

EFFECTIVENESS OF PUBLIC ENVIRONMENTAL POLICIES IN REDUCING CARBON EMISSION IN NIGERIA

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ABSTRACT: This work evaluated the Effectiveness of Public Environmental Policies in Reducing Carbon Emissions in Nigeria. The scope of the study spanned from 1990 to 2022. An ex-post facto research design was adopted. The objectives were to examine the impact of public environmental policies on carbon emissions in Nigeria and the relationship between public environmental policies and carbon emissions in Nigeria. To achieve the stated objectives of this work, ARDL Bounds Test technique was used. From the findings, the study discovered a positive and significant impact of public environmental policies on carbon emissions in Nigeria. A long-run relationship was found between public environmental policies and carbon emissions in Nigeria, as validated by the ARDL Bounds test. The Error Correction Model revealed evidence of a strong speed of adjustment in case of short-run distortions in carbon emission towards meeting the long-run equilibrium. Since the positive and significant impact of public environmental policies on reducing carbon emission was found both in the short-run and long-run, there is the need to strengthen the implementation of public environmental policies by enforcing the implementation of the policies by the government to ensure their maximum impact. Also, there is a need to ensure the adequate transition to renewable energy sources and support policies that can transition to cleaner energy options with a significant reduction of carbon emissions in Nigeria. Finally, policymakers should prioritise and incentivise sustainable farming practices that decrease emissions while maintaining productivity.

Keywords: Effectiveness, Public Environmental Policies, Carbon Emission

INTRODUCTION

One of the goals of government macroeconomic policies is the actualisation of economic growth and development. While the government strives to achieve these goals, it does not lose sight of good environmental conditions, which are crucial in enhancing the quality of life and the well-being of the people. A healthy environment provides the foundation for sustainable activities. Eneh and Agbazue (2011) opined that in pursuit of economic development, which seeks to increase the economic output without caring about the short and long-term deprivation of human and material resources arising from the process, the activities of people and nations conquer and wreck the world, rather than sustain it for the present and future generations. Progress in agriculture, industry, transportation and technology is usually the barometer of economic development in any nation.

The increasing global concern over climate change has heightened the need for effective environmental policies to mitigate the adverse effects of carbon emissions. Nigeria, Africa's most populous country and one of its largest economies, faces significant challenges in reducing carbon

emissions due to its reliance on fossil fuels, particularly oil and gas, which contribute to the country's GDP but also to environmental degradation (Ogbuigwe, 2018). Nigeria is a signatory to various international agreements aimed at addressing climate change, including the Kyoto Protocol and the Paris Agreement (Obi, 2020). However, despite these commitments, Nigeria's carbon emissions have continued to rise due to its dependency on fossil fuels for energy production and the growing demand for industrialization (Eboh, 2019). The Nigerian government has introduced several public environmental policies to reduce carbon emissions, including the National Environmental Policy (NEP), the Renewable Energy Master Plan, and efforts to promote cleaner energy sources such as solar and wind power. Despite these efforts, carbon emissions in Nigeria have not decreased at the expected rate (Adeniran & Bello, 2021). Factors such as poor implementation of policies, inadequate infrastructure, and low public awareness hinder the effectiveness of these policies.

Climate change, driven primarily by carbon emissions, is one of the most pressing challenges facing humanity today. Carbon dioxide (CO₂) and other greenhouse gases (GHG) contribute significantly to global warming, which leads to severe environmental and social economic impacts. Governments and international bodies have increasingly adopted environmental policies aimed at mitigating these emissions, but questions remain about the effectiveness of such interventions. This study explores how public environmental policies have influenced carbon emission reduction and evaluates the effectiveness of different strategies and their long-term impacts.

Despite Nigeria's commitment to international climate change agreements and the implementation of public environmental policies, the country continues to experience high levels of carbon emissions. The ineffectiveness of public environmental policies in reducing carbon emissions in Nigeria is due to a variety of factors, ranging from governance challenges to economic and infrastructural limitations. The major contributors to Nigeria's carbon footprint remain the oil and gas industry, deforestation and inefficient energy use (Nwafor, 2020). Nigeria's economy is heavily reliant on the oil and gas sector, which accounts for a significant portion of its GDP and export revenue. The extraction, refining and burning of fossil fuels for energy production are major sources of carbon emissions. Gas flaring, which is the burning off of excess natural gas during oil extraction, is a significant contributor to Nigeria's carbon emissions (Olalekan, et al., 2020)

Also, another major factor is weak policy enforcement and regulatory frameworks. While Nigeria has established various environmental policies aimed at reducing carbon emissions, enforcement remains weak due to institutional inefficiencies, corruption, and a lack of political will. For example, despite laws prohibiting gas flaring, the practice continues at high rates, largely due to the government's inability to enforce penalties on violators effectively (Eboh, 2020). Similarly, industries often bypass emission standards because regulatory agencies are underfunded and lack the capacity to monitor compliance (Ogunbiyi, 2019). This raises concerns about the adequacy of these public environmental policies in effectively reducing carbon emissions.

Additionally, the lack of technological innovation, capacity and inadequate funding impedes carbon emissions in Nigeria. The technological capacity to monitor and reduce carbon emissions in Nigeria is limited. Many industries, especially in the energy and manufacturing sectors, use outdated and inefficient technologies that emit large quantities of carbon. The lack of investment

in clean technologies and innovations hinders efforts to modernise industries and reduce their carbon footprints (Oladokun & Adeleke, 2019). In line with Oseni (2020), the absence of reliable data on emissions makes it difficult for policymakers to design and implement effective interventions. Reducing carbon emissions requires substantial investment in infrastructure, technology, and public awareness campaigns. However, funding for environmental policies in Nigeria is limited, with many government programs underfunded and dependent on external donors (Eboh, 2020). The lack of sufficient domestic financial resources makes it difficult for the government to implement long-term strategies to reduce emissions. Furthermore, private sector investment in carbon reduction initiatives is minimal due to a lack of clear financial incentives (Aderemi et al., 2019).

Activities of the transport sector and agricultural practices in Nigeria are major sources of carbon emissions. According to Aderemi et al. (2019), most vehicles on Nigerian roads run on petrol or diesel, and the sector is characterised by inefficient vehicles, poor road conditions, and traffic congestion, all of which increase fuel consumption and emissions. Certain agricultural practices, including livestock farming and burning of agricultural waste, release of methane and carbon dioxide into the atmosphere.

Although Nigeria has several environmental policies aimed at reducing carbon emissions, enforcement is often weak due to inadequate resources, corruption and lack of political will. This has led to continued gas flaring, deforestation and the widespread use of fossil fuels. There is limited research on the specific outcomes of these policies in Nigeria, creating a gap in understanding their impact and the challenges faced in their implementation.

This study seeks to address these gaps by assessing the effectiveness of Nigeria's public environmental policies in reducing carbon emissions, identifying the factors that contribute to or hinder their success, and providing recommendations for more effective policy design and implementation.

The primary objective of this study is to assess the effectiveness of public environmental policies in Nigeria in reducing carbon emissions. Specifically, the study aims to evaluate the impact of public environmental policies on reducing carbon emissions in Nigeria and also examine the relationship between public environmental policies and carbon emission reduction in Nigeria.

LITERATURE REVIEW

Conceptual Literature

Concept of Environment

Environment refers to the totality of surrounding conditions in which living organisms, including humans, exist and interact. It encompasses both natural elements and human-made components that affect life on earth. According to the Merriam-Webster Dictionary (1828)'s definition of environment, is the circumstances, objects, or conditions by which one is surrounded. It is also the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act

upon an organism or an ecological community and ultimately determine its form and survival. It is the aggregate of social and cultural conditions that influence the life of an individual or community. These include air, water, soil, flora, fauna and ecosystems, as well as social, economic and cultural influences.

Overview of Environmental Policies and Laws in Nigeria

There are several environmental policies and legislations in Nigeria with responsibilities of environmental protection as a measure to address environmental problems. ERA (2009) is of the view that there are two phases of environmental regimes in Nigeria: the era before 1988 and post-1988. The former consists of laws, including those formulated by the colonial state, in which protection of the environment from oil exploration and production activities was supposed to be implanted. In this era, there was no national policy for the protection of the environment. These regimes took the form of Acts, Decrees, Legislations and Edicts. Although many of them cannot stand alone as environmental laws, they are embedded in other substantive laws or policies that can be invoked for the protection of the environment. The Minerals Act (CAP 121) of 1958, for example, has provisions for measures that must be taken to prevent and regulate the pollution of ecosystems. This, to some extent, is admirable, for a colonial government, habitually berated for being insensitive to socio-economic and environmental needs of the colonized.

National Policy on Environment (NPE): An international workshop, which was held from September 12 to 16, 1988, in Lagos, led to the end of the pre-1988 era. The workshop introduced the new era by setting the stage for the emergence of an NPE, which was previously non-existent. Nigeria is committed to a national environmental policy that will ensure sustainable development based on proper management of the environment. This demands positive and realistic planning that balances human needs against the carrying capacity of the environment. This requires that a number of complementary policies, strategies and management approaches are put in place, which should ensure, among others, that:

- Environmental concerns are integrated into the major economic decision-making process;
- Environmental remediation costs are built into major development projects;
- Economic instruments are employed in the management of natural resources; environmentally friendly technologies are applied (ERA, 2015)

Environmental Impact Assessment Decree (EIA): The promulgation of the Environmental Impact Assessment Decree (EIA) No. 86 of 1992 has been a milestone in the provision of opportunities for the involvement of local communities in the prevention of oil pollution. Unfortunately, this has not been realised. The Act has the potential for the promotion of environmental democracy across the nation because it requires the participation and consultation of communities wherever large-scale projects are to be executed or where major land conversions are proposed to take place. It provides a tool for community engagement when lands are to be taken up for plantations, farms, industrial set-ups, etc. (Eneh & Agbazue, 2011).

Federal Environmental Protection Agency (FEPA): This agency was established as a result of the illegal dumping of toxic wastes of Italian origin on Nigerian soil at Koko in Delta state. the

uproar created by this illegal action led to the establishment of this agency. It was established by Decree N0 58 of 1988 (Adekola, 2011). The agency was fully accredited as the official Ombudsman of the nation's environment, an umbilical cord that connects FEPA and the National Policy on Environment. The law established the agency, among other things, to establish and prescribe national guidelines and standards for environmental management, such as water quality, air quality, and noise levels, to monitor and control the movement of hazardous substances, and supervise and enforce compliance with environmental law so that pollution can be prevented and controlled (Agbu, 2005).

National Environmental Standards and Regulation Enforcement Agency (NESREA) Act 2007 replaced the Federal Environmental Protection Agency (FEPA) Act. It is the embodiment of laws and regulations focused on the protection and sustainable development of the environment and its natural resources. NESREA has several regulatory bodies under it, which include the National Effluent Limitation Regulations, National Environmental Protection (Pollution Abatement in Industries and Facilities Producing Waste) Regulations 1991 and the Federal Solid and Hazardous Waste Management Regulations (1991). These regulatory bodies under NESREA are charged with the responsibility of regulating the activities of industrial and other companies on the protection of the environment (Eneh & Agbazue, 2011).

Water Resources Act 101 (1993): This law vests on the Federal government of Nigeria, through the Federal Ministry of Water Resources, the right to regulate, develop and license all water operators in Nigeria. There are several water regulation agencies in Nigeria, including the National Water Ways Authority, the River Basing Development Authority, the National Water Resources Institute, the Nigeria Shippers Council, the National Maritime Authority and the National Agency for Food and Drug Administration and Control (NAFDAC). There is also Navigation Waters Act provides for the implementation of the international convention for prevention of pollution of sea by oil and provide for remedies against such pollution (Christopher, 2004).

The Mineral and Mining Act: The process of minerals and mine exploration and exploitation is one that can result in serious environmental degradation and damage. Section 65 of the Act prohibits the pollution and causing to be polluted any water or watercourse by any person in the course of mining or prospecting for minerals. Furthermore, section 33(4) mandates any holder of a prospecting right upon completion of prospecting operations to fill up any shafts wells, holes or trenches made, and to restore the land to its original state. Section 254(1) of the Act provides for the establishment of the mines field police (drawn from Nigerian police) for the purpose of enforcing compliance with the provision of the Act (Uche, 2000).

The Harmful Waste (Special Criminal Provision) Act 1988: The Act was enacted with the specific object of prohibiting the carrying, depositing and dumping of hazardous wastes on any land, territorial waters and matters relating thereto. This Act is essentially a penal legislation. The offences are constituted doing any of the act or omission stated in the section 12 of the act. The Act sought to remove any immunity conferred by diplomatic immunities and privileges Act on any person for the purpose of criminal prosecution (Eneh & Agbazue, 2011). This jurisdiction, however, focuses mainly on criminal prosecution of damage and does not provide compensation to the victim of the damage.

Theoretical Review

Environmental Policy and Governance Theory

Environmental policy and governance theory provide a broad framework for understanding how governments and institutions create and enforce environmental policies. According to this theory, effective governance involves collaboration between different levels of government (federal, state, and local), industries, and civil society to address environmental issues such as carbon emissions (Newell, 2020). In Nigeria, the Federal Government's responsibility for formulating and enforcing environmental policies is critical to reducing emissions, particularly given the country's reliance on oil production, a major source of carbon emissions. However, challenges arise due to weak governance structures, corruption, and limited capacity at the local government level, which hinder the enforcement of these policies.

The Tragedy of the Commons

Garrett Hardin's theory of the "Tragedy of the Commons" explains how the over-exploitation of common resources (in this case, the atmosphere) leads to environmental degradation, including carbon emissions. In Nigeria, industries, especially oil and gas companies, contribute heavily to carbon emissions, driven by the absence of stringent regulations and the economic pressure to exploit natural resources. This theory highlights the importance of policy interventions like carbon pricing or emission caps to align individual and corporate interests with broader environmental goals (Hardin, 1968). Policies aimed at reducing emissions must ensure that industries internalise the social costs of pollution through mechanisms such as taxes or emission trading systems (Adeniran & Olagunju, 2021).

Economic Theories of Environmental Regulation

Economic theories of environmental regulation, such as Pigouvian taxes and Coase's theorem, are also relevant in analysing the effectiveness of Nigeria's carbon emission policies. A Pigouvian tax suggests that governments can correct negative externalities (e.g., pollution) by imposing taxes equal to the social cost of emissions. In Nigeria, carbon taxes are underexplored as a policy option, but they hold the potential for curbing emissions while generating government revenue (Olufemi, 2022). Coase's theorem, on the other hand, suggests that if property rights are clearly defined and transaction costs are low, private parties can negotiate solutions to externalities without government intervention (Coase, 1960). However, in Nigeria, the lack of well-defined property rights and high transaction costs due to legal and institutional challenges make this approach difficult to implement.

Empirical Review

Many scholars have paid attention to empirical studies on evaluating the effectiveness of public environmental policies in reducing carbon emissions.

Copeland and Taylor (1994) investigated the relationship between free trade and environment al quality among selected developing countries and suggested that free trade induces people's interest in the understanding of environmental issues and thus enable them to effectively embark

on pollution control and management policies. The study also observed that developing countries tend to attract pollution-intensive industries in their quest to attract foreign direct investment.

Nakata and Lamont (2001) conducted a forecast study to explore the effect of carbon and energy taxes on Japan's energy system. The study's conclusion supports the idea that such taxes are an effective instrument for reducing carbon emissions.

Bruvoll and Larsen (2004) examine the implications of carbon taxes on emissions change in Norway. Using an applied general equilibrium simulation, they found that environmental taxes significantly influenced on the reduction of CO₂, contributing to an overall two percent decrease. The study found out that the reduction in carbon emissions per a unit of GDP is significant and the immediate effect was a decrease in energy intensity and process emissions.

Vehmas (2005), in his study, considers Finland's experiences with environmentally based energy taxation and concludes that fiscally driven deviances from the model environmental tax have weakened the real purpose for which this tax system was formulated.

Liang, Fan and Wei (2007) in their study also arrived at the same conclusion with the aforementioned study after using a CGE model to investigate the impact of different carbon tax developments in China. The study recommended an appropriate use of tax system for different settings.

Convery, McDonnell and Ferreira (2007) investigate the effectiveness of the plastic bag levy, which was introduced in Ireland and started in 2002. The introduction of such a tax system was influential in promoting proper waste disposal management. The result showed that the purchase of plastic bags in retail outlets was reduced by ninety percent, and the yearly revenues from this tax were about 13 million euros. The study, therefore, recommended a form of this tax system to curb inappropriate waste disposal management.

Ighodalo (2007) analysed the challenges and possibilities of oil-environmental degradation and human security in the Niger-delta region of Nigeria. The study explored the nature of environmental degradation in the Niger-Delta, the threat it poses to people's lives and efforts to curb the situation. The study submitted that although the present civilian administration has made major efforts to ameliorate the suffering of the people of the region, their conditions remain pitiable and unless the present government's efforts are directed towards improving the peoples' socio-economic and political conditions, the restiveness and violence in the Niger-Delta region in particular and Nigeria in general would continue unabated.

Yan and Crookes (2009) explained in their study the significance of a scenario with fossil fuel taxes in dealing with the rapid growth of automobiles and energy demand in China. This particular scenario significantly led to a potential decrease in energy demand by 16.3%, petroleum demand

by 18.5% and GHG emissions by 16.2% in 2030 compared to the current scenario. Concrete empirical evidence, therefore, showed the effectiveness of such environmentally/carbon related taxes.

Omojolaibi (2010) conducted a study on environmental quality and economic growth in some selected West African countries to assess the Environmental Kuznets Curve. The pooled OLS results showed a consonance with EKC, while the fixed effects results were at variance with the applicability of the environmental Kuznets curve in West Africa. The study suggested that the countries should enact policies to ensure energy efficiency use and carbon emission reduction.

Abouie-Mehrizi, Atashi and Elahi (2012) conducted a study on the effect of population growth, urbanization and economic growth on CO₂ Emissions in Iran. In the study, the equivalence relation of five variables, CO₂ emissions, the intensity of energy use, gross domestic product growth rate, urban population and growth population, and their influences on each other in Iran for the years 1973 to 2008, were analysed. The results showed that variables of energy use, gross domestic product growth rate, urban population and population growth have positive effects on CO₂ emissions.

Seetanah and Vinesh (2012) studied the relationship between carbon emissions and economic growth in Mauritius. Their analysis suggests that the carbon dioxide emission trajectory is closely related to the GDP time path. The study also showed that emissions elasticity on income increased over time. Their test of the Environmental Kuznets Curve for 1975 to 2009 did not prove the existence of its 'U' shape for Mauritius, leading them to conclude that Mauritius could not curb its carbon dioxide emissions in the last three decades.

Odunjo and Oluronke (2013) examined why the country has yet to achieve sustainable environmental management. The study used secondary data and personal observations to make its findings. In its recommendations, the author proposes that the country pay more attention to environmental conservation and sanitation and adopt strict measures to achieve this objective.

Safdari, Barghandan and Shaikhi (2013) carried out an investigation into whether carbon emissions increased Iranian economic growth. They found that in recent decades, damages of environmental effects increased and that those damages were due to different factors like population growth, economic growth, energy consumption and industrial activities. The paper investigates the environmental effects of energy consumption and economic growth in Iran and found that a mutual causality exists between the Iranian economic growth and volume of carbon emission.

Mohammadi and Mohammadi (2013) studied the impact of population and energy consumption on the environment. The study investigates the causal relationship between the value of petroleum exports and GDP per capita in 13 OPEC countries over the period 2003-2011. The results of panel co-integration tests showed that the value of petroleum exports and GDP per capita have a stable long-run equilibrium relationship. We find that for all members of the panel. They also found that there is homogenous causality from the value of petroleum export to GDP per capita and vice versa for all members of the panel.

Ayadi (2014) conducted a study on economic integration, growth and the environment in Africa using Nigeria as a case study. Economic integration was lauded as a way of increasing world output based on the economies of scale property and exchange of technology, ideas and information. The study identified trade and foreign direct investment as the two major channels through which integration impacts growth. The study found that economic growth and foreign direct investment into Nigeria significantly fuelled pollution while trade was beneficial both in the short and long run.

Olatunji and Olaoye (2015) examined the developmental implications of environmental taxation in Nigeria. The study specifically analysed the relationship between environmental taxation and environmental quality and whether the former is capable of influencing cost-effectiveness. The study found out that environmental tax, though is significantly related to environmental quality, has no effect on firms' cost-effectiveness. The study therefore recommended that the government tightens its environmental tax system and rids it of any loopholes.

Iliya (2017) investigated the level of sustainable development that environmental taxes can achieve. The study employed both qualitative and quantitative method in analysing its data. After its findings, the study recommended that Nigeria's federal government should formulate a tax process that encompasses environmental tax policies such that a tax be levied on individual and corporations responsible for environmental problems.

Oyedokun, et al (2018) investigated the challenges in environmental accounting and taxation in Nigeria. The study recommended that the government of the country discharge its responsibilities by ensuring the full implementation of tax reforms on carbon emission mitigation.

Li et al. (2021) used panel data from 30 provinces of China to test the effectiveness of Environmental Protection Tax Law introduced in 2018 and found that, as compared to the pollution discharge fee policy, environmental taxes had a favourable influence on pollutant emission reductions in China. The study revealed that upon implementation of environmental tax laws, sulfur dioxide (SO₂), nitrogen oxide (NO_x), and dust emissions from fossil fuel power plants dropped by 2.186 (7.7%), 1.550 (6.84%) and 1.064 (16.1%) tons, respectively.

Nduka (2022) examined reducing carbon footprint by replacing generators with solar PV systems in Lagos. The study assessed household willingness to pay for solar PV, through the use of cost-benefit analysis. The result of the study showed that investment in solar PV for energy was profitable than the use of generator, hence the need to implement policies aimed at sealing up energy transition.

Dorband et al (2022) examined the double progressivity of infrastructure financing through carbon pricing in Nigeria. They adopted environmental extended input-output data, using detailed household survey. Their result suggested that lower-income households would bear a smaller consumption burden from carbon pricing than higher-income households. This implies that a higher tax should be imposed on higher-income household to mitigate carbon emission in the study area.

The UNCTAD (2024), with WTO, IMF, OECD, jointly examined the climate action on carbon pricing, policy spillover and global climate goals. Their report and climate action was aimed at ensuring a just and green transition, encourage and support developing countries in grafting the right policy mix to advance climate mitigation.

Summary of Empirical Literature

The literature suggests that while Nigeria has made strides in introducing public environmental policies aimed at reducing carbon emissions, their effectiveness has been limited by various factors. It points to weak enforcement, inadequate infrastructure and a lack of political will as major barriers to policy success. Going forward, Nigeria must strengthen its governance structures, enforce existing laws more rigorously, and invest in renewable energy to meet its carbon reduction targets. Hence, this study, unlike prior studies, provides a long-term evaluation of the effectiveness of public environmental policies on carbon emission reduction covering from 1990 to 2022 and contributes to the existing body of knowledge on public environmental policies.

METHODOLOGY

Research Design

The study employs an ex-post facto research design, a methodological approach that allows for the examination of relationships between dependent and independent variables after events have occurred. The primary objective of this paper was to find the impact of public environmental policies on carbon emission reduction in Nigeria. To achieve this objective, the study employed annual time series sourced from the World Bank and CBN statistical bulletin from the period of 1990 to 2022.

Model Specification

The model of this work is specified based on the objectives it set to achieve.

$$CAM = f(PEP) \text{-----} (1)$$

Transforming equation 1 from its functional notational form, it thus presented in equation 2 as follows:

$$CAM_t = \beta_0 + \beta_1 PEP_t + \beta_2 GDP_t + \beta_3 WC_t + \beta_4 TAC_t + \beta_5 TECN_t + \beta_6 TFEC_t + \beta_7 TEU_t + \mu_t \text{-----} (2)$$

Where:

CAM = Carbon Emission (Proxy as Carbon dioxide, CO₂ emissions from liquid fuel consumption from use of natural gas as energy in Nigeria)

WC = Weather Condition (Proxy as total rainfall in Nigeria)

GDP = Gross Domestic Product

GHEM = Public Environmental Policies in Nigeria (Proxy as total policies on Greenhouse gas emission in Nigeria)

TAC = Total Agricultural Output in Nigeria

TECN = Changes in Technology and Innovation (Proxy Scientific and Technical Services)

TFEC = Fossil fuel energy consumption (% of total)

TEU = Total Renewable Energy Consumption in Nigeria

Bi = parameters to be estimated

t = time series of the estimated variables

μ = error term

A priori Expectation

$$B_1 > 0; B_2 > 0; B_3 < 0; B_4 < 0; B_5 > 0; B_6 > 0; B_7 > 0$$

The sign (> 0 or < 0) associated with the B's represents the a priori expectation of each explanatory variable used in this study. An explanatory variable with a $B > 0$ (positive parameter) is expected to have a positive impact on the dependent variable and vice versa.

Nature and Sources of Data

The data used in this work are secondary data. They are annual time series from the period of 1990 to 2022 are sourced from the Central Bank of Nigeria Statistical Bulletin (CBN) and the World Bank.

Analytical Techniques

The analytical techniques employed in this study are based on the objectives earlier stated in section one of this work. To achieve the objectives of this study, all variables used were subjected to the Unit Root Test for the test of stationarity. For the stationarity test, the study employed the Augmented Dickey Fuller (ADF) unit root test.

Unit Root Test

The unit root was conducted to ascertain the order of integration (or stationarity) of a given series. In testing for the stationarity of the series, the Augmented Dickey Fuller (ADF) unit root test was

utilised. The test was conducted under the constant and trend assumption on the level and first difference of the series. Given a time series variable, say X , the test equation is presented below:

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \sum_{i=1}^m \alpha_2 \Delta X_{t-i} + \varepsilon_t \quad \text{--- (3)}$$

And that

$$\Delta X_t = \alpha_0 + \delta t + \alpha_1 X_{t-1} + \sum_{i=1}^m \alpha_2 \Delta X_{t-i} + \varepsilon_t \quad \text{--- (4)}$$

Where X_t is a time series, t is a linear time trend, Δ is the first difference operator, β_0 is a constant, i is the optimum number of lags in the independent variables, and ε_t is a random error term.

Autoregressive Distributed Lag (ARDL) Bounds Test Co-integration

The test for long-run equilibrium relationship is conducted for the model as specified. But before this is done, it is pertinent to specify the models in their algebraic forms.

$$CAM_t = \beta_0 + \beta_1 PEP_t + \beta_2 GDP_t + \beta_3 WC_t + \beta_4 TAC_t + \beta_5 TECN_t + \beta_6 TFEC_t + \beta_7 TEU_t + \mu_t$$

$$\begin{aligned} \Delta CAM_t = & \varphi_0 + \sum_{i=0}^p \varphi_1 \Delta PEP_{t-i} + \sum_{i=1}^q \varphi_2 \Delta GDP_{t-i} + \sum_{i=1}^q \varphi_3 \Delta WC_{t=i} + \sum_{i=1}^q \pi_4 \Delta TAC_{t=i} \\ & + \sum_{i=1}^q \varphi_5 TECN_{t=i} + \sum_{i=1}^q \varphi_6 TFEC_{t=i} + \sum_{i=1}^q \varphi_7 TEU_{t=i} + \sum_{i=1}^q + \lambda ECM \\ & + \theta ECM_{t=1} \quad \text{--- 5} \end{aligned}$$

DATA ANALYSIS AND DISCUSSION OF FINDINGS

This section present data used in the work, analysed the data and discussed the findings based on the data collected, which include correlation matrix, unit root test, Augmented Decay fuller test and other tests.

Table 4.1: Correlation Matrix Test Result among Variables in the Model

11.5	CAM	GDP	PEP	TAC	TECN	TEU	TEFC	WC
CAM	1							
GDP	0.501	1						
PEP	-0.002	-0.073	1					
TAC	-0.043	-0.391	0.017	1				
TECN	0.148	0.394	0.027	-0.055	1			
TEU	0.206	0.227	0.140	0.432	0.228	1		
TEFC	0.048	0.112	0.017	0.178	-0.079	0.540		
WC	-0.313	-0.295	-0.228	0.144	-0.207	-0.285	0.238	1

Source: Authors' computation 2024

From the table 4.1, it can be observed that all the matrix elements outside the leading diagonal are less than 0.8 which confirms absence of multi-collinearity.

Unit Root Test

Variables	Level	1st Difference	2nd Difference	Order of Integration
TAC	-2.130(0.234)**	-4.746(0.000)**	-----	1(1)
CAM	-5.779(0.000)**	-----	-----	1(0)
GDP	-3.643(0.013)**	-----	-----	1(0)
PEP	-6.781(0.000)**	-----	-----	1(0)
TECN	-3.159(0.032)**	-----	-----	1(0)
WC	-6.530(0.000)**	-----	-----	1(0)
TEU	-2.263(0.189)**	-8.105(0.000)**	-----	1(1)
TFEC	-2.651(0.093)**	-5.632(0.000)**	-----	1(1)

Source: Authors' computation 2024; Note: ** ADF probability values at 5% level of significance

The Augmented Dickey-Fuller test (ADF) unit root test for the variables used in model is presented on Table 4.2. The unit root test result for variables in the model are in mixed order of integrations (levels and first difference). Carbon Emission, Public Environmental Policies, Changes in Technology and Innovation, Gross Domestic Product and Weather Conditions were all stationary at level with the application of ADF while Total Agricultural, Total Energy Consumption and total Fossil Energy Consumption were stationary at first difference with the application of ADF. The outcome of the result of unit root necessitated the test for long run relationship (i.e., a test for cointegration), it was appropriate to adopt ARDL Bounds test.

Table 4.3: ARDL Optimal lag length selection Criteria for the Model

Total number of variables significant		
Dependent	Regressor	
1	1	5

The optimal lag lengths for model 2:2

Tables 4.4: ARDL Bonds Test Result for the model

Model	F-Statistic = 5.052	
CAM= f(TAC, GDP, PEP, TECN, TEU, TFEC and WC)	K = 7	
Critical Values	Lower Bound	Upper Bound
10%	1.92	2.98
5%	2.17	3.51

Source: Authors' computation 2024

Similarly, the F-statistic (5.052) is greater than the lower and upper bounds value at 5% level (2.17 and 3.51). Therefore, the null hypothesis of no long-run relationship is rejected and concludes that there is level long run relationship existing among dependent and independence variables.

Table 4.5: ARDL Error Correction Regression Estimate of the Short-Run Coefficients

Dependent Variable: CAM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	46.537	42.913	1.084	0.291
CAM(-1)*	-1.162	0.198	-5.846	0.000**
GDP(-1)	5.025	1.487	3.377	0.003**
PEP(-1)	0.534	0.286	1.865	0.076*
TAC**	0.755	0.287	2.624	0.016**
TECN**	-0.579	0.811	-0.714	0.483
TEU(-1)	-160.21	89.915	-1.781	0.090*
TFEC**	-0.923	2.551	-0.362	0.721
WC**	-0.074	0.429	-0.172	0.864
D(GDP)	3.211	0.981	3.272	0.003**
D(PEP)	0.134	0.169	0.791	0.437
D(TEU)	27.249	101.609	0.268	0.791
ECN(_{t-1})	-1.162	0.145	-7.978	0.000**

Source: Authors' Computation 2024; ** indicates level of significance at 5%;

*indicates level of significance at 10%

$R^2 = 0.772$ (77.2%)

Adj. $R^2 = 0.7533$ (73.3%)

Akaike info criterion = 7.838

Schwarz criterion = 8.022

Durbin-Watson stat = 2.164

The result of the short-run error correction regression for the model in Table 4.5 illustrates the effect of the short-run coefficient of the independent variables of public environmental policies in Nigeria on the dependent variable (carbon emission reduction). The Error Correction coefficient (ECM) has the correct sign (negative) and is significant. This confirms evidence of long-run relationship among the variables and thus implies that, in the case of any disequilibrium, carbon emission will correct itself from the short-run distortion towards reaching long-run equilibrium at every strong speed of 1.162%, showing evidence of overcorrection. Furthermore, Table 4.5 also indicates that the model has a good fit with an R^2 value 0.772 (77.2%), showing that variation in unemployment is explained by its variables at 77.2%. The remaining 28.8% are attributed to the stochastic error term in the model. If the R^2 is greater than the Durbin Watson Statistic, then the estimated regression model will produce spurious results. Therefore, given that the value of 2.16 (approximately 2) is less than the R^2 of 77.2, it implies that the result is not spurious and further suggests that, the model is free from autocorrelation.

The ECM result in table 4.5 shows that some of the variables employed in the study conformed to the already stated a-priori expectation while others did not. Total Agricultural Output shows positive relationship with climate-carbon emission control in the short-run, not as expected. Economic Growth shows a positive relationship with carbon emission in the short-run in support of a-priori expectation, and Public Environmental Policies show a positive relationship with carbon emission as expected during a-prior statement. Change in technology shows negative relationship with carbon emission against the expected outcome, while Weather Condition shows negative relationship with carbon emission reduction against a-priori expectation. Also, Total Energy Consumption shows a negative relationship with carbon emission, not in support of a prior expectation, and Total Fossil Emission shows a negative relationship with carbon emission reduction, not as expected.

From the result in table 4.5, the coefficient of public environmental polices is 0.534, which shows that, a unit increase in public environmental policies exerts a positive and significant impact of 0.5 units on carbon emission reduction in Nigeria. The coefficient of total agricultural output is 0.755, indicating that a unit increase in total agricultural output in the short-run in Nigeria exerts a positive and insignificant impact of 0.8 unit on carbon emission reduction in Nigeria. Also, the coefficient of total energy consumption is 27.249, showing that a unit increase in energy consumption exerts a positive and insignificant influence of 27.3 units on carbon emission reduction in Nigeria. Economic Growth coefficient is 3.211 showing that, a unit increase in trade openness in Nigeria exerts positive and significant impact of 3.2 units impact on carbon emission in Nigeria in the short-run. The coefficient of changes in technology and innovation is -0.579. This indicates that, a unit increase in technology and innovations bring about 1.6 units reduction in carbon emission reduction effort in Nigeria in the short-run. The total fossil fuel emission consumption coefficient is -0.923 thus implying that, a unit change in the Total fossil fuel emission consumption exerts 0.92 unit negative and insignificant impact on carbon emission in Nigeria. Weather condition

coefficient is -0.074 indicating that a unit change in weather condition impacts 0.7 unit increase in carbon emission reduction in Nigeria.

Table 4.6: Estimate of the Long-Run Coefficients for the Model

Dependent Variable: CAM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	4.321	1.350	3.200	0.004**
PEP	0.459	0.253	p1.812	0.085*
TAC	0.649	0.267	2.429	0.024**
TECN	-0.498	0.714	-0.697	0.493
TEU	-137.778	79.431	-1.734	0.098*
TFEC	-0.794	2.234	-0.355	0.725
WC	-0.063	0.368	-0.172	0.864
C	40.02043	39.41947	1.015245	0.322

Source: Authors' Computation 2024; ** indicates level of significance at 5%;

*indicates level of significance at 10%

From the estimates of the long-run results as indicated on table 4.6, the coefficient of public environmental policy is 0.459, implying that, a unit increase in public environmental policy brings a positive and insignificant impact on carbon emission reduction in Nigeria by 0.46 unit. The coefficient of total agricultural output is 0.649 showing that, a unit increase in agricultural output impacts carbon emission reduction by 0.184 units in Nigeria. The coefficient of Gross Domestic Product is 4.321 thus showing that, a unit increase in gross domestic product brings 4.3 units improvement in carbon emission reduction in Nigeria in the long-run. With the coefficient of total energy consumption -137.778 units, it means that, a unit increase in energy consumption leads to 137.8 units negative impact on carbon emission in Nigeria in the long-run. Technology and innovation coefficient is -0.498 showing that, a unit increase in technology and innovation improvement brings a positive and significant long-run improvement in carbon emission in Nigeria. A weather condition coefficient of -0.063 shows that a unit increase in weather condition will lead to a 0.06-unit negative impact on carbon emission reduction in Nigeria.

Table 4.7: Summary of Diagnostics Test Result for Model

Dependent Variable: CAM

Test	Null Hypothesis	F-Statistics	Probability Value
Normality Test	No Normal Distribution	0.737	0.691
LM Test	No Serial Auto-Correlation	1.224	0.282
Breusch-Godfrey Test	No Heteroscedasticity	1.652	0.158

Source: Authors' computation 2024

Table 4.7 shows that the value of histogram normal distribution is not statistically significant at 5%, as its p-value is 0.691. The F-Statistic value for the Serial Auto-Correlation (1.224) is statistically insignificant at 5% as its p-value was 0.282. Thus, the null hypothesis of no serial correlation is accepted. This shows that the model was free from auto-correlation. In the heteroscedasticity test, the F-Statistic (1.652) is not statistically significant as the p-value was 0.158. Thus, the null hypothesis of no heteroscedasticity cannot be rejected. This implies that, there is homoscedasticity in the regression result-constant variance.

Discussions of Findings

The study examined the impact of public environmental policies on reducing carbon emissions in Nigeria. The study has revealed the positive and significant impact of public environmental policies on reducing carbon emissions in Nigeria in Nigeria both in the short-run and long-run. The positive and significant impact of public environmental policies on carbon emissions reduction in Nigeria indicates the fact that, public environmental policies play an important role in curbing carbon emission in Nigeria. It further shows that before carbon emission can be reduced in Nigeria, public environmental policies are very important.

Other control variables of carbon emission reduction in the model such as total agricultural output revealed positive and significant impact on carbon emission reduction in Nigeria both in the short-run and in long-run.

Total renewable energy consumption revealed a positive and significant impact on carbon emission in both the short-run and long-run. The implication is that, as more renewable energy is consumed, it will affect carbon reduction in Nigeria positively. Gross Domestic Product showed a positive and significant impact on carbon emission reduction in the short-run, and positive a and insignificant impact in the long-run. This shows that, as the economy of Nigeria grows, carbon emission is impacted positively. Improvement in technology and innovation showed negative and significant impact on carbon emission both in the short-run and the long-run, indicating that as the technology and innovation improve in Nigeria, carbon emission is impacted negatively. Similarly, weather condition showed negative and insignificant impact on carbon emission in Nigeria both in the short-run and long-run. The implication is that, weather condition impacts carbon emission reduction in Nigeria but significantly in curbing carbon emission

Conclusion

This study has established the effectiveness of public environmental policies in reducing carbon emissions in Nigeria. The results have shown positive and significant impact of these policies. The findings from the research provide valuable insights for policymakers in Nigeria to develop comprehensive and effective strategies for reducing carbon emissions and promoting environmental sustainability.

Policy Recommendations

Based on the findings of this work, the following recommendations are proffered:

1. **The Need to Support Sustainable Agricultural Practices:** Given the positive impact of total agricultural output on reducing carbon emissions, policymakers should prioritise and incentivise sustainable farming practices that decrease emissions while maintaining productivity in Nigeria.
2. **Re-evaluation of Focus on Technological Improvements:** Despite showing a negative impact on carbon emission reduction, technology and innovation play a crucial role in sustainable development. It is essential to further investigate how technological advancements can be leveraged to reduce carbon emissions effectively.
3. **Alignment of Economic Growth with Environmental Sustainability:** The positive impact of GDP on carbon emission reduction implies that economic growth and environmental sustainability can be complementary. Policies should be designed to encourage economic activities that are environmentally friendly and promote green growth.
4. **Transition to Renewable Energy Sources:** As total fossil energy consumption showed a negative impact on carbon emission reduction, there is a need for Government to encourage a shift towards renewable energy sources. Policies supporting the transition to cleaner energy options should be encourage to significantly contribute to reducing carbon emissions in Nigeria and globally.
5. **Implementation of Public Environmental Policies:** The significant positive impact of public environmental policies highlights their effectiveness in reducing carbon emissions. It is crucial to strengthen the enforcement and implementation of such policies to ensure their maximum impact by various regulatory agencies within and outside the country.
6. **Adoption of Climate-Resilient Strategies:** Given the insignificant impact of weather conditions on carbon emission reduction, it is important to incorporate climate-resilient strategies into environmental policies. This will help mitigate the impact of changing weather patterns on carbon emissions.

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