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Exploring the Dynamic Interplay among Foreign Aid, Energy Usage, Economic Growth, and Carbon Emissions in Nigeria

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Abstract. In recent decades, Nigeria has emerged as a rapidly growing economy, while at the same time it faces pressing environmental concerns, particularly regarding rising carbon emissions. Although factors like foreign aid and energy usage contribute to economic prosperity, they just as well lead to increases in carbon emissions, causing concern about environmental degradation. This study investigates the complex links between foreign aid, energy usage, economic growth, and carbon emissions in Nigeria from 1990 to 2021. The autoregressive distributed lag analysis revealed mixed findings about how different economic elements relate to carbon emissions. While foreign aid, gross domestic product (GDP), and trade openness correlated positively but insignificantly, energy usage had an insignificant negative association with carbon emissions. Notably, financial development and remittances showed statistically significant inverse relationships with carbon emissions in the long run, and the speed of adjustment proved to be negative and significant in the short run. This research recommends policymakers to cut carbon dioxide while also acknowledging that the underlying dynamics are complicated.

Keywords: CO2 emissions, energy consumption, economic growth, foreign aid, ARDL, Nigeria

JEL Classification: O13 Q43 Q54 O55

1. Introduction

Public awareness of the growing threat posed by climate change has increased (Ogede and Tiamiyu, 2023), and greenhouse gas emissions, notably carbon dioxide (CO2) emissions, have been acknowledged as a key contributing factor. Literature has established that carbon dioxide (CO2) emissions have a negative influence on human and sustainable growth (see Acheampong, 2021). However, despite the efforts of international institutions to control CO2 emissions and safeguard the environment, emissions are still rising (International Energy Agency, 2018). Nigeria faces the dual task of fostering economic growth while also reducing emissions to lessen the effects of climate change. It is a developing country with a growing population and expanding economy. On the one side, Nigeria boasts a wealth of fossil fuel resources that have driven economic growth, including the ninth greatest proven crude oil reserves in the world (British Petroleum, 2020). However, just 40% of the population in Nigeria has access to power, and the country is also extremely vulnerable to the effects of climate change and environmental degradation (Abiodun, Lawal, Salami et al., 2013; World Bank, 2020).

Recent literature has examined various macroeconomic determinants of CO2 emissions, with a focus on the impacts of energy usage, economic growth, remittances, trade openness, financial inclusion, income inequality, and institutional quality, among others (see Anwar et al., 2021; Chen and Taylor, 2020; Charfeddine and Kahia, 2019; Ertugrul et al., 2016; Jamil et al., 2022; Liu et al., 2022; Mirza et al., 2022; Ogede and Tiamiyu, 2023; Ogede, Oduola, and Tiamiyu, 2023; Sun et al., 2019; Wang, Yang, Lim, and Wang, 2023). For instance, Ogede et al. (2023) examined whether income inequality increases CO2 emissions in sub-Saharan African countries from 2000 to 2018. Cross-sectional Autoregressive Distributed Lag (CS-ARDL) results showed that income inequality has a positive short- and long-run impact on emissions, indicating that pollution rises as the wealth gap widens. The square of income inequality negatively impacts emissions, though the magnitude varies by time frame. Interacting inequality with financial inclusion showed a continued positive effect on emissions in the short and long run. However, institutional quality was found to have a considerable negative effect when interacted, suggesting it significantly impacts the inequality-emissions nexus. Besides, using time series analyses and Fourier-Augmented Dickey–Fuller (FADF), Fourier Likelihood Maximum (FLM), and Fourier ARDL, Liu et al. (2022) reported that energy efficiency significantly reduces emissions in the long and the short term. The authors recommend policies to increase energy efficiency through investment, technology, and differential import tariffs. Also, Wang et al. (2023) argue that the impact of Foreign Direct Investment (FDI) on carbon emissions shifts from positive to negative at different income levels, with the turning point at a GDP per capita of $541.87. They verified this using group regression robustness tests.

Pinar (2023), however, used dynamic panel generalized method of moments (GMM) to conclude that green aid fragmentation reduces effectiveness, mitigated by strong institutions. As a result, the research currently available provides contradictory data about what causes emissions in wealthy and other emerging nations.

Even though international aid has the potential to be a significant external source of development financing many developing nations like Nigeria, the role of foreign aid flows has received little attention. Few research, such as those by Kilama (2016), Bakirtas and Akpolat (2018), Kretschmer et al. (2013), and Alshubiri and Elheddad (2020), examined the relationship between foreign aid and CO2 emissions; their findings were inconsistent among nations. Some theories suggest that aid, especially in education and health programmes, can enhance productivity, increase purchasing power, and subsequently lead to higher energy usage and CO2 emissions. Investments in health and education facilitated by aid could potentially raise public awareness and reduce fossil fuel utilization (Hahn and Metcalfe, 2016). Although empirical research on this subject, especially country-specific studies, is scarce, conducting comprehensive case studies in diverse countries could provide deeper insights into the link between the variables (Yang et al., 2020; Zafar et al., 2022). The foregoing suggests that foreign aid might either secure carbon-intensive routes by subsidizing fossil fuel infrastructure or promote "green" growth through clean energy investments and climate finance. It is essential for sustainable development policy to quantify these effects. In 2021, Nigeria received $3.36 billion in Official Development Assistance (ODA) for the Nigeria Energy Support Programme (NESP), a renewable energy project co-financed by the European Union and the German administration. The project aimed to improve investments in renewable energy and increase electricity access for marginalized rural communities, contributing to clean energy production and overall development in Nigeria. However, despite such aid, Nigeria still heavily relies on fossil fuels, which account for 74% of its total primary energy supply.

Therefore, examining the interactions between foreign aid, energy use, economic growth, and CO2 emissions is essential while employing the necessary methodology in order to provide accurate conclusions. In order to better understand how foreign aid, energy use, economic growth, and CO2 emissions interact dynamically in Nigeria, this study will examine this relationship. The driving force is the need to better understand how foreign aid affects emission trends while taking other important factors like energy use and economic growth into consideration. By employing recent time series data and strong econometric techniques, the study adds new evidence to the empirical literature about the relationships between aid, emissions, and growth for the largest economy in Africa. Specifically, the objectives are threefold: (i) to examine the impact of foreign aid on CO2 emissions; (ii) to analyse the role of energy usage in driving emissions; (iii) to assess the growth–emissions relationship in Nigeria. Annual time series data over 1990–2021 are

utilized and analysed using advanced time series techniques such as the ARDL bounds testing approach. The results will provide valuable information about how well foreign aid works to change Nigeria's emission trajectory in the face of obstacles to expanding energy availability and economic growth. The study intends to educate decision-makers on how to create the best plans for utilizing foreign aid for sustainable development. Understanding the factors influencing CO2 trends can help Nigeria meet its climate action pledges under the Paris Agreement given the country's increased global emission contribution. The following is a summary of the study's subsequent sections: The current literature is summarized in Section 2, the materials and techniques are described in Section 3, the results are presented and analysed in Section 4, and the conclusions are stated in Section 5.

2. Literature Review

The academic literature encompasses a growing body of research that examines the relationship between microeconomic variables and carbon emissions. This research explores various topics that transcend national borders. To start with, Yang et al. (2020) examined the effect of the inflow of remittances, energy consumption, and globalization on carbon dioxide (CO2) radiation, exploring a dataset consisting of 97 nations worldwide between 1990 and 2016. The utilization of system GMM yielded the finding that transfers and energy consumption suggest a favourable link with CO2 discharges, while globalization demonstrates a negative link with CO2 emissions. The research splits the universal trial to two distinct subsamples: the first subsample consists of advanced republics, while the second subsample comprises evolving countries. However, the outcomes show similarity in both subsets. Neog and Yadava (2020) examine the link between CO2 emissions and remittances in India and the asymmetrical correlation among inflow of remittances, financial expansion, and carbon discharges from 1980 to 2014 while employing a Non-linear Autoregressive Distributed Lag (NARDL) model. Their outcomes indicate that an optimistic exogenous influence on remittances is linked with a subsequent upsurge in carbon dioxide (CO2) discharges. Conversely, a negative exogenous impact on remittances is linked to a decline in CO2 discharges. The coefficient of financial development exhibits a positive direction, yet it loses its statistical significance.

Using data on China, Jafri et al. (2022) analyse the asymmetrical influence of remittances and FDI on CO2 emissions by exploring the NARDL method. The time frame for this investigation spans from 1981 to 2019. According to the empirical findings of the NARDL model, a diminution in remittances is associated with the short-term and long-term positive impacts on CO2 emissions. Findings suggest that alterations in FDI, whether positive or negative, have a favourable influence on CO2 emissions. Furthermore, it was detected that an optimistic change in

FDI has a relatively better long-term impact on CO2 emissions compared to an adverse change in FDI. The phenomenon of asymmetry is evident solely in terms of magnitude, rather than direction. In Nepal, Kishor and Bhattarai (2019) examined the link between economic progress, remittances, foreign aid, and CO2 emissions. The empirical results indicate that an upsurge in remittances and foreign aid is correlated with a reduction in CO2 emissions. Conversely, financial development and higher income levels are found to be correlated with an upsurge in CO2 discharges. The aforementioned findings underscore the significance of market mechanisms in effectively modifiable financial development and promoting higher revenue levels as a means to control CO2 emissions, all the while ensuring that competitiveness is not compromised.

In another development, Mahalik et al. (2021) investigated the comparative efficacy of foreign energy aid inflows and total foreign aid with carbon emissions in India from 1978 to 2014. It incorporates remittance inflows, FDI, economic progress, globalization, and energy usage as added features within a CO2 production function. The research investigated the usage of the ARDL bounds estimation to assess the occurrence of a statistically significant long-term association link between the variables under consideration. It is noteworthy that there exists an observed link between energy usage, globalization, and foreign aid inflows with a notable reduction in CO2 discharges. Conversely, inflows of remittances, foreign energy aid inflows, FDI, and economic progress are found to have an inducing impact on CO2 emissions. From the standpoint of climate mitigation policy, in an alternative progression, Saliba et al. (2022) evaluated the impacts of sources of renewable energy and remittances on carbon emissions, considering the influence of technological advancements, globalization, and economic development with data spanning from 1990 to 2019. The research applied bounds testing methodology to study the link between CO2 and the regressors, revealing significant long-term associations. The study also applied frequency-domain causality, which examines causality across several frequencies. Moreover, the findings from the ARDL model specify that there exists a helpful link between CO2 production and economic growth in the long and short term. Conversely, the variables of green energy, remittances, and globalization exhibit an adverse association with CO2 emissions, suggesting that they have a mitigating influence on ecological pollution. In conclusion, the utilization of the frequency domain causality approach unveiled that various features, such as renewable energy, economic advancement, globalization, remittances, and technological innovation, possess the ability to forecast long-term CO2 emissions. The robustness of these findings was determined using the Difference-in-DOLS and FMOLS regression methods.

Further, Farooq (2022) used Estimated Generalized Least Squares (EGLS), Two Stage Least Squares (2SLS), System Generalized Methods of Moments (SGMM), and Fully Modified Ordinary Least Squares (FMOLS) models to explore how

governance affects FDI, foreign aid, and CO2 emissions in Asia. The study found that FDI increases emissions through industrialization, while foreign aid and governance reduce emissions by promoting cleaner technology and regulating industry. However, foreign aid was found to undermine governance and its emission-reducing impact. The author recommends governance measures to curb FDI-related emissions. Liu et al. (2022) examined the impact of the efficiency of US energy on CO2 emissions alongside trade, growth, and population. Using time series analyses, Fourier-ADF, Fourier-LM, and Fourier ARDL, they found that energy efficiency significantly reduces emissions in the long and short term. The authors recommend policies to increase energy efficiency through investment, technology, and differential import tariffs. Also, recent studies have examined the relationship between FDI, foreign aid, and CO2 emissions using various econometric techniques. For instance, Wang, Yang, Li, and Wang (2023) used panel threshold estimation for 67 countries to find that the impact of FDI on carbon emissions shifts from positive to negative at different income levels, with the turning point at a GDP per capita of $541.87. They verified this using group regression robustness tests. Pinar (2023), however, used dynamic panel GMM methodology for 92 countries and found mixed results regarding the emission-reducing impact of green aid. The study found that green aid fragmentation reduces effectiveness, mitigated by strong institutions.

In Nigeria, for example, Cosmas et al. (2019) performed an econometric analysis to explore the macroeconomic factors that stimulate carbon dioxide (CO2) releases in Nigeria from 1981 to 2016 and adopted both the ARDL and the NARDL techniques. The results derived from the analysis of the environment–economy nexus challenge the credibility of the Environmental Kuznets Curve (EKC) and reveal the existence of an N-shaped affiliation in Nigeria. The analysis reveals that there exists a strong interrelation between changes in CO2 emissions and GDP per capita – specifically the impact of changes in GDP per capita on CO2 production is substantial. Additionally, there are signs of a bi-directional causal relationship between energy consumption and GDP per capita, with energy usage, in turn, leading to an upsurge in CO2 emissions. Akinlo (2022) employed NARDL to analyse data spanning the period of 1980–2018 to ascertain the effects of fluctuations in remittances on environmental deterioration in Nigeria. The findings show that the variables exhibit a sustained and interdependent relationship over an extended period. Research findings indicate that there exists an asymmetric relationship between remittances and ecological footprint (EFP), which serves as a metric for assessing environmental degradation. This asymmetry is observed both over the extended period and in short-term contexts. However, when considering CO2 emissions as a measure of environmental deterioration, the asymmetric connection with remittances is only evident in the long-term perspective. The study additionally discovered that the influx of remittances has a contributory

effect on environmental degradation in Nigeria over an extended period. Ekesiobi et al. (2022), however, utilized the autoregressive distributed lag procedure to argue that FDI has a causal impact on carbon discharges. Furthermore, there is a reciprocal relationship between international trade and carbon emissions, where both variables exert influence on each other. The empirical results obtained from the ARDL procedures depict that both FDI and international trade have a significant adverse impact on carbon emissions in the short term. In the long term, international trade and FDI have a beneficial impact on Nigeria's carbon footprint, thereby reinforcing its status as a long-term polluter haven.

The foregoing review of the extant literature suggests that remittance inflows and higher GDP per capita tend to increase emissions, while FDI, trade openness, and financial development can have mixed effects depending on the country context. Causality appears to run in both directions between emissions and economic growth indicators like GDP per capita. Hence, more research is needed on the specific mechanisms linking microeconomic factors to emissions beyond broad correlations, through channels like energy mix, technology, and composition of economic activity. Studies incorporating such granular analyses would provide sharper policy implications beyond general emissions–growth relationships.

3. Methodology and Sources of Data

3.1. Data

This study aims to investigate the impact of aid received, economic progress, and energy usage on CO2 emissions while considering the influence of financial development, trade openness, and remittances. The research utilizes annual time series data from the period of 1990–2021 in Nigeria due to its significance as the most densely populated black nation in Africa and the largest economy on the continent, as well as the availability of reliable data. The measurement of CO2 emissions is represented by metric kg per capita. Foreign aid (AID) is estimated using net official development assistance and official aid received (current US$). Energy usage (ENCON) is measured by percentage of renewable energy consumption to final energy consumption, and GDP per capita growth (annual %) is employed to gauge the economic growth, as previously used in related studies by Nasir et al. (2019), Kaidi et al. (2019), and Steenblik, Jones, and Lang (2012). Trade openness is introduced as a variable, calculated by dividing the total of imports and exports by GDP (TRDOP). This ratio is a widely used indicator of trade openness in existing studies such as Siddiki (2002), King and Levine (1993), and Murinde and Eng (1994). Financial expansion is approximated by domestic credit to the private sector (DCP), following the methods of Rani and Kumar (2018) and

Afolabi (2022). Remittances (REM) are measured as total remittances received (% of GDP). To simplify estimation, data on CO2 emissions, AID, and ENCON were converted into natural logarithmic form to ensure stationarity in variance. For a comprehensive understanding of the variables used in the study, please refer to *Table 1* for the explanation and sources.

Table 1. *Description of variables*

Abbreviation	Description	Source
Carbon dioxide emissions (CO)	CO_2 emissions (metric tons per capita)	World Development Indicator
Foreign Aid (AID)	Net official development assistant (Current US$)	World Development Indicator
Energy Usage (ENCON)	% of renewable energy consumption to final energy consumption	World Development Indicator
Economic Growth (GDP)	GDP per capita (constant 2015 US$)	World Development Indicator
Trade Openness (TRDOP)	% of trade to GDP	World Development Indicator
Financial Development (FD)	Domestic credit to the private sector (% of GDP)	World Development Indicator
Remittances (REM)	% of total remittances to GDP	World Development Indicator

Source: authors' compilation (2023)

Model Specification

The model for the implication of foreign aid, energy usage, growth, trade openness, financial expansion, and remittances on carbon emission is stated as:

$$CO_2 = F(AID + ENCON + GDP + FDEV + TRDOP + REM),$$

where CO_2 is the carbon emission (a proxy for CO measured by metric kg per capita), AID is a delegation for foreign aid, advancement in the economy by GDP per capita growth, $\beta 0$ is the constant term, $\beta 1$, $\beta 2$, $\beta 3$, and $\beta 4$ are the coefficients of the model, and $\varepsilon t1$ stands for the error term. *TRDOP* represents trade openness (import + export/GDP), domestic credit to the private sector (% of GDP), proxied for financial expansion, while remittance is a proxy of personal remittance received % of GDP. The adopted empirical strategy involves the estimation of the baseline equation through the ARDL procedure. ARDL techniques have been widely utilized in the field of econometrics for a considerable period. Their application has become increasingly accepted in recent years, particularly as a

means of analysing cointegrating connections (Adegboyega and Odusanya, 2014). Two significant contributions in this context are the works of Pesaran, Shin, and PSS (2001) – specifically Pesaran et al. (2001) and Pesaran and Shin (1998). The authors contend that ARDL techniques possess distinct advantages due to their capacity to effectively address cointegration while demonstrating resilience against the misrepresentation of integration orders of pertinent variables. The dynamic relationship is specified as:

$$CO_{2t} = \beta_0 + \beta_1 AID_t + \beta_2 ENCON_t + \beta_3 GDP_t + \beta_4 FDEV_t + \beta_5 TRDOP_t + \beta_6 REM_T + \varepsilon t_1$$

Further, the study aimed to analyse the impact of the dynamic interactions between foreign aid, energy usage, economic growth, trade openness, remittances, and financial progress on carbon emissions in Nigeria. Descriptive statistics were used to present and summarize the data effectively. Additionally, data normality was confirmed by examining means and Jarque–Bera values (Gujarati and Porter, 2010). Hence, to assess stationarity, the study conducted unit root tests using the ADF and Philips–Perron methods. Subsequently, ARDL estimation techniques were employed to investigate the variables' cointegration.

4. Results and Discussion

Descriptive Statistics

Table 2 presents the results of the descriptive statistics. The findings show that the mean and median values of all variables fall in the range of their maximum and minimum values. This suggests a high probability of a normal distribution for all features, namely carbon emission, aid, energy usage, growth in the economy, financial development, trade openness, and remittances. The Jarque–Bera statistics support this inference, as the series adheres to a normal distribution. Furthermore, the lack of statistical significance at the 5% level for all p-values of the series further confirms the acceptance of the alternative hypothesis, which states that each variable follows a normal distribution.

Table 2. *Descriptive statistics*

	CO_2	AID	ENCON	GDP	TRDOP	FD	REM
Mean	-0.398	20.585	6.595	1.636	0.361	10.274	3.370
Median	-0.399	21.099	6.607	1.809	0.365	9.395	3.819
Maxi	-0.087	23.159	6.666	12.27	0.532	19.625	8.333
Mini	-0.710	18.839	6.522	4.507	0.163	4.957	0.018
Std. dev	0.177	1.325	0.042	3.848	0.093	3.539	2.349
Skewness	0.142	0.064	-0.253	0.452	-0.157	0.821	0.179

	CO_2	AID	ENCON	GDP	TRDOP	FD	REM
Kurtosis	1.698	1.517	1.769	3.378	2.465	3.352	1.880
Observations	32	32	32	32	32	32	32

Source: authors' compilation (2023)

Notes: foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Test of Multicollinearity

To evaluate the existence of multicollinearity among the predictor variables – specifically aid, energy consumption, economic progress, openness in trade, financial development, and remittances –, a correlation matrix was generated. The correlation matrix is presented in *Table 3*. The analysis demonstrates that there is a lack of link between the variables, thus establishing the study's outcomes as highly reliable. *Table 3* also presents the outcome of the correlation matrix, indicating that the factors produce both positive and negative correlation coefficients. The absence of multicollinearity among the variables can be inferred from the correlation coefficient being less than 0.95, as noted by Baltagi, Bun, and Sarafidis (2015) and Wooldridge (2007).

Table 3. *Correlation matrix*

Variables	CO_2	AID	ENCON	GDP	TRDOP	REM	FD
CO_2	1.000						
AID	-0.814	1.000					
ENCON	-0.710	0.820	1.000				
GDP	0.045	0.014	0.031	1.000			
TRDOP	0.326	-0.353	-0.262	0.374	1.000		
REM	-0.803	0.890	0.655	-0.001	-0.184	1.000	
FD	-0.812	0.580	0.538	0.066	-0.229	0.658	1.000

Source: authors' compilation (2023)

Notes: foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Results in *Table 4* indicate that the factors exhibit stationarity at levels and the first difference. The empirical outcome revealed both the non-stationary characteristics of the factors and the covariance structure of the analysed dataset. We employ the ARDL technique to estimate the association of the factors of interest. The selection of the estimation strategy is crucial in this research, as it aligns with the observed patterns in the data. The determination of the most suitable lag duration is accomplished by utilizing the Schwartz information criteria. The process includes determining the lag duration value that minimizes the information criterion, specifically the Schwartz Criteria (SC), while simultaneously ensuring that the model does not display autocorrelation. The presentation includes the determination of the optimal lag length, as shown in *Table 5*.

Table 4. *Unit root test*

	Level				First difference			
Variables	**Intercept**		**Trend and intercept**		**Intercept**		**Trend and intercept**	
	ADF	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**
CO_2	-1.232	-1.083	-2.888	-2.962	-5.921**	-6.854**	-5.788**	-6.728**
AID	-0.907	-1.091	-3.185	-2.325	-5.393**	5.227**	-5.287**	-5.019**
ENCON	-1.406	1.215	-2.681	-2.370	-5.407**	7.275**	-5.313**	-7.083**
RGDP	-3.767**	3.892**	-3.680**	3.812**	-9.376**	20.114**	-9.154**	-20.989**
TRDOP	-2.809***	-2.809	-3.342	-3.304	-5.422**	-9.957**	-5.436**	-17.837**
FD	-2.567	-1.718	-3.773**	2.114	-5.054**	5.983**	-5.026**	-6.023**
REM	-2.069	-1.980	-2.470	-2.490	-5.685**	-7.047**	-5.641**	-7.889**

Source: authors' compilation (2023)

Note: ***, **, and * stand for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Table 5. *Lag length selection*

Lag length	**SC**
0	7.403
1	5.762*
2	7.788

Source: authors' compilation (2023)

Notes: ***, **, and * stand for 10%, 5%, and 1% respectively.

Bounds Test

The study employs the bounds testing procedure as proposed by Pesaran et al. (2001) to inspect the existence of extended period links among the variables. F-test is adopted to assess the assumption of the absence of co-movement among the factors in comparison to the hypothesis of its presence, which is represented as:

$:H_0: \beta_1=\beta_2=\beta_3=\beta_4=\beta_5=\beta_6= 0$, i.e. there is no cointegration among the variables.

$H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$, i.e. there is cointegration among the variables.

Table 6. *Bounds test results*

F-statistics	**1%**		**5%**		**10%**	
4.993	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
	2.88	3.99	2.27	3.28	1.99	2.94

Source: authors' compilation (2023)

Notes: ***, **, and * stand for 10%, 5%, and 1% respectively.

Based on the conclusions of the bounds test, as shown in *Table 6*, it is suggested to compare the F-statistic value with the critical value of Pesaran at the conventional significance level. Narayan (2005) detailed that the critical values outlined in Pesaran et al's (2001) study do not apply to a small number of sample sizes, as they are based on the assumption of huge sample sizes. Narayan (2005) allows critical values for sample sizes ranging from 30 to 80 observations. The observed values in this study fall within the range of 1.99–2.94 for a significance level of 10%, 2.27–3.28 for a significance level of 5%, and 2.88–3.99 for a significance level of 1%. The null hypothesis is not rejected based on the F-statistic of 4.993, which exceeds both the lower and upper bound critical values. Therefore, it can be concluded that all factors in the model exhibit co-movements in the extended period within Nigeria.

Table 7. *ARDL long-run estimates (Pesaran et al., 2001; Narayan, 2005); dependent variable: CO2*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LAID	0.002	0.045	0.040	0.968
LENCON	-0.141	0.782	-0.180	0.858
GDP	0.002	0.005	0.330	0.744
TRDOP	0.123	0.302	0.407	0.688
FD	-0.017	0.007	-2.338**	0.029
REM	-0.054	0.023	-2.310**	0.031
C	0.806	4.535	0.177	0.860
R-squared	0.748			
Adjusted R-squared	0.720			
Durbin–Watson stat	2.402			
F-statistic(Prob)	33.564**			

Source: authors' compilation (2023)

Notes: ***, **, and * for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Table 7 indicates that the explanatory variables of the model account for 72.08% of the variation in the regressand variable over the long term. The rest, 27.92% of the variation, was determined by factors outside of the model. The statistical significance of the model was confirmed by the F-statistic (33.56) at a significance level of 5%. The statistical analysis reveals that the model exhibited a positive serial correlation, as evidenced by the Durbin–Watson statistic of 2.402, which is within the acceptable range of 1.5–2.5, as established by previous research (Dufour and Dagenais, 1985; Durbin, 1960). The findings suggest that over the long term, the foreign aid received has a positive impact and is statistically irrelevant at a 5% level of significance. This suggests that an increase of a certain percentage in official aid and assistance

received will result in a corresponding 0.018 per cent increase in carbon emissions in Nigeria. Furthermore, energy consumption exhibits an adverse and statistically insignificant correlation at the 5% level. The aforementioned statement suggests that an upsurge of a certain percentage in energy usage will lead to a reduction of 0.141 per cent in carbon emissions. The coefficient of growth in economy and trade liberalization points to a positive direction, yet it loses its statistical significance with carbon emissions in Nigeria. Meanwhile, the statistical analysis reveals that both financial development and remittances exhibit an adverse and inconsequential correlation with carbon emission, suggesting that an increase of a certain percentage in remittance and financial development will result in a corresponding 0.05 per cent and 0.01 per cent reduction, respectively, in carbon emission in Nigeria.

Table 8. *ARDL short-run estimates; dependent variable: CO2*

Variable	Coefficient	Std. error	t-statistics	Prob.
D(TRDOP)	0.436	0.091	4.766**	0.000
D(FD)	-0.003	0.004	-0.852	0.403
D(REM)	-0.011	0.005	-2.133**	0.045
ECM(-1)	-0.701	0.095	-7.343**	0.000

Source: authors' compilation (2023)

Notes: ***, **, and * stands for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Findings suggest that over a short-term period, there exists a positive and significant (5%) level of correlation between openness in trade and carbon emission in Nigeria. Furthermore, it is noteworthy that financial development exhibits an adverse and statistically insignificant correlation at a 5% level of significance, while remittances exhibit an adverse and significant association with carbon emission, which implies that a rise in remittances in Nigeria will result in a reduction of 0.01 in carbon emission.

The results of the short-run effect of interplay among foreign aid, energy usage, economic growth, and carbon emissions in Nigeria are presented in *Table 8* above. Negative effects were revealed in the short term, which were found to be statistically significant at the 5 per cent level. Also, a relatively short transition period results in relatively small changes; even where there are imbalances, the return to equilibrium has been relatively high, with a value of 0.701 (70.1%) being registered in the first year.

Figure 1 demonstrated the normality stability test that indicates a normal distribution with the probability value of 0.337. Also, the results in *figures 2–3* depicted the CUSUM and CUSUM of squares, whose lines fall within the critical bounds of 5 per cent significance. This suggests that the series exhibits structural stability.

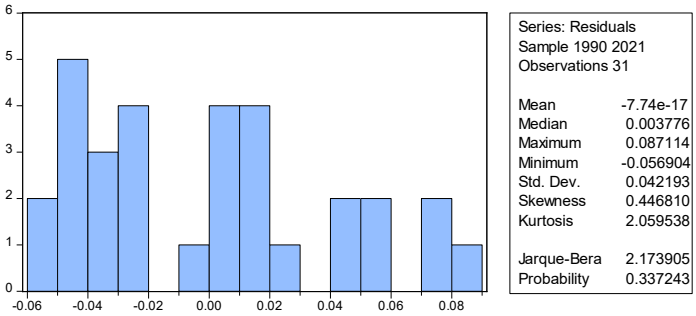

Figure 1. *Normality test*

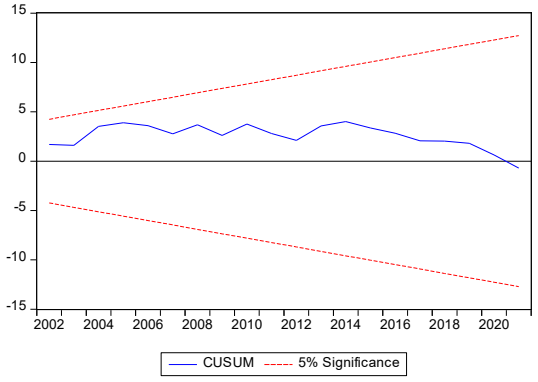

Figure 2. *CUSUM stability test*

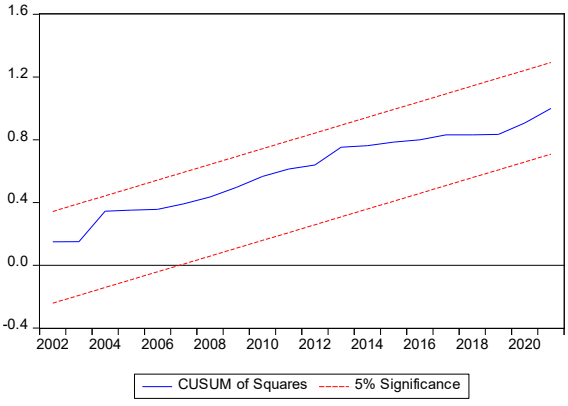

Figure 3. *CUSUM of squares*

5. Conclusions and Policy Recommendations

The relationship between energy use, economic growth, and carbon emissions has been extensively researched in the Nigerian academic discourse, taking into account elements such as financial development, trade openness, and remittance inflows. Foreign aid and its relationships with other variables are not being examined sufficiently in current research, which is one obvious gap in the field. To address this, our study used data from the World Development Indicator of the World Bank, spanning the years between 1990 and 2021 and using an Autoregressive Distributed Lag estimate approach. The results of the present study point to a positive correlation between foreign aid received and carbon emissions over an extended period in Nigeria. It is crucial to remember that this association loses its statistical significance beyond a certain point. In a similar vein, we have discovered that economic expansion and trade liberalization have no statistically significant impact on carbon emissions in Nigeria. These results contrast with the findings of Kishor Sharma and Badri Bhattarai (2019) and Mahalik et al. (2021), who reported a negative and statistically insignificant correlation between energy consumption and CO2 emissions. Moreover, a noteworthy and adverse association was observed between financial progress, remittances, and carbon emissions. In the short term, trade openness in Nigeria had a positive and statistically significant influence, while remittances showed a statistically significant negative correlation with carbon emissions. Specifically, an increase in remittances corresponded to a decrease of 0.011 in carbon emissions. However, financial development had an adverse and statistically irrelevant influence on CO2 in the short term.

The results of this study offer fascinating new insights into the complex interactions between many variables and carbon emissions in the context of Nigeria. These ramifications highlight the necessity of specialized policy interventions and shed light on the challenges associated with attaining sustainable development. First, despite losing statistical significance, the positive correlation between foreign aid and carbon emissions that has been found warrants further investigation. Foreign aid can be helpful in boosting economic growth, but it must be carefully considered for any potential effects on carbon emissions. Policymakers must carefully evaluate the type of help received and how it fits with the objectives of sustainable development. In order to evaluate the proposed projects based, for example, on their environmental impact, social benefits, and compatibility with emission reduction goals, a thorough sustainability assessment framework must be created. It is also practical to incorporate evaluation criteria such as carbon footprint, resource efficiency, and emission reduction potential. It is also crucial to set up systems for the continual evaluation and monitoring of the success of emission-reducing activities.

The necessity for comprehensive policy responses is highlighted by the statistically insignificant impact of trade liberalization and economic growth on carbon emissions.

There is no guarantee that merely increasing commerce or economic activity will reduce emissions. To decouple growth from emissions, a more comprehensive approach is needed. Such a mechanism would encourage environmentally friendly production and trade practices to reduce the environmental impact of the growing trade activity. Last but not least, the research showing a negative correlation between remittances, financial development, and carbon emissions suggests that some components of financial development could not be environmentally friendly. Therefore, it proposes that the stakeholders should take advantage of the discovered inverse relationship between remittances and carbon emissions and create strategies to encourage beneficiaries of remittances to finance green initiatives, ultimately cutting carbon emissions. Government entities and all other stakeholders should make sure that financial development is in line with sustainability goals and should promote investments in green technologies and environmentally friendly projects, given the negative correlation between financial progress and carbon emissions.

Nevertheless, further research should delve into the underlying mechanisms involved, considering variables such as the quality of institutions, regulatory measures within the financial sector, and the influence of specific industries on economic expansion and financial advancement.

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