Research Article

The Empirical Assessment of Renewable Energy Consumption, CO₂ Emissions and Economic Growth of Nigeria

Muhammad Mustapha, Mehdi Seraj[*], Huseyin Ozdeser

Department of Economics, Near East University, Nicosia, North Cyprus
E-mail: mehdi.seraj@neu.edu.tr

Abstract: The study captures the interconnection between economic growth, environmental impact, and energy use well as the role renewable energy and environmental practices play in these dynamics. which an investigation we carried out using data from the World Bank Development indicator. The link that connects CO2 emissions, renewable energy, fossil fuel energy, and economic growth in Nigeria between 1990 and 2020 was examined in this study. Due to the influence of other elements that different countries embrace, such as technology development and energy efficiency, the relationship is not always clear-cut. The result of the bound test was in favor of the variables' cointegration. The long-term equilibrium correction was calculated using the error correction model (ECM). This finding agrees with the majority of research findings in the body of literature that has already been published that discovered a negative impact between C02 emission and Renewable Energy both in the short and long term. Additionally, there is a short-term significant connection between CO2 emissions and fossil fuel energy, but this relationship will converge to a negative one over time (long run). Additionally, C02 emissions have a detrimental long-term and short-term impact on GDP. As a result, this study suggests using cleaner technology to maximize the benefits of renewable energy sources, particularly wood biomass, while reducing their drawbacks.

Keywords: renewable energy consumption, economic growth, CO2 emission, GDP

1. Introduction

The energy sector remains a very important key toward the development of all areas of the other sectors that makes up the economy. There certainly are assorted energy and environmental challenges to encounter around the world, including environmental economics, and environmental science among others. Countries like Turkey, Poland Brazil, etc. currently depend significantly on coal as a main source of energy. This can be related to its allocation and affordability in a certain region. This led to nations participating in industrial manufacturing that consumes greater energy. Moreover, energy related to CO2 represents approximately two-thirds (2/3) of all greenhouse gas emissions. According to (Akinwale1, Jesuleye1, & Siyanbola1, 2013), the stats around showed the world approximately 1.5 billion people which amounts to 22% of the population in the world (2013) lack access to electricity, mostly in urban places in sub-Saharan Africa and South Asia. Despite the extensive utilization of modern technology, it is predicted that approximately 1.3 billion individuals will not have energy access by 2030. This has driven developing nations to implement policies that may increase their electricity capacity productivity independent of their sources.

Several authors have addressed the association and relation between sustainable energy and economic growth but also the direction and connection between the two independent values have been widely addressed. A significant key in formulating policy recommendations for the government is the intent of assessing the causal direction. This helps policymakers develop future energy policies, such as increasing investments in the sector when sustainable energy drives economic expansion or implementing programs to reduce renewable energy consumption. Either one-way or two-way causality is possible. Thus, no clear causation between the two factors. A causal link may exist between rising economic growth and renewable energy consumption. When the utilization of sustainable energy is connected causally to economic growth, it signifies policies to minimize electricity consumption could well be adopted, and applied with almost no negative effect on economic growth, whereas when the causal chain links economic growth to sustainable energy, could well be adopted and applied with almost no negative effects on economic consumption.

The Nigerian government aims to have Nigeria among the top 20 economies by 2022, and the energy sector to be one of the key areas of constriction of development. Meanwhile, some Nigerian citizens believe that it's not necessary to change policy as there is low electricity consumption and generation in the country, while others argue that energy policy will be capable of addressing the problems facing the electrical sector, the development of electricity generation, which could be an impact on the economic development in Nigeria. And due to the country's generation gap, a large number of families and businesses now produce their produce electricity by utilizing petroleum fuels. This tendency has had a significant impact on carbon dioxide (CO_2) pollution in contrast to global warming and climate change. Among the many pollutants causing climate change, carbon dioxide (CO_2) pollution amounts to more than 75% of greenhouse gas pollution, with the energy sector producing around 80% of them. The link between energy consumption, climate contamination, and economic expansion has been the focus of two distinct bodies of literature up until recently. (Akbostanci, Turut-Asik, & Tunc, 2009) did research that concentrated on the link between economic growth and environmental pollution.

Oversight of the Nigerian electricity sector

Since the first electricity station was put in place in Lagos under the control of public works and Transport, one might say that electricity production in Nigeria officially started in 1898. Nevertheless, The Nigeria Electricity Supply Company (NESCO) began providing electricity in Nigeria in 1929 when a hydroelectric facility was built at the kurta in Jos, Plateau State. Ever since it undertook a series of revisions to link the entire country to the national electricity network. The Electricity Company of Nigeria ordinance, No.15 of 1950, was enacted by the British colonial government in 1950. The goal of the law was to consolidate the electricity supply to increase its effectiveness. In 1962, the first 132kv power grid was installed, and the Niger Dam Authority (NDA) got created. The ENC and NDA were subsequently combined to become the National Electric Power Authority (NEPA) by 1972 The estimated supply of power during the time of such an installation was 1030mw, whereas the highest create and operate a national electricity distribution system that was effective, regulated, and cost-effective thanks to the statute creating NEPA. Including an increase in tariffs, NEPA was largely industrialized in 1988, The Shiroro power plant was put in to serve in 1990. The plant added 600mw to the country's electricity supply. The Electric Energy Policy Reform Act 2005 was passed as part of the reorganization. The former NEPA is now called as Power Holding Company of Nigeria (Aladejare & Samson, 2014). Nigeria has had inconsistent and insufficient electricity supplies. The issues are ascribed to the electricity sector's failure to make sufficient money to keep the system running as a result of undercharging for electrical service. The sector's inability to produce sufficient revenue to pay operational expenses, as well as the significantly large investment requirements (NERC,2013) According to (Amadi S. , 2015), the lack of cost-reflective pricing was primacy cause of the energy industry's inability to deliver effective services. Through the creation of usable resources from trash, the world is moving closer to low-carbon energy (H, LIU, & Q, 2020). Unfortunately, it appears that Nigeria has only made use of its abundant renewable resources to produce electricity to address the issue of persistent water interruption in the nation (Oke, 2016). Nigeria's lack of power has hampered the country's economic development (OM, GA, & Z, 2017). Nigeria produces about 4000MW of power, which is insufficient to meet the needs of its population of over 206.14 million. Likewise, the necessity to fulfill growing needs necessitates the implementation of possible alternatives, including the conversion of trash to power to solve the economy's lack of reliable power sources (JO, EU, & ET, 2012; p, Efobi, E, & P, 2019)

This paper seeks to examine the connection between Nigeria's economic development, use of renewable energy, and carbon pollution. The connection in cause and effect between expansion, power, and pollution. For example, a significant connection between production and power use has linked both ways that the scarcity of it harms growth. Moreover, one-way causation from the production of electricity would indicate that programs for electricity reduction may be implemented without harming growth.

This research brings out different studies from the researcher on the view of renewable energy, CO_2 emissions, and economic expansion. Different research on the topic is the energy sector and economy are relatable,

serve beneficial purposes for the nation, and have nonrenewable effects on a nation in terms of pollution. The researcher's studies that support the renewable energy sector and economic expansion are relatable hypotheses including (Ito, 2017), (Shahbaz M., 2012), (Heidari H., 2015), (Saidi & Hammami, 2015), and (Al-Mulali & Sab, 2012). For beneficial purposes (Menegaki & Tugcu, 2016), (Nyiwul, 2017), (Govindaraju & Tang, 2013), and (Yang & Zhao, 2014). Having nonrenewable energy and causing pollution (Lean & Smyth , 2010), (Yao , Feng, & Hubacek , 2015), and (Inglesi-Lotz & Dogan , 2018), The main cause of this research is to investigate the correlating connection between economic development, CO2 emission, and energy utilization in Nigeria, various researchers identified that environmental pollution or corruption is caused by not using renewable energy sources and being environmentally friendly. The researcher's study provides new insight to policymakers to devise a new policy to secure a suitable environment and economic development.

2. Literature Review

The Relationship between Economics Growth and Renewable Energy Consumption.

The research on the causality impact of macroeconomic factors on energy usage has exploded in recent years. Energy is seen as a crucial contributor to the economic development of a country, as well as a crucial tool for overall development and a basic good (Ito, 2017). Researchers are interested to study of the relationship linking renewable energy and economic development. A study by Shahbaz (2012) discovered a constant association linking energy consumption and economic development. Another research on five ASEAN nations revealed a negative relationship between economic growth and energy use (H, T, & L, 2015). This study took a different approach from previous research that concentrated on how economic growth affects energy utilization, the study of (K & S., 2015) revealed how energy consumption is impacted by economic growth. This study discovered that economic growth had a favorable and highly meaningful impact on renewable energy consumption.

(M & H., 2012) Together with (U & C., 2012) research and study agreed with each other, leading to the discovery of a practical connection between economic growth and renewable energy. The temporary connection between basic energy use and economic development was also discovered by the study. (N. & T., 2016) used the sustainable economic welfare growth (ISEW) index as a stand-in for the gross domestic product (GDP), which was probably skewed aside from several other research on energy utilization and economic development because it discovered that renewable energy Granger causes ISEW and vice versa. A U-shaped inversion association involving economic development and renewable energy was discovered in another investigation (R, M, & I, 2017). The study (L, 2017) focused on the utilization of renewable energy in the Sub-Saharan Africa (SSA) region and concluded the economic expansion had a beneficial ion the consumption of renewable energy. The study then asserted that current economic expansion in the Sub- Saharan region doesn't correspond to the economic growth in progress and energy consumption, which is at odds with findings from other developing nations in the literature.

The Relationship between Economic Growth and CO2 Emissions

Economic development and CO2 emissions have a considerable one-way link, according to various research (C & F, 2013). However, the research by (S, 2010) shows a two-way relationship between India's economic expansion and short-term CO2 emissions. (Z & Y., 2014) Conducted a study that supported the findings made by (Govindaraju V. C., 2013). According to the study, although there was a one-way relationship between CO2 and renewable energy consumption there was a two-way association between CO2 and economic growth. Additionally, (Chang, 2010) studied China as a developing economy and discovered that the nation's high CO2 emissions were brought on by its rapid economic development. (K & Y., 2010) Supported the study in which a one-way relationship between CO2 emissions and economic development was discovered. Comparable research was conducted by (Farhani;, Chaibi;, & Rault, 2014)and focused on 11 Middle East and North Africa (MENA) nations. The study revealed that the outcome was enhanced and that urbanization had a favorable impact on CO2. The study by (Niu , Ding., Niu, Li , & Luo, 2011) 2121–21317 on eight Asia-Pacific nations showed a structure's long-term link between CO2 emissions, renewable energy consumption, and economic growth.

There is a correlation between renewable energy consumption, CO2 emissions, and economic growth, according to research (Chang, 2011) (Heidari , Katircioğlu , & Saeidpour , 2015); (Magazzino, 2016)and, (Cai, Sam, & Chang, 2018)research (Halicioglu, 2009)conclusion that money has a greater impact on CO2 emissions in Turkey than renewable energy consumption. (Pao & Tsai , 2011) discovered that (Halicioglu , 2009) study on the economy of Brazil has comparable findings. However, CO2 emissions and energy consumption was shown to have a considerable impact on the nation's economic growth in the ASEAN countries in a different study by (Lean & Smyth , 2010) And (Gozgor, Lau, & Lu Z, 2018)confirmed the findings of earlier research by demonstrating the short-and long-term effects of CO2 on Turkey's economic growth, whereas (Jafari, Ismail, Othman, & Mawar , 2015) discovered a similar directional relationship between renewable energy consumption and CO2 emissions.

(Menyah & Wolde-Rufael , 2010) found that there is a long-term, unidirectional causality relationship between renewable energy consumption, CO_2 emissions, and economic growth in their research of South Africa. This result is supported by (Pao & Tsai , 2011). According to (Menyah & Wolde-Rufael , 2010) analysis, nuclear consumption can reduce CO_2 emissions. This theory is also supported by (khoshnevis & Shakouri, 2018), who came to the same conclusion in their analysis and maintained that the key factor influencing the rise in CO_2 emissions is still economic growth. Utilizing coal and oil as the source of energy, (Acar & Lindmark , 2017) looked at how CO_2 emissions were linked in OECD nations. Two different periods were created by the researchers to separately work on the different study course. The first-time span is the OPEC oil price, during which the OECD's oil strategy was largely influenced by cold war economic worries and concerns about energy security. Across many OECD nations, environmental policies increased over the second time frame. Due to these situational variations, coal and oil exhibit different personalities during the two different economic expansions. According to (Asumadu-Sarkodie & Owusu, 2017A; Asumadu-Sarkodie & Owusu , 2017B), environmental deterioration, energy consumption, and economic growth all have correlating relationships (long-run equilibrium). According to the analyzed conflict of difference opinion results, energy growth and economic consumption both cause an increase in environmental pollution at various percentage rates respectively. They suggested that Sierra Leone's environmental pollution could be stopped in the coming year to come by adopting clean energy or finding renewable energy sources that contain environmentally friendliness. (Destek, 2017) found that nations that consume non-renewable, renewable energy have a beneficial impact on economic growth. (Lei, 2017) used different time duration data for an econometric model spanning the years 1995 to 2014 to ascertain a series of information about the relationship between environmental pollution, transportation, and economic growth in Beijing. The estimated findings indicated that CO_2 emissions and transport have a favorable impact on economic growth. According to. (N, JE, K, & Y, 2010) and (Zoundi, 2017), the use of renewable energy was constrained by a variety of factors, including the rate of economic growth in developing nations. According to (Shahbaz S. a., 2018), the initial high cost of establishing renewable sources of energy discourages developing nations from making investments in these sources. However, encouraging renewable energy in some developing nations may short-circuit their ability to advance economically. According to (Inglesi-Lotz & R, 2018), developing nations face difficulties in transitioning their electricity consumption from non-renewable natural gas to renewable energy sources. Because of advances in technological and economic factors, the non-industrialized and industrialized nations have various energy complexes.

The connection linking CO2 emissions, Economic growth, and Renewable Energy consumption

Due to the fact that increased productivity from increased renewable energy consumption also increases pollution, there is a significant connection linking energy utilization and CO_2 emissions which has been researched by (Dritsaki and Dritsaki, 2014; Farhani and Rejeb, 2012; Menyah and Wolde-Rufael, 2010; Pao and Tsai, 2010; Papież, 2013; Saidi and Hammami, 2015). In South Africa from 1965 to 2006, Menyah and Wolde-Rufael (2010) looked into the relational connection linking economic development, CO_2 emissions, and energy utilization. They found a unidirectional link that runs from the emission of pollutants with the use of a bound test approach for co-integration. It goes from energy utilization to economic development, and lastly energy utilization to CO_2 emission with the absence of feedback. Economic growth may need to be sacrificed, and energy consumption may need to be decreased at the rate of units of production, or both, according to the statistical analysis data which implies that South Africa may have to a percentage of its economic development and reduce energy utilization. On the other hand, creating a renewable energy source alternative to coal, the largest contributor to CO_2 emissions, is conceivable to both supply nations' energy demands and decreases CO_2 emissions over the long term. Pao and Tsai (2010) assessed the changing cause and effect between pollution, energy consumption, and production on the panel of BRIC nations from 1971- 2005. According to the co-integration analyses, there's a complex mixture of causal relationships linking energy utilization and emissions as well as a stable two-way causal connection between energy consumption and production. (Farhani & Rejeb, 2012) analyzed the causal connection linking energy consumption, GDP, and CO_2 emissions for 15 MENA nations including the yearly period 1973-2008, this study utilizes the panel combined tests, panel causality processes, and panel causality test. The analysis has determined that there is no clear correlation between GDP and energy consumption or between CO_2 emissions and energy use. It is possible that this relationship may change in the future, energy utilization and GDP are causally associated in one direction, additionally, the study employs the use of the Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) methods to evaluate the long-term connection between these three variables in order to account for country heterogeneity and endogeneity bias in regression analysis. Utilizing regression analysis for the Visegrad Group nations from 1992-2010 and panel vector error correction modeling approaches, (Papież, 2013) recently study examined the causal connections between CO_2 emissions, utilization of renewable energy, and economic expansion. The EKC theory cannot be supported by the outcomes of the Visegrad Group nations. The short-term Granger causality test suggests that there is a

mutual influence between CO2 emissions and economic growth, as well as a unidirectional link between the use of renewable energy and both CO2 emissions and economic growth in Visegrad Group nations

Numerous studies have attempted to examine the connection between renewable energy consumption, economic growth, and environmental harm, particularly in developing countries. Dritsaki and Dritsaki (2014) utilized panel root testing, panel cointegration techniques, and panel data estimation testing to investigate the relationship between energy consumption, GDP, and CO2 emissions in Greece, Portugal, and Spain from 1996 to 2009. The FMOLS and DOLS methods were applied to analyze the long-term correlation between the variables. The results indicate that there is a reciprocal relationship between the variables in the short-term. In the long-term, there is a two-way causality between CO2 emissions and renewable energy consumption, as well as a mutual causality between renewable energy consumption and economic growth.

3. Data and model specification

This research looks into the link connecting Nigeria's economic progress, trade liberation, renewable energy, and non-renewable to carbon dioxide emissions thirty-one years from 1990 to 2020 were covered by annual data. Data are gathered from the World Data Bank, a dependable index of development indicators. The five variables' interactions were empirically investigated using an interactive econometric model. Description of variable definitions;

Carbon Dioxide Emission (CO2)

Carbon dioxide (CO2) emissions are a major contributor to greenhouse gas emissions, which are responsible for climate change. These emissions are primarily produced by the combustion of fossil fuels such as coal, oil, and natural gas. In addition to CO2, the burning of these fuels also releases smaller amounts of other greenhouse gases, such as nitrous oxide (N2O) and methane (CH4). CO2 emissions are measured in metric tons and are a key indicator of a country's environmental impact.

Gross Domestic Product (GDP)

Gross Domestic Product (GDP) is a comprehensive measure of a nation's overall economic activity. It represents the total monetary value of all finished goods and services produced within a country's borders in a specific time period, typically annually or quarterly. GDP includes the sum of consumption, investment, government spending, and net exports (exports minus imports). It is commonly used to gauge the health of a country's economy and to compare economic performance between different countries or time periods.

Renewable Energy Consumption

Renewable energy consumption refers to the use of energy sources that can be replenished naturally within a human lifetime. These sources include geothermal energy, wind, solar power, and hydroelectric power. Renewable energy is considered more sustainable and environmentally friendly compared to fossil fuels, as it produces little to no greenhouse gas emissions. The use of renewable energy is measured in terms of the total amount of energy produced and consumed from these sources, and it plays a crucial role in reducing a nation's carbon footprint.

Fossil Fuel Energy Consumption

Fossil fuel energy consumption involves the use of non-renewable energy sources that are extracted from the Earth's crust. These fuels include coal, oil, and natural gas, which are burned to produce energy. Fossil fuels are a significant source of greenhouse gas emissions, contributing to climate change and environmental degradation. The consumption of fossil fuels is typically measured in terms of energy output (e.g., BTUs or kilowatt-hours) and is a critical factor in assessing a country's energy policy and environmental impact.

Trade

Trade refers to the voluntary exchange of goods and services between different economic entities or individuals. This exchange can occur domestically or internationally and is based on the principle that both parties involved in the trade believe they will benefit from the transaction. Trade is a fundamental component of a nation's economy, contributing to its GDP. It includes imports (goods and services brought into a country) and exports (goods and services sold to other countries). Trade policies and agreements can significantly affect a country's economic growth, employment rates, and international relations.

CO2: Carbon Dioxide Emission (Kilo Tons)
GDP: Gross Domestic Product (Current US$)
REC: Renewable Energy Consumption. (% of Total Energy Consumption)
FFE: Fossil Fuel Energy (% of Total Energy Consumption)
TRA: Trade (% of GDP)

This study employs four variables. C02 emission is the dependent variable while GDP, Renewable Energy Consumption, fossil fuel consumption, and trade liberation are the independent variables. Equation 1 defines C02 as a function of GDP, REC, FFE and TRA.

$$CO2 = F\ (GDP,\ REC,\ FFE,\ TRA) \tag{1}$$

Equation 2 is the time series variable equation.

$$C02_t = \beta_0 + \beta_1 GDP_t + \beta_2 REC_t + \beta_3 FFE_t + \beta_4 TRA_t + \mu_t \tag{2}$$

Where:

β_0= Coefficient of intercept/constant

$\beta_1 - \beta_4$= Coefficients of the exogenous variable.

μ = error term

t = time series data

To eliminate heteroscedasticity and determine the rate of rise of significant variables, all variables were logarithmically converted. Using the necessary logarithms from Equation 3, REC, FFE, and TRA were log-transformed, while CO2 emissions and GDP were transformed.

$$LNC02_t = \beta_0 + \beta_1 LNGDP_t + \beta_2 REC_t + \beta_3 FFE_t + \beta_4 TRA_t + \mu_t \tag{3}$$

To evaluate the connotations between the variables in Equation 4 for this inquiry, we used constrained ARDL approaches. ARDL models are finite element models that incorporate new variables into their calculations. Concrete and precise short-term results are achieved (Ghosh 2009). The ARDL method should be used to determine this error correction rate.

$$\Delta LNC02_t = \alpha_0 + \sum_{i=1} \alpha_1 \Delta GDP_{t-1} + \sum_{i=1} a_2 \Delta REC_{t-1} + \sum_{i=1} a_3 \Delta FFE_{t-1} + \sum_{i=1} a_4 + \beta_1 C02_{t-1}$$
$$+ \beta_2 GDP_{t-1} + \beta_3 REC_{t-1} + \beta_4 FFE_{t-1} + \beta_5 TRA_{t-1}\mu_{t-1} \tag{4}$$

Δ represents the difference between users. Where i and j are years. The null hypothesis in the estimation analysis is that the dependent variable and the explanatory variables should not have any relationship. The economy is defined as H0. β1 = β2 = β3 = β4 = β5 = 0, alternative H1. β1 = β2 = β3 = β4 = β5 = 0. Relationships are measured by Equation 4 along with profitability. Variables were set to zero to use the F-statistic to see if there was a longitudinal link between them. If the f-statistic is below both the upper and lower boundaries at 5%, the decision rule states that there is no long-term link between the variables. Nonetheless, it should be considered that the regressions are related to the dependent variable in the long run. Equation 5 is reached as a result of the cointegration equation.

$$\Delta CO2_t = \alpha_0 + \sum_{i=1} \alpha_1 \Delta GDP_{t-1} + \sum_{i=1} a_2 \Delta REC_{t-1} + \sum_{i=1} a_3 \Delta FFE_{t-1} \sum_{i=1} a_4 TRA_{t-1} + \theta ECT_{t-1} + \mu_t \tag{5}$$

Here is Error Correction Term (ECT) based on long-term relationships. The F-statistic for the explanatory variables ECM shows that the main effects are significant in the short term. Interrupted ECT scale t-statistics showed a significant main effect of length.
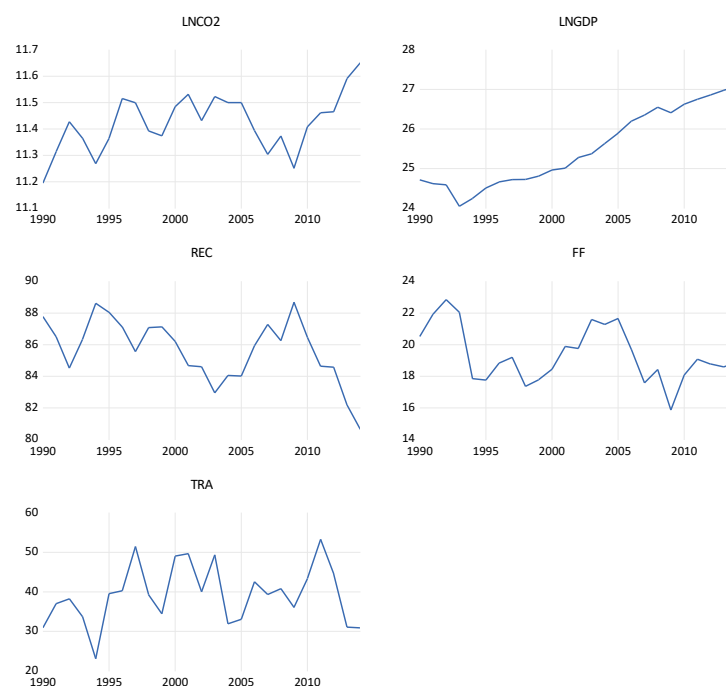
Figure 1 above illustrates of the time series data for all variables included in the study over the research period. This includes carbon dioxide emissions (CO2), gross domestic product (GDP), renewable energy consumption (REC), fossil fuel energy consumption (FFE), and trade (TRA). The graph provides a visual representation of how each variable has evolved over time, highlighting the trends and potential.

4. Results and Discussion

Table 1. Descriptive Statistics

	LNCO2	LNGDP	REC	FF	TRA
Mean	11.42344	25.50350	85.67090	19.34710	39.31048
Median	11.42748	25.27771	86.21000	18.87677	39.33693
Maximum	11.65121	27.07622	88.68000	22.84479	53.27796
Minimum	11.19506	24.04658	80.64000	15.85414	23.05924
Std. Dev	0.108200	0.969706	1.989039	1.750607	7.476892
Skewness	-0.109005	0.263663	-0.619624	0.322084	0.077678
Kurtosis	2.685821	1.583647	3.028071	2.372391	2.528309

Source: Author's Computation.

The mean of each variable represents the data's average value. For instance, the average CO2 emissions are 11.42344. The middle value is the median of each variable when the data are ordered numerically. For instance, there are 11.42748 CO2 emissions on average each year. By examining the maximum and minimum values for each variable, you can ascertain the highest and lowest values in the data set. For instance, 11.19506 and 11.65121, respectively, are the minimum and maximum CO2 emissions.

The standard deviation of each variable calculates how widely the data are spread out from the average (mean). When the standard deviation is low, the data is more likely to be centered on the mean. Whereas when the standard deviation is high, the data are more likely to be dispersed. For example, a standard deviation of 0.108200 exists for CO2 emissions. Skewness is a metric used to determine the asymmetry of data; positive skewness denotes a longer right tail and negative skewness denotes a shorter left tail. For instance, the skewness of CO2 emissions is -0.109005, which means that the left tail is a little longer. Kurtosis, which has higher values suggesting a more peaked distribution, is used to determine how peaked the data are. For instance, the kurtosis of CO2 emissions is 2.685821, which indicates that the distribution of these emissions is fairly peaky.

If the data's kurtosis and skewness diverge significantly from what would be predicted from a normal distribution, it can be determined using probability and the Jarque-Bera test. The test's p-value is the probability, and the data's skewness and kurtosis are taken into consideration.

For the Jarque-Bera if the probability is less than 0.05, the data's kurtosis and skewness are significantly different from those of a normal distribution. For example, the likelihood of

0.926663 and the Jarque-Bera statistic for CO2 emissions both show that the data's skewness and kurtosis are not appreciably different from those of a normal distribution.

Table 2. Unit Root Augmented Dickey-Fuller (ADF)

Variables	Level	Probability	1st Difference	Probability
LNCO2	-2.449380	0.1398	-4.234813	0.0153**
LNGDP	-1.650382	0.4425	-3.952830	0.0064***
REC	-3.024390	0.0468**		
FFE	-2.187731	0.2154	-4.610381	0.0014***
TRA	-3.745039	0.0098***		

Source: Author's Computation. *, ** and** indicate the significance of variables at 10%, 5% and 1% respectively.

Table 3. Unit Root Philip Peron (PP)

Variables	Level	Probability	1st Difference	Probability
LNCO2	-2.336817	0.1693	-4.857077	0.0008***
LNGDP	-1.625225	0.4548	-3.946289	0.0065***
REC	-3.029846	0.0463**		
FFE	-2.187731	0.2154	-4.602039	0.0014***
TRA	-3.664915	0.0118**		

Source; Author's Computation. *, ** and** indicate the significance of variables at 10%, 5% and 1% respectively.

The results of the ADF test and PP for unit roots in time series data are displayed in Tables 2 and 3 respectively. The first difference and level of each variable are tested using these two methods. The first difference between two successive observations of the data is the level of a variable, which is the raw data. While the level might still not be stationary even if the time series is stationary. A test statistic and related p-value are generated by the ADF test. If the p-value is less than a set limit, the alternative hypothesis of stationarity can be accepted rather than the null hypothesis of a unit root (typically 0.05). The p-values are shown in the "Probability" column of the table.

The variables LNCO2, LNGDP, FFE, and TRA in this table all have p-values in the first difference that are less than 0.05, indicating that they are stationary in first differences. The level of the variable REC has a p-value of less than 0.05, indicating that it is stationary. This means that a statistical model might be able to utilize these variables.

Table 4. ARDL Bound TEST

Test Statistics	Value	Significance	I(0)	I(1)
F-Statistic	7.719956	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Source: Author's Computation.

After executing both the ADF and PP unit root tests, the model was chosen based on past results. To demonstrate the long-term link connecting the variables, the ARDL bound test was applied rather than the co-integration test. The f-statistics value of 7.719956 from table 3.3 above is higher than the values at 10% significance, which are 2.20 for I (0) and 3.09 for I (1). Additionally, it is significant for 5% of I (0) and I (1) at 2.56 and 3.49, respectively, and for 1% of both I (0) at 3.29 and 4.37. (1).

Table 5. ARDL Short-Term Coefficients

Variables	Coefficient	Std. Error	T-Statistic	Prob.
LNCO2(-1)	0.373347	0.147127	2.537578	0.0219**
LNGDP	-0.033849	0.012006	-2.819291	0.0123**
REC	-0.050037	0.011035	-4.534271	0.0003***
FFE	0.009908	0.012264	0.807915	0.4310
FFE(-1)	-0.028454	0.008018	-3.548947	0.0027***
TRA	0.001573	0.001162	1.353565	0.1947
TRA(-1)	0.003370	0.001317	2.558796	0.0210**
C	12.46497	2.757734	4.520004	0.0003***
Coinex(-1)*	-0.072702	0.011866	-6.126939	0.0000***

Source: Author's Computation.

The outcomes of an autoregressive distributed lag (ARDL) model for short-term relationships in time series data are shown in this table. Taking into account both the level and lag of the variables, the ARDL model is a statistical model used to examine the short-term correlations between two or more time series variables. According to the model's specification. The estimated association between each variable and the dependent variable is shown in the table with the constant coefficient representing (LNCO2) when other variables are constant with a significant p-value. If the p-value is less than a specified threshold (0.05), the estimate is considered statistically significant.

The variables LNGDP, REC, FFE (-1), and TRA (-1) all have p-values below 0.05 in this table, indicating that they are statistically significant at the level of 5%. A percentage increase in GDP and REC decreases C02 by 0.03% and 0.05 respectively others are constant with significant p-values. This is true because when GDP increases, the income of the people will increase and more people will switch from using non-renewable energy to renewable energy. The application of more technology that will increase the use of renewable energy consumption instead of getting energy from non-renewable source will decrease C02 emissions in the country.

The f-statistics are significant at 0.0000(1%), the R-square is 91%, and the adjusted R-square is 87%.

Table 6. ARDL Long run Coefficients

Variables	Coefficient	Std. Error	T-Statistic	Probability
LNGDP	-0.054015	0.018702	-2.888237	0.0107***
REC	-0.079849	0.012739	-6.267955	0.0000***
FFE	-0.029595	0.011057	-2.676590	0.0165**
TRA	0.007888	0.002923	2.698761	0.0158**
C	19.89134	1.583786	12.55936	0.0000***

Source: Author's Computation.

The ARDL analysis of the explanatory variables over the long term is shown in Table 6 above. The coefficient of intercept, based on the outcome, is 19.89134 shows that the value of CO_2 when others are held constant with significant p-value. The coefficients demonstrate that a 1% increase in GDP decreases CO_2 by 0,054% when all other factors are held equal, an increase in REC by 1% will result in a decrease in CO_2 by 0.08%. A 1% increase in FFE will result in a decline in CO_2 by 0.03% assuming all variables are constant. As GDP rises, more people will shift from renewable-to-renewable energy, which will also enhance human capital. The nation's carbon footprint can be decreased by introducing new renewable energy sources that outperform non-renewable consumption sources. The long-term effects of using fossil fuels will decline as people switch from consuming non-renewable to renewable energy.

Additionally, TRA has a positive coefficient of 0.007888, which implies that, under the assumption that all other variables remain constant, it increases CO_2 by 0.008% when it rises by percentage. Their p-values are all significant and their coefficients are inelastic to the dependent variable (CO_2 emission).

Both short and long-term variables have similar effects on CO2 emissions. Al-mulali (2014) identifies numerous variables that contribute to the negative link between GDP growth and CO2 emissions. One possibility is that as economies develop and become more efficient, they may shift away from heavily polluting industries towards cleaner technologies and renewable energy sources.

Furthermore, advances in energy efficiency and environmental restrictions may add to the negative association (Bilgili et al., 2016). The observation that increasing renewable energy usage reduces CO2 emissions is consistent with the notion that renewable energy sources emit less greenhouse gases.

According to Zubair et al. (2020), CO2 has a beneficial influence since more commerce leads to increased economic activity, which may result in higher energy consumption and CO2 emissions, especially if the energy sources are mostly fossil fuels. Furthermore, the prevalence of undeveloped energy-consuming industries in Nigeria suggests that the economy may continue to rely largely on inefficient and polluting technology.

Table 7. Residual diagnostic test

Test Name	F-Statistics	Probability	Result.
Serial Correlation	1.530542	0.1161	No Serial Correlation
Heteroscedasticity	1.173774	0.7137	Homoscedasticity
Normality	1.207802	0.546674	Normally Distributed

Source: Author's Computation.

The tests of residual diagnostics of the variables are displayed in the tables 7 above. The serial relationship test is the first one that is run. It examines if a variable's lag is caused by that variable. For the serial correlation test, the favored null hypothesis is 'no serial correlation' Given that the probability value of the serial correlation test used above is greater than 0.05, the Null is failed to be rejected and confirms that the residuals are free from serial correlation. Heteroscedasticity is the second residual diagnostic test. 'Homoscedasticity' or 'no heteroscedasticity' is the null hypothesis for heteroscedasticity test. The test's p-value, which is greater than 0.05. There is no way to disprove the null hypothesis. The variables are hence homoscedastic. The normality test, which was also depicted in the graph, is the last residual diagnostic test. Jarque Bera's null hypothesis is 'normal distribution'. The normality test's p-value exceeds 0.05. So, it is impossible to rule out the null hypothesis.

Table 8. Granger Causality test

Null Hypothesis:	F-Statistics	Probability
TRA does not Granger Cause REC	3.60719	0.0482**

REC does not Granger Cause TRA	2.41388	0.1178
LNGDP does not Granger Cause REC	3.35195	0.0579*
REC does not Granger Cause LNGDP	0.10427	0.9015
TRA does not Granger Cause FF	7.60018	0.0040***
FF does not Granger Cause TRA	1.25416	0.3091
LNGDP does not Granger Cause LNCO2	2.96896	0.0769*
LNCO2 does not Granger Cause LNGDP	0.68318	0.5176
TRA does not Granger Cause LNGDP	2.91737	0.0799*
LNGDP does not Granger Cause TRA	0.97781	0.3952

Source: Author's Computation.

If a time series (such as the usage of renewable energy) can predict another time series (e.g., trade), it passes the Granger causality test. In this context, the first time series is said to Granger-causes the second time series if we reject the null hypothesis.

The F-statistic for the test "TRA does not Granger Cause REC" and its corresponding p-value.

The F-statistic for the test "LNGDP does not Granger Cause REC" and its corresponding p-value.

The F-statistic for the test "TRA does not Granger Cause FFE" and its corresponding p-value.

For the "TRA does not Granger Cause REC" test, the F-statistic and p-value are statistically significant at the 5% level. This implies that trade Granger-causes the usage of renewable energy. Similarly, the "LNGDP does not Granger Cause REC" test shows that the gross domestic product Granger-causes renewable energy consumption based on its F-statistic and p-value. Furthermore, the "TRA does not Granger Cause FFE" test's F-statistic and p-value are also statistically significant, indicating that trade Granger-causes the consumption of fossil fuels. However, in some tests, the F-statistics and p-values are not significant at the 5% level. This means there is no evidence to support the Granger causality hypothesis for those particular time series relationships. Overall, the findings from these Granger causality tests indicate that trade and gross domestic product Granger-cause the consumption of renewable energy, while trade also Granger-causes the consumption of fossil fuels. No significant evidence supports Granger causality for the other time series relationships tested.
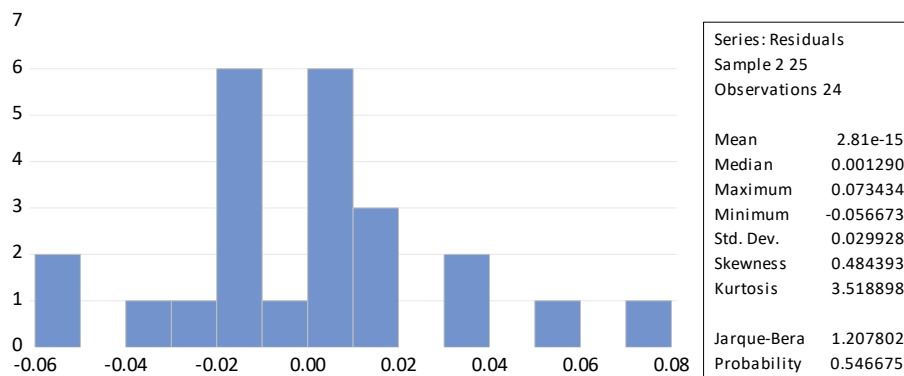

Figure 2. Jarque Berra normality test

The Jarque Berra normality test graph is shown in the figure above.

Stability test

The structural stability of the regression coefficients is assessed using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSK) tests. According to the figures below, both the CUSUM and the CUSUMSK test are within the critical limit of 5%, which proves that the model is stable at threshold. The figures (3&4) below illustrate it graphically.
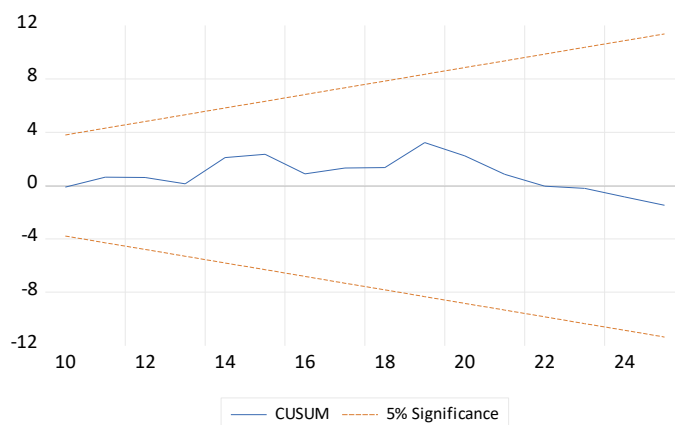
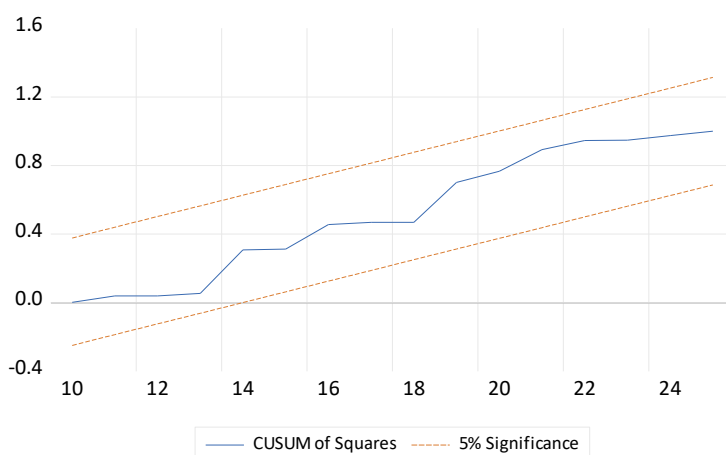**Figure 3.** Cumulative Sum

Figure 4. Cumulative Sum Square

5. Conclusion and Recommendation

This study explores the intricate relationships between economic growth, environmental impact, energy use, and the role of renewable energy and environmental practices in Nigeria. Utilizing an Autoregressive Distributed Lag (ARDL) model, we examined short-term correlations in time series data spanning from 1990 to 2020. The findings demonstrate that, despite having a negative effect on carbon emissions, renewable energy has a beneficial effect on commerce and GDP. This means that increasing the usage of renewable energy while decreasing the country's reliance on fossil fuels is crucial if Nigeria is to reduce its carbon footprint.

Overall, it is evident that in order to effectively manage carbon (CO2) emissions in Nigeria, a multifaceted strategy that takes into account economic development, trade liberalization, and renewable energy use is required. The government of Nigeria may help to lower carbon dioxide emissions and contribute to a more sustainable future by putting in place policies that promote the development and use of renewable energy sources while discouraging the use of fossil fuels. The government should also spend money on research and development to help Nigeria's renewable energy sector expand. This may entail funding for research initiatives, giving grants or loans to businesses developing renewable energy technology, and assisting in the creation of the infrastructure required for the expansion of the renewable energy industry.

In terms of policy recommendations, the Nigerian government should think about enacting measures that promote the creation and utilization of renewable energy sources. Incentives for corporations to fund renewable energy initiatives as well as subsidies or other forms of financial assistance for people and organizations to transition to renewable energy sources may fall under this category. The government should also take into account policies that discourage the use of fossil fuels, like carbon levies or emission limits. In terms of trade, the administration should think about establishing trade pacts that encourage low-carbon economic development and sustainable development. Fossil fuel use can be curbed by laws and related regulations that promote the use of renewable energy.

Increasing energy efficiency is a key component of Nigeria's carbon dioxide emissions reduction strategy. The government should think about enacting laws that encourage companies and people to utilize energy more effectively, including tax breaks or rebates for buildings or appliances that use less energy. Nigeria can lower its overall energy consumption, which will lower carbon dioxide emissions, by using energy more effectively. In order to share best practices and gain access to more resources and experience, the government should also think about working with foreign nations and organizations. For example, Nigeria can participate in programs such as the Ministerial Conference on Clean Energy and the United Nations Framework Convention on Climate Change, which unite authorities, corporations, and groups from civil society to work toward shared objectives relating to climate change and energy transition. Clearly defining objectives and targets for reducing carbon dioxide emissions is another crucial action the Nigerian government can take. This could involve creating countrywide emissions reduction targets or targets for cutting emissions in certain industries, like the transportation or manufacturing sectors. The government can help guarantee that policymaking is moving in the right direction and that steps are being taken to reduce emissions by setting clear goals and targets. Last but not least, it is crucial for the Nigerian government to make sure that the advantages of reducing carbon dioxide emissions are equitably spread among various groups and regions. This could entail establishing regulations that aid in the shift to a low-carbon economy without unduly burdening underserved areas or industries, as well as making sure that the economic gains of the change are equitably distributed.

Conflict of interest

There is no conflict of interest for this study.

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