International Journal of Sustainable Development & World Policy
2026 Vol. 15, No. 1, pp. 18-28.
ISSN(e): 2305-705X
ISSN(p): 2306-9929
DOI: 10.18488/26.v15i1.4684

Climate change, greenhouse gas emission and economic development in Nigeria

Ndubuaku, Victor Chijioke[1+]
IFEANYI, Ozioma Patricia[2]
Kalu, Gloria Chidubem[3]

[1,2]*Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria.*
[1]*Email: vcndubuaku@fcaishiagu.edu.ng*
[2]*Email: omatricia627@gmail.com*
[3]*Rome Business School, Nigeria.*
[3]*Email: gloriakalu48@gmail.com*

(+ Corresponding author)

Article History
Received: 20 November 2025
Revised: 30 December 2025
Accepted: 7 January 2026
Published: 9 January 2026

Keywords
Climate change
Developing countries
Economic development
Economic growth
Green economy
Greenhouse gases
Nigeria.

ABSTRACT

Climate change is a global environmental problem affecting both advanced and developing nations; it specifically poses economic development challenges for developing countries like Nigeria. This study observed the influence of greenhouse gas emissions on economic development in developing countries, with a particular focus on Nigeria. The climate variables of greenhouse gases used as independent variables were represented by carbon dioxide, methane, and nitrous oxide emissions, respectively; while the concept of economic development was proxied using gross domestic product per capita. The data spanned from 1990 to 2020, and the analytical model was formulated in line with the classical linear regression model. The model was analyzed using a combination of fully modified ordinary least squares, dynamic ordinary least squares, and canonical cointegrating regression. The results showed a mix of both negative and positive outcomes. The findings indicated a negative impact of carbon dioxide on gross domestic product per capita, a positive impact of methane on gross domestic product per capita, and a positive impact of nitrous oxide on gross domestic product per capita. It was recommended that developing nations like Nigeria should invest in renewable energy and adopt sustainable farming techniques to promote growth. The uniqueness of this research lies in the simultaneous investigation of the combination of greenhouse gas emissions, namely, carbon dioxide, methane, and nitrous oxide, within the climate-development framework, departing from most studies that focus on other measures of climate change and developed nations.

Contribution/Originality: This study contributes to the existing literature by simultaneously investigating the combined impact of carbon dioxide, methane, and nitrous oxide emissions on economic development in a developing nation like Nigeria. This approach contrasts with prior research that often focused on environmental impact and developed nations.

1. INTRODUCTION

Climate change is a global environmental problem for both advanced and developing nations and specifically poses economic development challenges for developing countries like Nigeria (Aye & Edoja, 2017; Bui et al., 2023; Nga, Tien, & Cuong, 2024). It has become a major human threat and has been increasing since the Industrial Revolution (Bui et al., 2023; Farajzadeh, Ghorbanian, & Tarazkar, 2022; Nga et al., 2024). The global community organized the Kyoto Protocol's mechanism to address global climate problems, but it had been criticized for focusing mainly on advanced economies, which created a vacuum for developing nations like Nigeria that lack the required resources and technology to implement effective climate strategies (Poulopoulos, 2016; Rosen, 2015). This raises questions about the reliability of systems available to developing economies to mitigate the impact of climate change (Poulopoulos, 2016; Rosen, 2015). It was opined that although Nigeria is not a significant emitter of greenhouse gases (GHG) compared to other developed countries, it faces substantial challenges related to climate change, as the country relies heavily on climate-sensitive sectors such as agriculture, energy, natural resources, manufacturing, trade, and services, among others (Butu, Okeke, & Okereke, 2022).

Therefore, with the intent of tackling climate change, the Nigerian government initiated various policies to reduce emissions and enhance resilience, including the National Climate Change Policy and the National Adaptation Strategy (AFDB, 2021; Butu et al., 2022; Ryan, 2022). The impacts of these interventions are, however, subject to debate, and probably more needs to be done. Furthermore, it was observed that numerous studies employed varied methodological approaches and investigated the growth-climate concept, especially in developed countries, with varied outcomes (Alaganthiran & Anaba, 2022; Kalkuhl & Wenz, 2020; Wang, Li, & Li, 2024). However, only a handful had addressed the climate-growth concept, especially in developing countries (Butu et al., 2022).

The EKC theory, which guides the climate-development concepts, posits that as the economy develops, pollution initially increases; but after reaching a certain growth stage, the trend reverses, leading to improved environmental quality (Horobet et al., 2024). This can be expressed figuratively using the inverted U-shaped curve, where the x-axis signifies income per capita and the y-axis denotes environmental degradation (Fernandes, Veiga, Ferreira, & Hughes, 2021; Horobet et al., 2024; Raihan, 2023). In advanced economies, it is believed that higher income levels correlate with greater environmental awareness and stronger regulatory frameworks, leading to improvements in environmental quality (Fernandes et al., 2021; Horobet et al., 2024; Raihan, 2023).

Additionally, the debate on the impact of climate change on developing countries persists because, while it is generally agreed that GHG emissions are higher in rich countries, the negative impacts are generally highly felt in developing countries (Burke, Hsiang, & Miguel, 2015; Butu et al., 2022; Kalkuhl & Wenz, 2020). However, some critics with counter research disputed this theory and suggested that the assumption does not apply across the board, especially in developing countries (Horobet et al., 2024; Laverde-Rojas, Guevara-Fletcher, & Camacho-Murillo, 2021).

This research aims to address this gap by examining the relationship between climate change and economic development in developing economies, with a focus on Nigeria, providing an impartial perspective on the effects on developmental outcomes. The study specifically seeks to assess how GHG emissions, carbon dioxide, methane, and nitrous oxide affect economic development in Nigeria, measured by GDP per capita.

The addition of this research to knowledge was the simultaneous investigation of the combination of greenhouse gases (that is, CO_2, CH_4, and N_2O), departing from most studies that focused on other measures of climate change, such as sea level rise, precipitation, and temperature, among others. Also, the adoption of a combination of cointegration regression tools (FMOLS, DOLS, CCR) in the climate-development framework for validity and robustness was quite unique, which had been used by only a few known studies in the context (Filonchyk, Peterson, Zhang, Hurynovich, & He, 2024; Laverde-Rojas et al., 2021).

Further contributions to knowledge also relate to the national or country-wide scope of the study, in comparison to most climate-development studies, which have focused on global and regional scopes. The countrywide focus on Nigeria, which is a developing country and has the unique characteristic of being the most populous black nation in the world, plus it also sits as one of the largest economies in Africa and relies heavily on climate-sensitive sectors, provides a sound justification for its investigation in the climate-development discourse see Butu et al. (2022). The research contribution lies in its ability to educate policymakers and stakeholders on the essential connections among climate change, the environment, and economic development. The rest of the paper is organized into the literature review, methodology, results with discussion, and conclusion.

2. ASSESSMENT OF THE RELATED LITERATURE

2.1. Environmental Kuznets Curve (EKC) Proposed as the Theoretical Foundation

Grossman and Krueger (1991) and Grossman and Krueger (1995) expounded the EKC, which served as the theoretical foundation for this study, effectively capturing the conceptual variables involved. It clearly expresses the interaction between economic growth and environmental degradation, encapsulating the variables comprehensively (Horobet et al., 2024). The origin of the EKC can be traced back to the early 1990s, particularly to Simon Kuznets' work on income inequality, which proposed that economic growth initially increases inequality but eventually reduces it as a country develops (Horobet et al., 2024).

Despite the broad recognition of the EKC, critics argued that the underpinnings of the EKC do not hold universally across all pollutants, climates, regions, or countries; and some studies have found no clear turning point for certain environmental indicators, suggesting that the relationship may be more complex than the EKC implied (Husnain, Haider, & Khan, 2021). Others believe that proponents of the EKC oversimplify the interplay of economic growth and environmental quality, dismissing intricate factors such as governance quality, technological innovation, and other social dynamics that can influence environmental outcomes (Husnain et al., 2021). Other critics assert that the EKC predominantly emphasizes production-related emissions while neglecting the environmental consequences associated with consumption, especially in wealthy nations that transfer pollution-heavy businesses to developing nations (Haider, Bashir, & ul Husnain, 2020).

The EKC is intricately linked to the Kyoto principles of common but differentiated responsibilities (CBDR), which recognize that wealthy countries have been the primary contributors to GHG emissions and therefore should bear greater responsibility for emission reduction efforts (Haider et al., 2020). The EKC thus presents both opportunities and challenges for emerging economies such as Nigeria, as economic growth involves balancing developmental progress with environmental sustainability. It is expected that the early stages of industrialization will correlate with increased emissions; however, advancements in clean technologies could facilitate economic growth while minimizing environmental impact (Husnain et al., 2021).

The Environmental Kuznets Curve (EKC) suggests that developing countries may require international support to transition to cleaner technologies and practices. The Kyoto Protocol appears to offer this support mechanism, which considers the Clean Development Mechanism (CDM), proposing that developing countries can effectively and efficiently transition to cleaner energy sources. However, the effectiveness of the CDM has been subject to criticism (Haider et al., 2020; Husnain et al., 2021). Nonetheless, the EKC provides a useful framework for assessing developmental progress concerning the climate-growth relationship. Its application to developing economies like Nigeria requires careful consideration of local contexts, policies, and the existing climate support systems, which are often inadequate.

2.2. Empirical Assessment Relating to Climate-Development Concept

A review of contrasting findings on several studies on the climate-development outcome has shown that there are contrasting results regarding the interplay of climate change and economic development. Arguments include the positive versus negative viewpoint; others are the significant versus non-significant viewpoint. Consequently, some studies have reported a positive impact, some a negative impact, some significant, and others non-significant impacts of climate change on economic development.

For instance, Burke et al. (2015); Kahn and Zivin (2016); Hallegatte, Vogt-Schilb, Bangalore, and Rozenberg (2016); Kalkuhl and Wenz (2020); Djoukouo (2021); Chamma (2025) and Dua and Garg (2024) favoured the significant negative viewpoint of climate development and found that climate change adversely affected labour productivity, production levels, income levels, and economic development; particularly in developing countries where agriculture was the primary economic driver, and these nations are plagued with limited financial and technological constraints.

Conversely, Jithitikulchai (2023) advanced the non-significant viewpoint on the climate-development concept with the study, which indicated that countries that diversify their economies beyond agriculture may experience less severe impacts from climate change. Also, Mastrorillo et al. (2016) advanced the non-significant viewpoint and suggested that while climate change posed several risks, effective adaptation strategies can mitigate negative impacts and support economic resilience in developing countries. Horobet et al. (2024) advanced the non-significant viewpoint with a study of Colombia and concluded that the EKC theory may not be consistently applicable across European countries. Similarly, Laverde-Rojas et al. (2021) further advanced the non-significant viewpoint, suggesting that EKC does not apply to developing countries. Khoualfia and Bardi (2025), with an examination of 20 European countries, it was concluded that there is a positive impact of CO_2 emissions on economic growth in the sample countries.

Also, there appeared to be variation in results based on the scope of studies concerning regional differences and the developmental stages of the countries, which presented varying results (Khoualfia & Bardi, 2025; Marques, Fuinhas, & Leal, 2018; Rahman & Vu, 2020). For example, Khoualfia and Bardi (2025) favoured the negative and significant viewpoint on developed countries with the study of 20 European countries; Nga et al. (2024) supported the negative and significant viewpoint of climate change on development in ASEAN countries; while, Ehigiamusoe, Lean, Dogan, Binsaeed, and Ramakrishnan (2024) did a comparative study on climate-growth in Malaysia (developed) and Nigeria (developing); and concluded with the negative and significant viewpoint that climate has a larger impact on Malaysia compared to Nigeria. Zhao and Liu (2023), with a study of diverse climatic regions in Africa, found an inverted U-shaped effect on the economic growth of countries in tropical rainforest and tropical dry climate zones, but a U-shaped relationship in warm temperate humid regions.

On one hand, though few, the results of N_2O using the EKC present dissenting findings; e.g., Bui et al. (2023); did a study on the correlation of nitrous oxide and economic growth in Vietnam using the ARDL and found a negative correlation between N_2O and GDP, which agreed with the negative significant findings of a previous study of Zambrano-Monserrate and Fernandez (2017). Contrastingly, the results of Haider et al. (2020) portrayed an N-shaped relationship, while Naser and Alaali (2021) posited an inverted U-shaped EKC relationship between N_2O and economic growth in Bahrain.

There was variation in results based on the proxies employed, and different methodologies have been used to assess climate change and development. These include meta-analysis, non-linear analysis, longitudinal analysis, FMOLS, ARDL, and dynamic modeling, among others, with varied outcomes (Khan et al., 2019; Laverde-Rojas et al., 2021; Naser & Alaali, 2021; Yin et al., 2022). Few studies have combined FMOLS, DOLS, and CCR, as this study has proposed, despite the strength of their validity and robustness.

3. METHODOLOGY

The study employed the '*ex post facto*' research design, which comprised historical data sourced from the archives of the World Development Index and the Central Bank of Nigeria (CBN) related to the period 1990 to 2020. The main objective was to determine the impact of climate change on economic development in Nigeria, and the specific objective was to assess the impact of carbon dioxide, methane, and nitrous oxide emissions on gross domestic product per capita. The datasets are annualized time series that are secondary in nature, and the time frame was guided by the Kyoto Protocol assessment period of 1990-2020. The robustness of the results was analyzed using an array of pre- and post-estimation tests, which included log transformation, unit root tests, and descriptive analysis. The model was analyzed using the FMOLS, DOLS, and CCR techniques (see Pedroni (2001)).

3.1. Model Specification

The Grossman and Krueger (1991) Environmental Kuznets Curve (EKC) created the theoretical context, and in a bid to relate the principles to the Nigerian perspective, Ogbuabor and Egwuchukwu (2017) conceptualized the dynamics in their model, which was further adapted for this study. Therefore, the classical linear regression model (CLRM) was employed and expressed in its functional form as:

$$y_t = \delta_0 + \delta_1 X_{1_t} + \delta_2 X_{2_t} + \delta_3 X_{3_t} + \delta_4 X_{4_t} + \delta_5 X_{5_t} \ldots\ldots\ldots\ldots\ldots . \delta_n X_{n_t} + \varepsilon_t \quad (1)$$

Where:

Y = dependent variable (Explained variable).

X = independent variable (Explanatory variable).

δ_0= Constant term (i.e., value of Y when X is zero).

δ_1-δ_n= Coefficient of the parameter estimates.

ε_t= error term (Residual term).

The study models were restated in line with the objectives as follows;

$$GDPpc_{it} = \beta 0 + \beta 1\ CO_{2it} + \beta 2_{it}\ CH_{4it} + \beta 3 N2O_{it} + \beta 4_{it} FOREST_{it} + \beta 5\ INFLATION_{it} + \beta 6\ POPU_{it} + \beta 7 REXR_{it} + \beta 8 GCAP_{it} + \varepsilon_t \quad (2)$$

To address the exponential variances in the dataset, a log transformation was employed, and the model is reformulated as Equation.

$$InGDPpc_{it} = \beta 0 + \beta 1\ InCO_{2it} + \beta 2_{it}\ InCH_{4it} + \beta 3 InN_2O_{it} + \beta 4_{it} InFOREST_{it} + \beta 5 In\ INFL_{it} + \beta 6\ InPOPU_{it} + \beta 7 InREXR_{it} + \beta 8 GCAP_{it} + \varepsilon_t \quad (3)$$

Where,

GDPpc = Gross domestic product per capita.

FOREST = Forest area.

CEM = Carbon emission (kt), a measure of greenhouse gases.

INFL = Inflation.

REXR = Average official exchange rate (Naira to dollar).

POPU = Population growth rate.

GCAP = Gross capital.

βo = Intercept, β1 -β6 are the partial slope coefficients.

εt = Stochastic error term.

Carbon emissions, methane, and nitrous oxide were employed as the primary climatic (independent) variables because they constitute the significant greenhouse gas (GHG) pollutants, accounting for approximately 75% of greenhouse gas emissions. These gases are frequently utilized in the application of the climate-development concept and the Environmental Kuznets Curve (EKC) analysis (Abbasi & Riaz, 2016; Aye & Edoja, 2017; Edoja, Aye, & Abu, 2016; Tutulmaz, 2015). The inclusion of other control variables in the model was justified based on the previous work of Ogbuabor and Egwuchukwu (2017).

Some of the empirical backing on the relationship between economic growth and environmental quality oversaw varied responses (Aye & Edoja, 2017; Charfeddine & Khediri, 2016; Marques et al., 2018; Rahman & Vu, 2020; Zaidi, Zafar, Shahbaz, & Hou, 2019). In the Nigerian context, as revealed by Ogbuabor and Egwuchukwu (2017), results indicated that economic growth degrades and is degraded by increasing greenhouse gases. Consequently, this study anticipated a negative impact of GHG on economic development.

4. DATA PRESENTATION AND ANALYSIS

4.1. Descriptive Analysis

The variables of GDP per capita (InGDPPC), carbon dioxide ($InCO_2$), inflation (InINFL), methane emissions ($InCH_4$), nitrous oxide emissions (InN_2O), population (InPOPU), and real exchange rate (InREXR) were analyzed in the descriptive analysis (Table 1). The average values for methane emissions ($InCH_4$) ranged from 11.87 to 0.93 for population (InPOPU). The median figures are close to the mean for most variables, indicating a relatively symmetrical distribution. The standard deviation metric showed that most of the variables had a moderate spread around the mean.

The skewness values indicated the asymmetry of the distribution. Negative skewness was observed in InGDPPC, InINFL, $InCH_4$, and InREXR, which implied that the distributions had longer left tails. $InCO_2$ and InN_2O showed near-zero skewness, which implied a more symmetrical distribution. The kurtosis showed the tails and peak of the distribution; InINFL had a kurtosis of 4.34, indicating a distribution with heavier tails compared to a normal distribution, while other variables like $InCO_2$ and InN_2O had lower kurtosis values, indicating lighter tails.

The Jarque-Bera statistic indicated that the variables were normally distributed, with values ranging from 1.27 ($InCH_4$) to 4.11 (InINFL). This suggests that all the variables were normally distributed at the 5% significance level.

Table 1. Showing Descriptive Analysis.

Statistics	InGDPPC	$InCO_2$	InINFL	$InCH_4$	InN_2O	InPOPU	InREXR	InGCAP
Mean	11.65	3.03	2.47	11.87	10.27	0.93	4.43	2.43
Median	12.01	3.02	2.32	11.88	10.29	0.93	4.85	2.49
Maximum	13.51	3.74	4.32	11.96	10.62	0.98	5.88	3.06
Minimum	8.55	2.36	-0.37	11.72	9.91	0.89	2.08	1.69
Std. Dev.	1.51	0.53	0.93	0.06	0.21	0.03	1.09	0.39
Skewness	-0.55	0.03	-0.58	-0.38	-0.01	0.04	-0.73	-0.04
Kurtosis	2.13	1.30	4.34	2.38	1.89	1.33	2.24	1.65
J-Bera	2.55	3.73	4.11	1.27	1.57	3.58	3.55	2.34
Probability	0.27	0.15	0.12	0.52	0.45	0.16	0.16	0.30

4.2. Unit Root Test

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used in the investigation of unit roots (see Table 2). The variables were integrated in a combination of I(1) and I(0), according to the ADF and PP results. Given that some of the variables exhibit unit roots, i.e., they are non-stationary I(1), it is expected that FMOLS can effectively estimate long-run relationships between these variables while accounting for the non-stationarity, considering its superiority over traditional Ordinary Least Squares (OLS) regression, which can lead to spurious results when applied to non-stationary data.

Table 2. Augmented Dickey-Fuller and Phillips-Perron unit root test.

Variable	ADF Stat	1%	5%	10%	Pv	Infer	PP Stat	1%	5%	10%	PV	Infer
InDev	-4.58	-4.30	-3.57	-3.22	0.00	I(1)	-3.61	-4.30	-3.57	-3.22	0.04	I(1)
InForest	-8.30	-4.37	-3.60	-3.23	0.00	I(1)	-5.08	-2.64	-1.95	-1.61	0.00	I(0)
$InCO_2$	-3.24	-3.68	-2.97	-2.62	0.03	I(1)	-3.27	-2.64	-1.95	-1.61	0.00	I(1)
$InCH_4$	-4.50	-4.30	-3.57	-3.22	0.01	I(1)	-4.44	-4.30	-3.57	-3.22	0.01	I(1)
InN_2O	-6.52	-4.30	-3.57	-3.22	0.00	I(1)	-3.63	-2.64	-1.95	-1.61	0.00	I(1)
InRexr	-5.15	-4.30	-3.57	-3.22	0.00	I(1)	-5.25	-4.30	-3.57	-3.22	0.00	I(1)
InInfl	-4.78	-4.29	-3.56	-3.21	0.00	I(0)	-5.03	-4.29	-3.56	-3.21	0.00	I(0)
InPopu	-3.25	-3.67	-2.96	-2.62	0.00	I(1)	-3.61	-4.30	-3.57	-3.22	0.04	I(1)

4.3. Cointegration Analysis

The test suggested four cointegrating equations were present at the 5% significance level, which indicated a long-term stable relationship among the variables analyzed (Table 3). The eigenvalues and corresponding trace statistics showed a decreasing trend, which is typical in cointegration tests. The highest eigenvalue (0.85) corresponds to the first cointegration relationship, indicating a strong long-term relationship. The results imply that the variables in the model are cointegrated, meaning they share a long-term equilibrium relationship. This was particularly important for econometric modeling of the FMOLS model, which assumes the requirement of cointegration (Khan et al., 2019).

Table 3. Showing Johansen cointegration test for variables.

No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value (0.05)	Prob.
None *	0.85	178.17	125.61	0.00
At most 1 *	0.74	122.95	95.75	0.00
At most 2 *	0.69	82.94	69.81	0.00
At most 3 *	0.60	48.49	47.85	0.04
At most 4	0.35	21.50	29.79	0.32
At most 5	0.23	8.62	15.49	0.40
At most 6	0.03	0.98	3.84	0.32

Note: *showing cointegration.

4.4. Regression Model Analysis

The adoption of FMOLS was justified due to its ability to handle non-stationarity, model cointegrated relationships, correct for endogeneity, and provide robust estimates in the presence of serial correlation (Khan et al., 2019). The application of FMOLS has been widely supported in the literature for analyzing relationships involving economic growth, emissions, and other macroeconomic variables (Khan et al., 2019). Studies have shown that FMOLS provides superior estimates compared to other methods like OLS or Dynamic Ordinary Least Squares (DOLS) when dealing with non-stationary data (Khan et al., 2019). The different models are analyzed below.

4.4.1. Model 1

Hypothesis 1: There was no positive and significant impact of greenhouse gases (CO_2, CH_4, N_2O) on gross domestic product per capita.

Table 4. Regression analysis.

Dependent Variable: InGDPPC	FMOLS			DOLS			CCR		
Variable	Coefficient	t-Stat	Prob.	Coefficient	t-Stat	Prob.	Coefficient	t-Stat	Prob.
$InCO_2$	-0.70	-3.08	0.01*	-0.82	-2.10	0.04*	-0.45	-1.02	0.31
$InCH_4$	2.61	2.35	0.03*	2.69	1.98	0.05*	2.86	1.73	0.09
InN_2O	4.23	3.20	0.00*	4.0	2.71	0.01*	4.3	2.3	0.02*
InFOREST	0.29	0.34	0.73	0.11	0.86	0.93	0.28	0.22	0.82
InPOPU	3.36	0.76	0.45	0.53	0.06	0.94	6.84	1.00	0.32
InGCAP	-0.81	-4.75	0.00*	-0.78	-2.23	0.03*	-0.87	-3.70	0.00*
InINFL	-0.10	-1.93	0.06	-0.09	-1.73	0.09	-0.12	-1.14	0.26
InREXR	0.33	2.32	0.03*	0.32	2.31	0.03*	0.36	1.65	0.11
C	-63.88	-2.74	0.01*	-59.86	-1.69	0.10	-71.50	-2.12	0.04*
R^2	0.98			0.98			0.97		
Adjusted R^2	0.97			0.97			0.97		
S.E. of regression	0.22			0.22			0.23		
Long-run variance	0.03			-			0.03		

Note: * Significant at 5% level of significance.

5. RESULT AND DISCUSSION OF FINDINGS

The results of FMOLS, DOLS, and CCR showed the relationship between environmental variables, economic variables, and GDP per capita (see Table 4). The negative coefficients for $InCO_2$ across FMOLS (-0.70) and DOLS (-0.82) indicated a significant inverse relationship with GDP per capita (see Table 4). This suggests that higher carbon emissions (CO_2) are associated with lower gross domestic product per capita, possibly due to the impact of climatic factors on labor productivity, health, and agricultural output, among others (Kahn & Zivin, 2016; Kalkuhl & Wenz, 2020). This result implies that increased carbon emissions significantly affected the economic well-being of people in developing countries (as shown in (Djoukouo, 2021; Hallegatte et al., 2016; Jithitikulchai, 2023; Kalkuhl & Wenz, 2020; Mastrorillo et al., 2016). This may be partly due to the fact that developing economies depend on climate-sensitive sectors such as agriculture, which may further limit the rate of growth and the speed of their development, aligning with common knowledge, a priori expectations, EKC, and empirical expectations (Kalkuhl & Wenz, 2020).

The positive coefficients for InCH_4 in FMOLS (2.61) and DOLS (2.69) suggest that methane emissions are positively associated with GDP per capita. This indicates that as methane (CH_4) levels increase, GDP per capita also increases, which could reflect economic activities related to methane production, such as agriculture and fossil fuel extraction, contributing to short-term economic growth (as reflected in Djoukouo (2021)). However, this finding contradicts natural intuition, a priori expectations, and the Environmental Kuznets Curve (EKC). Nonetheless, the results align with the study by Djoukouo (2021), which reported cointegration and bidirectional causality between CH_4 emissions and GDP per capita, but disagreed with Hallegatte et al. (2016), which suggested climate change aggravates poverty. The significant positive coefficients for InN_2O (4.23 in FMOLS and 4.0 in DOLS) suggest that nitrous oxide is positively related to GDP per capita, which indicates that as methane (CH_4) levels increase, GDP per capita also increases; this could reflect the economic activities associated with methane production, such as agriculture and fossil fuel extraction, which can contribute to short-term economic growth (as shown in (Bui et al., 2023; Yusuf, Abubakar, & Mamman, 2020)). This disagreed with natural thinking, a priori expectation, the EKC, and empirical results of Hallegatte et al. (2016), but it reemphasized that agricultural practices, which contribute to nitrous oxide emissions, are linked to economic output (Bui et al., 2023; Yusuf et al., 2020).

6. CONCLUSION

This study investigated climate change on economic development in Nigeria, with a special focus on greenhouse gases, which included CO_2, CH_4, and N_2O, while the index for economic development was GDP per capita. The focus on Nigeria is premised upon the strategic composition of having the largest population and being the largest economy in Africa, with a probable high level of emission of greenhouse gases.

The negative coefficients for InCO_2 (-0.70 in FMOLS and -0.82 in DOLS) indicated a significant inverse relationship with GDP per capita, which aligned with several empirical findings, theoretical expectations, and empirical literature; suggesting that increased CO_2 emissions are associated with environmental degradation that can hinder economic growth (see (Burke et al., 2015; Chamma, 2025; Djoukouo, 2021; Dua & Garg, 2024; Hallegatte et al., 2016; Kahn & Zivin, 2016; Kalkuhl & Wenz, 2020). The CO_2 emission results support the Environmental Kuznets Curve (EKC) theory, which posits that while developing economies may initially experience rising emissions during growth, they eventually transition to lower emissions as they become more affluent and adopt cleaner technologies (see (Aye & Edoja, 2017; Horobet et al., 2024; Kasman & Duman, 2015); but disagreed with Laverde-Rojas et al. (2021) which advanced the non-significant viewpoint, suggesting that the assumption of EKC does not apply to developing countries. In contrast, the positive coefficients for InCH_4 (2.61 in FMOLS and 2.69 in DOLS) and InN_2O (4.23 in FMOLS and 4.0 in DOLS) suggest that methane and nitrous oxide emissions are positively and significantly associated with GDP per capita, which disagreed with empirical results of Zambrano-Monserrate and Fernandez (2017); Haider et al. (2020); Naser and Alaali (2021) and Bui et al. (2023). This relationship may reflect the economic activities linked to methane and nitrous oxide production (particularly agriculture and fossil fuel extraction), which can contribute to short-term economic growth, especially in an agrarian country like Nigeria, where almost 70-90 percent of its population is linked to agriculture (Akano, Oderinde, & Omotayo, 2023). This finding defies commonplace and empirical expectations, as most studies concentrated on CO emissions, and the results were generalized as greenhouse gas expectations. This, however, highlighted the dual nature of emissions, where certain factors (which contributed to greenhouse gas emissions) may drive or inhibit economic performance.

On the theory application, it can be concluded that no specific theory, including the EKC hypothesis, can single-handedly explain the climate-development dynamics, because the nature of degradation depends on characteristics of the economy, technology, and the use of fossil fuels, as opined by Laverde-Rojas et al. (2021). This study, therefore, showed that these variables of climate change, when disaggregated and analyzed, produced opposing effects on economic development. Finally, it is recommended that to reduce reliance on environmentally unfriendly fossil fuels and cut greenhouse gases, emerging nations like Nigeria should invest in renewable energy. This includes adopting sustainable farming methods that have the capacity to reduce N_2O emissions without significantly negatively impacting agricultural productivity. Additionally, enacting strict guidelines on greenhouse gas emissions would guide the economic activities of high emitters toward cleaner alternatives and ensure compliance.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abbasi, F., & Riaz, K. (2016). CO2 emissions and financial development in an emerging economy: An augmented VAR approach. *Energy Policy, 90*, 102-114. https://doi.org/10.1016/j.enpol.2015.12.017

AFDB. (2021). *Africa adaptation acceleration program*. Retrieved from https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/africa-adaptation-acceleration-program

Akano, O. I., Oderinde, F. O., & Omotayo, A. O. (2023). Agricultural yield, food nutrition and dietary energy supply in Nigeria: Evidence from nationally representative data. *Journal of Agriculture and Food Research, 11*, 100525. https://doi.org/10.1016/j.jafr.2023.100525

Alaganthiran, J. R., & Anaba, M. I. (2022). The effects of economic growth on carbon dioxide emissions in selected Sub-Saharan African (SSA) countries. *Heliyon, 8*(11), e11193. https://doi.org/10.1016/j.heliyon.2022.e11193

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics & Finance, 5*(1), 1379239. https://doi.org/10.1080/23322039.2017.1379239

Bui, H. M., Van Nguyen, S., Huynh, A. T., Bui, H. N., Nguyen, H. T. T., Perng, Y. S., . . . Nguyen, H. T. (2023). Correlation between nitrous oxide emissions and economic growth in Vietnam: An autoregressive distributed lag analysis. *Environmental Technology & Innovation, 29*, 102989. https://doi.org/10.1016/j.eti.2022.102989

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature, 527*(7577), 235-239. https://doi.org/10.1038/nature15725

Butu, H. M., Okeke, C. U., & Okereke, C. (2022). *Climate change adaptation in Nigeria: Strategies, initiatives, and practices.* Working Paper No. 3. APRI. Berlin, Germany.

Chamma, D. D. (2025). Climate change and economic growth in Sub-Saharan Africa: An empirical analysis of aggregate-and sector-level growth. *Journal of Social and Economic Development, 27*, 813–845. https://doi.org/10.1007/s40847-024-00377-x

Charfeddine, L., & Khediri, K. B. (2016). Financial development and environmental quality in UAE: Cointegration with structural breaks. *Renewable and Sustainable Energy Reviews, 55*, 1322-1335. https://doi.org/10.1016/j.rser.2015.07.059

Djoukouo, A. F. D. (2021). Relationship between methane emissions and economic growth in Central Africa countries: Evidence from panel data. *Global Transitions, 3*, 126-134. https://doi.org/10.1016/j.glt.2022.02.001

Dua, P., & Garg, N. K. (2024). Impact of climate change on productivity growth in India. *Indian Economic Review, 59*, 259-286. https://doi.org/10.1007/s41775-024-00229-9

Edoja, P. E., Aye, G. C., & Abu, O. (2016). Dynamic relationship among CO2 emission, agricultural productivity and food security in Nigeria. *Cogent Economics & Finance, 4*(1), 1204809. https://doi.org/10.1080/23322039.2016.1204809

Ehigiamusoe, K. U., Lean, H. H., Dogan, E., Binsaeed, R. H., & Ramakrishnan, S. (2024). Impact of climate change on economic growth in developing countries: Unravelling the moderating role of globalization. *Environmental Economics and Policy Studies*, 1-33. https://doi.org/10.1007/s10018-024-00427-y

Farajzadeh, Z., Ghorbanian, E., & Tarazkar, M. H. (2022). The shocks of climate change on economic growth in developing economies: Evidence from Iran. *Journal of Cleaner Production, 372,* 133687. https://doi.org/10.1016/j.jclepro.2022.133687

Fernandes, C. I., Veiga, P. M., Ferreira, J. J. M., & Hughes, M. (2021). Green growth versus economic growth: Do sustainable technology transfer and innovations lead to an imperfect choice? *Business Strategy and the Environment, 30*(4), 2021-2037. https://doi.org/10.1002/bse.2730

Filonchyk, M., Peterson, M. P., Zhang, L., Hurynovich, V., & He, Y. (2024). Greenhouse gases emissions and global climate change: Examining the influence of CO2, CH4, and N2O. *Science of the Total Environment, 935,* 173359. https://doi.org/10.1016/j.scitotenv.2024.173359

Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement.* NBER Working Paper No. 3914; National Bureau of Economic Research Inc.: Cambridge, MA, USA.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377. https://doi.org/10.2307/2118443

Haider, A., Bashir, A., & ul Husnain, M. I. (2020). Impact of agricultural land use and economic growth on nitrous oxide emissions: Evidence from developed and developing countries. *Science of the Total Environment, 741,* 140421. https://doi.org/10.1016/j.scitotenv.2020.140421

Hallegatte, S., Vogt-Schilb, A., Bangalore, M., & Rozenberg, J. (2016). *Unbreakable: building the resilience of the poor in the face of natural disasters.* USA: World Bank Publications.

Horobet, A., Belascu, L., Radulescu, M., Balsalobre-Lorente, D., Botoroga, C.-A., & Negreanu, C.-C. (2024). Exploring the nexus between greenhouse emissions, environmental degradation and green energy in Europe: A critique of the environmental Kuznets curve. *Energies, 17*(20), 5109. https://doi.org/10.3390/en17205109

Husnain, M. I. U., Haider, A., & Khan, M. A. (2021). Does the environmental Kuznets curve reliably explain a developmental issue? *Environmental Science and Pollution Research, 28*(9), 11469-11485. https://doi.org/10.1007/s11356-020-11402-x

Jithitikulchai, T. (2023). The effect of climate change and agricultural diversification on the total value of agricultural output of farm households in Sub-Saharan Africa. *African Journal of Agricultural and Resource Economics, 18*(2), 152–170. https://doi.org/10.53936/afjare.2023.18(2).10

Kahn, M. E., & Zivin, G. J. (2016). *Industrial productivity in a hotter world: The aggregate implications of heterogeneous firm investment in air conditioning.* NBER Working Paper No. 22962. National Bureau of Economic Research.

Kalkuhl, M., & Wenz, L. (2020). The impact of climate conditions on economic production. Evidence from a global panel of regions. *Journal of Environmental Economics and Management, 103,* 102360. https://doi.org/10.1016/j.jeem.2020.102360

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. *Economic Modelling, 44,* 97-103. https://doi.org/10.1016/j.econmod.2014.10.022

Khan, M. W. A., Panigrahi, S. K., Almuniri, K. S. N., Soomro, M. I., Mirjat, N. H., & Alqaydi, E. S. (2019). Investigating the dynamic impact of CO2 emissions and economic growth on renewable energy production: Evidence from FMOLS and DOLS tests. *Processes, 7*(8), 496. https://doi.org/10.3390/pr7080496

Khoualfia, A., & Bardi, W. (2025). The effect of climate change on economic growth in European countries: An empirical evidence from Panel ARDL approach. *Environmental Science and Pollution Research, 32*(2), 736-748. https://doi.org/10.1007/s11356-024-35788-0

Laverde-Rojas, H., Guevara-Fletcher, D. A., & Camacho-Murillo, A. (2021). Economic growth, economic complexity, and carbon dioxide emissions: The case of Colombia. *Heliyon, 7*(6), e07188. https://doi.org/10.1016/j.heliyon.2021.e07188

Marques, A. C., Fuinhas, J. A., & Leal, P. A. (2018). The impact of economic growth on CO2 emissions in Australia: The environmental Kuznets curve and the decoupling index. *Environmental Science and Pollution Research, 25*(27), 27283-27296. https://doi.org/10.1007/s11356-018-2768-6

Mastrorillo, M., Licker, R., Bohra-Mishra, P., Fagiolo, G., Estes, L. D., & Oppenheimer, M. (2016). The influence of climate variability on internal migration flows in South Africa. *Global Environmental Change, 39*, 155-169. https://doi.org/10.1016/j.gloenvcha.2016.04.014

Naser, H., & Alaali, F. (2021). Mitigation of nitrous oxide emission for green growth: An empirical approach using ARDL. *Advances in Science, Technology and Engineering Systems Journal, 6*(4), 189-195. https://doi.org/10.25046/aj060423

Nga, P. T. H., Tien, P. C., & Cuong, N. Q. (2024). The impact of climate change on economic growth: A study of ASEAN countries. *Journal of Financial and Marketing Research, 15*(2), 16-29. https://doi.org/10.52932/jfm.vi2.518

Ogbuabor, J. E., & Egwuchukwu, E. I. (2017). The impact of climate change on the Nigerian economy. *International Journal of Energy Economics and Policy, 7*(2), 217-223.

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels, Nonstationary panels, panel cointegration, and dynamic panels. In (pp. 93-130). USA: Emerald Group Publishing Limited.

Poulopoulos, S. G. (2016). *Environment and development: Basic principles, human activities, and environmental implications*. USA: Elsevier.

Rahman, M. M., & Vu, X.-B. (2020). The nexus between renewable energy, economic growth, trade, urbanisation and environmental quality: A comparative study for Australia and Canada. *Renewable Energy, 155*, 617-627. https://doi.org/10.1016/j.renene.2020.03.135

Raihan, A. (2023). Exploring environmental Kuznets curve and pollution haven hypothesis in Bangladesh: The impact of foreign direct investment. *Journal of Environmental Science and Economics, 2*(1), 25-36. https://doi.org/10.56556/jescae.v2i1.451

Rosen, A. M. (2015). The wrong solution at the right time: The failure of the kyoto protocol on climate change. *Politics & Policy, 43*(1), 30-58. https://doi.org/10.1111/polp.12105

Ryan, S. (2022). *The great green Wall.National geographic. National Geographic*. Retrieved from https://education.nationalgeographic.org/resource/great-green-wall/

Tutulmaz, O. (2015). Environmental Kuznets curve time series application for Turkey: Why controversial results exist for similar models? *Renewable and Sustainable Energy Reviews, 50*, 73-81. https://doi.org/10.1016/j.rser.2015.04.184

Wang, Q., Li, Y., & Li, R. (2024). Rethinking the environmental Kuznets curve hypothesis across 214 countries: The impacts of 12 economic, institutional, technological, resource, and social factors. *Humanities and Social Sciences Communications, 11*(1), 292. https://doi.org/10.1057/s41599-024-02736-9

Yin, Y., Wang, Z., Tian, X., Wang, Y., Cong, J., & Cui, Z. (2022). Evaluation of variation in background nitrous oxide emissions: A new global synthesis integrating the impacts of climate, soil, and management conditions. *Global Change Biology, 28*(2), 480-492. https://doi.org/10.1111/gcb.15860

Yusuf, A. M., Abubakar, A. B., & Mamman, S. O. (2020). Relationship between greenhouse gas emission, energy consumption, and economic growth: Evidence from some selected oil-producing African countries. *Environmental Science and Pollution Research, 27*(13), 15815-15823. https://doi.org/10.1007/s11356-020-08065-z

Zaidi, S. A. H., Zafar, M. W., Shahbaz, M., & Hou, F. (2019). Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia Pacific Economic Cooperation countries. *Journal of Cleaner Production, 228*, 533-543. https://doi.org/10.1016/j.jclepro.2019.04.210

Zambrano-Monserrate, M. A., & Fernandez, M. A. (2017). An environmental Kuznets curve for N_2O emissions in Germany: An ARDL approach. *Natural Resources Forum, 41*(2), 119–127. https://doi.org/10.1111/1477-8947.12122

Zhao, Y., & Liu, S. (2023). Effects of climate change on economic growth: A perspective of the heterogeneous climate regions in Africa. *Sustainability, 15*(9), 7136. https://doi.org/10.3390/su15097136