Carbon Pricing Mechanisms and Sustainable Development in Nigeria

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Abstract:
Utilizing greenhouse gas emission as key environmental indicator of sustainable development, this study empirically analysed Nigeria's experience of the effects of carbon pricing mechanisms over the annual data time frame, 1990 to 2024. With carbon pricing mechanisms adopted as carbon tax, carbon trading, green tax and policy compliance rate, relevant data were gathered from Development Indicators of World Bank, Statistical Bulletin of Nigeria's Central Bank, Bureau of Statistics of Nigeria, International Energy Agency, Climate Change Framework Convention of United Nations, and Economic Co-operation and Development Organisation. Applied as technique of analysis is the procedure of Autoregressive Distributed Lag (ARDL) framework. Established from the estimates are that; carbon tax, carbon trading, green tax and policy compliance rate had short and long runs negatively significant effects on Nigeria's greenhouse gas emission for the sampled period. Concluding from the study outcome, carbon pricing policy measures have immensely contributed to reducing greenhouse gas emission thus, promoting Nigeria's sustainable development. Considering the results and drawn conclusion, the study emphasized that government consistently strengthen expand and implementation carbon tax policy net across major emission-intensive sectors such as oil and gas, manufacturing, and transportation. Since the research outcome revealed significant reducing effect of carbon pricing on emission over short and long runs, revenues generated should be deliberately applied for environmental protection programmes, clean energy subsidies, and institutional capacity building to enhance emission-reducing benefits.

Keywords: *Carbon Pricing Mechanisms, Greenhouse Gas Emission, Sustainable Development, Nigeria, ARDL*

JEL Classifications: H23, Q56 Q58

1.0 Introduction

Climate change and environmental degradation as critical issues confronting man have in recent decades attracted global attention, and emission of greenhouse gas is acknowledged as the main factor in global warming and its environmental impacts. Interpretation of sustainable development, conceived as development that meets the needs of the present without compromising the ability of future generations to do the same, is grounded on the need to pursue economic growth while maintaining the environment's quality (Brundtland, 1987). Nigeria, as one of the largest African economies and a leading fossil fuel producer, is confronted with a severe version of this difficulty as the country's legacy of fossil fuel production, gas flaring, energy intensive economic and industrial activities have significantly contributed the bulk of its greenhouse gas emissions and environmental degradation (International Energy Agency, 2023). Governments around the world have introduced new mechanisms to put a price on carbon emissions, i.e., implement carbon pricing measures, in order for emitters to internalize the environmental costs of pollution and to create a roadmap for shifting to cleaner modes of production. Most carbon pricing schemes include carbon tax, carbon trading or emissions trading schemes, green tax or environmental penalty charges, and policy compliance regimes which ensure compliance with environmental policy (Tietenberg, 2006). The World Bank (2023) estimates that the number of carbon pricing initiatives worldwide has nearly tripled in the last 20 years, showing increasing international consensus on the importance of relying on price-based instruments to tackle climate change.

Although carbon pricing policy measures are now being implemented across the world, Nigeria's experience with the instruments is rather at the emerging stage, lacking adequate regulatory environment, institutional and policy coordination as well as effective monitoring and enforcement mechanisms (Fwadwabea, *et al*., 2025). Nigeria has witnessed steady increase in green-house gas emissions in the last 30 years, especially as evident by gas flaring in the oil and gas industry, deforestation, and the country's strengthening urbanization rate and industrialization. Therefore, this scenario begs the question if the nation's trajectory of emissions could be sufficiently mitigated by the existing and well-known carbon pricing instruments including the carbon tax, carbon trading, green tax and policy compliance mechanism. Though, Nigerian governments had made preliminary efforts at initiating emission deterrent tax measures such as the National Policy on Climate Change, and the Climate Change Act 2021, there are still some noticeable inadequacies in the shaping, implementing and enforcing of the wide-ranging carbon price mechanisms (Oludare, Olufemi & Olamileke, 2021). These developments highlight crucial concerns the efficacy of carbon pricing policy tools as designed and implemented in Nigeria to reduce GHG pollution, and whether weak institutional enforcement and policy change undermines its impact. Therefore, this study is designed to determine the Nigerian experience on how carbon pricing policy measures impacted on sustainable development (measured as GHG emissions). To achieve the preceding broad goal, the study specifically set for Nigeria, diagnosed the effect of carbon tax on GHG emission, determined how carbon trading impact GHGs emission, evaluated green tax's effect on GHGs emission and assessed the implication of compliance rate of emission control policy on the nation's GHGs emission.

2.0 Related Literature

2.1 The Underpinning Theories

As associated with the focus of this study, the adopted theories are discussed as follow:

i. Kuznets' Environmental Curve Theory

This popular environmental theory is unquestionably linked to Simon Kuznets who first proposed the well-known Kuznets Curve model in 1955 to elucidate the direction of income inequality connection with economic development. Later, the environmental variant conceptualization was link to Grossman and Krueger (1991, 1995). The theory posits that environmental degradation firstly increased with increase in economic growth and later decreased when certain income growth level is achieved, thus, generating an inverted-U shaped association of pollution and income growth. This is elucidated that during early stages of development, pollution emanating from increased industrial activity and the lack of institutional protection for the environment rises with income; in the late stages of development, pollution starts to decline as economies become wealthier, technologies become cleaner, and institutions put more emphasis on environmental protection. The theory assumes that as people's income levels rise, societies grow more concerned about adopting better environmental standards and regulations, and that as a society's education and institutional development improves, its environmental awareness increases, which in turn gives Governments an impetus to introduce environmental taxes, carbon pricing and other pollution reducing regulations (Stern, 2004).

The Kuznets Curve (EKC) theory of environment is a relevant background to understanding how carbon pricing mechanisms—the carbon tax, carbon trading, and green tax—in Nigeria will affect greenhouse gas (GHG) emission. The Nigerian economy traditionally depended on fossil fuel extraction and energy intensive industrial activities that have made contribution to climatical change and environmental degradation. From the EKC point of view, the implementation of carbon pricing mechanisms can help shift the curve from the up phase of pollution to the down phase of faster improvement of environmental quality. Carbon pricing policy helps Nigeria advance a growth path where Green House Gases (GHH) are reduced while the economy grows by ensuring industries become more mindful of carbon costs and thus use of cleaner technologies to reduce carbon emissions, and improve energy efficiency, including use of renewable energy sources.

ii. Cap-and-Trade Theory

The Cap-and-Trade theory was started by the Canadian economist John Harkness Dales, and was first introduced in 1968 as a formal concept in his book Pollution, Property and Prices. Dales suggested an approach in which governments establish a total level of pollution (pollution cap) and allocate or auction 'emissions permits' to firms that can then be traded in the market. Indeed, the overarching concept of the cap and trade is that overall environmental protection can be more efficiently achieved by market-based arrangements such as allowing firms with a lower cost of reducing emissions to sell their unused emissions reduction allowances to firms with higher costs of abatement, with the overall amount of emissions limited by a well-designed emissions cap set by environmental protection regulators (Dales, 1968; Stavins, 2003).

The Cap-and-Trade theory is relevant to the case of Nigeria in understanding how Carbon Pricing mechanisms may affect emission of GHG. Carbon Pricing instruments like carbon trading, carbon tax and green tax are intended to generate price signals to limit emission. The cap-and-trade solution could allow for a national emission ceiling, and the emission license could be issued to firms in the energy and big industrial sectors; since the emissions limit is strictly binding, firms with “banked emissions” below the national cap will be able to auction to other firms who are struggling to meet their obligations, thereby rewarding the innovators of cleaner technologies by providing them with monetary gains. The cap-and-trade policies in Nigeria could allow massive cuts in greenhouse gas emission, enhance innovation, energy efficiency, and investment in renewable energy, especially for Nigeria which has reasonable environmental problems, like gas flaring and air pollution.

2.2 Empirical Review

Ugor and Eshabi (2025) in Nigeria analyzed how carbon emission, energy usage, and economic growth are related using the ARDL framework on data for 1981 to 2023. Based on the unit root

stationarity estimates, all variables under analysis exhibited first difference stationary behaviour. The results showed that the intercept value was negative, and the coefficient value of carbon emission, which indicated that 1% carbon emission reduction resulted in a decrease in percentage of GDP. The study suggested that government should do better on electricity supply to increase economic activities and reduce emissions. Ogujiuba, Maponya and Semenya (2025) offered one of the few studies providing empirical econometric evidence that directly connects environmental tax instruments to energy transition outcomes in South Africa, using ARDL model on annual time-series data on energy transition outcomes ranging from 2000 to 2023. What their results found was that both environmental taxes and renewable energy trade caused a reduction in the value of greenhouse gas emissions in the short and long term, with 1% boost in the revenue volume of environmental taxes indicating a reduction in CO2 emissions that exceeds both statistical and economic significance. The study suggested strengthened tax administration/enforcement to maximize emission reductions. Dossa and Miassi (2024) conducted a detailed analysis of carbon pricing policies on economic growth and green innovation in eight developing economies, such as Argentina, Brazil, China, India, Mexico, and Indonesia, Colombia and South Africa. The analysis revealed that a few developing countries have adopted environmental fiscal reforms for the mitigation of GHG emissions, some countries continue to provide the distorting cost of environmental subsidy, and carbon pricing safeguards can support businesses' transition to sustainability. Overall, the study suggested that more complex, socioeconomic-specific carbon pricing mechanisms be developed to facilitate the transition towards the low carbon future in developing countries. Using the Toda-Yamamoto approach, Ugwunna, Ezidimma and Ejeogu (2024) assessed the impact of carbon emission in Nigeria and concluded that carbon emission affects economic growth (bidirectional link). The cointegration result revealed presence of a long-run link, showing two-way causality between economic growth and Nigeria's emissions of carbon. The researchers suggested that because of the potential risks to the environment, the impact of carbon emission shouldn't be ignored. Osayande and Akunoma (2024) undertook a study on the relationship between carbon emission and economic growth in Nigeria and Ghana in the period of 1980 to 2021, relying on Environmental Kuznets Curve framework and using the ECM-ARDL estimation technique. They failed to confirm the EKC for the two countries, and the economic growth activities in Nigeria significantly increased carbon emissions over the short and long runs whereas electricity consumption significantly decreased long-run carbon emissions. Thus, changing to renewable energy production technology, such that emissions can be reduced to promote environmental sustainability, was recommended.
Ajeigbe and Ganda (2024) applying Fully Modifying OLS (FMOLS) and Dynamic OLS (DOLS) to ascertain the implication of carbon emissions and the cause-and-effect link between variations in carbon emissions and their effects on the environment, finance, and growth for 65 economies from 2010 to 2021. The empirical outcome showed that the model's estimated slopes for carbon emissions appeared negatively significant, which indicated that indeed the rise in the carbon emissions and pollution is harmful to environmental quality. The study called for stricter fiscal and monetary policy in the emerging economies along with deliberate enforcement in the environmental and carbon emission tax areas.

Nwogo (2024) researching the influence of environmental taxes on the performance of electricity generation by firms in Nigeria, with particular emphasis on Afam Power Limited. Using the OLS regression model on secondary data spanning 12 years between 2012 and 2023, it was shown that total assets, carbon emission tax, and electricity value-added tax are significant variables when assessing the influence of environmental taxes on Afam Power Limited's performance. The results revealed that environmental taxation exhibits negative correlation with performance of the firm and that, in particular, carbon emission tax is significant and is negatively correlated with the performance of the electricity-generating firm. The study proposed a review of tax rate on carbon emission to avoid adverse impact on the generating companies.

Adopting ex-post facto research design, Jolaiya (2024) diagnosed how Green Taxation impact on the financial performance of selected Oil and Gas Companies in Nigeria 2017-2022. Based on Johanesen test, the model variables were found to exhibit long run implication, and the adjustment speed of (32.01) was found to be fast with 32.01 per cent a year, and carbon emission tax had significant and negative financial performance effect. Thus, a rethinking of the carbon emission fee was suggested to reduce negative effects on tax impacted companies while maintaining its effectiveness to reduce pollution. Obayagbona (2023) studied the economic development effects from carbon footprint in Nigeria and Ghana from 1990 to 2020. Utilizing the following variables in the analysis: greenhouse gas emissions, consumption of renewable energy sources, electricity consumption, and trade openness, on GDP per capita by applying the FM-OLS and PDLS techniques, It was established that, firstly, greenhouse gas emissions negatively affected economic development of Nigeria and Ghana, and, secondly, consumption of energy from renewable sources is negatively correlated with economic development of both countries. The study suggested that use of biomass and soil organic combustion emissions targets as part of tax policy in carbon-pricing legislation should be initiated by the governments. With quarterly data and a Vector Autoregressive (VAR) model, employed by the writers, Abraham and Okpara (2023), they highlighted the effect of carbon dioxide emission on economic growth of the Nigerian economy over 1990 through 2022 quarterly data. The granger causality test outcomes showed that GDP per capita indeed produced the response effect on population growth. The study suggested that for sustainability to be achieved, as policy focus should be directed at GDP per capita since its implication exerted on population growth rate exacerbate carbon dioxide emission.

Hammayo and Kamal (2023) exploring empirically to ascertain how carbon footprint impact economic growth for Nigeria and Ghana, sampling 1990 to 2020, and using FMOLS and PDOLS approaches. The estimate outcome portrayed emissions of greenhouse gas, consumption of renewable energy, electricity consumption, as well as openness to trade as regressors against GDP per capita. The results show emissions and utilization of renewable energy to have significantly influenced the countries' growth, albeit negatively. It has emphasized governments consideration to adopt policies for deterrence of that indiscriminate emission generating activities.

Adetunji and Olusola (2023) analysed the effect of carbon emission on inclusive growth in Nigeria from 1970 to 2022 based on the Environment Kuznets Curve and the application of ARDL model. The result of the regression shows short term positive and long run negative effects of carbon emissions for inclusive growth, while respectively not significant and significant for the period sampled. The research suggested policy makers should emphasize focus on measures to reduce carbon emissions, while sustaining economic development. Using a nonlinear ARDL estimation approach with data for the period 1980 to 2020, Enisan (2023) studied the asymmetric effect of oil sector on carbon emissions per capita for Nigeria. The analyses outcome showed that with the specifications of asymmetric relationship, the asymmetry between change in the oil sector and carbon emissions were confirmed for the long and short periods. Also, positive and negative oil sector shocks generated decreasing carbon emissions. The study suggested that "tough environmental regulations enforcement action" and oil sector expansion targeted at cutting carbon emissions. Dansofo, *et al*., (2023) study looked into carbon emissions' causal link with gas flaring and Nigeria's economic growth in the sample period of 1980 to 2021. Based on the findings, growth and energy utilization are observed to be key determinants of energy-related carbon emissions, where economic growth through income increase has contributed to rising fossil fuel consumption and further industrial development, which has led to energy-related carbon emissions affecting environmental sustainability. This study emphasized the importance of SDG 7 for sustainable energy. Ogbeide and Ugbogbo (2022) examined the correlation between carbon footprint and economic performance in Nigeria in 1980-2021, and employed the generalised method of moments (GMM) estimation technique to ascertain the relationship. The outcomes indicated that carbon emission is negatively related with the country's economic growth. Thus, the study put forward the recommendations of severe measures on the part of individuals, corporate bodies and governments to minimize the carbon footprint. Jibrin, Ibrahim and Aliyu (2022) assessed the effect of carbon dioxide emission and financial development considering Nigeria's growth of the economy over 1981 to 2021 data period by applying the bounds ARDL testing specification. According to the bound estimation, co-integrating association was found to among the variables, as increasing emission exerted significant positive effect on growth. The study suggested that government should employ suitable policy for mitigating pollution and prescribe applicable punishment for defaulters. Rotimi (2021) investigated the effects of environmental tax in controlling Nigeria's pollution level, with particular focus on carbon tax and its implications on air, water and waste pollution. To actualize target objectives the analytical process employed primary data obtained from 183 questionnaires using descriptive statistic based on planned behaviour theory and value-belief-norm theory of environmentalism. Findings showed a positive impact from environmental tax in controlling pollution in Nigeria above 90% respondents agreed to this effect. The study insisted that IRS must design suitable pollution tax system to be imposed on polluter. It was studied by Chindo and Abdul-Rahim (2018) to ascertain how CO2 emission influence population growth in Nigeria by employing Recursive ARDL framework to variant of sample periods over 1971-2000, 1971-2005, and 1971-2010. The findings suggest that population size is not a determinant of long run CO2 emissions, and that, only growth of the economy is discovered as emission determinant of this study, but population growth, growth of the economy, and energy utilization were established as determinants of short run CO2 emissions, alluding that further studies be conducted on how effectively population growth and emission relations could be manage. Ejuvbekpokpo (2014), analysed carbon emissions effect on economic growth of Nigeria for period, 1980 to 2010 using secondary data for the indicators (GDP, emissions from fossil fuels, gas fuels, liquid fuels and solid fuels), which were subjected to ordinary least square framework estimation. The t-test results presented an inverse property showing that carbon emission affects Nigeria's economy negatively. The study encouraged the Oil producing nations such as Nigeria to be compensated under the Kyoto Protocol agreement and that policy options be applied to cut down greenhouse gas emissions.

Anietie (2011) investigated the causal relationship between CO2 emission and economic growth of the Nigerian economy for the period 1980-2009 using standard version of Granger causality and Restricted Vector Error Correction specification. Evident from the measurement revealed that short run effects of carbon emission patterns is more prominent on growth but exhibited long run neutral effect, whereas consumption of electricity and gas stimulates short and long run growth. These findings are anticipated to be applied for Nigeria's policy guide to mitigate climate change.

The Study Gap

Having studied existing related literature, three critical gaps which motivated the current study were discerned. One, the theoretical gap in the literature is apparent, as existing studies tend to apply single theoretical frameworks; often the Environmental Kuznets Curve or Pigouvian Tax theory, to explain the relationship between environmental policies and economic or environmental outcomes. Few studies integrate complementary theories such as the Cap-and-Trade theory to provide a holistic understanding of how carbon pricing mechanisms influence Greenhouse Gas Emission. This limited theoretical application constrains the ability to explain the multifaceted interactions between policy instruments and environmental dimension of development in Nigeria, leaving a conceptual vacuum that the current study aims to address through a bi-theoretical framework. Furthermore, time and data limitations further characterize the gaps in existing research. Many studies have relied on relatively short or outdated periods, such as 2010–2020 or 2017–2022, and some use cross-country data that do not capture Nigeria-specific policy contexts and institutional dynamics. Recent policy developments, including the Climate Change Act (2021) and initiatives like the Nigerian Gas Flare Commercialisation Programme, have not been fully incorporated into empirical analyses. Consequently, there is a need for a comprehensive study utilizing long-run annual time series data spanning 1990 to 2024, which can more inclusively capture trends, policy impacts, and changes in Nigeria's carbon pricing policy landscape and its effect on the environment.

Methodologically, existing studies often employed models that analyze single carbon pricing instruments or focus exclusively on economic indicators such as Gross Domestic Product or firm financial performance. Few studies have simultaneously examined multiple carbon pricing mechanisms within a unified econometric framework, and there is limited application of robust pre- and post-estimation diagnostics to ensure the reliability and validity of results. By adopting an ex-post facto research design with advanced time series techniques, including unit root, cointegration, and ARDL modeling alongside diagnostic tests for normality, serial correlation, heteroscedasticity, Ramsey RESET, and stability, this study addresses these methodological shortcomings. This approach allows for a more comprehensive and rigorous assessment of the combined effect of carbon pricing mechanisms on both Greenhouse Gas Emission in Nigeria.

3.0 Methodological Process

The current study promoted application of the *ex-post facto* principles of research design, as considered suitable for a study which examines cause and effect indicators using historical data, without manipulating or exercising undue influence over the variables under investigation. Additionally, the sample 1990 to 2024 annual based data were obtained from the Development Indicators of World bank, Statistical Bulletin of Nigeria's apex bank, Bureau of Statistics of Nigeria, International Energy Agency data base, United Nations' Framework Convention for Climate Change, and the Organization for Economic Co-operation and Development sources.

3.1 Model Specification

Consciously, the environmental Kuznets Curve (EKC) theory is the adopted theoretical foundation of this study's analytical framework, in that it represents how carbon pricing instruments drive the transition from increasing to decreasing levels of greenhouse emissions as economies shift to cleaner technologies and more stringent environmental control policies, and the Cap-and-Trade Theory, which offers a market-based reason on how carbon trading and other pricing instruments can achieve carbon emission reductions at the lowest possible cost. In addition, the model used in this study is adapted to the study conducted by Dossa and Miassi (2024) which studied the effect of Carbon Pricing policies on economic growth for selected countries. However, with necessary modification to suit the objectives of the current study, the framework specification of the functional model is presented below:

$$GHGE_t = f(CBT_t, CTD_t, GRT_t, PCR_t) \quad (3.1)$$

Model 1 above is transformed into mathematical model as follows:

$$GHGE_t = \delta_0 + \delta_1 CBT_t + \delta_2 CTD_t + \delta_3 GRT_t + \delta_4 PCR_t \quad (3.2)$$

More explicitly, model 2 above is transformed into econometric model as follows:

$$GHGE_t = \delta_0 + \delta_1 CBT_t + \delta_2 CTD_t + \delta_3 GRT_t + \delta_4 PCR_t + \varepsilon_{1t} \quad (3.3)$$

The expected theoretical results are: $\delta_1 < 0$: $\delta_2 < 0$: $\delta_3 < 0$: $\delta_4 < 0$

GHGE = Greenhouse Gas Emissions as environmental measure of sustainable development, CBT = Carbon Tax, CTD = Carbon Trading, GRT = Green Tax, PCR = Policy Compliance Rate, t = Time lag, δ_0 = Constant variable, $\delta_1 - \delta_4$ = Coefficients of the model, ε_{1i} = Error term

3.2 Method of Data Analysis

Considering that the outcome of the Dickey Fuller analyses of unit roots established mixed orders of I(0) and I(1) stationarities, the empirical application hinges on the modelling approach of the Autoregressive Distributed Lag (ARDL) which is suitable for data analysis in the scenario. Therefore, the ARDL framework specification of the model is presented below.

Greenhouse Gas Emissions (GHGE) ARDL Model Specification

$$\begin{aligned}\Delta\ln(GHGE_t) = {} & \delta_0 + \delta_1\Delta\ln(GHGE_{t-1}) + \delta_2\Delta\ln(CBT_{t-1}) + \delta_3\Delta\ln(CTD_{t-1}) + \delta_4\Delta\ln(GRT_{t-1}) \\ & + \delta_5\Delta\ln(PCR_{t-1}) + \sum_{t=i}^{p}\varphi_1\Delta ln(GHGE_{t-1}) + \sum_{t=i}^{p}\varphi_2\Delta ln(CBT_{t-1}) \\ & + \sum_{t=i}^{p}\varphi_3\Delta ln(CTD_{t-1}) + \sum_{t=i}^{p}\varphi_4\Delta ln(GRT_{t-1}) + \sum_{t=i}^{p}\varphi_5\Delta ln(PCR_{t-1}) \\ & + \varepsilon_{1t} \qquad (4)\end{aligned}$$

4.0 Analyses Results and Discussions

4.1 Descriptive Diagnosis

The characteristic analyses of the variables are tabulated in Table 4.1 as follow:

Table 4.1: Descriptive Measurements

	$GHGE_t$	CBT_t	CTD_t	GRT_t	PCR_t
Mean	46.03814	44.37714	0.695429	81.81429	42.45714
Median	46.94300	33.50000	0.140000	66.00000	41.40000
Maximum	54.46400	128.5000	3.110000	198.9000	58.00000
Minimum	33.15300	1.400000	0.040000	12.40000	22.60000
Std. Dev.	5.576530	34.24010	0.898863	45.24388	8.616410
Skewness	-0.380671	0.904273	1.371365	1.099887	0.024558
Kurtosis	2.490748	2.847108	3.607545	3.563585	2.471943
Jarque-Bera	1.223510	4.804068	11.50871	7.520094	0.410166

Probability	0.542398	0.090534	0.003169	0.023283	0.814580
Sum	1611.335	1553.200	24.34000	2863.500	1486.000
Sum Sq. Dev.	1057.321	39861.08	27.47047	69598.28	2524.246
Observations	**35**	**35**	**35**	**35**	**35**

Source: *Authors' Computation, 2026, EViews 12.0 Result.*

Displayed in Table 4.1 are the idiosyncratic diagnostic outcomes of the variables used for the study, namely greenhouse gas emissions, life expectancy, carbon tax, carbon trading, green tax, and policy compliance Rate covering the period from 1990 to 2024 with 35 observations. Descriptive statistics are presented in order to provide information on the average figures of the employed variables (and their dispersions), their distribution behaviour, and normality features. The results indicated that the mean value of emissions of greenhouse gas (GHG) was 46.03814 which represents the average level for emission of greenhouse gas (GHG) over the sampled time frame. The maximum value of 54.46400 and the minimum value of 33.15300 suggest that there is moderate variations in emissions over time. The statistical value of the standard deviation (5.576530) indicates that emissions of the Greenhouse Gases (GHG) was reasonably varied during the time under study. As calculated, the probability value of Jarque-Bera exceeds 0.05, which confirmed that the distribution of greenhouse gas emission is normal. The descriptive statistics of carbon tax indicates that the mean value is 44.37714 which means that it averaged to moderate level during the period of the study. The maximum value of 128.5 and minimum value of 1.4 show considerable growth in carbon taxes throughout the years. Its value of standard deviation is 34.24010 which is showing a high level of deviation from average point in the study period. The probability of 0.090534 for its Jarque-Bera overwhelmed 0.05, which indicates normality for carbon tax during the study period. Further, the descriptive statistics for compliance rate of policy for sustainability environment showed mean = 42.45714; it is an average level of compliance policies during the period sampled. The maximum value of 58.0 and the minimum value of 22.6 reveal that the overall level of compliance increased significantly over time, although it experienced fluctuations. The standard deviation of 8,616410 indicates that there was moderate variability with respect to policy compliance rate during the study period. With Jarque-Bera Probability showing 0.814580, which climax 0.05, implies policy compliance rate is normally distributed. Moreover, the descriptive statistics of carbon trading appeared with mean value at 0.695429, which represents the average level of carbon trading activities throughout the study period. With maximum at 3.11 and minimum at 0.04, it indicates that carbon trading activities significantly increased over time. Statistically, the standard deviation-0.898863 pointed towards high level of variation in carbon trading during the period of study. The probability value for Jarque-Bera is below 0.05 (0.003169) which indicates that the distribution of Carbon Trading is not normal in the period sampled. More so, the result demonstrated Green tax exhibited a mean value of 81.81429, this mean value of shows on average, the level of green tax throughout the study period. It showed a maximum of 198.9 and a minimum of 12.4, which implies that green tax policy increased significantly over the years. A high standard deviation of 45.24388 indicates that there is a high degree of dispersion and variability in green tax for the study period. There is evidence of non-normality in the distribution of green tax as the Jarque-Bera probability value in the study time frame is less than 0.05 threshold.

4.2 Unit Root Test

Test of stationarity to ascertain presence or absence of unit root was applied in this study. To practically know the level of unit root for the representative variables in this study, the methodical tool of Augmented Dickey-Fuller (ADF) was applied and the results summarized in the below table: The findings of the applied Augmented Dickey-Fuller unit root test, are shown in Table 4.2. According to the decision rule, a variable is deemed stationary if the Augmented Dickey-Fuller statistic's absolute value surpasses its critical Mackinnon value at the five percent significance threshold. The result revealed that greenhouse gas emissions, and policy compliance rate were stationary at level because their Augmented Dickey-Fuller statistics exceeded the respective critical values in absolute terms; hence, they exhibited no unit root, denoted as I(0). Conversely, because their Augmented Dickey-Fuller statistics at first difference were higher than the critical values in absolute terms, carbon tax, carbon trading, and green tax exhibited unit roots at levels then, integrated on first differencing. Following the outcomes, the reference indicators appeared in order one, or I(1) stationarity. In totality, having established mixed variables' integrations at both I(0) and I(1), with none of the variables integrated beyond first difference, this underpins the necessity to utilize the empirical framework of Autoregressive Distributed Lag estimation technique for the dynamic analysis.

Table 4.2: Results of Unit Root Test

	Level Outputs		First Difference Outputs		
Variables	**ADF Stats**	**Mackinnon Critical Figures @ 5%**	**ADF Stats**	**Mackinnon Critical Figures @ 5%**	**Orders of Integration**
In$GHGE_t$	-3.088408	-2.951125	-	-	I(0)
InCBT_t	-0.053715	-2.957110	-4.171673	-2.963972	I(1)
InCTD_t	0.302527	-2.951125	-14.66050	-2.957110	I(1)
$lnGRT_t$	-1.546264	-2.954021	-7.046650	-2.954021	I(1)
InPCR_t	-2.914847	-2.951125	-	-	I(0)

Source: *Authors' Computation, 2026, EViews 12.0 Result.*

4.3 Optimum Lag Selection Outcomes

The estimated outcomes of criteria selecting optimum lag length are scheduled below.

Table 4.3: Estimates for Selecting Maximum Lag

Lag	LogL	FDIM	FPE	AIC	SC	HQ
0	-468.4237	NA	4875332.	29.58898	29.81800	29.66490
1	-245.2529	362.6525	20.82952	17.20331	18.57744	17.65879*
2	-225.1119	26.43516*	31.92835	17.50699	20.02622	18.34205
3	-198.0384	27.07349	39.68901*	17.37740*	21.04174*	18.59202

Source: *Authors' Computation, 2026, EViews 12.0 Result.*

The lag length selection criteria used to choose the best lag structure for the econometric analysis are shown in Table 4.3. The outcomes demonstrated that lag 3 was chosen as the best lag length for the investigation. This implies that the current values of the dependent variables are influenced by their past values and the past values of the explanatory variables up to three periods. The selection of an appropriate lag length helps to ensure reliable estimation results and prevents problems associated with under-parameterization or over-parameterization of the model.

4.4 Bounds Cointegration Estimates

The cointegration analysis outcomes are displayed in the below table:
In view of the fact that the calculated F-statistic (6.505173) in Table 4.4 below exceeds the critical value (3.49) at 5% significance benchmark, there exists enough statistical evidence to uphold existence of long run association or cointegration among the variables GHGE, CBT, CTD, GRT, and PCR. This reinforced existence of long run link as a pre-condition for estimating the ARDL model where the indicative quantities are already of mixed integration. Therefore, the estimates short and long runs coefficients using ARDL of order 1, 3, 1, 2, 2 followed.

Table 4.4: Cointegration Estimates

Null Hypothesis: Long-Run Association Does not Exist				
			Critical Bounds	
T-statistic	Value	Significance	I(0)	I(1)
F-statistic	6.505173	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Source: *Authors' Computation, 2026, EViews 12.0 Outcomes.*

4.5 Model Estimation Outcomes

The established dynamic analyses outputs of short run and long run for Autoregressive Distributed Lag greenhouse gas (GHG) emissions model are presented in Table 4.5 below. Evidently tabulated in the table are the short-run and long-run ARDL results showing the relationship between carbon tax, carbon trading, green tax, policy compliance rate, and greenhouse gas emissions. Carbon tax shows significant negative short run effect on greenhouse gas emissions in the current period, with a coefficient of -0.744210 and a p-value of 0.0191, implying that 1% increase in carbon tax led to about a 0.74% reduction in greenhouse gas emissions in the same period. However, its lagged effect in the previous period is positive and significant (coefficient = 0.323787, p = 0.0140), meaning that a 1% increase in Carbon Tax in the previous period increases emissions by about 0.32%, while the second lag shows a weaker but still positive effect, indicating adjustment dynamics in emissions response over time. Also, carbon trading in the short run showed a negative and significant relationship with greenhouse gas emissions, with a coefficient of -0.162547 and p-value of 0.0124, meaning, 1% increase in carbon trading reduces emissions by about 0.16% in the current period. This suggests that active carbon market participation immediately helps reduce emissions through trading incentives and emission caps. Green tax also shows a significant short-run negative effect with a coefficient of -0.257670 and p-value of 0.0235, implying, 1% increase in green tax reduces emissions by about 0.26% in the current period, although its lagged value is positive, suggesting short-term fluctuations in response to taxation policies.
Furthermore, policy compliance rate in the short run had strong negative and statistically significant effect on greenhouse gas emissions, with a coefficient of -0.319334 and p-value of 0.0028, suggesting that 1% increase in compliance rate reduces emissions by about 0.32% in the current period. Its lagged value also remains negative, though weaker, indicating sustained

compliance effects over time. These results suggest that stronger enforcement of and adherence to environmental regulations produce immediate and continuing reductions in greenhouse gas emissions.

Table 4.5: Estimated Outcomes for ARDL Model

	Outcomes for Short-Run Dependent Variable = In$GHGE_t$			
Variables	**Coefficients**	**Std. Errors**	**t-Statistics**	**Probs.***
D(InCBT_t)	-0.744210	0.289189	-2.573434	0.0191
D(InCBT_{t-1})	0.323787	0.119027	2.720290	0.0140
D(InCBT_{t-2})	0.177771	0.090074	1.973605	0.0640
D(InCTD_t)	-0.162547	0.058527	-2.777306	0.0124
D(InGRT_t)	-0.257670	0.104078	-2.475734	0.0235
D(InGRT_{t-1})	0.209994	0.102751	2.043710	0.0559
D(InPCR_t)	-0.319334	0.092273	-3.460740	0.0028
D(InPCR_{t-1})	-0.146976	0.070326	-2.089912	0.0511
CointEq(-1)*	-0.120963	0.014544	-8.316833	0.0000

R-squared = 0.714634; Adjusted R-squared = 0.615377; Durbin-Watson stat = 2.412763

Outcomes for Long-Run
Dependent Variable = In$GHGE_t$

Variables	**Coefficients**	**Std. Errors**	**t-Statistics**	**Probs.***
InCBT_t	-0.216175	0.093718	2.306642	0.0332
InCTD_t	-0.253807	0.051028	-4.973912	0.0001
InGRT_t	-0.544834	0.133033	4.095485	0.0007
InPCR_t	-0.592815	0.154475	-3.837610	0.0012
C	2.503718	0.614997	4.071105	0.0007

Source: *Authors' Computation, 2026, EViews 12.0 Result.*

The outcome of the error correction term, CointEq (-1), is negative and highly significant with a coefficient of -0.120963 and a p value of 0.0000, which means that there is a stable long run relationship among the variables. This means that some 12% of the short-run deviation from a GHG target is corrected in each period, indicating a gradual and steady adjustment towards their respective long-run targets following any shock to the system. Furthermore, the R-squared adjusted value at 0.615377 suggests that approximately 62% of greenhouse gas emissions reduction are helped by carbon tax, carbon trading, green tax, policy compliance rate, whereas 38% is explicated by measures not exogenous of the model,

As related with the preceding outcomes, long run estimate revealed 1% change in carbon tax results in an approximated 0.22% greenhouse gas emissions reduction with coefficient as -0.216175, and p-value of 0.0332. Thus, it means that carbon tax is more effective in reducing emissions in the long run compared to the short run. Furthermore, there is a more significant and stronger negative effect of carbon trading in the long run, with a coefficient of -0.253807, at 0.0001 level, which indicates that 1% increase in carbon trading leads to about 0.25% long run decrease in GHG emissions. Similarly, green tax also exhibited a significant inverse long run effect with coefficient value of −0.544834 and the p-value ss 0.0007; so that, 1 percent rise in green tax reduced greenhouse gas emissions by 0.54 percent, hence it appears to be one of the best instruments for the long run improvement of the environment. Lastly, the long-run relationship between policy compliance rate and greenhouse gas emissions showed the highest significance with the coefficient of -0.592815 and p-value of 0.0012, which means that when policy compliance rate rises by 1%, it predicts about 0.59% reduction in emissions. This emphasizes the importance of enforcement and compliance to environmental policies as a long-term but the most effective emission cutting methods, and that building capacities and enforcing regulations are important in securing long-term environmental sustainability.

4.6 Post-Estimation (Diagnostic) Tests

Post-estimation (diagnostic) test of the emission model is performed to examine the proficiency of the model and to ensure that the empirical outcomes appeared in line with the basic assumptions of ordinary least square (OLS) which are serial correlation, functional form, normality, heteroscedasticity, etc. The results from the diagnostic tests are summarized in Table 4.6, and discussed below:

Table 4.6: Diagnostic Test Outcomes

Test	Statistics	P-Value	Null Hypothesis	Decision
(a). Normality	0.150496	0.92751	**H_0:** Normally Distributed	Accepted H_0
(b). Serial Correlation	2.383338	0.1242	**H_0:** No serial Correlation	Accepted H_0
(C). Heteroskedasticity	1.374322	0.2612	**H_0:** Homoscedasticity	Accepted H_0
(D). Functional Form	0.848285	0.4081	**H_0:** Correctly Specified	Accepted H_0

Source: *Authors' Computation, 2026, EViews 12.0 Result.*

Table 4.6 captured the diagnostic tests of the current Autoregressive Distributed Lag (ARDL) model for Greenhouse Gas Emissions aimed at showing the reliability and validity status of the model estimated. The Normality test indicated Normality statistic of 0.150496 and significance value of 0.92751 which is higher than the 0.05, indicating that the residuals are normally distributed and not rejecting the Null Hypothesis of normality. This means that the errors are normally distributed, and the model can be used for statistical inference. The serial correlation estimate statistic is 2.383338 with probability 0.1242 is also greater than 0.05, so there is hardly evidence of autocorrelation among the residuals, so the null hypothesis that there is no autocorrelation in the series is not rejected. Furthermore, the test for heteroskedasticity, showed a value of 1.374322 with a probability greater than 0.2612, indicating that there is no heteroskedasticity and that the variance of the error term remains constant over time. Also, the Ramsey RESET test for correct Functional form has a statistic of 0.848285 and probability value of 0.4081 which means there is no evidence of omitted variables or miss-specification of functional form. The diagnostic tests for the overall probability values are all greater than 0.05 indicating that the ARDL model is well specified, statistically reliable and appropriate for inferences to be drawn on the relationship between the variables.

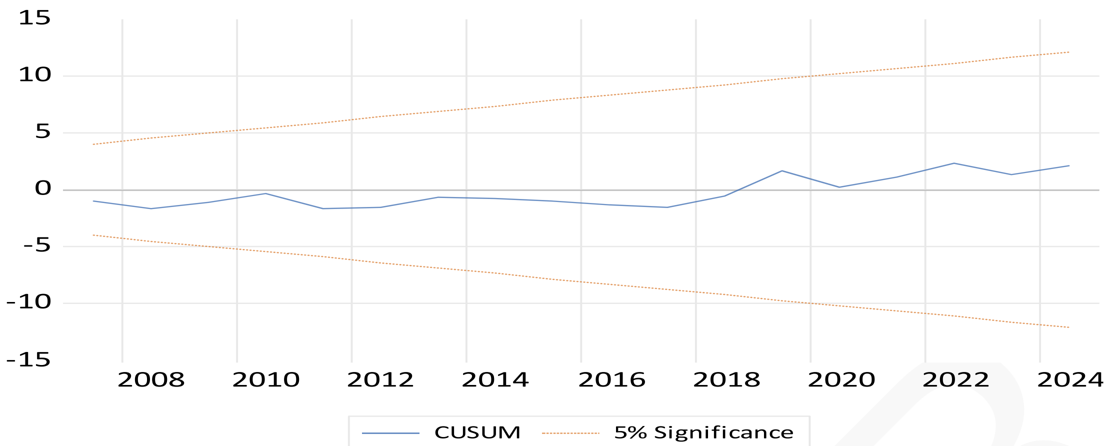

Figure 4.1: Stability CUSUM Test

The stability of the short and long runs dynamics coefficients was checked by estimating the CUSUM. It can be seen from the result of stability test graph in figure 4.1 that the CUSUM line stayed in-between the 5 percent critical bounds and never touched the 5 percent critical lines. This means that the long run parameters of regressors affecting the Nigeria's GHG emissions are stable.

4.7 Discussion of Findings

The Autoregressive Distributed Lag (ARDL) regression technique and E-Views 12 statistical package were used to analyze the impact of carbon pricing instruments on GHGs in Nigeria for the period 1990-2024. Analysis is carried out and the results are discussed as follows:

Based on the results of the present empirical study, it can be concluded that Carbon tax negatively influences greenhouse gas emission in Nigeria, both in short run and long run and thus, a percentage increase in carbon tax caused decrease in emission. and it exhibits statistically significant effect. This indicates that environmental fiscal instruments are indeed effective for discouraging pollution intensive production as suggested by the Environmental Kuznets Curve theory; that carbon pricing can help promote the shift from an upward to downward emissions curve. This finding concurs with the conclusions of Mulwa and Kyongo (2025) that carbon taxation would lead to environmental benefits if it is used to fund sustainable activities and Ogujiuba, Maponya and Semenya (2025) establishing that environmental taxes are effective at cutting emissions in both the short and the long term. In similar outcome, carbon trading showed a significant negative implication on greenhouse gas emissions, which is in line with the Cap-and-Trade Theory, stating that firms respond to financial incentives – such as carbon trading – by using cleaner production processes. This corroborates the findings of Ogbeide and Ugbogbo (2022) that the economic activity indicators and carbon footprint are inversely related, but the benefits of carbon trading are dependent on institutional strength and regulation implementation.

In addition, the green tax, appeared to have significantly moderated emission of Green House Gases, suggesting that taxing economic activities which are environmentally harmful motivate firms and households to adopt sustainable technologies. This finding is reinforcing as Jolaiya (2024) revealed a significant effect of carbon emission taxes on the operations of oil and gas firms in Nigeria, and Rotimi (2021) determined environmental tax to exert a significant positive effect on pollution control in Nigeria. It is, however, important to consider studies that revealed non-significant relationship between the classic Environmental Kuznets Curve in Nigeria such as Adetunji and Olusola (2023) and Osayande and Akunoma (2024), thus hinting that the emission reducing impact of carbon pricing instruments might be challenging to come by in Nigeria. Lastly, out of all four proxies, policy compliance rate had the most negative impact on the GHG emissions, suggesting that the rate of compliance with environmental regulations can have a significant impact on mitigating GHG emissions. This indicates that policy instruments alone are not enough; it is necessary to have compliance mechanisms with which one can make sure whether firms and individuals comply with the instruments. This is in tandem with the findings of Nwogo (2024) as well as Ugor and Eshabi (2025) that institutional compliance of carbon pricing policy is needed to effectively translate the policy to actual emission reduction in the Nigerian environment.

5.0 Conclusion and Policy

5.1 Conclusion

The impacts of the carbon pricing mechanisms on Green House Gases (GHG) emission is empirically studied in Nigeria. The results of the study revealed that both in short-run and long-run, carbon tax, carbon trading, green tax and policy compliance rate have negative and significant effects on GHGs emission in Nigeria over the sampled period. Sequel to the empirical revelations, the research highlights concludes that introduction of carbon pricing mechanism is very important in reducing GHGs emissions for achieving Sustainable development in Nigeria.

5.2 Policy Suggestions

The following recommendations are proffered based on the findings of this study:

i. Government should reinforce and scale up carbon tax policy net by enabling deliberate implementation across major emission-intensive sectors such as oil and gas, manufacturing, and transportation, with accruing revenues transparently applied to finance programmes of environmental protection.

ii. Regulatory authorities are encouraged to advance and formalize carbon trading infrastructure in such a way to make carbon market involvement in emission reduction very credible and effective by establishing comprehensive systems of monitoring, reporting and verifying emissions.

iii. It is also important that green tax rate for pollution is assessed by the Government periodically and adjusted such that it is sufficiently high to serve as disincentive to pollution generating activities but should not be too crippling to discourage critical productive sectors.

iv. An institutional development for monitoring and enforcing policy compliance should be enhanced by environmental regulatory agencies because the “policy compliance rate” had the largest impact on reduction in emissions, among the adopted carbon pricing policy measures.

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