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Application of Decoupling Approach to Evaluate Electricity Consumption, Agriculture, GDP, Crude Oil Production, and CO_2 Emission Nexus in Support of Economic Instrument in Nigeria

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Abstract: The paper appraised the nexus between electricity consumption, agriculture, GDP, oil production, and carbon dioxide (CO_2) emissions in Nigeria using a decoupling approach. The result showed that agriculture, electricity, and GDP were predictive variables for CO_2 emissions in the Granger causality analysis. The relationship between GDP and CO_2 emissions also indicated that the amount of CO_2 released tends to rise as the economy's output and industrial sectors grow, making GDP and CO_2 emissions increasingly relevant indicators as a driver of CO_2 emissions. Modern agriculture is reliant on large-scale use of fossil fuels and fertilizer production, as well as GHG emissions from crop and livestock production. However, increasing per capita real production can help to enhance quality of the environment, and speed up the uptake of renewable energy which can consequently help to ameliorate global warming. As a result of this study's policy implications, policies in the agricultural sector that could combat CO_2 emissions, including deforestation, land clearing, fertilization with highly environmentally destructive chemicals, neglected integration of agroforestry, and social forestry practices, can help reduce CO_2 emissions in the agricultural sector. In addition, the study recommends that the financial markets' monetary policy should regulate the GDP to charges to compensate for their various sectors' contributions to CO_2 emissions. This investigation might help policymakers in Nigeria to define the CO_2 emission monetary and fiscal strategies. In addition, more alternative energy sources such as biofuels, hydropower, solar energy, and other renewable resources should be embraced in Nigeria as sustainable substitutes for fossil fuels.

Keywords: climate change; renewable energy; non-renewable energy; environmental-economic factors; decoupling method; Nigeria

1. Introduction

Globally, in recent decades, there has been a continuous growth in the contents of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NOx), and sulfur oxide (SOx) [1]. Rapid increase in GHGs concentrations is leading to global warming and climate change due to a consequential increase in the Earth's surface temperature. Among these GHGs, CO_2 has been reported as the key contributor of greenhouse gases, with at least 60% of the total atmospheric concentrations of the GHGs [2]. This rapid rise in the concentration of CO_2 is mainly associated with anthropogenic activities such as fossil fuel burning in the form of crude oil production and electricity consumption for different purposes, including agriculture. Electricity (or energy) consumption in the production process is known as a prerequisite for achieving sustainable economic growth and development [3]. In the global economic sector, energy has been known as a vital factor of production, although the value of its share compared with the value of other inputs' share on the output is about 3.5%, which is low relative to labor and capital [4]. It is essential for the economic endeavors of any nation because all production and consumption activities are directly related to energy consumption which consequently enhances the progress and well-being of the consuming public [5].

In addition to energy consumption and the burning of fossil fuels, other human activities such as agriculture and poor forestry practices have been held responsible for the recent rise in CO_2 emissions. A recent special report from the Intergovernmental Panel on Climate Change (IPCC) revealed that anthropogenic GHGs emissions, especially from agricultural activities, have significantly contributed to climate change [6]. Agricultural production alone accounts for about 10–12% of all anthropogenic GHG emissions, and it continues to increase [7]. It is important to note that the share of total GHG emissions differs based on the continent. For example, Europe accounts for about 11% of the global GHG emissions from agriculture, Asia records about 44%, Africa has 15%, Australia and Oceania 4%, and North and South America are responsible for 9% and 17%, respectively [8]. Nigeria and South Africa account for the highest percentage from Africa's 15% global share from agricultural activities [9]. In a scenario where GHG emissions from agriculture are increased by the amount generated by the rest of the food production sector, it is projected that it could amount to one quarter of all anthropogenic GHG emissions [8,10]. In considering such a high carbon footprint, the ecological performance of food production should be a crucial component of climate change policy [11,12]. Agricultural activities can increase the CO_2 emissions in various ways; for instance, the use of excessive amounts of fertilizer results in pollution harms the climate and the ecosystem [13], slash and burn farming practices that are traditional methods in Nigeria and other developing countries [14], intensive deforestation of the tropical rainforests and savanna belts [15]. These unsustainable agricultural practices lead to a rise in CO_2 emission because excess CO_2 is released into the atmosphere, while the vegetation and the soil, which have high potentials for carbon sequestration, are in turn degraded according to Nwaogu et al. [16]. In Nigeria, for example, more than 70% of the population depends on agriculture for livelihood and income [9]. Poverty and lack of necessary tools made a larger percentage of farmers practice unsustainable farming such as slash and burn, deforestation, and tillage. In addition to causing low soil fertility and poor yields, these primitive farming activities consequently increase the content of CO_2 emitted from the agricultural sector in Nigeria [17,18].

The importance of electricity consumption, agriculture, and GDP on CO_2 emissions has been an intense area of focus for research activities [19–25]. For instance, Suleiman et al. [2] found that in Nigeria, there is a long run relationship between energy consumption, CO_2 emissions, and GDP. The authors found that CO_2 emissions presented a significant positive impact on GDP in both the long and short run. This signifies that an increase in CO_2 emissions facilitates GDP growth in the country. The nexus among electricity consumption, agricultural production, GDP, crude oil production, and CO_2 emission is either unidirectional or bidirectional. For example, a recent study by Odugbesan and Rjoub [25] covering selected countries in Africa, Asia, South America, and Europe revealed both unidirectional and bidirectional causality between economic growth, energy consumption, and CO_2 emissions. The authors reported a unidirectional causality between the variables in Nigeria and Indonesia, while those of Mexico and Turkey showed a bidirectional relationship. Al-Mulali and Sab [26] found that in both long run and short run, the relationship between economic growth and energy consumption is bidirectional. In 2013, Govindaraju and Tang found a significant unidirectional relationship between economic growth and CO_2 emissions, while in India, a study by Ghosh [27] showed a bidirectional relationship between economic growth and CO_2 emissions in the short term.

As an energy-intensive growing economy, Nigeria tends to solely rely on crude oil, which contributes to over 95% of its export earnings and about 85% of government revenues [4]. Nigeria faces the challenging issue of generating more barrels of crude oil to address the energy needs of its dense population, while at the same time battling with the threats of ameliorating greenhouse gas (GHG) emissions with CO_2 as the highest. With either the continuous fluctuation or increase in the price of crude oil at the global market, Nigeria has been subjected to increasing its crude oil production with little or no attention given to renewable energy sources. Overdependence on crude oil as a key energy source causes an increase in CO_2 emission, except such a country reaches a high technological development and per capita income. In this context, it is expedient to study the existing relationships among energy consumption, economic growth, and CO_2 emission in Nigeria. However, some studies on the nexus between electricity consumption, economic development, and environmental implications in Nigeria have been reported [2,22,25,28]. Most of these studies focused on only two of the variables (such as energy consumption and CO_2 emission or economic growth and energy consumption), and they failed to apply an integrated framework in analyzing the causal relationship among energy consumption, economic development, and CO_2 emission. Thus, this present study is significant because (i) it will help to fill the missing gap on the knowledge and nexus among GDP, electricity consumption, agriculture, crude oil production, and CO_2 emission in Nigeria using one economic method called decoupling theory; (ii) it will support existing information by exposing the threats of some major socioeconomic activities (such as crude oil exploitation and unsustainable agricultural practices) on the environment through the inducement of atmospheric CO_2 in Nigeria; (iii) it will encourage the government and other stakeholders on health and environmental safety to swiftly establish and implement necessary laws, regulations, policies, and actions that will preserve the environment without compromising the country's economic status; (iv) there are scarce studies in the country that focused on similar indices and approach, therefore the present study will serve as a good foundation for future research on this issue.

2. Literature Review

The impacts of greenhouse gases (GHGs) especially CO_2 on our planet, Earth, has been at an alarming rate in the recent decades. High risks and adverse environmental and human health effects associated with elevated rise in CO_2 emissions have led many international institutions and various governments to hold several meetings to ameliorate the problem. For instance, in 1998 in Kyoto, Japan, the United Nations Framework Convention on Climate Change (UNFCC) was held and protocols were established towards stabilizing the GHGs emissions by encouraging different nations to be committed in their goals to reduce their GHG emissions. The legally binding accord was signed by at least 165 countries. In addition, in 2015 in Paris, 189 countries joined the Paris Agreement to combat climate change through reduction in CO_2 emissions. Apart from the above-mentioned summits, there has been many others, yet the issue of climate change is still unresolved. This is partly because the majority of the countries (developed and developing alike) only agreed to be committed in theory and on paper, not in action and practice. Therefore, each nation is facing its own impacts from climate change induced by rise in CO_2 emissions. In Nigeria, for example, it has been forecasted that there may be a rise in sea level up to 0.3 m between 2020 and 2025 and also 1 m by 2050, and temperature may rise by up to 3.2 °C by 2050 [29]. The report emphasized that a rise of 1 m could cause the loss of 75% of the Niger Delta region through flooding. PACJA [30] reiterated that from 2020, if no precautionary measures are taken, about 2–11% of Nigeria's GDP might be potentially lost. Nigeria's average GDP growth has been around 6% since the last decade. The national power grid in Nigeria has low capacity to provide regular electricity, thus the supply of electricity which is supposed to be the main source of energy in Nigeria is epileptic. The consequence of this is a shift from electricity usage to other alternative sources of energy that require exacerbated burning of fossil fuels. This therefore caused a higher increase in CO_2

emissions. The energy consumption index in Nigeria increased from 1.9% in 2009 to 2.8% in 2010, and to more than 3.0% in 2020 [2,31]. This situation led to a consequent increase in CO_2 emissions from 71,505,270 tons in 2009 to more than 85 million tons in 2019 [31]. In sum, the average change of pollutants emitted in Nigeria between 1960 and 2019 was above 51.2% which has growing adverse impacts on climatic scenarios and subsequently elevates global warming. Conclusively, climate change is currently becoming an issue associated with development relative to an environmental issue, as it affects the Nigeria's sustainable development. Liddle [32] reveals that in the coming decades, increase in population could increase industrialization and energy use which in turn will elevate CO_2 emissions. Several studies have been conducted on the implications of population, energy consumption, and economic growth on CO_2 emissions in different countries using different environmental-economic models and approaches [33–36]. For instance, Ohlan [33] examined the roles of population density, electricity consumption, industrialization, and economic growth on CO_2 emissions in India between 1970 and 2013 using the autoregressive distributed lag (ARDL) model. Ohlan discovered that population density, economic growth, and electricity consumption have a significant positive impact on CO_2 emissions.

The decoupling approach can be described as a method of breaking the connection between environmental pressure and economic performance [36]. This means that the decoupling indicator measures the relative growth rate of environmental factors and economical driving forces in space and time. The decoupling analysis could be applied in determining whether a parameter grows (decreases) while another parameter is increasing (decreasing) or decreasing (increasing). In a scenario where both parameters are growing (declining), the decoupling technique can be used to ascertain if the growth (decrease) rate of this variable is faster or slower than that of the other variable. Thus, decoupling analysis is an effective tool to analyze the relationship between two or more distinct parameters. The decoupling method used in this study is preferred to econometric model because their results are precisely determined through the known relationship among the investigated variables without giving room for random variations unlike the econometric model which is known for randomness and elements of uncertainty. Decoupling as an economic model is a good statistical analytical tool that is effective in estimating the probability of an event occurring based on historical data. The decoupling approach is good at studying the economic relationship between different economic indices unlike the econometric model that measures the values of parameters in an economic relationship. In addition, the decoupling method is more suitable for this study when compared with the econometric model which requires significant testing of all the variables before their application. Further, the decoupling approach can be further categorized into "relative decoupling" and "absolute decoupling" when economic productivity increases. Relative decoupling signifies the case in which the growth rate of an environmental parameter is positive and lower than the economic output, whereas absolute decoupling shows a negative growth of ecological pressure. The decoupling approach can be performed in two techniques, namely, the OECD decoupling analysis and Tapio decoupling method. In comparison to the OECD [36] decoupling approach, the results derived from the Tapio decoupling method are often stable and unaffected by changes in statistical dimension as well as providing supplementary details about the decoupling condition. Thus, to further comprehend the cohesion and association between CO_2 emissions and energy consumption, GDP, agriculture, and crude oil production, this work employed the decoupling approach to analyze the decoupling states between the indicators.

Many studies have been conducted using the decoupling analysis method [37–43]. Some authors have researched the decoupling relationship between CO_2 emissions, energy consumption, and economic growth in different regions [38–44]. For example, Tapio was used to investigate the decoupling nexus between electricity consumption and GDP in China and Colombia in different years [38,43,44]. Wang [45] evaluated the correlation between China's electricity use and economic growth based on the OECD decoupling indicator. Further, in China, Chen [46], Liu et al. [47], Gran et al. [48], and Liu [49] applied the Tapio decoupling method to study the decoupling state of regional or urban economic growth and energy consumption. On the other hand, Luciano et al. [50], Liu et al. [42], and Muangthai et al. [51] investigated the decoupling link between CO_2 emissions and GDP using the OECD decoupling index method. Similarly, Freitas et al. [52], Zhang et al. [37], Grand [39], Ronioti [40], and Wu [41] respectively discussed the decoupling relationship and degree of economic growth and carbon emissions in Brazil, China, Argentina, Greece, and the world through the establishment of the Tapio decoupling model. One of the latest studies on the application of the Tapio model was conducted to reflect the relationship between the agricultural CO_2 emissions and agricultural output across the provinces of China [53]. These authors' study revealed that Inner Mongolia, Jilin, Jiangsu, Guangxi, and Xinjiang provinces showed huge emission reduction potential in 2030 when compared with the other provinces in China [53]. Recently, in Bangladesh, the decoupling study of agricultural energy-driven CO_2 emissions from agricultural sector development was performed by Hossain and Chen [54]. Other authors in 2021 reported that improvement in financial development, renewable energy electricity, and human capital index caused a decline in CO_2 emissions [55,56]. In contrast, other studies in South Africa and Europe attested that renewable energy consumption, economic growth, and financial development exact a deteriorating impact on the environment [57,58]. There is a vast body of literature on the use of the decoupling approach in analyzing the relationship between electricity consumption, agriculture, GDP, crude oil production, and CO_2 emissions in different countries with little or none focusing on Nigeria. It is in this context that this work aims at appraising the nexus between GDP and different sectors (such as electricity consumption, agriculture, crude oil production, and CO_2 emission) in Nigeria using the decoupling theory approach.

3. Materials and Methods

3.1. Study Area

Nigeria is a West African country. Nigeria is bordered on the west by the Republic of Benin, on the east by Chad and Cameroon, and on the north by Niger. To the south is the border of the Gulf of Guinea, while to the northeast lies the border of Lake Chad. Adamawa Plateau, Mambilla Plateau, Jos Plateau, Obudu Plateau, Niger River, Benue River, and Niger Delta are all significant landmarks in Nigeria [59]. Nigeria is in tropical and subtropical regions all year round. Nigeria is influenced by four distinct climate zones, arranged in descending order from south to north. The lower Niger River canal runs south through the eastern region of the country and into the Gulf of Guinea. Wetlands and mangrove forests on the south coast produce lowland areas. In the south, these lowlands are hilly and in the north they are plains. Wood veneers can be found in the interior. The total land area is 923,768 square kilometers, with water areas covering 13,000 square kilometers. Petroleum, tin, columbite, iron ore, coal, limestone, lead, zinc, natural gas, hydroelectric power, and arable land are among Nigeria's natural resources [60].

3.2. Data Collection and Data Analysis

The data for this study spanning from 1981 to 2014 were extracted from the World Development Indicators (WDI) database. This period was chosen because (i) it coincided with the most radical transformation in the Nigeria industrial and economic sectors, and (ii) it is the period with complete available data on all the measured indicators. Nigeria became a choice for this study because of its position in the demographic statistics of Africa and the world. Nigeria is the most rapid-growing human population on record. In addition, the position of Nigeria among the global crude oil and agricultural productions cannot be overemphasized. The data used are carbon emission per capita (CO_2), electricity energy consumption per capita (Elec), agriculture value added (Agric) constant 2010 USD, real GDP per capita (GDP) constant 2010 USD, and crude oil production (COP). Annual data of the variables are taken based on data availability. It is important to mention that some limitations of the study were exclusion of data from the solid mining sector and neglect of human population as a factor. Aside from these few limitations, data were successfully collected and collated. We transformed all the variables into natural log by applying a log-linear specification for the empirical analysis to overcome a heteroscedasticity problem and achieved a reliable and consistent result [34]. Past studies documented the importance of the selected variables as determinants of CO_2 emissions. First, the study started with checking the descriptive statistics for the variables and then proceeded with the unit root test. To check for the unit root test, Augmented Dickey Fuller (ADF) and Phillip Perron (PP) were employed. These tests have the following equation.

$$\Delta X_t = \pi_1 + \pi_2 t + \pi_3 X_{t-1} + \gamma_i \sum_{i=1}^{k} \Delta X_{t-i} + \varepsilon_t \tag{1}$$

where Δ is the difference operator; ΔX_t is the first difference from X; π_1 is the intercept; π_2 is the coefficient for trend; π_3 is the coefficient of the lagged value of X; and γ_i is the coefficient for X lag difference. However, the ADF and PP techniques are disadvantaged by their inability to check for structural breaks. This problem is accounted for using advance ADF and Zivot and Andrew test of unit root. The Zivot and Andrews unit root test accounts for a structural break point in the level. It is specified as follows:

$$\Delta X_t = \alpha + \alpha X_{t-1} + bT + cD_t \tag{2}$$

$$\Delta X_t = \delta + \delta X_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \Delta X_{t-j} + \varepsilon_t \tag{3}$$

$$\Delta X_t = \pi + \pi X_{t-1} + ct + dDT_t + \sum_{j=1}^{k} d_j \Delta X_{t-j} + \varepsilon_t \tag{4}$$

$$\Delta X_t = \Omega + \Omega X_{t-1} + ct + dD_t + dDT_t + \sum_{j=1}^{k} d_j \Delta X_{t-j} + \varepsilon_t \tag{5}$$

where D is a dummy showing the shift in mean at each point and DT_t is a trend shift. The criterion for decision goes as follows.

H_0: c = 0; presence of unit root and absence of structural break,

H_1: c $\neq$ 0; trend stationary with unknown time break.

We consider the ARDL technique to evaluate the long run relationship between the variables since the variables are characterized by the presence of structural breaks. This technique has advantages over other methods. Firstly, nested within it are both short-run and long-run parameters. Secondly, it can be employed irrespective of order of integration of variables. Thirdly, it is efficient for small sample size and gives unbiased estimates [38,40]. It also accounts for the problem of autocorrelation. In line with Pesaran's work, the following model is to be estimated in our study.

$$\begin{aligned} CO2_t = \vartheta_0 + & \sum_{i=1}^{p} \vartheta_{i,1} CO2_{t-i} + \sum_{j=0}^{q} \vartheta_{j,2} GDP_{t-j} + \sum_{j=0}^{q} \vartheta_{j,3} Elec_{t-j} \\ & + \sum_{j=0}^{q} \vartheta_{j,4} COP_{t-j} + \sum_{j=0}^{q} \vartheta_{j,5} Agric_{t-j} + \varepsilon_t \end{aligned} \tag{6}$$

where $\vartheta_{i,1}$is the coefficient of the lagged dependent variable; $\vartheta_{j,2}$, $\vartheta_{j,3}$, $\vartheta_{j,4}$, and $\vartheta_{j,5}$ are the coefficients of the GDP, electricity consumption, crude oil production, and agricultural value added, respectively. ε_t is the error term. The estimation procedure begins with the ARDL specification, i.e., Equation (6). The next step is to estimate the Error Correction

Model (ECM) which accounts for the short run dynamics of the variables. This also includes the adjustment parameter from short run to the long run. The ECM is specified as follows:

$$\begin{aligned}\Delta CO2_t = \beta_0 + \beta_1 CO2_{t-1} + \beta_2 GDP_{t-1} + \beta_3 Elec_{t-1} + \beta_4 COP_{t-1} \\ + \beta_5 Agric_{t-1} + \sum_{i=1}^{p} \vartheta_{i,1} \Delta CO2_{t-i} + \sum_{j=1}^{q} \vartheta_{j,2} \Delta GDP_{t-j} \\ + \sum_{j=1}^{q} \vartheta_{j,3} \Delta Elec_{t-j} + \sum_{j=1}^{q} \vartheta_{j,4} \Delta COP_{t-j} + \sum_{j=1}^{q} \vartheta_{j,5} \Delta Agric_{t-j} \\ + \psi ECM_{t-1} + \varepsilon_t\end{aligned} \tag{7}$$

where β_0 is constant, β_1, β_2, β_3, β_4, and β_5 are long term coefficients; ϑ_j represents error correction dynamics; ECM_{t-1} is the error term indicating the adjustment parameter from short run to long run equilibrium level.

Finally, we proceed to check the direction of causality. In this regard, the Granger causality test is employed. This method model is specified as follows.

$$y_t = \sum_{i=1}^{m} \alpha_i y_{t-i} + \sum_{j=1}^{m} \beta_j x_{t-j} + \varepsilon_{1t} \tag{8}$$

$$x_t = \sum_{i=1}^{m} \rho_i x_{t-i} + \sum_{j=1}^{m} \sigma_j y_{t-j} + \varepsilon_{2t} \tag{9}$$

The causality run in either direction or both. This model implies a period value of $x(y)$ causes $y(x)$. β_j and σ_j are measure of influence of $x_{t-j}(y_{t-j})$ on y_{t-j} (x_{t-j}).

If $H_0 : \beta_j = 0$ $(H_0 : \sigma_j = 0)$ is rejected, then this implies Granger causality between the two variables.

4. Results

4.1. Descriptive Statistics, Stationarity, and Correlation Results

The descriptive statistics of the variables were shown in Table 1. The Jarque–Bera test reveals that the variables are normally distributed, except for CO_2 and COP, which are positively skewed.

Table 1. Descriptive statistics for the variables.

Variable	CO_2	Elec	GDP_p	COP	Agric
Mean	11.17896	4.667219	7.451882	14.61208	7.815913
Median	11.41557	4.637483	7.399784	14.60000	7.905411
Maximum	11.78817	5.054953	7.844033	14.78000	8.574667
Minimum	10.42470	4.310673	7.201630	14.46000	7.299648
Std. Dev	0.489239	0.243838	0.226656	0.093110	0.470897
Skewness	−0.355421	0.017379	0.384370	−0.00294	0.154261
Kurtosis	1.460396	1.645694	1.623936	1.946431	1.408644
Jarque–Bera	2.875676	1.835352	2.484512	1.110042	2.627601
Prob	0.237441	0.399446	0.288732	0.574060	0.268797
sum	268.2951	112.0132	178.8452	350.6900	187.5819
Sum Sq. Dev	5.505158	1.367515	1.181577	0.199396	5.100107
obs	24	24	24	24	24

Source: Authors' computation.

All the variables are positively skewed except CO_2 and COP (Table 1). Table 2 on the other hand shows the correlation matrix among the variables CO_2, agriculture, electricity, and GDP. As indicated on the table below, the correlation from CO_2 with agriculture, COP, electricity, and GDP was 0.889, 0.845, 0.760, and 0.839, respectively.

Table 2. Correlation matrix.

Correlation	CO_2	AGRIC	COP	ELEC	RGDP
CO_2	1.000				
AGRIC	0.8890 *	1.000			
COP	0.8456 *	0.8091 *	1.000		
ELEC	0.7609 *	0.9108 *	0.6845 *	1.000	
RGDP	0.8394 *	0.9749 *	0.7453 *	0.9315 *	1.000

Source: Authors' computation. * Statistically significant at $p < 0.001$ level of confidence.

The correlation from agriculture with COP, electricity, and GDP was 0.809, 0.910, and 0.974, respectively. The correlation of COP with electricity and GDP was 0.684 and 0.745, respectively. The correlation of electricity with GDP was 0.931. All the correlations noted in the table below were statistically significant. Further, the autoregressive distributed lag (ARDL) result was significant for electricity consumption and CO2 emission (Table S1 in the Supplementary Materials).

As indicated in the unit root results (Table 3), the ADF results for CO_2, electricity, and agriculture were stationary in first difference while GDP and COP were stationary in level form. Using the Z-A, the variables electricity and GDP were stationary in first difference, while the rest were stationary in level form.

Table 3. The stationarity results for the variables of interests, using the ADF and Z-A tests. Unit root tests results.

	ADF_T			Z-A			
Variable	**Level**	**1st Diff**	**Remark**	**Level**	**1st Diff**	**Break**	**Remark**
CO_2	−2.090407	−4.331513	I(1)	5.358892	—	1999	I(0)
Elec	−2.066594	−5.333021	I(1)	−3.543077	−7.022446	2002	I(1)
GDP_p	−3.881247	—	I(0)	−4.609172	−5.714715	2001	I(1)
COP	−3.679848	—	I(0)	−5.795812	—	2009	I(0)
Agric	−2.370965	−4.393601	I(1)	−6.328174	—	2001	I(0)

Source: Authors' computation.

Table 4 below shows the bounds F-test for cointegration. As indicated below, the F-statistic is greater than both the I(0) and I(1) values at 1%, 2.5%, 5%, and 10%, which entails the rejection of the null hypothesis of non-cointegration. As a result, the error correction model including the short run and long run regressions was desirable.

Table 4. Bound Test.

Bounds Test		
Signif.	**I(0)**	**I(1)**
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37
F-statistic		4.529581
K		4

Source: Authors' computation; Model (1,0,1,2,2).

Tables 5 and 6 show the short run with error correction model and the long run model, respectively. As noted in Table 4, the variables agriculture, electricity, GDP, and CO_2 converge to equilibrium at the speed of 0.587177, or 58.7177%, which is adjustment for a period of up to 1.703 years. In the long run, the impact of the variables on CO_2 was not statistically significant. However, a unit increase in COP, agriculture, and GDP increased

CO_2 by 2.043713, 0.176811, and 3.113737 units, respectively, while that of electricity reduced CO_2 emissions by −2.527638 units.

Table 5. Short run result.

Variable	Coefficient	*p*-Value
D(AGRIC)	−1.069375	0.0352
D(ELEC)	0.191872	0.5076
D(ELEC(-1))	1.271831	0.0023
D(RGDP)	5.107419	0.0022
D(RGDP(-1))	−2.800421	0.0207
ECM(-1) *	−0.587177	0.0001

Source: Authors' computation. * Statistically significant at $p < 0.001$ level of confidence.

Table 6. Long run result.

Variable	Coefficient	*p*-Value
COP	2.043713	0.1109
AGRIC	0.176811	0.8862
ELEC	−2.527638	0.0597
RGDP	3.113737	0.1978
C	−31.4467	0.135

Source: Authors' computation.

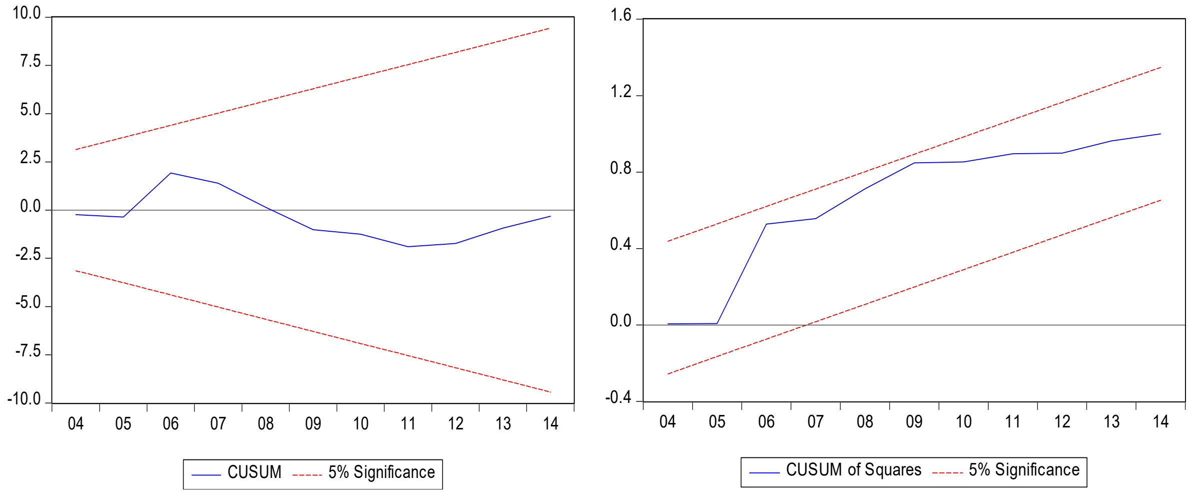
Table 7 below shows the post estimation results for the model for serial correlation and heteroskedasticity. As indicated the F-statistic value for serial correlation is not statistically significant with a probability of 0.3656, implying that the null hypothesis of no serial correlation is not rejected. In like manner, the null hypothesis of no heteroskedasticity using the Breusch–Pagan–Godfrey and ARCH is not rejected with the F- statistic's probability values of 0.8525 and 0.6701, respectively.

Table 7. Post estimation tests.

Serial Correlation LM Test: Breusch–Godfrey			
F-statistic	1.127731	Prob. F	0.3656
ObsR-squared	4.408541	Prob. X^2	0.1103
Heteroskedasticity Test: Breusch–Pagan–Godfrey			
F-statistic	0.50728	Prob. F	0.8525
ObsR-squared	6.943505	Prob. Chi-Square	0.7308
Scaled explained SS	1.752069	Prob. Chi-Square	0.9979
Heteroskedasticity Test: ARCH			
F-statistic	0.187222	Prob. F	0.6701
ObsR-squared	0.20491	Prob. Chi-Square	0.6508

Source: Authors' computation.

The model was tested for stability and structural breaks using the CUSUM test and CUSUM of square tests, respectively (Figure 1a,b). As noted in Figure 1a, the blue margin line lies within the 5% levels (red dotted lines), meaning that the model is stable. In like manner, the CUSUM of square test indicates that the model is not impacted by structural breaks (Figure 1b). All the analysis and post estimation steps suggest that the model is well fitted and appropriate.



(**a**) (**b**)

Figure 1. The model test for stability and structural breaks using (**a**) the CUSUM test; (**b**) CUSUM of square tests.

4.2. Causality Test Result

The causality test of the variables in estimating their impact on CO_2 emissions is shown in Table 8. With *p*-values of 0.0031, 0.0056, and 0.0368, respectively, agriculture, electricity, and GDP were shown to be statistically significant predictors of CO_2 emissions in Nigeria.

Table 8. Granger causality tests.

Granger Causality Test					
Hypothesis	**F**	***p*-Value**	**Hypothesis**	**F**	***p*-Value**
$CO_2 \overset{GC}{\Rightarrow}$ Agric	8.26643	0.0031	Agric $\overset{GC}{\Rightarrow} CO_2$	0.86629	0.4383
COP $\overset{GC}{\Rightarrow}$ Agric	1.59097	0.2326	Agric $\overset{GC}{\Rightarrow}$ COP	3.04998	0.0738
Elec $\overset{GC}{\Rightarrow}$ Agric	1.80116	0.1952	Agric $\overset{GC}{\Rightarrow}$ Elec	3.50468	0.0532
RGDP $\overset{GC}{\Rightarrow}$ Agric	0.76146	0.4823	Agric $\overset{GC}{\Rightarrow}$ RGDP	4.38699	0.0291
COP $\overset{GC}{\Rightarrow} CO_2$	0.52149	0.6028	$CO_2 \overset{GC}{\Rightarrow}$ COP	1.11883	0.3496
Elec $\overset{GC}{\Rightarrow} CO_2$	0.40343	0.6743	$CO_2 \overset{GC}{\Rightarrow}$ Elec	7.12835	0.0056
RGDP $\overset{GC}{\Rightarrow} CO_2$	0.62832	0.5454	$CO_2 \overset{GC}{\Rightarrow}$ RGDP	4.03691	0.0368
Elec $\overset{GC}{\Rightarrow}$ COP	0.34000	0.7165	COP $\overset{GC}{\Rightarrow}$ Elec	0.87768	0.4338
RGDP $\overset{GC}{\Rightarrow}$ COP	4.82771	0.0219	COP $\overset{GC}{\Rightarrow}$ RGDP	1.96319	0.171
RGDP $\overset{GC}{\Rightarrow}$ Elec	4.88593	0.0211	Elec $\overset{GC}{\Rightarrow}$ RGDP	1.01821	0.3822

Source: Authors' computation.

5. Discussion

Agriculture, crude oil production, electricity, and GDP all move in the same direction with CO_2 since all the variables were statistically significant. Agriculture is more closely related to electricity than the other components. While crude oil output was mostly related to GDP, GDP was primarily related to agriculture. As a result, it is consistent with the findings by other scholars which affirmed that agriculture is a significant factor in CO_2 emissions when considering economic growth [61]. This means that there is a proportional link between CO_2 emissions and agricultural investments, with mechanized and commercial agriculture being a major contributor in emitting CO_2 into the atmosphere. The relationship between GDP and CO_2 emissions also indicates that the amount of CO_2 released tends to rise as the economy's output and industrial sectors grow, making GDP and CO_2 emissions increasingly relevant indicators as a driver of CO_2 emissions. This is in line with the Edoja's results [62]. The evidence presented by Vasylieva [63] is consistent with this study, and it also emphasizes that electricity has been an important variable connected with the release of CO_2 emissions due to the combustion of fossil fuels in generating electrical energy. Furthermore, the report of Abumunshar [64] was compatible with this study, revealing that crude oil production was correlated with various rates of oil consumption, significant amounts of oil combustion, and varying amounts of CO_2 emission.

For advancing with process, unit root tests are necessary to acquire the maximum integration order (d) of variables utilizing Augmented Dickey–Fuller (ADF) and Z-A tests. As a result, according to the literature, unit root tests are explicitly developed for the null hypothesis that a series I(1) has low power to reject the null hypothesis (Engel and Granger) [65]. From this study, CO_2, electricity, and agriculture variables were stationary while crude oil production and GDP were stationary with ADF and Z-A tests, respectively. The report by Maji [17] stresses that CO_2 emission, electricity, and agriculture were cognitive variables associated much more with each other in considering CO_2 emission. GDP and crude oil production, on the other hand, were considered as factors that are cognitive as a determinant of CO_2 emission, which is consistent with the report of the World Bank (Magazzino) [66]. The outcome of the study is that a rise in agricultural added value contributes to CO_2 emissions, which contrasts with the findings of Dogan and Seker [60,67], who found that an increase in agricultural value added reduced emissions in North African nations from 1980 to 2011. Modern agriculture relies on the large-scale use of fossil fuels and fertilizer production and GHG emissions from crop and livestock production. However, increasing per capita real production can help enhance the quality of the environment, and speeding up the uptake of renewable energy can help battle global warming. In this study, energy was also highlighted as a contributory variable to CO_2 emissions, despite data from Jebli and Youssef [68] showing that electric power derived from non-renewable resources is one of the primary sources of emissions in most acknowledged energy use.

Strong decoupling was recorded between CO_2 and GDP, and these displayed expensive decoupling association in the short run. The result shows that CO_2 was increasing at a maximum level as GDP. This finding was in agreement with the report from other studies [17]. In this decoupling, the CO_2 is correlated with GDP. When the economy rises, CO_2 also rises. The influences that encourage the decoupling state can offset only a small portion of its restraining effects. Similarly, strong decoupling was revealed between crude oil production and CO_2 emissions. This indicated that CO_2 emissions became elevated with a rise in crude oil production especially at a short period. This could be attributed to the fact that the activities and processes involved in the exploration and exploitation of the non-renewable fuels released excess CO_2, thus exacerbating the atmospheric content of CO_2. In contrast, a weak decoupling was observed between electricity consumption and CO_2 emissions. This means that though electricity was used, CO_2 emissions from the electricity sources were lower when compared with those emitted from crude oil production.

The findings of this study, which used the Granger causality test to evaluate if there is feedback or causality from one variable to another, as well as the dimension of such causation [69], are as follows. Agriculture, electricity, and GDP were shown to be predictive variables for CO_2 emissions in the Granger causality study. Furthermore, according to Cline [70], baseline global warming by the 2080s will result in a 16% drop in GDP (output per hectare) without carbon fertilization and a 3% reduction if carbon fertilization benefits occur. In this study, energy emitted from electrical sources was also claimed as a predictive cause of CO_2 emissions, which is consistent with the findings by Jeli et al. [71], who stated that non-renewable energy sources such as electricity and heat are among the world's leading causes of CO_2 emissions. Countries that have a poor standard of living, have crucial need for carbon-sequestering resources, such as the natural resources [72]. As a result, this study emphasizes the low Gross Domestic Product as a determining variable of CO_2 emission. As a result, it is clear that various characteristics or variables influence CO_2 emissions.

6. Conclusions

The decoupling approach is a good method for achieving efficient output through economic instruments. This is because the decoupling approach is a robust system that enables the integration of multiple economic and environmental indicators. For example, agriculture, power, GDP, and crude oil production were investigated as determinants of CO_2 emissions in Nigeria. The stationary form in the dataset series was tested using the ADF and Z-A unit root tests in this study. The data show that a 1% increase in crude oil Production, agriculture, and GDP causes CO_2 emissions to rise by 2.04, 0.18, and 3.11 units, respectively, whereas electricity reduces CO_2 emissions by -2.53 units. As a result, the Granger causality test was used to determine the direction of causation among studied variables. The Granger causality test revealed that the variables have a unidirectional causal relationship. CO_2 and agriculture, on the other hand, have a directional causation. According to the findings of the study, agriculture should be one of the sectors where CO_2 emissions could be reduced by activities such as mechanization, land clearance, fertilization, and others. The loss of CO_2 sequestration components was prone to significant loss owing to a variety of agricultural practices, whether direct, indirect, or cumulative. As a result, the Nigerian government has been made aware of how agricultural techniques used by Nigerian farmers do not help CO_2 emissions, but rather reduce them. Furthermore, because CO_2 and electricity are closely related, our findings suggest that efficient energy use from fossil fuels and conversion to other energy sources to renewable sources can significantly minimize CO_2 emissions in the country. Furthermore, CO_2 and GDP were found to have a direct causal relationship. As a result of the findings, CO_2 emission reduction guidelines based solely on energy utility and GDP may not prove to be effective, as expansion is an important component of the CO_2 emission mitigation approach. As a result, financial growth is extracted to improve CO_2 emission with reference to the many sectors of Nigeria's economy growth.

7. Recommendations

Findings from this study prompt recommendations on policies in the agricultural sector that could combat CO_2 emissions, such as deforestation, land clearing, fertilization with highly environmentally destructive chemicals, neglected integration of agroforestry, and social forestry practices, can help reduce CO_2 emissions in the agricultural sector. Meanwhile, the financial markets' monetary policy regulates the GDP to charge to compensate for their various sectors' contributions to CO_2 emissions. However, the Nigerian financial division and its numerous sectors have had a non-significant volume component in recent years and would have to go through an incredibly stretched mode before reaching its ideal position. In this regard, the government may help the financial markets by releasing a robust strategic plan that creates long-term value for CO_2 emission reductions and continual provisions for the growth of fresh technology instruments that can help steer a country with low carbon concentrations. Furthermore, well-organized capital and financial markets may be an alternate policy option that is acceptable. As a result, organizations may reduce their liquidity risks and activate required funds via portfolio divergence, which would be extremely beneficial in the long term in creating a broad technical base. Furthermore, this study suggests that further study is needed to investigate which aspects of the agriculture sector, electricity consumption and its rates, and GDP are most important in terms of CO_2 emissions in Nigeria. Then, using a scientific framework, it should be investigated how various other variables being researched may better their actions to contribute to CO_2 emission reductions. This might help policymakers in Nigeria define CO_2 emission monetary and fiscal strategies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14063226/s1, Table S1: Autoregressive distributed lag (ARDL) Result.

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