



**Energy Consumption, Economic Growth, and Environmental Trade-Offs in West
Africa: Nexus of Foreign Direct Investment**

Nathan Udoinyang ¹

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ABSTRACT

Environmental degradation has become a significant concern across the West African region; this study examines the impact of energy consumption, economic growth (GDP), and foreign direct investment (FDI) on environmental degradation measured by CO₂ emission in four West African countries: Nigeria, Ghana, Niger, and Mali from 1980 to 2023 with reference to the Environment Kuznets Curve (EKC). Using secondary data from the World Development Indicators, the study employed various econometric techniques. First, it evaluated the stationarity of the variables by means of unit root tests. Long-run connections were then established using panel cointegration tests. While three panel ARDL estimation approaches (PMG, MG, and FE) were used to estimate the models, descriptive statistics provided a summary of the data. Finally, a heterogeneous panel causality study was done to look at causal links between the factors. In the short run, energy consumption and GDP have a notable positive effect on greenhouse gas emissions, according to the results. Although in the long run, energy consumption and FDI have a positive and significant impact, whereas GDP squares representing the inverted U-shaped EKC exert a negative and significant impact, thereby validating the EKC. Furthermore, based on these results, several environmental welfare improvement-related policy suggestions are suggested, including promoting green investment, monitoring and regulating foreign direct investment, fostering sustainable economic growth, and encouraging economic diversification, while encouraging the exploration of alternative economic indicators for future work.

Keywords: Environmental degradation, Foreign direct investment, Economic growth, Greenhouse gas emission, GDP.

JEL Codes : C33, F21, O44, Q43, Q53

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¹  Department of Economics, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State, Nigeria. nathannathanudoinyang@gmail.com

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1. INTRODUCTION

West Africa is a rich area, an expanding, developing economy endowed with vast natural resources that enrich the region. But lately, West Africa has seen growing worry over environmental damage. Understanding the macroeconomic forces affecting the quality of the environment in this area has hence become crucial. Especially exports, West African economies have considerably helped to determine world output. West African countries have had problems preserving their environmental resources despite their quick expansion and influence. Concerning air quality, for example, Nigeria, Ghana, Mali, and Niger, four areas with the highest economies, are among the most polluted nations in the world. West Africa is also home to 44 of the 80 most badly polluted cities worldwide. (World Air Quality Index (AQI) Ranking; 2023). On the other hand, though the overall Greenhouse Gas (GHG) emissions increased more than 2.4 times between 2000 and 2023, the aggregate per capita carbon dioxide (CO₂) emissions in West African countries almost doubled. Responding to this worry, the United Nations Framework Convention on Climate Change (UNFCCC) was established to fight climate change on a global level. Reducing greenhouse gas emissions is the main way to address climate change; many nations have agreed to do so through treaties, such as the Kyoto Protocol. A recent call calls for a worldwide pledge to achieve net-zero emissions by 2050. In this regard, there is increasing curiosity in grasping the economics of these emissions and identifying the socioeconomic factors driving them so as to meet policy objectives within a framework of sustainable development (Mikhaylov et al.2020).

Mikhaylov et al. (2020) report, however, that GHG emissions have steadily climbed across the 21st century. Since GHG emissions have significantly impacted the economic ties and spatial connection between Nigeria, Ghana, Mali, and Niger, among the top twenty GHG emitters globally, a regional study of emissions and their causes is vital. Correct environmental management and planning depend on knowledge of the spatiotemporal changes in GHG emissions among nations in a particular area. Given these opposing trends in economic and environmental well-being, it is fair to assume that West African economic growth has caused negative environmental backwardness. Countries in the West African area are expected to reach the SDGs specified by the United Nations by 2030. Understanding the connection between environmental, economic, and financial stability is vital. With policy ideas for reducing GHG emissions while supporting economic expansion, the present research will cover how the results relate to Sustainable Development Goals (SDG) 13 (Climate Action) and 11 (Sustainable Cities and Communities). All four nations are working on SDGs and are party to international climate agreements like the Paris Agreement, which aims to reduce worldwide temperature and GHG emissions. Using EKC methodology, a battery of pooled panel data econometric methods, and the secondary data source World Bank Development Indicator (WDI), this study aims to analyse the drivers of GHG emissions in the chosen West African nations, Nigeria, Ghana, Mali, and Niger, from 1980 to 2023. Most of the past research on GHG emissions has concentrated on either developed economies or developing ones, neglecting the countries of West Africa. Moreover, there are no thorough investigations on the causes of West African GHG emissions.

Therefore, this research seeks to fill that gap by employing a panel data analysis approach to identify the leading causes of GHG emissions in these nations. Formulating successful policies and strategies to lessen the negative impacts of climate change depends on an awareness of the elements affecting GHG emissions in this area. Recent research on the influences of GHG emissions in Asia and West Africa has examined a variety of environmental and economic factors (Pandey et al., 2020, and Sattar et al., 2022). Still, there is not enough thorough research on the panel-level factors influencing regional GHG emissions. The results will offer insightful information for governments in West African nations to create successful initiatives to lower GHG emissions while fostering economic development and luring foreign investment. Developing policies that advance the SDGs as well as solve climate change problems would depend on an understanding of the connections between energy usage, economic expansion, and foreign direct investment.

Additionally, this study will add to the scholarly literature on environmental economics, particularly within the setting of West Africa, an area underrepresented in prior studies. Most current EKC hypothesis research emphasizes rich countries or significant developing economies. There is not enough thorough study of how this idea relates to the particular environmental and economic situations of West African nations. Limited data accessibility or inadequate longitudinal studies across long periods could cause earlier research to suffer. This study seeks to overcome these restrictions by means of an all-encompassing dataset covering 1980 to 2023. Empirical data is required to assist decision-makers in West Africa on how to harmonize financial plans with environmental sustainability. The research offers practical advice for creating successful policies to lower GHG emissions while encouraging financial and economic growth.

2. THEORETICAL LITERATURE

Many works have investigated the connection between economic expansion and environmental degradation. The Environmental Kuznets Curve (EKC) theory holds that there is an inverted U-shaped link between economic growth and environmental damage (Kuznets, 1955). According to the EKC idea, environmental deterioration rises with economic growth at low levels of income but declines with economic growth at higher levels of income. The EKC theory has been blasted for simplifying the complicated connection between environmental degradation and economic expansion, though (Stern, 2004). The Environmental Kuznets Curve (EKC) theory is pertinent for this research, given its great link between economic expansion and environmental deterioration.

2.1 Empirical Literature Review

The Environmental Kuznets Curve (EKC) points to the link between per capita income and several environmental markers, as Stern (2004) notes. Rising pollutant emissions and decreasing environmental quality define early economic expansion. However, economic expansion over a specific level of per capita income, which varies according to several factors, reverses this trend and results in environmental improvement. This means that the connection between per capita income and environmental effect or emissions follows an inverted U-shaped curve. Changes in the structure of the economy and technology, known as the scaling effect, can lead to greater pollution and environmental issues following economic growth. This argument advances the traditional theory that economic growth and environmental quality are

mutually incompatible. Proponents of the EKC theory contend, nevertheless, that at later stages of development, environmental deterioration levels stabilize and reduce as structural changes toward information-intensive enterprises, better technology, environmental legislation, and greater investments occur. Figure 1 shows the inverse U-shaped graphical representation of the theory as follows. The independent variable is environmental deterioration; it is proxied by deforestation and all forms of air, water, soil, and land pollution. The independent variable here is per capita income.

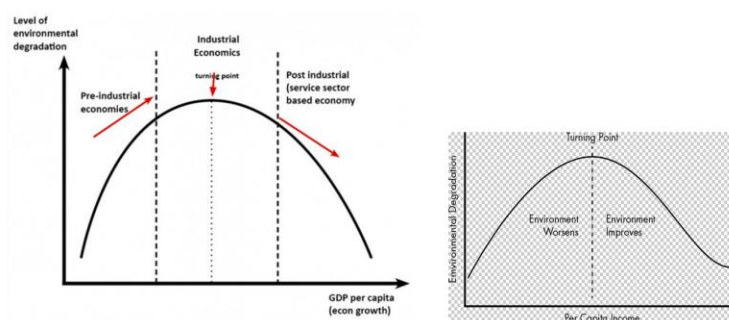


Fig 1: The Environment Kuznets Curve

Source: The Kuznets Curve for the Sustainable Environment and Economic Growth (Mishra, 2020)

2.2. Energy Use and Greenhouse Gas Emissions Linkage

In 2024, Udoinyang et al. considered renewable energy and sustainable economic growth in Rivers State, Nigeria. Data from the whole were gathered using a survey approach in this research. Population of Rivers State. From each of the three senatorial constituencies, 318 people filled out the survey. The survey used the Taro Yamane formula to ascertain a sample size of 400. was suitable. Using a mean criterion of 3.0, the statistical methods of the Statistical Package for the Social Sciences (SPSS) were used to examine the study's research subjects.

Regarding the long-term economic development in Rivers State, renewable energy promotes energy Efficiency, lowers greenhouse gas emissions, and helps to sustain social-economic growth. Raises quality of living, pollution, and climate change No renewable energy regulation implementation, lack of investor attraction strategies, lack of technology, lack of developers of renewable energy; inadequate credit options available to renewable energy developers; Low renewable energy awareness is also highlighted as a barrier to the status of Rivers, Nigeria's Renewable energy industry is investigated. Sustainable economic development can be achieved through the use of renewable energy. According to the report, the use of renewable energy should be encouraged. Researchers begged the government of Rivers State and policymakers to create credit to train additional renewable energy developers. Structures and an enabling environment for the use of renewable energy, assign money, and create policies for renewable energy.

Mehmood (2022 examined the person and interaction effects of renewable energy, economic growth, government performance, and FDI on CO₂ emissions across four South Asian countries: India, Sri Lanka, Pakistan, and Bangladesh. Annual data from 1996 to 2019 were examined in the research. The results show that renewable energy and its interactions with government effectiveness and FDI have favourable ecological consequences. In 24 OECD

nations over the years from 1980 to 2014, Destek and Sinha (2020) investigated the effects of several variables, including renewable and non-renewable energy, on environmental degradation. Employing second-generation panel data approaches like the PMG estimator and the ecological footprint as a gauge of environmental quality, their results showed that non-renewable energy causes the ecological footprint to grow, whereas renewable energy helps to lower it.

Using FMOLS and DOLS, Chen et al. (2019) examined how renewable and non-renewable energy affected CO₂ emissions in China between 1995 and 2012. The study found that non-renewable energy favourably contributed to CO₂, while renewable energy had a detrimental effect, which differed by region. Zhang and Liu (2019) investigated the link between CO₂ emissions, non-renewable and renewable energy in eleven Northeast and Southeast Asian countries between 1995 and 2014. Their results show that while renewable energy has the capacity to reduce CO₂ emissions, non-renewable energy is the primary source of them.

2.3. Foreign Direct Investment and Greenhouse Gas Emissions Nexus

Malik et al. (2020) examined whether Pakistan was a pollution haven between 1971 and 2014 using ARDL and NARDL approaches. The study showed that both short and long-run FDI raised CO₂ emissions. Bildirici et al. (2020) projected that FDI into Afghanistan, Nigeria, Pakistan, the Philippines, Somalia, Iraq, Syria, Thailand, and Yemen dramatically increased CO₂ emissions between 1975 and 2017. In their study, Shahbaz et al. (2019) examined how FDI affects the quality of the environment in the United States and discovered that it leads to substantially more CO₂ emissions. Nasir et al. (2019) confirmed that a rise in FDI leads to more environmental degradation in emerging Asian nations.

2.4. Nexus of Economic Development and Greenhouse Gas Emissions

With energy strategies for climate change critical for development, Udoinyang (2024) investigates how important agriculture is in the economic expansion of emerging countries. The effects of farming, non-renewable energy, trade openness, and economic development on CO₂ emissions are investigated in this 1965–2022 Nigerian study. Through ARDL analysis, the data were discovered to be static, and a long-term correlation was confirmed. Results revealed that 0.42% and 0.20% respectively, were added to CO₂ emissions from a 1% increase in agricultural output and trade openness. While economic growth also had a part, increasing renewable energy use helped to decrease emissions. Implementing renewable energy, developing a low-carbon economy, trade reforms, and strong environmental policies will benefit the agriculture sector and green economy in Nigeria. From 1981 to 2015, Usama et al. (2020) used the ARDL methodologies to examine the real GDP per capita and CO₂ emission in Ethiopia.

Their results lend credence to the EKC idea. Using panel cointegration and long-term estimate methods across OECD countries from 2000 to 2015, Erdogan (2020) similarly validated the theory. In China, Ahmad et al. (2020) discovered an inverted U-shaped relationship between CO₂ emissions and income; Suki et al. (2020) used the QARDL method to support the EKC hypothesis in Malaysia from 1970 to 2018. Utilizing the spatial spill-over technique, Pontarollo et al. (2020) examined the EKC hypothesis in Romanian counties from 2000 to 2014. The data showed a U-shaped link, therefore implying that the EKC hypothesis does not apply in this setting. On West African country data between 1970 and 2017, Halliru et al. (2020) used quantile regression. The results indicated a U-shaped relationship between

economic development and CO₂ emissions. Using the ARDL approach, which combines ecological footprint and CO₂ emissions, Pata et al. (2020) also found comparable results in China between 1980 and 2016. Sarkodied et al. (2019) applied the ARDL approach to Kenyan data from 1971 to 2013. The EKC idea is supported and confirmed by the findings. Figure 2 presents the Research Model of the present study.

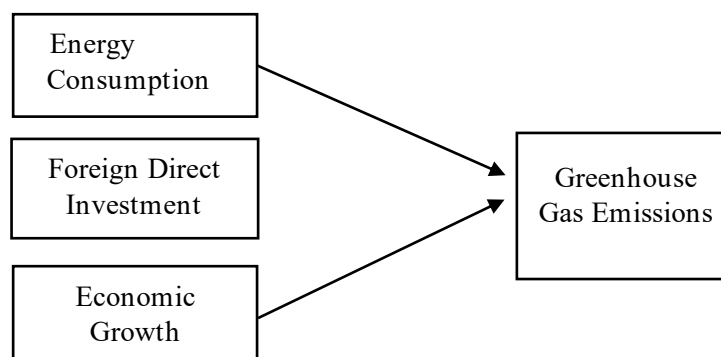


Fig 2: Research model of the Current Study

3. METHODOLOGY

3.1 Chosen Variables, Countries, and Secondary Data Source

The goals of this study were met using a panel data method. The advantages of panel data, namely more information and statistical efficiency, motivated the researcher's investigation. Individual heterogeneity and temporal trends may be studied with panel data, therefore deepening knowledge of variables affecting results. Addressing endogeneity concerns, it also accounts for personal variations and time-varying changes. Using econometric techniques like dynamic panel data models and random effects reinforces the analysis, therefore enabling stronger conclusions regarding causal relationships.

While other environmental economics and financial aspects serve as explanatory variables, the dependent variable is Greenhouse gas emissions. For the four West African nations, Nigeria, Ghana, Niger, and Mali, the study uses annual balanced panel data from 1980 to 2023. Secondary sources are used in the analysis.

Table 1. lists the sample employed in the study.

Country	Observation
Nigeria	40
Ghana	40
Niger	40
Mali	40

The variables utilized in the current study and the unit of measurement are shown in Table 2.

TABLE 2. Definition and source of variables

Variable	Short Name	Unit	Data source
Dependent Variable			
Environmental Degradation	GHG	Total Greenhouse Gas Emission (kt of CO2 equivalent)	World Bank Development Indicators
Independent Variables			
Energy Consumption	EC	Energy Use (kg of oil equivalent per capita)	World Bank Development Indicators
Economic Growth	GDP	Gross Domestic Production Per Capita	World Bank Development Indicators
Foreign Direct Investment	FDI	Foreign Direct Investment, Net Inflows (BoP, current US\$)	World Bank Development Indicators

3.2. Method of Data Analysis

There are four phases in the ARDL process. First, assess the panel unit root tests and ideal lag choice. Then, try the cointegration test and lastly estimate the panel ARDL along with the Hausman specification test to find the most relevant model for the chosen data. The STATA program is used to carry out the study. Many previous studies have used these techniques and tests. Most of these techniques and testing have been used in their research by Djellouli et al. (2022), Irfan & Ojha (2022), Zardoub (2021), Nazah et al. (2021), Bandy & Aneja (2019), Bergstresser (2018), Abidin et al. (2015), and Acaravci & Ozturk (2010).

3.3. An Empirical Model for the Research

Furthermore, developed in this study is an empirical model mirroring results from Djellouli et al., 2022; Irfan & Ojha, 2022; Zardoub, 2021; Nazah et al., 2021; Bandy & Aneja, 2019; Bergstresser, 2018; Abidin et al., 2015; Acaravci & Ozturk, 2010;

The following functional form allows one to express the model

$$GHG = f(EC, GDP, GDP^2, FDI) \quad (1)$$

Following the quadratic model equation, the present research also investigates the EKC's presence.

$$GHG_{i,t} = \beta_0 + \beta_1 EC_{i,t} + \beta_2 GDP_{i,t} + \beta_3 GDP_{i,t}^2 + \beta_4 FDI_{i,t} + \mu_i + \varepsilon_{it} \quad (2)$$

The signs of the coefficients for GDP and GDP2 define the form of the EKC curve, says Chang (2019). Therefore, one can verify the existence of the EKC hypothesis as follows:

- If $\beta_1 > 0$ and $\beta_2=0$, GDP and GHG emissions illustrate a monotonically increasing relationship.
- If $\beta_1 < 0$ and $\beta_2=0$, GDP and GHG emissions illustrate a monotonically decreasing relationship.
- Suppose $\beta_1 > 0$ and $\beta_2 < 0$, GDP and GHG have an inverted U-shaped relationship. Furthermore, the EKC hypothesis is valid.

If $\beta_1 < 0$ and $\beta_2 > 0$, GDP and GHG have a U-shaped relationship.

GDP and GHG emissions demonstrate a monotonically increasing link when $\beta_1 > 0$ and $\beta_2 = 0$. If $\beta_1 > 0$ and $\beta_2 = 0$, GDP and greenhouse gas emissions show a monotonically decreasing relationship. GDP and GHG have an inverted U-shaped correlation when $\beta_1 > 0$ and $\beta_2 = 0$. Moreover, the EKC theory is appropriate. GDP and GHG have a U-shaped link if β_1 is negative and β_2 is positive. Because it is appropriate regardless of the order of the variables, either I (0), I (1), or a mix of both, and further allows for the study of both short and long-run effects, this technique was chosen. The experimental ARDL model (p, q, q, ..., q) created by Pesaran et al. (1999) is expressed below:

$$Y_{it} = \sum_{j=1}^p \lambda_{ij} Y_{i,t-j} + \sum_{j=0}^q \delta'_{1ij} X_{1,t-j} + \sum_{j=0}^q \delta'_{2ij} X_{2,t-j} + \sum_{j=0}^q \delta'_{3ij} X_{3,t-j} + \sum_{j=0}^q \delta'_{4ij} X_{4,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

Where $x_{i,t}$ ($k \times 1$) the vector of explanatory variables (EC, GDP, FDI) for group i , $\delta'_{i,t}$ is ($k \times 1$) denoted by the coefficient vectors of the regressors, the dependent variable (GHG) $\lambda_{i,t}$ represents the coefficients of the lagged dependent variables, and μ_i denotes the fixed effects, $i = 1, 2, \dots, N$ $t = 1, 2, \dots, T$ and the error correction model can be stated as follows,

$$\Delta Y_{it} = \theta ECT + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{1ij} \Delta X_{1,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{2ij} \Delta X_{2,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{3ij} \Delta X_{3,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{4ij} \Delta X_{4,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

It calls for conditions like extended-run relationship verification, serial correlation-free residuals, external explanatory variables, and sizable time periods. The MG method evaluates regressions for every country, averaging coefficients without weights applied by Pesaran and Smith (1995). Though reliability depends on enough time series data dimensions, it enables coefficient variance across countries and time frames. The DFE estimator lets country-specific intercepts and guarantees consistent speed of adjustment coefficients and short-run coefficients across nations, as well as uniform cointegrating vector coefficients over all panels. It fits country-specific intercepts and preserves slope coefficient homogeneity and error variances. Its cluster option calculates intra-group correlation with standard errors, therefore taking into account possible dependencies within nations or panels. (Nazah et al., 2021) and (Zardoub, 2021).

3.4. Cross Correlation

According to Chatfield, cross-correlation is a statistical technique used in time series analysis to evaluate the resemblance or interaction of two time series, depending on time lag, to detect probable lead-lag relationships and temporal dependencies. Detecting possible lead-lag relationships, cyclical patterns, and other kinds of temporal dependencies between variables is aided by the cross-correlation function (CCF). The cross-correlation of two time series, X_t and Y_t , with lag k is estimated using the following formula:

$$CCF(k) = \frac{\sum_{t=1}^{N-k} (X_t - \bar{X})(Y_{t-k} - \bar{Y})}{\sqrt{\sum_{t=1}^{N-k} (X_t - \bar{X})^2 \sum_{t=1}^{N-k} (Y_{t-k} - \bar{Y})^2}} \quad (5)$$

Where X_t and Y_t are the two time series being explored, and indicate their mean values, respectively, for the time series X_t and Y_t . The length of the time series is N . The cross-correlation is computed at lag k .

3.5. Test of panel unit root

Because many macroeconomic data sets are non-stationary, estimating the panel ARDL model calls for a study of the stationarity of the sample variables. If the mean and autocovariance are consistent over time (Venkatesan & Ponnammma, 2017), a time series is considered stationary. Investigating the stationarity and establishing the order of integration of all respective variables considered in the present study, the unit root test helps one to determine if the series is integrated with the order $I(0)$ or $I(1)$. Should the variables include a combination of $I(0)$ and $I(1)$ or all $I(1)$, the panel ARDL model may be properly evaluated (Zardoub, 2021). Two kinds of first-generation panel unit root tests are used in the study: common tests like Levin and Breitung for constant persistent parameters, and individual tests like Im, Pesaran, and Shin W-stat, Fisher-ADF, and Fisher-PP for changing parameters. Verick, 2018. All of these tests are grounded in the following simple ADF model.

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \Delta y_{it-j} + X_{it}' \delta + \varepsilon_{it} \quad (6)$$

With the null hypothesis being rejected if the test statistical probability value is less than the significance level, which points to a stationary time series, the study employs intercept and trend specifications.

Panel Cointegration Test

The long-term equilibrium link among factors is examined in this study utilizing the panel cointegration test recommended by Pedroni (1999, 2004). The null hypothesis holds that there is no cointegration, but the rejection implies that variables are cointegrated and travel together over time, therefore pointing to a stable relationship in spite of short-term fluctuations.

Test by Pedroni (1999, 2004). Widely used method for investigating cointegration in panel data contexts, Pedroni's Panel Cointegration test extends classic cointegration tests, enabling heterogeneous intercepts and slopes across panel units. Based on the Engle-Granger methodology, the test formula employed in this study allows for long-run equilibrium and the shared significance of the level equation. (Djellouli et al., 2022). The following test formula has been used in the current study.

Panel-Rho Statistics

$$T\sqrt{N}Z_{\hat{\rho}_{N,T-1}} \equiv T\sqrt{N}i,t \left(\sum_{i=1}^N \sum_{j=1}^T \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{i=1}^N \sum_{j=1}^T \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1}^2 \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right) \quad (7)$$

Panel-t Statistics

$$Z_{tN,T}^* \equiv \left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^N \sum_{j=1}^T \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1/2} \sum_{i=1}^N \sum_{j=1}^T \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \Delta \hat{e}_{i,t} \quad (8)$$

Group-Rho Statistics

$$TN^{-1/2}Z_{\hat{\rho}_{N,T-1}} \equiv TN^{-1/2} \sum_{i=1}^N \left(\sum_{j=1}^T \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{j=1}^T \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1}^2 \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right) \quad (9)$$

Group-t Statistics

$$N^{-1/2}Z_{tN,T}^* \equiv N^{-1/2} \sum_{i=1}^N \left(\sum_{j=1}^T \tilde{s}_{N,T}^{*2} \right)^{-1/2} \sum_{j=1}^T \hat{e}_{i,t-1}^2 \Delta \hat{e}_{i,t} \quad (10)$$

Pesaran-Yamagata (2008) Homogeneity Test; (7) Panel-Rho Statistics; (8) Panel-t Statistics; (9) Group-Rho Statistics; (10) Group-t Statistics

The homogeneity test Pesaran-Yamagata (2008) assesses the panel data model long-run coefficients' consistency. It finds out whether the coefficients of explanatory variables are uniform across all entities using the conventional delta test and the modified test. Homogeneous implies a common long-run relationship among variables. (Djellouli et al., 2022). The standard delta test statistic is given by,

$$\bar{\Delta} = \frac{1}{\sqrt{N}} \left(\frac{\sum_{i=1}^N \bar{d}_i - k_2}{\sqrt{2k_2}} \right) \quad (11)$$

lag Selection Rules

Particularly in ARDL models, the lag order in dynamic models is significant. The order for each country is determined using lag length selection criteria, including Modified Bayesian Information Criterion (MBIC), Modified Akaike Information Criterion (MAIC), and Modified Quasi-Likelihood Information Criterion (MQIC) among researchers. As employed by Djellouli et al. (2022), Ifran & Ojha (2022), Ifran & Ojha (2022), Zardoub (2021), Nazah et al. (2021), the lowest lag value is chosen. Test Haussman (1978)

Assuming homogeneity in long-run policy parameters, the Hausman test (1978) assesses the efficacy of PMG, MG, and DFE estimators. Using the Hausman type of test (Chu & Sek, 2014), one can establish how heterogeneity affects the averages of the coefficients. The Hausman test statistic's general form is:

$$H = \left(\hat{\beta}^1 - \hat{\beta}^{11} \right)' \left[Var\left(\hat{\beta}^1 \right) - Var\left(\hat{\beta}^{11} \right) \right]^{-1} \left(\hat{\beta}^1 - \hat{\beta}^{11} \right) \quad (12)$$

The null hypothesis of the test asserts no significant difference between PMG and MG estimates or PMG and DFE estimates. Rejection of the null hypothesis occurs when the probability value is lower than the significance level; hence, the more effective estimator MG is preferable (Nazah et al., 2021).

To verify heteroscedasticity in the residuals of the fitted model, the Heteroscedastic Test has been tested using Breusch Pagan's chi-square test.

$$BP = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij,T}^2 \quad (13)$$

Serial correlation in the residuals of the model is examined using pearson CD tests.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \quad (14)$$

Normal Test: The Jarque and Bera test uses the normality test.

$$JB = \frac{n}{6} \left(\frac{\hat{\mu}_3}{\hat{\mu}_2^{3/2}} \right)^2 + \frac{n}{24} \left(\frac{\hat{\mu}_4}{\hat{\mu}_2^2} - 3 \right)^2 \quad (15)$$

In panel data situations, the panel Granger causality test helped the researcher to ascertain the direction and degree of causal linkages among variables. This test evaluates cross-sectional dependency and heterogeneity, therefore determining whether fluctuations in one variable influence other over several entities and over time. These assessments help one to evaluate the connection between variables. (Chu & Sek, 2014).

4. DATA ANALYSIS AND DISCUSSION OF FINDINGS

Understanding the kind and features of the data used in the research depends on the descriptive statistics of every factor. Table 3 provides a thorough description of the descriptive statistics for all variables.

Table 3. Descriptive statistics

Variable		Mean	Std. Dev.	Minimum	Maximum	Observations
GHG	Overall	7694000	8593718	66412.1	20000000	N=160
	NGR	2380268	418620	247131	1352471	n = 40
	GHA	23000000	8455806	11200000	60000000	n = 40
	MAL	2566382	1376638	2005771	6442838	n = 40
	NEG	442736.8	94989.25	97643.2	685843.8	n = 40
EC	Overall	4833.06	2877.39	438.17	9352.62	N=160
	NGR	3399.61	918.42	438.17	8837.42	n = 40
	GHA	2367.65	3671.75	3622.68	3365.73	n = 40
	MAL	3010.37	924.75	1432.22	3876.69	n = 40
	NEG	369.58	2496.05	2476.84	6854.81	n = 40
GDP	Overall	3375.09	670.82	582.38	6186.51	N=160
	NGR	862.67	532.03	573.92	2694.84	n = 40
	GHA	795.95	642.67	534.29	9163.86	n = 40
	MAL	683.98	863.62	1624.43	5775.67	n = 40
	NER	3455.11	2449.62	940.20	6577.82	n = 40
GDP2	Overall	3415700	4691926	361945.5	612000000	N=160
	NGR	523668.71	584941.40	438855.80	5235286.0	n = 40
	GHA	2425247.0	1182194	361993.6	5266884.0	n = 40
	MAL	2515568	249.67	884.65	2595.69	n = 40
	NEG	7245332.1	7653068.0	647908.91	41200000	n = 40
FDI (‘0000)	Overall	486000	2200000	-4520	8220000	N=160
	NGR	83200	95600	-604	8670000	n = 40
	GHA	2840000	2690000	-4732	3550000	n = 40
	MAL	242000	362000	-700	669000	n = 40
	NEG	43400	48200	-132.76	151000	n = 40

Source: Author's Calculate

The data reveal a notable disparity between Nigeria and Ghana in terms of greenhouse gas emissions, energy consumption, and GDP. With 20,000,000, Nigeria has the most significant GHG emission value; Ghana has the lowest at 11200000. This shows how active Nigeria is industrially and how severely it affects the environment. Nigeria has the highest energy use,

with a maximum of 8837.42 and a minimum of 438.17. With an average of 9163.86, Ghana has the highest GDP. The squared GDP indicates Ghana's significant economic scale and volatility. With the most FDI of 8670000, Nigeria shows a good investment environment. Ghana, Mali, and Niger have lower FDI numbers and intermittent periods of disinvestment. Nigeria is the leading nation overall in emissions, energy consumption, and FDI; Ghana has the highest GDP; hence, there are different economic and environmental profiles among these nations.

4.1 Cross Correlation

Cross-correlation among the four variables is shown in Table 4. At lag 0, the research reveals a high positive link between energy use and greenhouse gas emissions, therefore indicating rising emissions. At lag 2, however, this connection weakens, implying a relatively little influence of past energy use on present emissions.

With a slight positive correlation, GDP has a poor connection with GHG emissions at lag 0. There is a weak correlation between GDP2 and GHG emissions, with a little negative correlation, increasing at lag 1, then weakening at lag 2, and finally at lag 3. This suggests that over time, GDP has a diminishing influence on GHG emissions. The study reveals a little rise at lag one and a weak positive link between FDI and GHG emissions. The influence of FDI on GHG emissions diminishes over time.

Table 4. Cross-Correlation

Lag	EC	GDP	GDP2	FDI
0	0.7436	0.0834	-0.2258	0.0056
1	0.5113	0.0549	-0.2283	0.0630
2	0.2547	0.0578	-0.0467	0.0353
3	0.1417	0.0466	-0.0430	0.0136

Source: Author's Calculated.

Energy use has the most immediate and significant impact on environmental degradation; nevertheless, its effect declines over time. With GDP2 exhibiting a somewhat negative relationship, GDP and GDP2 show weaker and dwindling linkages. Weak and short-term influence of foreign direct investment on environmental deterioration points to complicated and time-dependent links between these elements and environmental results in certain West African nations.

4.2. Testing for Unit Root

Considering intercept and trend, Table 5 displays the panel unit root test results—including Levin, Lin & Chu t^* and Breitung t -statistics for variables at both level and first differences. The unit root test reveals that most variables initially grow stationary at first differences. The Levin, Lin & Chu t^* statistic indicates non-stationarity at the level but great stationarity at the first difference throughout intercept and intercept. At a level, the EC exhibits non-stationarity, but it becomes stationary at the first difference. In the Levin, Lin & Chu t^* test with significant p -values (< 0.05) at a 5% level of significance, GDP and FDI also show stationarity at the level. The associations of $I(0)$ and $I(1)$ variables indicate that a long-term relationship is best investigated with an ARDL model.

Table 6 presents the results of panel unit root testing with individual unit root processes for the variables, namely the ADF - Fisher Chi-square, PP - Fisher Chi-square test, and Im,

Pesaran, and Shin W-stat under two specifications: with an intercept only and with both intercept and trend.

Table 5. Panel Unit Root Tests (Common Unit Root Process)

Variable	Levin, Lin & Chu t				Breitung t-stat	
	Intercept		Intercept with trend		Intercept with trend	
	1st diff.	Level	1st diff.	Level	1st diff.	Level
GHG	4.761	-10.322***	-0.515	-13.058***	2.964	-3.546***
p-value	1.0	0.00	0.158	0.00	0.8779	0.00
EC	4.511	-7.817***	-0.665	-7.769***	1.432	-0.371***
p-value	0.8875	0.00	0.3861	0.00	0.924	0.3553
GDP	-0.356	-24.788***	-11.473***	-	-0.587**	-
p-value	0.6301	0.00	0.00	-	0.0453	-
GDP2	-3.118**	-	-3.060**	-	-4.24***	-
p-value	0.3325	-	0.018	-	0.00	-
FDI	-3.063**	-	-1.650*	-12.056***	-2.679***	-
p-value	0.0195	-	0.0749	0.00	0.0069	-

Source: Author's Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

At the interception and trend definitions, the GHG variable displays non-stationarity but settles at the first difference. Although the EC and GDP factors also display non-stationarity and change into stationarity upon the first difference. Without differencing, FDI and GDP2 are naturally stationary. Since it can accommodate both I (0) and I (1) variables without needing previous transformation and enables investigation of short and long-run dynamics inside the panel data structure, the panel ARDL model is a suitable econometric technique for assessing the connection among these variables.

Table 6. Panel Unit Root Tests (Individual Unit Root Process)

Variable	ADF - Fisher Chi-square				Im, Pesaran, and Shin W-stat				PP - Fisher Chi-square			
	Intercept		Intercept with trend		Intercept		Intercept with trend		Intercept		Intercept with trend	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
GHG	3.5	64.7***	4.5	109.1***	3.5	-7.5***	0.4	-10.7***	2.6	3.4*	5.2	105.2***
EC	0.6	67.1***	6.5	61.3***	5.4	-7.9***	0.4	-8.4***	0.9	122.0***	7.0	125.7***
GDP	50.2**	-	105.5***	-	-11.0***	-	-7.4***	-	95.4***	-	127.7***	-
GDP2	55.4***	-	53.3***	-	-7.3***	-	-3.5***	-	131.6***	-	143.5***	-
FDI	32.6***	-	33.2***	-	-4.5***	-	-2.5***	-	17.8**	-	17.8**	-

Source: Author Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

Homogeneity Test

Results According to Pesaran and Yamagata, P-values of 0.00 on the Delta statistic (41.027) and adjusted Delta statistic (33.451) show great statistical significance and decisive rejection of the null hypothesis at a 1% level, hence demonstrating considerable heterogeneity among cross-sectional units in the panel data set.

Table 7. Homogeneity Test of Pesaran and Yamagata (2008).

	Delta Value	p-value
	41.027***	0.00
Adjusted	33.451***	0.00

Source: Author Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

Cointegration Test

Table 8 shows the results of the cointegration test, which show a notable long-term equilibrium connection between the panel variables. Strong cointegration at the 1% level is indicated by a v-statistic of 5.4472. At 10%, the rho-statistic is -1.5577, the panel t-statistic is -1.5769, and the panel ADF statistic is -1.7683, indicating less evidence of cointegration at the group level.

Table 8. Cointegration Test

Cointegration Test Statistics	Statistic	
	Panel	Group
V	5.4472*** (0.000)	
Rho	-1.5577 * (0.0751)	-0.5349 ** (0.0963)
T	-1.5769* (0.0830)	-0.3654 (0.6426)
Adf	-1.7683 * (0.0607)	-0.5424 (0.2937)

Source: Author Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

Find the best length for the lag.

Table 9 shows the best lag length for a model employing MBIC, MAIC, and MQIC criteria. The model with the smallest lag length is regarded as best since it implies a better fit with fewer parameters. Validated crosscorrelation analysis lets one lag model strike simplicity and fit.

4.3. Model Estimation

Table 10 compares the predicted coefficients and standard errors for several economic variables using three different estimators: PMG, MG, and DFE. The results of every estimator are examined to determine the influence and importance of these factors on the dependent variable. The research examined three approaches for capturing long-term and short-term interactions between variables. With a 5% level of significance, the PMG and MG models revealed notable short-term ECT. Rates of 75.55% and 45.42% per period, respectively, corresponded with deviations from long-term equilibrium. While the DFE model's coefficient was non-significant, indicating it might not properly capture short-run adjustments, the PMG model showed faster adaptation.

Table 10. Results of PMG, Mg, and DFE Estimators

Variables	PMG		MG		DFE	
	Coefficient	Std. Err	Coefficient	Std. Err	Coefficient	Std. Err
Short Run						
ECT	-0.7555**	0.038	-0.4542***	0.1184	0.0073	0.020
p-value	0.040		0.002		0.767	
D.EC	617.9175*	617.81	452.72	504.63	2065***	213.79
p-value	0.070		0.350		0.00	
D.GDP	4322.094**	1532.02	5378.65**	1736.44	4467.65***	1628.04
p-value	0.016		0.016		0.005	
D.GDP2	-2.1146	1.4211	1.508	1.5089	-0.5658***	0.1991
p-value	0.137		0.111		0.004	
D.FDI	-0.00004	0.0000	-0.00006*	0.00003	0.0000	0.0000
p-value	0.186		0.066		0.350	
Constant	1344969.3	170151	588816	446142.3	246221.8**	114403.2
p-value	0.429		0.187		0.031	
Long Run						
EC	5876.38***	775.92	1211.336	1264.79	-27844.06	105126.9
p-value	0.00		0.338		0.791	
GDP	-6042.097**	2714.55	6120.68	7397.83	145936.1	513500.8
p-value	0.026		0.408		0.776	
GDP2	-0.1141	0.4373	-1.3244	1.7834	-22.1282	76.7301
p-value	0.794		0.458		0.773	
FDI	0.0001***	0.00004	0.00022	0.0001	-0.0012	0.0052
p-value	0.002		0.150		0.813	

Source: Author's Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

With coefficients of 4322.094 in PMG, 5378.65 in MG, and 4467.65 in DFE, GDP has a good and major effect on all models, showing its relevance in the near term. But the quadratic form of GDP is only relevant in the DFE model, which points to a negative short-run quadratic effect. Across all models, foreign direct investment has little effect and is mostly not very significant. While the MG and DFE models fail to catch significant long-run effects, the PMG estimator reveals a considerable positive long-term link between energy usage and GDP. The PMG model's ability to accurately represent long-run equilibrium relationships and short-run dynamics makes it the estimator of choice in this study.

4.4. Selection of Model

The chi-square statistic for the PMG and MG models is 5.75, signifying no substantial difference, and hence either model would be appropriate for the data. The PMG and DFE models have chi-square values that are not noticeably different, therefore suggesting equal suitability; the MG and DFE models have no notable discrepancy. Hence, the PMG model is warranted since it displays relatively slight variance from the other models.

Table 11. Hausman Test

Model	Chi-Square	p-value
PMG, MG	5.75	0.40
PMG, DFE	0.04	1.00
MG, DFE	0.00	1.00

Source: Author's Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

The PMG estimate results for nations including Nigeria, Ghana, Mali, and Niger reveal different economic dynamics shown in Table 12. With an ECT of -0.1061, Ghana has a protracted shift toward equilibrium, indicating a gradual adjustment. With Nigeria adjusting quickly, Nigeria, Mali, and Niger show different rates of adaptation and economic indicators. Mali had a powerful, favourable near-term impact; Niger showed a mild adjustment rate. The findings on balance point out variations in the rate of adjustment to equilibrium and the influence of economic factors across these nations.

Table 12. Short-Run Results of PMG by Each Country

Variables	Nigeria		Ghana		Mali		Niger	
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
ECT	-0.1152**	0.4317	-1.752***	0.6559	-0.0183***	0.0063	-0.0157**	0.0059
p-value	0.014		0.008		0.002		0.015	
D.EC	588.17	544.60	1906.73**	880.99	452.029***	132.35	-54.69	45.97
p-value	0.391		0.038		0.00		0.274	
D.GDP	6459.91	5697.60	7418.25	5238.05	3055.52	2851.69	-89.30	384.48
p-value	0.269		0.166		0.284		0.816	
D.GDP2	-6.131***	1.6234	-0.2948	1.5824	-2.1057**	0.9621	0.0735	0.04798
p-value	0.00		0.852		0.029		0.125	
D.FDI	-0.00002	0.0014	-0.00001	0.0000	0.788***	0.00002	-0.0001***	0.000002
p-value	0.860		0.119		0.000		0.00	
Constant	41061.47	131339.6	637450.8**	2916913.8	-100840.3	61324.87	-39686.7	31831.76
p-value	0.31		0.029		0.10		0.212	

Source: Author's Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

The results from the post-estimation diagnostic tests provide insights into the assumptions of the fitted model shown in Table 13.

Table 13. Post Estimation Tests

Test Name	Test Value	Probability
Breusch Pagan test	4.32*	0.0756
Pearson CD test	4.32*	0.0583
Jarque-Bera Test	260.2***	0.0025

Source: Author Calculated. *** $p < .01$; ** $p < .05$; * $p < .10$

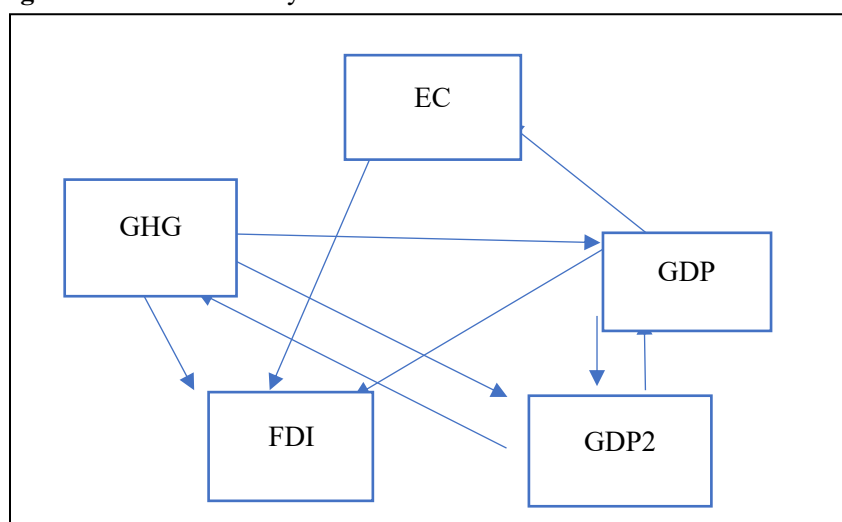
The Breusch-Pagan test examines for heteroskedasticity; the test confirms the null hypothesis of homoskedasticity, thereby suggesting constant variance in residuals across observations, with results of 4.32 and a p-value of 0.0756 at the 5% significance level, which means constant variance in the residuals. The Pearson CD test indicates little proof of serial correlation in residuals, which implies problems with residual dependence at the 10% significance level. With a test statistic of 260.2 and a p-value of 0.0025, the Jarque-Bera test,

which evaluates the normal distribution of residuals, rejects the null hypothesis. Generally speaking, diagnostic tests show violations of normality and poor serial correlation in residuals despite heteroskedasticity not being a significant issue.

4.5. Test of Panel Causality

Highlighting several important connections between economic factors, Table 3 summarizes the Dumitrescu & Hurlin (2012) Granger non-causality test results. Remarkably, Granger-causes GDP GHG emissions, implying that variations in GHG emissions precede fluctuations in GDP, but GDP does not Granger-cause GHG emissions. Equally, GDP2 exhibits considerable bidirectional causality with GDP, hence pointing to a strong two-way interaction. While EC Granger-causes FDI, FDI does not Granger-cause GHG emissions; EC does not Granger-cause GHG emissions. Furthermore, FDI Granger drives GDP; GDP does not. The results show significant causal impacts mainly including GHG emissions, GDP, and GDP2, with little or no significant causality seen in other variable pairs.

Fig 3. Result of Causality test



Source: Author Calculated.

5. CONCLUSION AND RECOMMENDATIONS

The study emphasizes the complex links between economic expansion, foreign direct investment, energy use, and greenhouse gas emissions. Particularly in the short run, the results show that GHG emissions have the strongest and most constant positive link with energy consumption. This emphasizes how quickly energy consumption affects the environment and how crucial it is to switch to renewable energy sources to slow down climate change. The long-term persistence of this connection underscores the need to lower dependency on fossil fuels. While energy consumption continues to be a major driver of emissions in both the short and long run, the positive short-run relationship between GDP and emissions reflects economies' ongoing dependence on energy-intensive activities. These results highlight the need for more efficient energy use and a quicker switch to cleaner energy sources.

Weak yet favourable correlation between emissions as measured by Gross Domestic Product and economic growth reduces over time. Although this result contradicts Zardoub

(2021), it implies that initially, economic growth raises emissions but may cause environmental benefits as countries embrace more environmentally friendly technologies. The inverse relationship between GDP squared and emissions strengthens the Environmental Kuznets Curve theory, which holds that environmental damage could decrease at greater degrees of economic development.

FDI plays a challenging part in environmental results. In the short term, foreign direct investment (FDI) shows little connection with emissions, but over the long run, it significantly affects environmental deterioration. This emphasizes the need for sustainable investment policies to strike a balance between economic development and environmental consciousness. Without suitable legislation, outside investments may cause environmental damage, therefore emphasizing the necessity of matching foreign direct investment to sustainability targets.

A comparative study of Mali, Nigeria, Ghana, and Niger shows noteworthy changes in their financial reactions to long-run equilibrium. Niger reveals a comparatively inflexible economic system where FDI negatively affects short-term growth, and statistically insignificant changes in energy consumption and GDP persist. This implies structural difficulties in adjusting to outside financial forces. Ghana, on the other hand, has a moderate adjustment pace with few near-term disruptions. Nigeria leads with the quickest adjustment, profiting from the good short-term effects of energy consumption.

Though slower in adapting, Mali shows a more reactive economy with significant short-term impacts from energy use and a complicated connection between GDP and general performance.

Niger's economic rigidity might result from political restrictions, structural inefficiencies, or investment-related difficulties when contrasted with its regional peers. These results point up the necessity for policy changes meant to increase economic flexibility, boost response to outside influences, and promote long-term sustainable development. The different paths impacted by particular policy settings and structural features are underlined by the fluctuations in economic dynamics among these nations.

5.1. The Reality of the Environment - Hypothesis of the Kuznets Curve

Among the econometric panels, the long-run estimators acquired from the PMG framework present strong evidence for the EKC hypothesis. The model's negative coefficient on the GDP squared variable shows an inverted U-shaped relationship between economic expansion and environmental damage. This implies that when countries reach greater income levels, the negative impact of more environmental growth disappears and eventually becomes favourable. The results imply that, on average, nations inside the panel show an increase in environmental damage as they move from low to middle-income levels, but this trend reverses as they approach higher income levels, therefore lowering their environmental impact.

Comparatively examining EKC across Mali, Nigeria, Ghana, and Niger shows notable differences in the link between environmental deterioration and economic growth. Early EKC features in Mali include economic growth driving more environmental damage, but a possible turning point with more degradation. Nigeria has a more advanced EKC, with a more definite turning point where economic expansion supports environmental improvements, yet the degree of this change is constrained. On the other hand, Ghana provides little concrete evidence to support the EKC hypothesis, indicating that it is still in the early stages of economic development when environmental damage keeps pace with GDP increase.

Niger shows a distinctive EKC pattern, showing successful control of economic growth while preserving environmental sustainability. This is unlike other nations, where economic growth results in environmental deterioration. Proactive environmental policies and greater environmental consciousness might account for Niger's success. The heterogeneity in economic and ecological dynamics across West Africa is emphasized by these results, which also underline the various degrees of economic growth and environmental management approaches amongst the researched nations. The variations in EKC patterns highlight the intricate interaction between economic expansion and environmental sustainability, moulded by country-specific policy frameworks, economic structures, and levels of environmental consciousness.

According to the study, West African nations should give green growth top priority, implement policies for sustainable energy use, encourage green investments, and work on regional energy projects. These policies can encourage economic diversification, advance sustainable development, and lower greenhouse gas emissions. Carbon taxes, emissions trading systems, and financial incentives are among the main initiatives. Green investments in infrastructure and technologies are necessary to lessen long-lasting environmental effects. Cooperation between public and private partners can promote innovation and extend sustainable solutions. Governments should encourage environmentally friendly technologies to draw foreign direct investment, assisting sustainable development while reducing contamination.

Sustainable development and long-term economic and environmental stability depend on regional and international collaboration. Sustainable growth balances development and environmental protection, and policymakers must promote eco-friendly practices to guarantee a sustainable future while fostering economic progress. Encouraging long-term sustainability requires objectives for lowering greenhouse gas emissions and establishing a legal framework for moving to a low-carbon footprint economy. Continuous monitoring and assessment of environmental laws are vital to guarantee their efficiency in minimizing environmental damage. In essence, the results emphasize how important it is to include ecological as well as financial aspects in an integrated approach to development planning. Future research should concentrate on sector-specific studies to pinpoint major causes of GHG emissions and energy consumption in every nation. Investigating other economic measures like the Human Development Index (HDI) and green GDP can also help one to better grasp a sustainable economy, therefore improving the dependability of future research and enabling strong analysis.

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