CHAPTER EIGHTEEN

THE GREEN GROWTH INITIATIVE IN NIGERIA: IS CARBON DECOUPLING FROM ECONOMIC GROWTH AMIDST INSTITUTIONAL QUALITY AND RENEWABLE ENERGY CONSUMPTION A VIABLE OPTION?

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Abstract
Against the backdrop of worsening environmental quality in Nigeria, albeit mitigation attempts by the authorities, this study examines the effect of decoupling carbon emissions from economic growth while controlling for institutional quality and renewable energy use. The study utilized the Autoregressive Distributed Lag (ARDL) bound testing and the Tapio decoupling index for analysis from 1990–2021. A long-run cointegration among the variables was established, though the series exhibited a mixed order of integration. Results demonstrate that only the first lag of GDP, energy intensity, institutional quality, and renewable energy consumption are major predictors of carbon emissions in the short-run. However, all the determinants significantly explained the model in the long-term, except energy intensity and institutional quality. Renewable energy consumption depressed carbon emissions in the short to long-terms, while institutional quality insignificantly exacerbated it. The EKC theory is supported, but only over the long-term. The Tapio decoupling elasticity index results reveal weak decoupling with absolute income and consumption/ production-based properties. The study considers carbon decoupling from output growth amidst institutional quality and renewable energy consumption as *sin-qua-non* to the economy's green growth agenda. It recommends, amongst others, further decoupling of the GDP from carbon emissions. The government should consciously diversify the energy portfolio in favor of renewable sources. The government should also resuscitate the quality and performance of institutions in addition to the

strict enforcement of environmental regulatory laws to guarantee improvement in environmental quality.

Key words: Green growth; Nigeria; Carbon decoupling; Institutional quality; Renewable energy consumption

Introduction

All nations often seek to achieve the vital macroeconomic goal of sustainable optimal growth. But growth is not without its accompanying cross. A major manifestation of this scenario is environmental degradation, which, if not curtailed, often tends to wither away growth gains. Therefore, given the devastating consequences imposed by growth on the environment, all countries are constantly searching for a way forward to checkmate this trend. Environmental degradation, often fueled by artificial and climate change factors, which are, in turn, induced by the rise in Green House Gases (GHGs) emissions, poses serious global health and economic concerns to humanity. Carbon dioxide constitutes over 75% of atmospheric GHGs (Olivier and Peters, 2020).

The World Health Organization (WHO) COP27 has recently acknowledged climate change as the greatest menace to global health in the 21st century (WHO, 2022). It is projected that the average climate change-related deaths between 2030-2050 are expected to reach over 250, 000 people per annum, mainly attributed to diseases and heat effects. This corresponds with a total forecasted loss of between US $2-4 billion annually by 2030 (WHO, 2022). Other environmental pressures imposed by climate change include unprecedented global warming with its associated rising sea level, flooding, drought, desert encroachment, air pollution, acid rain, respiratory diseases, mental stress, human displacement, hunger, poverty, and adverse ecological footprint (WHO, 2022). The global total carbon emissions in 2021 stood at 37.9 Gigatons. Out of this figure, China recorded the highest rate of 11.47 billion metric tons, followed by the USA, EU, and India with 6.34, 3.5, and 2.65 billion metric tons respectively. With 11 metric tons per capita, Lybia was Africa's biggest emitter, followed closely by South Africa and the Seychelles, which each emitted about 7.3 and 5.3 metric tons0, respectively. South Africa and Egypt both released the most.

In the same year, Nigeria registered 127,029.25 Kilotons or 0.6 tons per person. Between 1960 and 2021, Nigeria produced an average of 3,406 Kilotons of greenhouse gases. Nigeria is one of the most vulnerable and high-risk regions globally despite having relatively low total GHG emissions rates due to low industrial concentration (International Energy Agency, IEA 2022). The Department for International Development (DFID, 2009) had earlier predicted that Nigeria is likely to lose between 6-30% of her potential GDP to climate change disasters by 2050, corresponding with about US $100 billion- US $460 billion, given the average 3% rise in global temperature per annum. The Ministry of Environment (MoE, 2021) identified the sources of GHG emissions in Nigeria to include waste, forestry, electricity, oil and gas, industry, residential, transport, and agricultural activities.

Given its imperative in the global developmental agenda, the United Nations captured the issue of environmental sustainability as one of its ten fundamental goals for sustainable development, launched in 2016. The cardinal target is facilitating the attainment and sustenance of a low-carbon (green) economy while boosting its critical economic driver (output). Nigeria keyed into the Green Growth Agenda by signing the carbon pledge agreement in Paris in 2016, ratified in 2017. The broad objectives are captured in the Economic Recovery and Growth Plan (ERGP), a short-term national development plan for Nigeria that spanned 2017-2020. The ERGP considers weak institutions, illiteracy, ignorance, and poor waste disposal culture as the main constraints to sustainable environmental development in Nigeria. The overriding strategic target of the plan was focused on building and promoting a holistic approach to environmental protection and management culture, including a shift to renewable energy consumption while attracting financial support for environmental management projects. Nigeria was also a signatory to the Glasgow COP26 Agreement with the net-zero carbon emissions target by 2060, which was immediately proceeded by the signing into law of the new climate bill, which provides for a five-year emissions budget, to achieve the long-term target by 2050 and 2070 (Ministry of Budget and National Planning- MoBNP, 2017).

The 2050 Low Carbon Emissions Development Strategy (LT-LEDS) was equally launched in response to Article 4.19 of the Paris Agreement which requires Nationally Determined Contributions (NDCs) from individual member countries. The key focus is to reduce GHGs emissions by 50%, which is expected to drive growth and facilitate the adoption of low-carbon technologies, climate-smart agriculture and land use technologies, and the enablement of legal, policy, political, and institutional environment. Decoupling has been identified as a key strategy for attaining these elegant goals (MoE, 2021). However, researchers and stakeholders continue to have grave concerns about implementing these policies because it appears that the net zero goal has not been achieved.

Decoupling as a cost-saving/conservation strategy contextually requires consciously scaling down the amount of resources used to generate economic growth while trimming the rate of environmental damage and ecological scarcity by emitting low carbon content of both the production and consumption units.

Growth has typically been established to be a key driver of environmental quality (Acheampong *et al* 2021). There is, therefore, a functional relationship involving the volume of national productivity and the amount of carbon emitted. This relationship is partially explained by the Environmental Kuznets Curve (EKC) hypothesis. Also, the quality of institutions determines the degree of regulations and, hence, the decoupling behavior of a firm or nation. In contrast, renewable energy consumption may engender productivity and trade in an environmentally clean state. Thus, sound institutions promote environmental quality by guaranteeing efficient resource utilization, entrenchment of the rule of law, freedom of speech, and sound and inclusive governance, as well as ensuring formidable regulatory quality, which in turn creates value for money and minimizes wastages (Khan & Rana 2021).

Apart from its vulnerability, Nigeria has a low capacity for mitigating carbon emissions. The heated debate surrounding the impact of decoupling growth from carbon emissions continues unabated (Shabaz *et al*. 2015, Wang and Feng 2019, Sharif *et al*. 2019 and Sheraz *et al*. 2021). Thus, the increased rate of environmental pollution in the country is suspected to be driven by the sustained rise in the weak institutional and regulatory framework, coupled with the low tendency to adopt renewable energy consumption for growth over the years, which has propelled the need to evaluate the nature and impact of decoupling carbon emissions from economic growth and trade in the region, hence, this study.

Moreover, literature on decoupling resources from environmental pressure, particularly in Nigeria, appears rather scanty. This is more so as it presents a fresh model of renewed insight into mitigating the climate change crisis. The existing studies are mostly directed to the advanced industrialized economies, even though the incidence and impact of climate change seems to be mostly felt in the less developed countries. Moreover, the literature is inconclusive on the nature of the decoupling strategy (relative, absolute, extensive, expansive, or weak) that has been applied in Nigeria. The role of institutional quality and renewable energy use in moderating the decoupling behavior in Nigeria is an obvious gap in the literature this study intends to fill, given their peculiar criticality in the development agenda.

The above premises have prompted the following lines of thought: 1. What is the nature and impact of the decoupling strategy adopted in Nigeria? 2. How do institutional quality and the use of renewable energy affect carbon emissions in Nigeria? This study, therefore, controls for these two variables to isolate their interfering role in attaining green growth or growing green initiatives in Nigeria. The remaining portion of this study is as follows: part 2 features a brief theoretical and empirical review, just as the work methodology is treated in section 3. Next is unit 4, which features the presentation and discussion of results, while the conclusion and recommendation are in segment 5.

Theoretical and Empirical Review

This study was anchored on the Environmental Kuznets Curve (EKC) theory (propounded by Kuznets in 1950), the green economy theory and Copeland and Taylor's (1994) pollution haven hypothesis and Porter's (1991) Porter hypothesis are two examples. The EKC theory explains the connection between growth and environmental quality. However, the impact of institutional quality and renewable energy utilization on mitigating carbon emissions shall be explored with the aid of the pollution haven hypothesis. Since Grossman and Krueger's (1991) fundamental work emphasizes a nonlinear relationship between wealth and environmental pollution, many empirical verifications of the actual relationship have been pushed in the literature, with varying degrees of success. According to several authors (including Ogundipe (2015), Dong *et al*. (2010), Egbetokun *et al*. (2010), Acheampong, 2021, Bekun *et al*. 2021, and Iorember *et al*. 2022), the model's validity has continued to be in question. For instance, while Ogundipe (2015) validates the model in Nigeria, Falade *et al*. (2022) only verifies the short-run validity of the model in the industrial sector while invalidating the agricultural sector. Hilaru *et al*. (2020) could not obtain evidence in support of the validity of the model in West Africa. The variation in results may be due to differences in the choice of methodology, scope, or sample frame used. The EKC hypothesis postulates that at the initial stage of development of an economy, pollution increases with the rise in income up to a critical point, after which it reduces as the income level falls, thus yielding the inverted U-shaped relationship between output growth and carbon emissions. The EKC hypothesis is supposed to hold in the event of the critical twist from relative to absolute decoupling state or when the critical turning point is attained (Tenaw, 2020). The validity of this model or otherwise shall be verified by this study in the context of the Nigerian economy.

The pollution haven hypothesis postulates that multinational firms would always naturally tend to shift their operational base from countries with stringent environmental regulation laws (like the developed economies) to those with relatively looser regulations (the developing economies), with the latter increasingly becoming a beehive of environmental pollution. It further establishes a case for how environmental rules and vice versa impact exports. The seeming weak institutional quality and loose environmental regulations in Nigeria have worsened the state of environmental degradation. For instance, people often cut down trees or kill wild animals in the country indiscriminately without replacing them and are not prosecuted. Such actions have continuously exposed the region to the danger of erosion, flood, desert encroachment, or loss of animal species. The activities of the Multinational Corporations in the Niger Delta region are a living testimony to this claim. Finally, the Porter hypothesis suggests the possibility of firms instead gaining from environmental regulatory laws since well-conceived and strict ecological laws tend to engender innovations, which will, in turn, stimulate the productivity of the firm or the nation. Innovation and technology have been key catalysts to replenishable energy use, just as the latter is empirically verified to constitute a strong negative driver of carbon emissions (Mirziyoyeva & Salahodjaev 2022; Zhang *et al*. 2023).

The role of institutional quality in influencing environmental quality has been prominently documented in the literature. The general submission is that the quality of institutions facilitates the mitigation of carbon emissions (Egbetokun *et al*. 2020; Yuan *et al*. 2020; Khan & Rana 2021; Karim *et al*. 2022; Salman *et al*. 2019). Others, however, allude to its worsening impact (Obobisa *et al*., 2022). Replenishable energy use is generally considered a panacea to carbon emissions (Bekun *et al*. 2021; Fatima *et al*. 2021; Duo *et al*. 2021; Cheng *et al*. 2019; Dong *et al*. 2020). These studies are unanimous that since renewable energy sources are mostly replenishable with less fossil composition and emission capacity, they have a high prospect for mitigating carbon emissions and thus ensuring the attainment of the green growth agenda.

Interestingly, the Kaya identity, the Logarithmic Mean Divisia Index (LMDI) approach, and the Tapio decoupling index were the most frequently used analytic methodologies in most studies examined. For instance, Liu and Cheng (2020) used the LMDI decomposition with extended Kaya identity and the Tapio decoupling models to explore the relationship between the GDP of China's national and provincial areas and the CO2 emissions associated with transportation. At the national level, there was extensive decoupling (between 2004 and 2010), but due to the drop in energy intensity, there was also weak decoupling (between 2010 and 2016). Extensive coupling was found at the national level (between 2004-2010) but was also weak (2010-2016), owing to the reduction in energy intensity, which invariably influenced the decoupling status of the economy. Studies such as (Hsu *et al*. 2021; Wang *et al*. 2018; Wang & Xu 2020; Wang & Jiang 2020; Zhang *et al*. 2020; Rosita *et al*. 2021) are also included in this category. The study by Hsu *et al*. (2020) involving 57 Belt and Road Initiative (BRI) countries for 1991-2016 noted strong and intensive decoupling among the higher-income countries. Energy intensity negatively impacted CO2 emissions, while population growth increased in all the sampled countries.

Wang *et al*. (2018) reported both expansive coupling and weak decoupling in China, with the USA witnessing weak and strong decoupling states between 2000- 2014. Similarly, Wang & Su (2020) established the decoupling pattern of developed countries to coincide with a stable and weak state, thus collapsing towards a strong case from a global sample of 192 countries, with no clear decoupling process found among the developing countries. The strongest and longest decoupling states, with the nature of expansive coupling state, weak decoupling, and expansive negative decoupling, were confirmed by Wang & Jiang (2020) in Russia and South Africa, respectively. The strongest consistent cases were obtained in India, China, and South Africa. In V4 countries, Vavrek and Chovancova (2016) found that a significant decoupling of GDP from carbon emissions had positive effects. Notably, most of the decoupling cases reviewed were relative or absolute, consumption or pollution volume, and the authority's desired policy direction at any point in time.

Methodology

Model Specification

First, the EKC hypothesis postulates a positive relationship between the growth in GDP and environmental pressure, given as

$$P = f\,(GDP) \qquad (1)$$

Where P stands for Environmental pressure (pollution), GDP is a proxy for economic growth. The study uses the STIRPAT model, which stands for Stochastic Impacts by Regression on Population, Affluence, and Technology, which is a popular framework for evaluating the environmental impact of economic activities in a typical economy. The model was subsequently refined by Dietz and Rosa (1994). In its original form, the model is conceptualized and stated as follows:

$$P = \alpha P^{\beta 1} A^{\beta 2} T^{\beta 3} \mathrm{e} \qquad (2)$$

Where P = Environmental impact (proxied by CO_2E), α= constant term that scales the model, β_1, β_2 & β_3 are the parameters to be determined, Population (P), Affluence (A), captured by GDP in this model, and Technology (T) are the regressors while e represents the error term. Thus, closely following the work of Tenaw (2020), this study uses energy intensity as a proxy for technology. Thus, by taking the natural log transformation to linearize the equation, our new model becomes

$$InCO_2E_t = \beta_0 + \beta_1 InPOP_t + \beta_2 InGDP_t + \beta_3 InEI_t \qquad (3)$$

However, given the curvilinear nature of the standard EKC curve, the affluence factor (GDP) is squared to determine the precise connection between economic expansion and carbon emissions. Similarly, institutional quality [IQ, a dummy variable] and renewable energy consumption (REC) have been captured to examine their moderating roles in the system. Thus, our new dynamic model is explicitly restated to be econometrically compliant in partial log-linear form as:

$$InCO_2E_t = \beta_0 + \beta_1 InPOP_t + \beta_2 InGDP_t + \beta_3 InEI_t + \beta_4 InGDP_t^2 + \beta_5 IQ_t + \beta_6 InREC_t + \beta_7 InCO_2E_{t-1} + e_t \qquad (4)$$

Where β_1- β_6 = are the parameters to be computed, e_t = is the white noise term. On a priori ground, $\beta_1, \beta_{2,}$ $\beta_1 and$ β_3 are expected to be positive, while $\beta_{4,}$ β_5 and β_6 are expected to yield negative results. Given its adaptable nature and inherent capacity this study uses the autoregressive distributed lag (ARDL) to provide efficient and unbiased estimates even in the face of a series with mixed order of integration to capture both the short-run and long-run link among variables. It is stated as

$$InCO_2E_t = \beta_0 + \sum_{t=1}^{p} \beta_i\, CO_2E_{t-1} + \sum_{j=0}^{q1} \beta_j POP_{t-j} + \sum_{k=0}^{q2} \beta_k GDP_{t-k} + \sum_{m=0}^{q4} \beta_m GDP_{t-m}^2 + \sum_{n=0}^{q5} \beta_n IQ_{t-n} + \sum_{r=0}^{q6} \beta_r REC_{t-r} + \mu_t \qquad (5)$$

The general error-correction representation of the equations, with the short-run dynamics is given as

$$InCO_2E_t = \beta_0 + \sum_{t=1}^{p} \beta_i\, \Delta CO_2E_{t-1} + \sum_{j=0}^{q1} \beta_j \Delta POP_{t-j} + \sum_{k=0}^{q2} \beta_k \Delta GDP_{t-k} + \sum_{l=0}^{q3} \beta_l \Delta EI_{t-l} + \sum_{m=0}^{q4} \beta_m \Delta GDP_{t-m}^2 + \sum_{n=0}^{q5} \beta_n \Delta IQ_{t-n} + \sum_{r=0}^{q6} \beta_r \Delta REC_{t-r} + \mu_t \qquad (6)$$

In this equation, ECT stands for the error correction term (factor) and is the speed of adjustment, which shows how quickly the system returns to long-term equilibrium after the initial shock. The Tapio decoupling index is then used to calculate the economy's decoupling status. The model which uses the degree of elasticity of carbon emissions to changes in economic growth is specified as

$$e = \frac{\%\Delta CO_2E}{\%\Delta GDP} = \frac{CO_2E_t - CO_2E_0}{CO_2E_0} \Big/ \frac{GDP_t - GDP_0}{GDP_0} = \frac{\Delta CO_2E}{CO_2E} \Big/ \frac{\Delta GDP}{GDP} \tag{7}$$

While *e* represents the decoupling elasticity index, 0 and 1 illustrate the initial and current periods, respectively. The indicator system is divided into three states by the index: decoupling, negative decoupling, and connecting or coupling. Tapio uses 0, 0.8, and 1.2 as the critical values for the three fundamental states. Based on the critical values, the index is further classified into eight types: recessive coupling, expansive coupling, recessive decoupling, strong negative decoupling, strong decoupling, weak negative decoupling, and weak decoupling. The Tapio indicators are described in Table 1 based on the corresponding elasticities.

Table 1: Tapio decoupling indicator

Decoupling Status	Decoupling values			**Detail explanation**
	ΔCO_2	ΔGDP	Decoupling index (*e*)	
Strong negative decoupling	>0	<0	<0	CO_2 increases while economic growth declines
Strong decoupling	<0	>0	<0	CO_2 declines while economic growth increases.
Weak negative decoupling	<0	<0	$0 < e < 0.8$	The change rate of CO_2 (negative value) is greater than economic growth.
Weak decoupling	>0	>0	$0 < e < 0.8$	The change rate of CO_2 is obviously smaller than economic growth.
Recessive coupling	<0	<0	$0.8 < e < 1.2$	The change rate of CO_2 (negative value) is approximately equal to economic growth.
Expansive coupling	>0	>0	$0.8 < e < 1.2$	The change rate of CO_2 is approximately equal to economic level
Recessive decoupling	<0	<0	>1.2	The change rate of CO_2 (negative value) is obviously less than economic growth.
Expansive negative decoupling	>0	>0	>1.2	The change rate of CO_2 is obviously greater than economic growth

Source: Adapted from Feng (2017)

Data

Annual data were sourced from the World Bank Development Indicators (WDI) on Carbon Emissions ($C0_2$ E, measured in metric tons), Gross Domestic Product (GDP) per capita at 2015 constant prices in Billions of Naira (as a proxy for economic growth), Population (POP in millions), Institutional Quality (IQ, Proxied by the Country Policy and Institutional Assessment (CPIA) for Environmental Sustainability Rating (1=low to 6= high), Energy Intensity (EI measured as the share of primary energy to GDP) and Renewable Energy Consumption (REC, Measured in Gigawatt-Hour Equivalent of Million Kilowatt-Hour as a share of total final energy consumption) from 1990 to 2021. Apart from data availability and the ease of estimation, the choice of the base year is further predicated on the evaluation of the economy following the aftermath of the Structural Adjustment Programme (SAP), which commenced in 1986 but which had a real impact on the economy being felt as from the 1990s since fiscal policies normally take reasonable time lag to produce tangible impact on the economy.

Estimation Techniques

The study uses ARDL and Tapio decoupling index for estimation, in addition to pre-and post- estimation tests such as the Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) unit root tests, the Breusch-Godfrey serial Correlation LM test and Breusch-Pagan-Godfrey test for heteroskedasticity, the CUSUM and CUSUM square tests of stability.

Results

First, descriptive statistical properties of the series were conducted, and the results are in Table 2. The tests reveal that the data series exhibit a normal distribution, given that the probability of the Jacque-Bera statistic is statistically insignificant at a 5% level, except for population, GDP, and its square, which may be due to the erratic nature of demographic pattern and income flow in the economy. It is also moderately negatively skewed and mesokurtic, as the Kurtosis values are closer to zero for virtually all the variables. The data equally possesses low standard errors. These characteristics render our data set suitable for analysis and proper policy formulation.

Table 2: Descriptive Statistics of the Data Used

	CO2E	POP	GDP	EI	GDP2	IQ	REC
Mean	0.587213	18.81054	12.41780	6.876875	25.36216	3.387500	85.97016
Median	0.586481	18.80116	12.57843	6.820000	25.51245	3.500000	85.30000
Maximum	0.758677	19.20249	12.84596	7.991667	25.69191	3.900000	94.01500
Minimum	0.324524	17.42560	11.23452	6.040000	24.48095	3.000000	80.64000
Std. Dev.	0.125454	0.324596	0.485938	0.465118	0.319610	0.302410	3.757534
Skewness	-0.747231	-2.480778	-1.543024	0.684435	-1.491853	-0.106212	0.539389
Kurtosis	2.744930	11.63343	4.274898	3.088603	4.187982	1.699532	2.300447
Jarque-Bera	3.064639	132.2043	14.86542	2.508871	13.75174	2.315120	2.204183
Probability	0.216034	0.000000	0.000592	0.285237	0.001032	0.314252	0.332176
Observations	32	32	32	32	32	32	32

Source: Author’s computations

Further, a unit root test was conducted for the entire series to ascertain their stationarity properties using the ADF and the PP tests. The results are in Table 3. The results indicate that all the variables exhibited stationarity at levels except for population and energy intensity, which achieved stationarity after first-differencing them. The series is said to be of mixed order of integration. It is, therefore, suitable for meaningful policy formulation and forecasting. Therefore, this study employed the ARDL approach to estimate the model. This is because, unlike other methods, ARDL could be suitably used, given its flexibility, as it could be employed even when the series does not possess a uniform order of integration.

Table 3: Result of Unit Root Tests

	ADF Unit Root Test results			PP Unit Root Test Results			
Variable	**Critical value at 5% level**	**Critical value at 1st difference**	**Order of integration**	**Critical value at 5% level**	**Critical value at 1st difference**	**Order of integration**	**Decision**
CO2E	-2.981038 (0.0119)	-2.967767 (0.0000)	I(0)	-2.960411 (0.0000)	-2.963972 (0.0000)	I(0)	Reject H_0
POP	-0.528911 (0.8718)	-2.963972 (0.0000)	(1(1)	-2.960411 (0.001)	-2.963972 (0.0000)	I(1)	Reject H_0
GDP	-2.976263 (0.0216)	-2.981038 (0.0003)	I(0)	-2.960411 (0.0441)	-2.963972 (0.0000)	I(0)	Reject H_0
EI	-2.960411 (0.9105)	-2.963972 (0.0000)	I(1)	-2.960411 (0.9105)	-2.963972 (0.0000)	I(1)	Reject H_0
GDP2	-2.963972 (0.003)	-2.963972 (0.0961)	I(0)	-2.960411 (0.0002)	-2.963972 (0.0961)	I(0)	Reject H_0
IQ	-2.960411 (0.003)	-2.963972 (0.0001)	I(0)	-2.960411 (0.0003)	-2.963972 (0.0001)	I(0)	Reject H_0
REC	-2.960411 (0.2537)	-2.963972 (0.0001)	I(1)	-2.960411 (0.2622)	-2.963972 (0.0001)	I(1)	Reject H_0

Note: Values in parenthesis are probability values
Source: Author's Computations using EViews 10

Long-Run and Short-Run ARDL Model Results

The model was estimated using lag 2 as the optimum lag length. The long-run results are in Table 4. Since the F-statistic value of 21.407636 is higher than the Pesaran Upper Bound critical value of 3.28 for the actual sample size and 3.96 for the finite sample size at 5% level of significance, the result indicates a long-run cointegrating relationship among the variables included in the model. This means cointegration between the variables, which suggests no tendency for the variables to drift apart over time.

Table 4: The ARDL Bound Test Results

Level of significance	F-Statistic Value	Lower bound I(0)	Upper bound I(1)
10%		2.27	3.28
5%	21.4076	2.685	3.96
1%		2.794	4.148

Source: Author's Computations using EViews 10

Having established that there is a long-run relationship among the variables, the ARDL long-run and short-run coefficients are estimated as contained in Tables 5 and 6.

Table 5: ARDL Long- run Result

Dependent Variable: Carbon emissions (CO_2E)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
POP	-0.327283	0.171307	-1.910509	0.0768
GDP	4.179036	1.549037	2.697828	0.0173
EI	-0.046860	0.036519	-1.283179	0.2203
GDP2	-0.178108	0.065415	-2.722752	0.0165
IQ	0.085642	0.051197	1.672779	0.1166
REC	-0.041156	0.006168	-6.672335	0.0000
C	-14.07310	10.94008	-1.286380	0.2192

Source: Author's Computations using Eviews

The result of the short-run dynamics of the model are presented in Table 6.

Table 6: ARDL Error Correction Regression

Dependent variable: Carbon emission (CO_2E)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(POP)	-0.217984	0.111733	-1.950941	0.0714
D(GDP)	-3.566062	2.151054	-1.657821	0.1196
D(GDP(-1))	0.122641	0.039041	3.141344	0.0072
D(EI)	0.207581	0.040226	5.160326	0.0001
D(GDP2)	0.158472	0.090650	1.748172	0.1023
D(IQ)	0.041764	0.029916	1.396022	0.1845
D(IQ(-1))	-0.070197	0.026388	-2.660212	0.0187
D(REC)	-0.026207	0.006926	-3.783963	0.0020
D(REC(-1))	0.009982	0.006310	1.581785	0.1360
CointEq(-1)*	-1.723866	0.107555	-16.02784	0.0000
Adjusted R-squared	0.950466		Durbin-Watson	1.676001

Source: Author's computations

Table 7 indicates the coefficient of the error correction term, which depicts the speed of adjustment of any temporary displacement from the long-run equilibrium, which is negative and statistically significant at a 5% level in the short-term. This result implies the possibility of adjustment to long-run equilibrium is obvious. Theoretically, its value falls between 0 and -2. The value of -1.724 means that the system is convergent yet has an oscillatory adjustment process.

The findings show that population has a favorable effect on carbon emissions in both the short- and long-term; however, these effects are not statistically significant. Population growth of 1% would result in short- and long-term reductions of carbon emissions of 0.22% and 0.33%, respectively. This result is contrary to a priori expectations, as ceteris paribus, carbon emissions are expected to increase with a rise in population due to the environmental impact of human activities. However, the result suggests that mere changes in the population size may not be an important determinant in Nigeria. This outcome may be attributed to the recent increase in awareness and adult literacy that may have accounted for the phenomenon. This result agrees with Yang *et al*. (2015) in Beijing but contrasts with Hashmi & Alam (2019), who found its reducing impact in the OECD countries.

Although the influence of GDP in the near term has a positive and considerable impact in the short-term, it reduces carbon emissions by 3.567%. However, in the long run, output benefits environmental pollution, increasing it by 4.18% over time for every 1% growth in GDP. This result demonstrates that given that GDP is a function of production, which produces carbon emissions through industrial expansion, its effects are likely to intensify in Nigeria as new sectors emerge over time, barring the implementation of effective mitigation measures. Additionally, despite inflation and other macroeconomic distortions, the low average real income per person may have had an equal impact.

Energy intensity exhibits a positive and significant relationship in the short-run, but in the long run, it changes to a negative and negligible association by 0.208 and -0.05 units, respectively. The degree of concentration of primary energy sources such as fossil fuel or carbon dioxide for producing clean electricity dictates the carbon footprint in the economy. In the short-term, many Nigerians still rely heavily on primary energy sources with low technological know-how to diversify their energy portfolios. In the long-term, the strict enforcement of environmental laws by the authorities will help reduce this trend. As the share of secondary energy sources deepens, carbon emissions decline in Nigeria. Zhang *et al*. (2023) also obtained a significant positive impact on energy intensity in Morocco from 1990-2020, whereas Yang *et al*. (2015) found a negative effect on China.

Also, while the coefficient of GDP2 is positive and inconsequential in the short-run, it has produced considerable results over the long-term. This outcome suggests that the inverted u-shaped EKC theory might be realized immediately. The negative coefficient indicates a tendency to obtain, in the long-run, a hyperbolic maximum or critical turning point for the EKC curve and shows that the EKC hypothesis only applies to or is true in Nigeria in the long run. Yang *et al*. (2022) also validate the EKC model in China. The findings of the current study also agree with Falade (2022) and Ogundipe (2015) for Nigeria, Acheampong (2021), and Bekun *et al*. (2021). However, this contradicts that of Hilaru *et al*. (2022) for West Africa).

Furthermore, institutional quality lowers carbon emissions through its regulatory framework. This outcome indicates a 0.042 and 0.086 unit positive and negligible influence over the short and long-terms. This is unmistakably a sign of the economy's inadequate institutional foundation. Nigeria has poor regulatory capacity, disregards the rule of law, and exhibits poor governance at all tiers of government. Environmental regulatory laws/agencies, such as the Nigeria Environmental Standards and Regulatory Enforcement Agency (NESREA), are often weak. Citizens merely interpret their actions as “a toothless bulldog”. As such, a mere improvement in the nation’s institutional rating may yield sterile effects. The finding contrasts with those of Obobisa *et al*. (2022), but it is in agreement with those of Egbetokun *et al*. (2020), Salman *et al*. (2019), Karim *et al*. (2022), and Yuan *et al*. (2020).

Consuming renewable energy has both short-term and long-term detrimental effects. As a result, we observe a short-term beneficial effect at an initial lag that is negligible. In the short and long-term, a unit increase in renewable energy consumption would reduce carbon emissions by 0.026 and 0.041 units. This result demonstrates that environmental pollution in Nigeria tends to decline as better energy sources are used. These findings will significantly impact the development and prescription of economic policy will be significantly impacted by these findings. The conclusion supports that of Liu *et al*. (2017). A. Duo *et al*. (2019) Cheng *et al*. Dong and others (2020), Bekun *et al*. (2021), Mirziyoyeva and Salahodjaev (2022), Zhang *et al*. (2018), and Fatima *et al*. (2021). The results are consistent with those of Liu *et al*. (2017), Duo *et al*. (2021), Cheng *et al*. (2019), and Dong *et al*. (2020). Bekun *et al*. (2021), Mirziyoyeva and Salahodjaev (2022). Fatima *et al*. (2021) discovered similar evidence in Morocco, precisely as Zhang *et al*. (2022) did.

The Tapio Decoupling Elasticity Model

Table 7: CO2 emissions and economic growth in Nigeria: Decoupling elastic index and decoupling status

Country	ΔCO_2E	ΔGDP	Decoupling index (*e*)	Status
Nigeria	2.432948	3.634571	0.478562	Weak decoupling

Source: Authors' computations

Given that the decoupling elasticity index value of 0.478562 is less than 0.8 and the change rate of carbon emissions and economic growth is greater than 0 (positive), Table 7 demonstrates that Nigeria has only undergone modest decoupling. This result shows that Nigeria's attempt to keep to the carbon pledge has not yielded the desired result over the years as national productivity continues to outgrow the pace of reduction in environmental damage. This outcome may have been reinforced by the authorities' lack of serious commitment and political will to prioritize environmental matters consciously. Socio-cultural ties, increased poverty, and increased threat of climate change effects may have equally fueled this scenario. It could also be inferred from the above results that the nature of decoupling in Nigeria is absolute, with elements of consumption and production-based. Since actual per capita income has a substantial long-term impact on economic carbon emissions, it is also based on income. This finding partially corresponds with that of Wang *et al*. (2018), who obtained weak and strong decoupling for the USA and expansive coupling with a weak decoupling state for China. It also partially corroborates with that of Wang and Su (2020), who found a stable and weak case for developed countries but no clear case for developing countries. Vavrek and Chovancova (2016) established a link between carbon emissions and economic growth in the V4 countries. Still, Wang and Jiang (2020) earlier validated the strongest and lengthier decoupling scenario for Russia and South Africa. Again, the variation in the choice of method, scope, and sample size may have accounted for the variation in the results obtained. These findings have grave implications for policy prescription in Nigeria.

Robustness Check

This study used a few post-diagnostic tests to assess the model's stability and robustness and the accuracy of the residual estimations. The Breusch-Godfrey Serial Correlation LM test was employed to determine whether autocorrelation existed. The outcome displays an F-statistic of 0.743028 with a probability of 0.4043, leading us to reject the null hypothesis of serial correlation and conclude that there is no evidence of serial correlation among the residuals. The Durbin-Watson value, which is 1.75 and falls within the permissible range of 1.4-2.5, further supports this. Due to the null hypothesis, the Breusch-Pagan-Godfrey test likewise displays a joint statistical value of 1.524 with a probability of 0.217, indicating the lack of heteroskedastic disturbances.

This study performed a few post-diagnostic tests to evaluate the model's stability and robustness as well as the precision of the residual estimations. The Breusch-Godfrey Serial Correlation LM test was used to ascertain whether autocorrelation exists. We reject the null hypothesis of serial correlation and conclude that there is no evidence of serial correlation among the residuals based on the result, which has an F-statistic of 0.743028 and a probability of 0.4043. This finding supports the Durbin-Watson value, which is 1.75 and is within the acceptable range of 1.4 -2.5. The Breusch-Pagan-Godfrey test also exhibits a combined statistical value of 1.524 with a probability of 0.217 under the null hypothesis, demonstrating the absence of heteroskedastic disturbances.

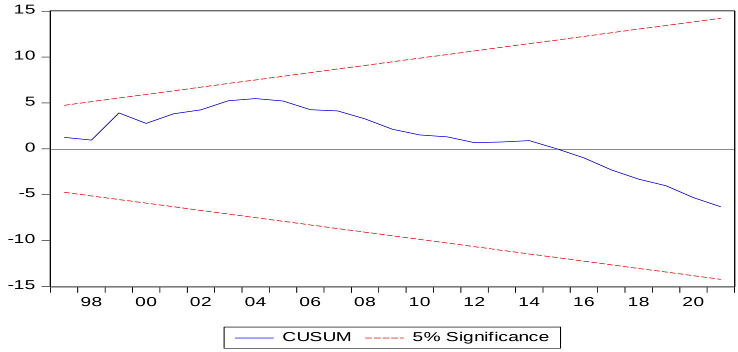

Figure 1 A: CUSUM Graph

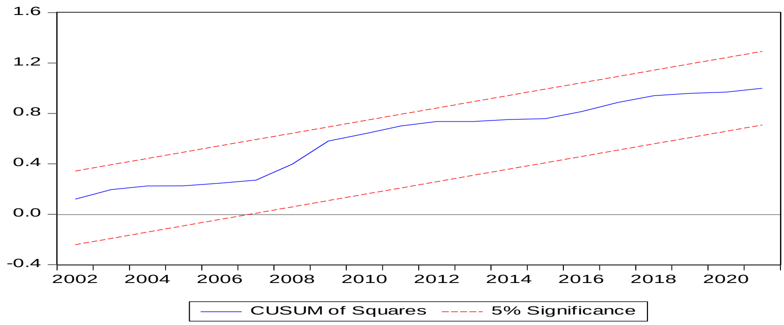

Figure 1B: CUSUM of Squares Graph

Source: Author's Computations using Eviews 10

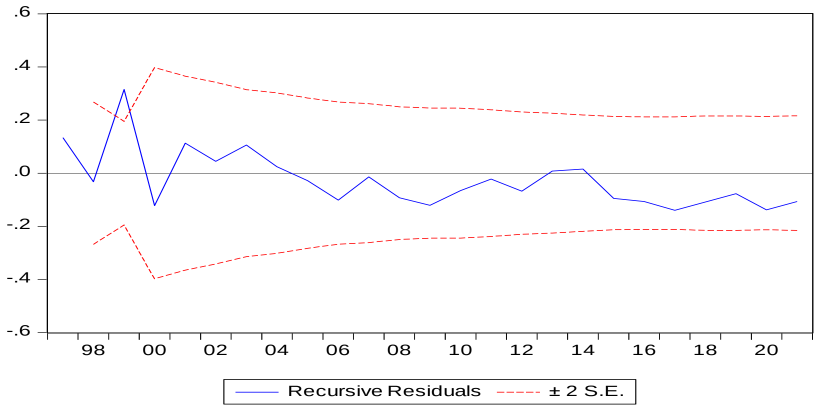

Fig. 2: Cumulative Sum of Recursive Residuals Plot
Source: Estimates by the author

The blue line in Figures 1A and B falls between the two red lines, demonstrating stability in the parameter estimates throughout the investigation, which leads us to accept the null hypothesis. This finding suggests that the system is intact and has no structural flaws. We conclude that the residuals are normally distributed over time given the likelihood of the Jarque-Bera value of 0.96, which is small compared to the Kurtosis value of 3.05 and a very low standard deviation of 0.0324. The model was properly defined and fitted, as seen in Figure 2. This shows that the parameter estimations are steady and trustworthy for use in insightful analysis and the development of policies.

Conclusion and Recommendations

Motivated by the persistent environmental deterioration fueled by climate change effects, this study uses the ARDL model to examine the effects of decoupling carbon emissions from economic growth in Nigeria. The study establishes a weak decoupling state with features of absolute income, consumption, and production base emissions in Nigeria. It submits that the inverted u-shaped EKC hypothesis is valid in Nigeria, but only in the long run, and that renewable energy consumption is a significant adverse driver of carbon emissions, while institutional quality exacerbates it. Overall, institutional quality and renewable energy consumption are a *sin-qua-non* to the green growth initiative of the Federal Republic of Nigeria.

This study considers carbon decoupling from economic growth as a viable option that should be explored by the government to mitigate environmental pressure, even though weak decoupling has been confirmed. It therefore recommends further decoupling of the GDP from carbon emissions. Also, conscious diversification of Nigeria's energy portfolio in favor of renewable sources should be prioritized as a matter of urgency. In addition to strictly enforcing environmental regulatory legislation, the government should increase the quality and effectiveness of institutions to ensure an improvement in environmental quality. Nigeria should uphold the terms of the UN carbon pledge accord to which she also agreed.

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