \ln GDP_{t-1}^2 \\ & + \beta_4 \ln GDP_{t-1}^3 + \beta_5 \ln CAPSTK_{t-1} + \beta_6 COC_{t-1} \\ & + \beta_7 \ln GDPXCOC_{t-1} + \beta_8 RGQ_{t-1} \\ & + \beta_9 \ln GDPXRQG_{t-1} \\ & + \sum_{i=1}^p \alpha_1 \Delta CO_{2t-i} + \sum_{j=0}^q \alpha_2 \Delta \ln GDP_{t-j} + \sum_{k=0}^r \alpha_3 \Delta \ln GDP_{t-k}^2 \\ & + \sum_{l=0}^s \alpha_4 \Delta \ln GDP_{t-l}^3 + \sum_{m=0}^u \alpha_5 \Delta \ln CAPSTK_{t-m} \\ & + \sum_{n=0}^v \alpha_6 \Delta COC_{t-n} + \sum_h^w \alpha_7 \Delta \ln GDPXCOC_{t-h} \\ & + \sum_i^y \alpha_8 \Delta RGQ_{t-i} + \sum_g^z \alpha_9 \ln GDPXRQG_{t-g} + \mu_t \end{aligned} \tag{3}$$

where ΔCO_2 represents the first difference in carbon emissions, $\ln GDP$, $\ln GDP^2$ and $\ln GDP^3$ represent the three stages of economic growth, $\ln CAPSTK$ represents the country’s capital stock, which represents a capital investment, and COC and RGQ are the control of corruption and regulatory quality, respectively, which represent effective environmental laws aimed at controlling and preventing environmental degradation, $\ln GDPXCOC$ represents the interaction of economic growth with control of corruption and $\ln GDPXRQG$ represents the interaction of economic growth with regulatory quality in Nigeria. The short-run maximum lags of the variables are *p*, *q*, *r*, *s*, *u*, *v*, *w* and *z*, while the information criteria will be used to determine the optimal lags. Carbon emission CO_2 , economic growth (GDP), capital stock (CAPSTK) and institutional quality (COC and RGQ) have long-run impacts of β_1 , β_2 , β_3 and β_4 , respectively, while β_0 is the constant term and α_1 , α_2 , α_3 , α_4 , α_5 , α_6 , α_7 , α_8 and α_9 are the short-run impacts of these variables. Capital stock and institutional quality are control variables. The elasticity of the income coefficients for the short and long runs can be understood as the elasticity of income, whereas μ_t represents the idiosyncratic variable (error term). GDP per capita and capital stock are logged. Furthermore, to capture the error in our cointegrating equation, we state the necessary ECM equation as follows:

$$\begin{aligned} \Delta CO_{2t} = & \beta_0 + \beta_1 CO_{2t-1} + \beta_2 \ln GDP_{t-1} + \beta_3 \ln GDP_{t-1}^2 + \beta_4 \ln GDP_{t-1}^3 \\ & + \beta_5 \ln CAPSTK_{t-1} + \beta_6 COC_{t-1} + \beta_7 \ln GDPXCOC_{t-1} + \beta_8 RGQ_{t-1} \\ & + \beta_9 \ln GDPXRQG_{t-1} + \sum_{i=1}^p \alpha_1 \Delta CO_{2t-i} + \sum_{j=0}^q \alpha_2 \Delta \ln GDP_{t-j} \\ & + \sum_{k=0}^r \alpha_3 \Delta \ln GDP_{t-k}^2 \\ & + \sum_{l=0}^s \alpha_4 \Delta \ln GDP_{t-l}^3 + \sum_{m=0}^u \alpha_5 \Delta \ln CAPSTK_{t-m} + \sum_{n=0}^v \alpha_6 \Delta COC_{t-n} \\ & + \sum_h^w \alpha_7 \Delta \ln GDPXCOC_{t-h} + \sum_i^y \alpha_8 \Delta RGQ_{t-i} + \sum_g^z \alpha_9 \ln GDPXRQG_{t-g} \\ & + \theta ECM_{t-1} + \mu_t \end{aligned} \tag{4}$$

Here, while other variables remain as previously defined, θ represents the error correction coefficients indicating the speed of adjustment in the long run.

Quantile regression

The quantile regression in this study is used to authenticate the output of the ARDL. According to Allard et al. (2018), the unequal variations that result from statistical data can cause the relationship between variables to change at different points in the dependent variable’s conditional distribution. Based on this, estimation methods that are built on the mean values could give incorrect results. Thus, the use of the quantile regression becomes ideal as it presents a more valid picture of the relationship that exists among variables. Furthermore, the quantile regression can be used to capture the heterogeneity among the various income and market groups (Allard, et al. 2018). The general specification of the quartile regression model is stated below:

$$Y_i = X_i' \delta_\rho + \epsilon_{\rho i} \tag{5}$$

where Y_i denotes the dependent variable and X_i' is a vector of explanatory variables $K \times 1$. Similarly, δ_ρ and $\epsilon_{\rho i}$ are used to represent the unknown vector of estimated regression parameter $K \times 1$ for the values of ρ ranging between 0 and 1 and unidentified disturbance (error term), respectively. By transforming Eq. (5) we can obtain the quantile conditional process as follows:

$$\varphi_\rho \left(\frac{Y_i}{X_i} \right) = X_i' \delta_\rho \tag{6}$$

According to Rehman et al. (2021), the functional form of the vector δ_ρ can be measured by decreasing the corresponding value of ρ . Furthermore, since the quantile regression can follow either the generalized moment techniques or the basic linear algorithm programming, it is possible to put the number of weighted error conditions to minimal by restriction. The goal is to allow the error conditions to vary while weighing the positive and negative

Table 1 Descriptive statistics

	CO ₂	lnGDP	lnGDP ²	lnGDP ³	lnCAPSTK	COC	lnGDPXCOC	RGQ	lnGDPXRGQ
Mean	0.666417	11.66652	138.3421	1664.261	14.86480	-1.176498	-13.64478	-0.921344	-10.64965
Median	0.654964	12.02279	144.5474	1737.863	14.80287	-1.172974	-13.78646	-0.907262	-10.12364
Maximum	0.862605	13.52555	182.9404	2474.369	16.78849	-0.891883	-10.34105	-0.659629	-8.200535
Minimum	0.481063	8.555482	73.19628	626.2294	14.65394	-1.431231	-16.75480	-1.351967	-15.96011
Std. dev	0.080902	1.519469	34.26189	587.7880	0.365866	0.123662	1.750183	0.170664	1.958414
Skewness	0.442992	-0.552084	-0.392413	-0.248299	4.893926	-0.187057	0.166137	-0.821965	-0.939694
Kurtosis	3.234609	2.126978	1.903585	1.749386	26.34081	2.936723	2.120890	3.362898	3.296862
Jarque–Bera	1.085012	2.559251	2.348353	2.338750	827.4360	0.185954	1.140852	3.660845	4.676127
Probability	0.581290	0.278141	0.309073	0.310561	0.000000	0.911214	0.565285	0.160346	0.096514
Sum	20.65892	361.6622	4288.604	51,592.08	460.8089	-36.47144	-422.9881	-28.56166	-330.1393
Sum sq. dev	0.196353	69.26363	35,216.30	10,364,842	4.015727	0.458767	91.89425	0.873789	115.0616
Observations	31	31	31	31	31	31	31	31	31

Source: Author's computation

residuals in the chosen quantile. Thus, the interactions between the interest variables can be stated as follows:

$$\begin{aligned} \Delta CO_{2t} = & \beta_0^e + \beta_1^e CO_{2t-1} + \beta_2^e \ln GDP_{t-1} + \beta_3^e \ln GDP_{t-1}^2 + \beta_4^e \ln GDP_{t-1}^3 \\ & + \beta_5^e \ln CAPSTK_{t-1} + \beta_6^e COC_{t-1} + \beta_7^e \ln GDPXCOC_{t-1} + \beta_8^e RGQ_{t-1} \\ & + \beta_9^e \ln GDPXRGQ_{t-1} + \mu_t \end{aligned} \quad (7)$$

where all the variables and terms remain as earlier defined; we proceed to estimate the coefficients of the quantile process which will range between the 1st and 9th quantile (Table 1).

Result presentation and discussions

Figure 1 presents the outcome of the descriptive statistics which from all indications looks good and normal. While lnGDP, lnGDP², lnGDP³, COC, RGQ and lnGDP × RGQ are negatively skewed, the rest of the variables are positively skewed. A look at the mean, maximum and minimum values on a comparative basis indicates that the effectiveness of control of corruption (COC) and regulatory quality (RGQ) which are institutional quality measures is on the decline. Similarly, lnGDP and CO₂ are on the increase but emissions tend to increase more rapidly than income.

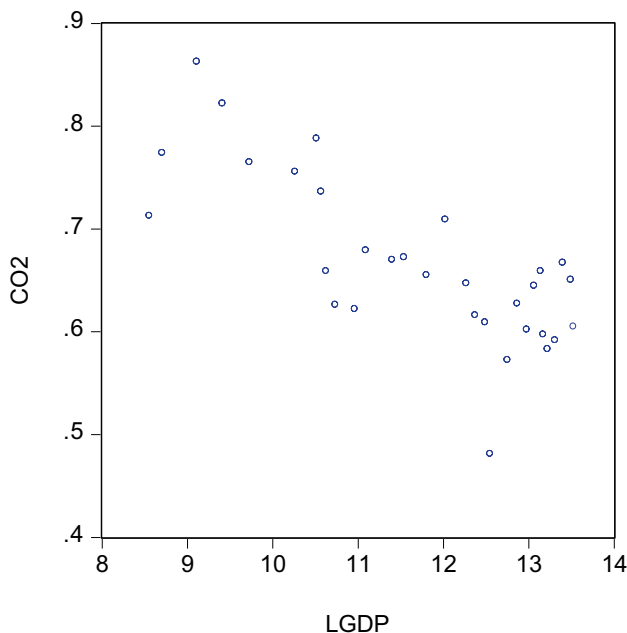


Fig. 1 Scattered plot for CO₂ per capita and lnGDP per capita in Nigeria

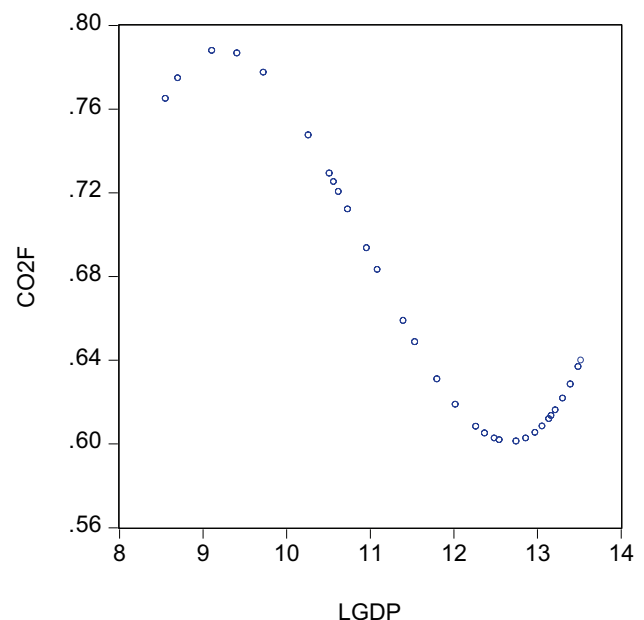


Fig. 2 Scattered plot for fitted CO₂ per capita and lnGDP per capita in Nigeria

Figures 1 and 2 are scattered plots showing the relationship between CO₂ per capita and IGDP per capita in Nigeria. Figure 1 reveals that the relationship between CO₂ per capita, and InGDP per capita in Nigeria takes the form of an N-shaped curve. This is further clarified in Fig. 2, which is the fitted figure. Figure 1 gives us an insight into the manner in which CO₂ emissions respond asymmetrically to the changes in InGDP which in turn could be attributed to the income (InGDP) response to the variations in macroeconomic variables in Nigeria. This is valid looking at the fact that Nigeria within the period considered in this study has remained oil-dependent, i.e. crude oil has been the major export product for the country and the key contributor to the GDP. It is noteworthy that, even though the prices of crude oil are exogenously determined by the OPEC body, this has not significantly impacted on Nigeria’s crude oil production or CO₂ emissions.

The results in Table 2 show that within the framework of ADF unit root testing, all the variables are integrated of order I(1) except the three levels of InGDP which shows the presence of unit root. Similarly, within the framework of Philips-Perron (PP) unit root testing, all the variables are integrated of order I(1) except InGDP which is integrated of order I(0). This implies that the use of ARDL bound test cointegration is justified, since the Pesaran et al. (2001) approach of modelling the ARDL permit the use of variables that are jointly integrated. It also implies that we should reject the null hypothesis which says that the variables have unit roots and accept the alternative of no unit roots.

The results in Table 3 show the ARDL bound test for cointegration. The results indicate evidence of cointegration among the variables. This is validated by the value of the *F*-statistic for the joint significance of the variables which is greater than the upper bound at both 1% and 5% levels of significance. The results of the test conclude that there is a long-run relationship among variables of interest. Ideally, the cointegration test of the ARDL is built on the proposition that the long-run relationship between the predicted variable and predictive variables is singular (Orji et al. 2021; Pesaran et al. 2001). The bound *F*-test has two outstanding features. Firstly, in checking for the joint significance of the ARDL, it converts all the variables of the model into dependent variables, and secondly, it is highly influenced by the number of lags it is subjected to (Orji et al. 2021). Hence, this study adopted the lag of 2 whereas the optimum lag was decided by Akaike Information Criterion (AIC).

In Table 4, the results of the normalised short-run and long-run coefficients are presented. The results from the short run indicate that the lag of CO₂ emissions has a negative significant effect on the current CO₂ emissions. The implication of this result is that previous emissions will offer the policymakers in the country clue on the need to regulate current emissions. Contrarily, this outcome will be an indicator to new investors especially in the mining sector that the country has an effective emission regulatory framework, thus giving them the notion that they too do not have the freedom to pollute due to strict emission control.

Table 2 Stationarity results

Variable	ADF (constant only)		PP (constant only)	
	Level	First difference	Level	First difference
InGDP	-2.7722*	-2.2094	-4.7739***	-2.7992*
InGDP ²	-2.5840*	-2.2869	-3.5152**	-3.2612**
InGDP ³	-2.1522	-2.4713	-2.2719	-3.7586***
CO2	-1.7713	-5.3902***	-1.7167	-6.7192***
InCAPSTK	-1.4852	-3.6312**	-1.3394	-3.7342***
COC	-2.3086	-6.7221***	-2.4164	-6.7229***
InGDP × COC	-2.5078	-6.3826***	-2.4677	-6.3835***
RGQ	-2.9761**	-8.6056***	-3.0523**	-8.7327***
InGDP × RGQ	-3.1540**	-8.4439***	-3.1849**	-8.5466***

NB: *, ** and *** imply significance at 10%, 5% and 1% level of significance

Source: Author’s computation

Table 3 ARDL bound test results with intercept and trend

Test tatic	5% critical value		1% critical value	
	Lower bound	Upper bound	Lower bound	Upper bound
<i>F</i> -statistic	1(0)	1(1)	1(0)	1(1)
5.698420***	2.04	2.08	2.5	3.68

NB: *** implies significance at both 1%

Source: Author’s computation

Table 4 Normalised short-run and long-run coefficients. Dependent variable—CO₂

Variable	Panel A short-run coefficient	Std. error	Variable	Panel B long-run coefficient	Std. error
$\Delta\text{CO}_2(-1)$	-0.826161***	0.200950	InGDP	7.937128***	2.609109
ΔInGDP	14.03196**	5.335862	InGDP^2	-0.796046***	0.243441
ΔInGDP^2	-1.401982**	0.495220	InGDP^3	0.024729***	0.007503
ΔInGDP^3	0.045612**	0.015275	InCAPSTK	0.780546*	0.381012
$\Delta\text{InCAPSTK}$	0.644857**	0.290629	COC	4.914986**	1.950065
ΔCOC	2.133835	1.309837	$\text{InGDP}\times\text{COC}$	-0.415104**	0.159583
$\Delta\text{InGDP}\times\text{COC}$	-0.167859	0.108929	RGQ	-2.110325	1.845243
ΔRGQ	-1.743469	1.380528	$\text{InGDP}\times\text{RGQ}$	0.171004	0.153981
$\Delta\text{InGDP}\times\text{RGQ}$	0.147218	0.115427		-24.42258**	10.07780
$\text{ECM}(-1)$	-0.826161***	0.078451			
		R^2	0.94		
		Adjusted R^2	0.86		
		F -statistic	11.949 (0.0000)		
		DW	2.51		
		ARCH	0.0383 (0.8464)		
		LM test	2.4586 (0.1310)		
		Reset	0.4777 (0.6415)		
		Normality	.4670 (0.1766)		

***, ** and * imply significance at 1%, 5% and 10%, respectively

Source: Author's computation

This is because uncontrolled emissions serve as an incentive for more pollution and as such the intending investor would have to consider the burden of emission control. Furthermore, the variable of interest which is InGDP, representing the initial stage of economic growth in Nigeria, has a positive relationship with CO₂ emissions. This relationship with CO₂ emissions is statistically significant. Its coefficient is 7.937128, which implies that a 1 unit increase in GDP will increase CO₂ emissions by 794%, if all other explanatory variables are kept constant. This result confirms the existence of scale effects in Nigeria's economic growth at this level. This means that no attention was given to environmental control measures at the kick-off growth (Zhang 2021). Similarly, InGDP^2 which is used to capture the second stage of economic growth has a negative relationship with CO₂ emissions. This relationship according to the coefficient value (-0.796046) is highly statistically significant with the potential of reducing CO₂ emissions by 80% with every 1 unit increase in InGDP^2 . This validates the presence of compositional or technological effects, which is characterized by effective environmental regulations (Zhang 2021). Furthermore, InGDP^3 which is used as a representation of the advanced level of economic growth has a positive relationship with CO₂ emissions and this relationship is statistically significant, according to the coefficient value (0.024729). The short-run income assumed a similar trend as the long-run. The initial growth result suggests that a 1 unit increase in the initial GDP will increase CO₂ emissions

by 14.03196. Because this effect is statistically significant, it only points to the existence of scale effects resulting from economic growth without environmental regulations. Similarly, the InGDP^2 which depicts the second level of economic growth has a negative relationship with CO₂ emission in Nigeria. This relationship is shown to be statistically significant and has the potential to reduce emissions by 1403% as shown by the coefficient value (-1.401982). The major factor responsible for this relationship between environmental degradation and economic growth at this level is technological effects. The third level of economic growth which is depicted as InGDP^3 has a positive link with CO₂ emissions. Because this link is statistically significant, it portends that a 1 unit increase in growth at this level will amount to a corresponding 5% increase in CO₂ emissions as indicated by the coefficient value (0.045612). This is brought about by technological obsolescence. The conclusion shows that, while GDP has a positive association with CO₂ emissions in both the short and long term, this relationship is statistically significant. This is an evidence of technological obsolescence effects. This suggests that technological effects have reached their maximum limit; thus, scale effects now out crowd technological effects resulting in environmental deteriorations. The overall results from the different levels of economic growth suggest that the growth of the Nigerian economy could accurately predict CO₂ emissions in the country. Also, the results vividly suggest that the economic growth-carbon dioxide nexus in Nigeria does not follow the pattern of the

environmental Kuznets curve hypothesis and as predicted by Narayan and Narayan (2010) but conform with the findings of Akpan and Chuku (2011) and Akpan and Abang (2014). According to this result, rather than the U-shaped curve as posited by the EKC theory what is obtainable in Nigeria is an N-shaped curve. It is noteworthy that the initial level of income in the long run and short run maintained high-coefficient values; this is a perfect demonstration of how the Nigerian economy worked within the study period. This is valid, for between 1990 and recently, the oil sector has remained the main sector contributing significantly to the GDP of Nigeria while the other sectors were gradually abandoned. Thus, this has given room for the high and significant emissions of CO₂ in the country.

Furthermore, the long-run InCAPSTK is positive as its coefficient (0.780546) suggests and statically insignificant but the short-run scenario shows positive significance at 5%. This result suggests that one unit increase in InCAPSTK will increase CO₂ emissions by 64% and implies that the marginal effect of CAPSTK on CO₂ emissions supports the view that capital investment in Nigeria does not have pollution abatement equipment with which to regulate and eliminate pollutants produced in the process of manufacturing. Consequently, as capital investment increases in Nigeria, carbon emission also increases. This implies that an increase in capital investment will increase CO₂ emissions through increased activities of the business sector, such as dumping of waste, emissions from power generating plants of the business sector and transport sector emissions. This is a possible sign of technological obsolescence. More so, in view of the long-run and short-run outcomes on a comparative basis, a major reality is brought to light. The reality is that right from the 2008/2009 global financial crisis which was hard on the country's financial market with varying impacts both on investment and employment, and with rising security threats in some regions of the country, there has been a drastic drop in capital investment especially from abroad. This has tremendously impacted on the overall output and possibly on environmental outcomes in the country as amplified by the insignificant long-run result.

Moving further, control of corruption (COC) which is one of the measures of the quality of institution in Nigeria is statistically significant in the long run while regulatory quality (RGQ) is insignificant, although the RGQ correspond with economic expectation in terms of relationship with CO₂ emissions in Nigeria, whereas, control of corruption which is expected to decrease the level of emissions ended up increasing emissions. This is an indication that efforts to control corruption in Nigeria are not yielding significant results as shown by the long-run result. However, when COC is allowed to interact with income, it significantly reduced CO₂ emissions by 42%. This is not true for environmental regulatory quality (RGQ) which

is insignificant even when it is allowed to interact with income. This portends that the existence of corruption in Nigeria is majorly due to the high level of poverty; thus, the control of corruption in Nigeria can only yield significant results when poverty is drastically reduced. When this is achieved, COC will then enable the successful implementation of environmental laws in Nigeria. In addition to this, its insignificant effect on CO₂ emissions indicates that Nigeria may have put in place some environmental laws, but there may be no adherence to the laws due to problems of enforcement, indiscipline and corruption in Nigeria's institutions (Ladan 2012). This outcome brings to mind the reality that Nigeria's per capita income does not imply what it seems to portray, owing to the growing income inequality. In reality, the larger portion of the country's income is distributed among the ruling political class with those capitalist classes having a close affinity with this ruling political class. This income gap has continued to widen and thus breeding corruption. As a result, the prevailing decay in the country's institutions is corruption brought about by poverty. Poverty has further strengthened the bane of corruption in Nigeria making the existing institutions ineffective. On many occasions, members of these institutions set up by the government have been indicted with corrupt practices and bribery and when investigated it was confirmed to be true. The rest of the short-run results are generally insignificant; this is also the case with the rest of the long-run variables.

The constant term (C) has a negative and significant effect on CO₂ emissions. This suggests that there are variables that contribute to CO₂ emissions in the country which were not included in the model, variables like foreign direct investment (FDI), trade openness and future energy use which may likely be environmentally friendly. Therefore, the long-run results suggest the existence of an N-shaped curve rather than the U-shaped curve proposed by the EKC hypothesis. Similarly, the coefficient of the error correction mechanism (ECM (-1)) which has a negative sign and is significant at 1% suggests that the result conforms to a priori expectation. Its value of -0.826161 indicates the speed of adjustment to long-run equilibrium. In other words, about 83% of the disequilibrium will be corrected in the next period. Its negative sign shows that a convergence from short-run to long-run equilibrium is possible. It can be concluded that there is a rapid speed of adjustment towards long-run equilibrium. Finally, the diagnostic tests indicate that the model is correctly specified, meeting all of the tested statistics' conditions of non-autocorrelation, good fit, normal distribution of residuals, no misspecification errors and the absence of heteroscedasticity. The *F*-statistic is robustly significant at 1%, suggesting that the independent variables have a reasonably joint effect on the dependent variables. This outcome is further validated by the outcome of the cusum and cusum-squared test presented in Fig. 3A and B.

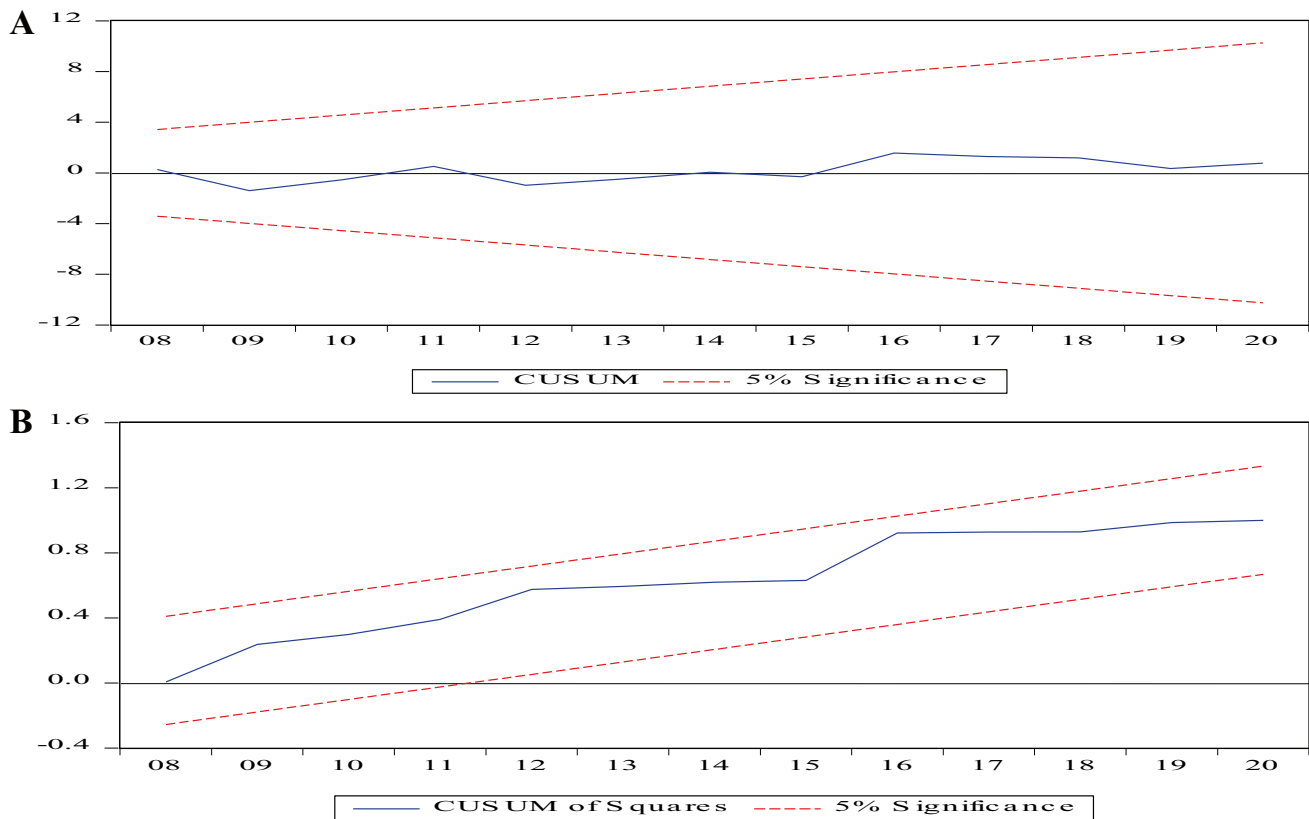


Fig. 3 A, B Result of stability test (cusum and cusum-squared)

It is interesting to note that the long-run and short-run results confirm that the economic growth–carbon dioxide relationship in Nigeria is not consistent with the EKC hypothesis. This happened because the long-run and short-run coefficients of the various levels of $\ln\text{GDP}$, though significant, suggest that instead of the U-shaped curve postulated by the EKC hypothesis, an N-shaped nexus

exists between GDP and the emissions of CO_2 . Thus, the study rejects the EKC hypothesis in Nigeria as proposed by Mobosi et al. (2017), Adewuyi and Adeleke (2016) and Narayan and Narayan (2010). The result is in line with that of Akpan and Chuku (2011) and Akpan and Abang (2014).

The quantile regression results in Table 5 above confirmed the findings from the ARDL regression. It shows that in all

Table 5 Results of the quantile regression

Explanatory variables	10 th	20 th	30 th	40 th	50 th	60 th	70 th	80 th	90 th
$\ln\text{GDP}$	4.634***	4.819***	5.133***	4.177***	3.262***	3.702***	3.013**	3.97***	3.014***
$\ln\text{GDP}^2$	−0.468***	−0.477***	−0.506***	−0.420***	−0.332***	−0.369***	−0.323***	−0.394***	−0.291***
$\ln\text{GDP}^3$	0.014***	0.014***	0.015***	0.012***	0.010***	0.011***	0.009***	0.012***	0.009***
$\ln\text{CAPSTK}$	−0.013	−0.019	−0.019	−0.015	−0.005	−0.019	−0.018	−0.020	−0.040
COC	3.458**	3.742**	4.161***	4.259***	4.747***	4.314***	4.590***	2.569*	−2.150
$\ln\text{GDP} \times \text{COC}$	−0.301**	−0.310**	−0.342***	−0.347***	−0.382***	−0.344***	−0.374***	−0.215*	0.154
RGQ	−1.465	−1.220	−1.507	−1.878	−2.238*	−2.369*	−0.265	0.664	3.522**
$\ln\text{GDP} \times \text{RGQ}$	0.106	0.092	0.115	0.146	0.175*	0.184*	0.013	−0.055	−0.279**
Constant	−13.101**	−13.531**	−14.544***	−11.130***	−8.003**	−9.757**	−5.723	−10.393**	−8.513*

(***), (**) and (*) indicate significance at 1%, 5% and 10%, respectively

Source: Author's computation

the quantiles, $\ln\text{GDP}$, $\ln\text{GDP}^2$ and $\ln\text{GDP}^3$ are all significant at a 5% level of significance, with the impact aligning with the results of the ARDL regression. Similarly, the ICAPSTK is insignificant at all quantiles, thus closely conforming to the long-run outcome of the ARDL regression. According to the quantile regression, COC and $\ln\text{GDP} \times \text{COC}$ are both statistically significant from the 10th up to the 70th quantile; this result agrees with the ARDL long-run result but contrasts with the short-run outcome. Furthermore, the quantile regression results indicate that at all the quantiles, regulatory quality (RGQ) in Nigeria has no significant impact on CO_2 emissions. This is also true when the regulatory quality is interacted with economic growth ($\text{RGQ} \times \ln\text{GDP}$), confirming the result from the short-run and long-run ARDL.

The causation results in Table 6 indicate that there is causality going from $\ln\text{GDP}$, $\ln\text{GDP}^2$ and $\ln\text{GDP}^3$ to CO_2 emissions in Nigeria. Thus, the null hypothesis that the three levels of economic growth used to examine the existence of EKC does not Granger cause CO_2 emissions is rejected. This further buttresses that the EKC hypothesis applies to the economic growth–carbon emissions relationship in Nigeria. Institutional quality variables (COC and RGQ) do not have any causal effect on CO_2 emission, meaning that environmental laws are not vigorously pursued in Nigeria. Similarly, when the institutional quality variables interact with $\ln\text{GDP}$, the null hypothesis is rejected. However, the null hypothesis that CAPSTK does not cause CO_2 emissions is rejected. The study instead concludes that increased capital investment will increase CO_2

emissions due to increased business activities of both local and foreign investors. Altogether, this result strengthens the ARDL dynamic results which show that an increase in GDP does not affect CO_2 emissions in Nigeria. This supports the findings of the study that GDP has a positive relationship with CO_2 emissions, implying that the level of production activities is significant enough to cause CO_2 emissions. The emissions observed in the country are caused by the overall economic activities in the country, most especially from fossil fuel production and combustion, agricultural production, household and commercial activities and low waste management (Ogwu 2021; Ekesiobi et al. 2017).

Conclusion and recommendations

This study examined the relationship between economic growth and carbon dioxide emissions in Nigeria, bearing in mind the moderating influence of institutional quality. To determine this relationship, the ARDL regression analysis was employed on CO_2 emissions, GDP, capital stock (CAPSTK) and institutional quality (COC and RGQ). Furthermore, the quantile regression and Granger causality test were used to corroborate the findings from the ARDL regression. The study found that the three levels of GDP identified to have a significant effect on CO_2 emissions. The nature of these relationships supports the existence of an N-shaped curve rather than the U-shaped curve proposed by the EKC hypothesis. Also, CAPSTK was found to stimulate CO_2 emissions in the short and long run, but more in the long run. This outcome could be attributed to the worsening security situation in the country which is depleting the country's capital stock (CAPSTK) by scaring away investors, but the long-run outcome gives hope that investment will significantly improve once normalcy is restored. Furthermore, control of corruption (COC) which is a measure of institutional quality has a significant impact on CO_2 emissions in the long run; this is also true when COC interact with income ($\ln\text{GDP}$). However, regulatory quality (RGQ) has an insignificant impact on CO_2 emissions in the long run and short run even when interacted with income. The result for $\ln\text{GDP} \times \text{COC}$ implied that corruption control in Nigeria can only reduce CO_2 emissions if poverty is reduced. This infers that there is no effective policy targeted at pollution reduction and control in Nigeria without addressing poverty levels.

The study, therefore, recommends as follows; since economic progress is likely to raise carbon emissions, restricting growth to minimize environmental degradation does not augur well for the economy, especially given the risk of denying the majority of Nigerians the gains of development. While the pursuit of environmental sustainability is imperative, it should not come at a huge cost to the economy. To provide the best quality of life, government economic

Table 6 Pairwise Granger causality test at lag 1

S/N	Null hypothesis:	F-statistic	Prob	Remarks
1	$\ln\text{GDP} \rightarrow \text{CO}_2$	8.45443	0.0072	Rejected
	$\text{CO}_2 \rightarrow \ln\text{GDP}$	0.01644	0.8989	Accepted
2	$\ln\text{GDP}^2 \rightarrow \text{CO}_2$	7.11578	0.0128	Rejected
	$\text{CO}_2 \rightarrow \ln\text{GDP}^2$	0.02224	0.8826	Accepted
3	$\ln\text{GDP}^3 \rightarrow \text{CO}_2$	5.93765	0.0217	Rejected
	$\text{CO}_2 \rightarrow \ln\text{GDP}^3$	0.22929	0.6359	Accepted
4	$\text{COC} \rightarrow \text{CO}_2$	2.24957	0.1453	Accepted
	$\text{CO}_2 \rightarrow \text{COC}$	0.21584	0.6460	Accepted
5	$\ln\text{CAPSTK} \rightarrow \text{CO}_2$	9.13377	0.0054	Rejected
	$\text{CO}_2 \rightarrow \ln\text{CAPSTK}$	9.40819	0.0049	Rejected
6	$\ln\text{GDP} \times \text{COC} \rightarrow \text{CO}_2$	0.43582	0.5147	Accepted
	$\text{CO}_2 \rightarrow \ln\text{GDP} \times \text{COC}$	1.71710	0.2011	Rejected
7	$\ln\text{GDP} \times \text{RGQ} \rightarrow \text{CO}_2$	0.25811	0.6155	Accepted
	$\text{CO}_2 \rightarrow \ln\text{GDP} \times \text{RGQ}$	0.03640	0.8501	Accepted
8	$\text{RGQ} \rightarrow \text{CO}_2$	0.51339	0.4798	Accepted
	$\text{CO}_2 \rightarrow \text{RGQ}$	1.45139	0.2388	Accepted

Rejecting the null hypothesis indicates that one variable actually Granger causes the other, whereas accepting the null hypothesis confirms that there is no causation between variables at either 1%, 5% or 10% level of significance. This is used to indicate the direction of causality

growth policies should be structured to be environmentally sustainable, inclusive and equitable. From our findings, economic growth-centred policies will not be sufficient to mitigate environmental pollution, beckoning for a multifaceted approach. Therefore, further recommendations include the effective management of the capital stock in the economy through the adoption of green industrialisation investments, to decouple manufacturing and production away from harmful environmental externalities by optimizing the use of renewable energy, sustainable supplies and clean technology. Foreign direct investment and financial sector policies, in general, have to be geared towards promoting rapid economic progress in the country and at the same time reinforcing environmental sustainability. Institutional development is also a prerequisite for the furtherance of environmental quality, as the presence of a potent judicial process, an effective and equitable allotment of capital, as well as the enforcement of rules and regulations, fosters economic growth by resulting in a curtailment in carbon emissions. To enhance regulatory control, the government must intensify its efforts to make institutions more proactive and capable of enforcing environmental laws and regulations, so that economic growth does not undermine environmental quality.

Also, the independence of the different tiers (federal, state and local) and arms (executive, legislature and judiciary) of government need to be guaranteed for improved regulatory control, to ensure equal power sharing and delineation of responsibilities, so they can work in sync (horizontally and vertically) devoid of undue interference. Tougher environmental laws should be imposed on polluting industries and sanction violators with carbon taxes, fines and other penalties to compensate for the societal cost of pollution. A good place to start should be the recent Petroleum Industry Act to checkmate gas flaring and other harmful crude oil-related pollution. Also, the National Environmental Standard and Regulation Enforcement Agency (NESREA) needs to be revitalised to deliver on its core mandate which is to “ensure a cleaner and healthier environment for Nigerians”. It is also imperative for anti-corruption efforts in the country to be bolstered to tackle the menace of bribery and corruption. As a result, the Independent Corrupt Practices and other Related Offences Commission (ICPC) and the Economic and Financial Crimes Commission (EFCC) should take renewed and concerted strides in the battle against corruption, by instigating legal action against corrupt offenders and warding off future diversion and abuse of public resources designated for financing economic expansion programmes.

To conclude, future carbon emission abatement is a real concern for present environmental preservation and sustainable development initiatives. While this research makes a modest attempt to provide policy insights into the

growth-pollution-institutional quality debate, it is far from exhaustive. Another limitation of this work stems from the data period; hence, the study could not capture the period when oil began to overshadow the other sectors of the economy in terms of contribution to GDP. Other measures of institutional quality such as rule of law, government effectiveness and political stability have been reckoned as key players in the growth of the Nigerian economy, most especially, the issues relating to the disturbance of peace in some regions of the country which frequently interrupt economic activities in these regions. As a result, there are intrinsic constraints that provide an impetus for additional research investigations. Examining findings across nations and regions to draw parallels with respect to nationality, culture, faith, dialect and system of government will be beneficial. Cross-country comparisons of advanced and budding economies, which differ in many other ways, might be another area of research. Research in this area also should be continuous with the availability of new data, theories and methodology. These actions would further pave the way to achieve decarbonisation and mitigate climate change for the welfare of the present and future generations.

Author contribution Maduka, Ogwu and Ekesiobi conceived the study. Data collection and analysis were done by Ogwu. Maduka drafted the initial version of the manuscript. Ekesiobi revised the introduction and literature sections. Maduka, Ogwu and Ekesiobi read, revised and approved the final manuscript.

Data availability The datasets used and/or analysed during the current study are available in the World Bank Development Indicator (WDI) repository, <https://wdi.worldbank.org>

Code availability Not applicable.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

References

- Acheampong AO, Amponsah M, Boateng E (2020) Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies. *Energy Economics* 88:104768
- Adams S, Boateng E, Acheampong AO (2020) Transport energy consumption and environmental quality: does urbanization matter? *Sci Total Environ* 744:140617

- Adeyuyi AO, Adeleke AM (2016) Role of institutions and resource abundance in inclusiveness of Nigeria's economic growth. *The Nigerian Journal of Economic and Social Studies* 58(1):21–52
- Akpan FU, Abang ED (2014) "Environmental quality and economic growth: a panel analysis of the "U" in Kuznets". Online at <http://mpr.aub.uni-muenchen.de/54461/MPPA> Paper No. 54461
- Akpan U, Chuku A (2011) "Economic growth and environmental degradation in Nigeria: beyond the environmental Kuznets curve" Available at: <https://www.semanticscholar.org/paper/Economic-Growth-and-Environmental-Degradation-in-Akpan-Chuku/cdee2c46127de476890b8a70de159c63fb25eeef>. Accessed 15/03/2022
- Alege PO, Ogundipe AA (2013) "Environmental quality and economic growth in Nigeria: a fractional cointegration analysis". *International Journal of Development and Sustainability* 2(2). Retrieved from <http://www.isdsnet.com/ijds>. Accessed 15/03/2022
- Allard A, Takman J, Uddin GS, Ahmed A (2018) The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. *Environ Sci Pollut Res* 25:5848–5861. <https://doi.org/10.1007/s11356-017-0907-0>
- Álvarez-Herranz A, Balsalobre Lorente D (2016) Economic growth and energy regulation in the environmental Kuznets curve. *Environ Sci Pollut Res* 23(16):16478–16494
- Ayadi FS (2014) Economic integration, growth and the environment in Africa: a study of Nigeria. *Journal of Emerging Issues in Economics, Finance and Banking* 3:1274–1289
- Ben Amar A (2021) Economic growth and environment in the United Kingdom: robust evidence using more than 250 years data. *Environ Econ Policy Stud* 23:667–681. <https://doi.org/10.1007/s10018-020-00300-8>
- Coondoo D, Dinda S (2002) "Causality between income and emission: a country group-specific econometric analysis". *Ecological Economics* 40(3):351–367. Available at <https://econpapers.repec.org/scripts/showcites.pf?h=repec:eee:ecolec:v:40:y:2002:i:3:p:351-367>. Accessed 15/03/2022
- Dada JT, Ajide FM (2021) The moderating role of institutional quality in shadow economy–pollution nexus in Nigeria. *Manag Environ Qual* 32(3):506–523. <https://doi.org/10.1108/MEQ-10-2020-0238>
- Danish, Ulucak R (2020) The pathway toward pollution mitigation: does institutional quality make a difference? *Bus Strateg Environ* 29(8):3571–3583. <https://doi.org/10.1002/bse.2597>
- Dimnwobi SK, Ekesiobi C, Madichie CV, Asongu SA (2021) Population dynamics and environmental quality in Africa. *Sci Total Environ* 797:149172
- Dimnwobi SK, Nwokoye ES, Ekesiobi CS, Igbunugo IC (2018) "Determinants of investment in energy efficiency by selected firms in Onitsha business clusters." Paper presented at the 11th International Conference of the Nigeria Association of Energy Economics/International Association of Energy Economics, Themed: New Era in Global Energy Landscape: Implications for an Emerging Economy, 22nd - 24th April, 2018 at the PTDF Building, Abuja, Nigeria
- Egbetokun S, Osabuohien E, Akinbobola T, Onanuga OT, Gershon OE, Okafor V (2020) Environmental pollution, economic growth and institutional quality: exploring the Nexus in Nigeria. *Management of Environmental Quality: An International Journal* 31(1):18–31
- Ekesiobi CS, Ude DK, Madueme S, Nwokolo C (2017) Energy Labels and End-use Efficiency: a study of selected households in Awka, Anambra state. *Nigerian Association for Energy Economics. 10th NAAEE/IAEE Annual International Conference Proceedings*. April 23–26, 2017. Pp 32–65
- Elsalih O, Sertoglu K, Besim M (2020) "Environmental performance, comparative advantage of crude oil and the role of institutional quality." *Environ Sci Pollut Res* 27(3):3489–96.
- Engle RF, Granger CWJ (1987) Co-integration and error correction: representation, estimation and testing. *Econometrica* 55:251–276. <https://doi.org/10.2307/1913236>
- Farhani S, Jaleeldine BR (2012) "Energy consumption, economic growth and CO2 emissions: evidence from panel data for MENA region". *International Journal of Energy Economics and Policy*, 2(2), 71–81. www.econjournals.com. Accessed 15/03/2022
- Godil DI, Sharif A, Agha H, Jermsittiparsert K (2020) The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: new insights from QARDL approach. *Environ Sci Pollut Res* 27(19):24190–24200
- Grossman GM, Krueger AB (1991) Environmental impacts of a north american free trade agreement. *NBER Work Pap* 3914
- Grossman GM, Krueger A (1995) Economic Growth And The Environment. *Q J Econ* 110(2):353–377. <https://doi.org/10.2307/2341482>
- Haldar A, Sethi N (2021) Effect of institutional quality and renewable energy consumption on CO2 emissions – an empirical investigation for developing countries. *Environ Sci Pollut Res* 28(12):15485–15503
- IEA (2021) Flaring emissions, IEA, Paris. Available at <https://www.iea.org/reports/flaring-emissions>. Accessed 15/03/2022
- Jardón A, Kuik O, Tol RSJ (2017) "Economic growth and carbon dioxide emissions: an analysis of Latin America and the Caribbean." *Atmósfera* 30(2):87–100
- Joshi P, Beck K (2018) Democracy and carbon dioxide emissions: assessing the interactions of political and economic freedom and the environmental Kuznets curve. *Energy Res Soc Sci* 39:46–54. <https://doi.org/10.1016/j.erss.2017.10.020>
- Kankara AI (2013) "Examining environmental policies and laws in Nigeria". *International Journal of Environmental Engineering and Management*. 4(3):165–170. <http://republication.com/ijeem.htm> Accessed 15/03/2022
- Kasperowicz R (2015) "Economic growth and CO2 emissions: the ECM analysis." *J Int Stud* 3(3):90–97. <https://doi.org/10.14254/2071-8330.2015/8-3/7>
- Koenker R, Bassett G (1978) "Regression Quantiles". *Econometrica* 46(1):33–50. <https://doi.org/10.2307/1913643>
- Kuznets S (1955) Economic growth and income inequality. *Am Econ Rev* 45(1):1–28. <https://www.jstor.org/stable/1811581>
- Ladan MT (2012) "Review of NESREA Act 2007 and Regulations 2009–2011: a new dawn in environmental compliance and enforcement in Nigeria. *Law, Environ Dev J* 8(1):116. <http://lead-journal.org/mobile/abstracts/12116.htm>
- Le TH, Nguyen PC (2020) The impact of tourism on carbon dioxide emissions: insights from 95 countries. *Appl Econ* 00(00):1–27
- Le HP, Ozturk I (2020) The impacts of globalization, financial development, government expenditures, and institutional quality on CO2 emissions in the presence of environmental Kuznets curve. *Environ Sci Pollut Res* 27(18):22680–22697
- Lise W (2006) Decomposition of CO2 emissions over 1980–2003 in Turkey. *Energy Policy* 34:1841–1852
- Lv Z, Li S (2021) How financial development affects CO2 emissions: a spatial econometric analysis. *J Environ Manage* 277:111397. <https://doi.org/10.1016/j.jenvman.2020.111397>
- Maduka AC, Akunna N, Ekesiobi CS, Okafor SN, Chukwuemeka DE (2021) "Modelling environment-economic progress nexus for improved quality of life in Nigeria: a test of the Green Solow model". Paper presented at the 14th Conference of the Nigerian Association of Energy Economics, Themed: Strategic Responses of the Energy Sector to COVID-19 Impacts on African Economies, July 25–28, 2021 at the PTDF Building, Abuja, Nigeria.
- Menyah K, Wolde-Rufael Y (2010) CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy* 38(6):2911–2915

- Mesagan E (2015) Economic growth and environment nexus: the role of foreign direct investment. *A Research Journal on Contemporary Issues and Development* 4(3):44–52
- Mesagan E, Ekundayo P (2015) Economic growth and carbon emission in Nigeria”. *IUP Journal of Applied Economics* 3(2):44–56
- Mishra MK (2020) “The Kuznets curve for the sustainable environment and economic growth”, ZBW – Leibniz Information Centre for Economics, Kiel, Hamburg. Available at <https://www.econstor.eu/handle/10419/216734>. Accessed 15/03/2022
- Mobosi IA, Madueme SI, Osuntuyi BV (2017) Impact of income growth on environmental quality in Nigeria: an empirical test of the environmental kuznets hypothesis. *Nigerian J Econ Soc Stud* 59(2):121–152
- Narayan P, Narayan S (2010) Carbon dioxide emissions and economic growth: panel data evidence from developing countries. *Energy Policy* 38(1):661–666
- National Bureau of Statistics (2021) Nigerian Gross Domestic Product Report Q4 2021. Available at <https://nigerianstat.gov.ng/download/1241137>. Accessed 15/03/2022
- National Geographic Society (2019) Non-renewable Resources. <https://www.nationalgeographic.org/encyclopedia/nonrenewable-resources> Accessed 15/03/2022
- Nunez C (2019) “Renewable Energy 101”. National Geographic. <https://www.nationalgeographic.com/environment/article/renewable-energy> Accessed 15/03/2022
- Ogwu SO (2021) Economic analysis of cooking energy cost, multiple cooking fuels, and air pollution in Nigeria. Department of Economics, University of Nigeria. Nsukka, Nigeria, Unpublished MSc Research Project Work
- Okoye EI, Nwoye UJ, Ekesiobi C, and Obiorah, J. (2018) Repositioning democratic governance in Nigeria: implications on national economy. *Asian Journal of Economics, Business and Accounting* 8(3):1–20. <https://doi.org/10.9734/AJEBA/2018/44731>
- Olubusoye OE, Musa D (2020) Carbon emissions and economic growth in Africa: are they related? *Cogent Economics & Finance* 8(1):20–35. <https://doi.org/10.1080/23322039.2020.1850400>
- Omojolaibi JA (2010) Environmental quality and economic growth in some selected West African countries. *J Sustain Dev* 12(8):35–48
- Orji A, Ogwu SO, Mba PN, Anthony-Orji OI (2021) Energy demand and cooking energy cost in an oil-rich economy: a new evidence from Nigeria”. *Studia Universitatis “Vasile Goldis”. Arad-Economic Series* 31(1):1–21. <https://doi.org/10.2478/sues-2021-0001>
- Ouédraogo M, Peng D, Chen X, Hashmi SH, Sall MI (2021) Dynamic effect of oil resources on environmental quality: testing the environmental Kuznets curve hypothesis for selected African countries. *Sustainability* 13(3649):1–23. <https://doi.org/10.3390/su13073649>
- Panayotou T (1997) Demystifying the environmental Kuznets curve: turning a black box into a policy tool. *Environ Dev Econ* 2(4):465–484
- Perman R, Stern D (2003) Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics* 47(3):325–347
- Pesaran MH, Shin T, Smith RJ (2001) Bounds testing approach to the analysis of level relationships. *J Appl Econ* 16(3):289–326
- Pope CA, Dockery DW (2006) Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manage Assoc* 56:709–742. <https://doi.org/10.1080/10473289.2006.10464485>
- Rehman A, Ma H, Ozturk I (2021) Do industrialization, energy importations, and economic progress influence carbon emission in Pakistan. *Environ SciPollut Res* 28:45840–45852. <https://doi.org/10.1007/s11356-021-13916-4>
- Richmond AK, Kaufmann R (2006) Is there a turning point in the relationship between income and energy use and/or carbon emissions? *Ecol Econ* 56(2):176–189
- Roca J Padilla E, Farre M, Galletto V (2001) Economic growth and atmospheric pollution in Spain: Discussing the environmental kuznets curve hypothesis. *Ecol Econ* 39(1):85–99
- Sarkodie SA, Adams S (2018) Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa. *Sci Total Environ* 643:1590–1601
- Simon HA (1954) Spurious correlation: a causal interpretation. *J Am Stat Assoc* 49(267):467–479. <https://doi.org/10.1080/01621459.1954.10483515>
- Soytas U, Sarı R (2009) Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. *Ecol Econ* 68(6):1667–1675
- Teng JZ, Khan MK, Khan MI et al (2021) Effect of foreign direct investment on CO₂ emission with the role of globalization, institutional quality with pooled mean group panel ARDL. *Environ SciPollut Res* 28:5271–5282. <https://doi.org/10.1007/s11356-020-10823-y>
- U.S Energy Information Administration (2021) Data analysis, an overview. <https://www.eia.gov/beta/international/analysis.php?iso=NGA>. Accessed 15/03/2022
- UNECA (2012) A green economy in the context of sustainable development and poverty eradication: what are the implications for Africa? RIO+20 United Nations Conference on Sustainable Development; United Nations Economic Commission for Africa: Addis Ababa, Ethiopia, pp. 1–27.
- United Nations (2015) The sustainable development agenda. Retrieved from <https://www.un.org/sustainabledevelopment/development-agenda/>. Accessed 02 March 2022
- Wawrzyniak D, Doryń W (2020) “Does the quality of institutions modify the economic growth-carbon dioxide emissions nexus? Evidence from a group of emerging and developing countries” *Economic Research-Ekonomska Istraživanja* 33(1):124–144. <https://doi.org/10.1080/1331677x.2019.1708770>
- Whiting K (2019) 5 facts to know about Africa’s powerhouse – Nigeria. Retrieved from <https://www.weforum.org/agenda/2019/08/nigeria-africa-economy/> Accessed 15/03/2022
- World Bank (2021) Seven countries account for two-thirds of global gas flaring. Press Release No: 2021/143/Eex. Retrieved from: <https://www.worldbank.org/en/news/press-release/2021/04/28/seven-countries-account-for-two-thirds-of-global-gas-flaring> Accessed 15/03/2022
- World Health Organization (2018) Household air pollution and health. WHO, Geneva, Switzerland
- Yule G (1926) Why do we sometimes get nonsense-correlations between time-series? A Study in Sampling and the Nature of Time-Series. *J Roy Stat Soc* 89(1):1–63
- Zaidi S, Ferhi S (2019) “Causal relationships between energy consumption, economic growth and CO₂ emission in Sub-Saharan: evidence from dynamic simultaneous-equations models”. *Modern Economy* 10:2157–2173 <https://www.scirp.org/journal/me>.
- Zhang J (2021) Environmental Kuznets curve hypothesis on CO₂ emissions: evidence from China. *J Risk Financ Manag* 14:93. <https://doi.org/10.3390/jrfm14030093>

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