Energy Consumption, CO_2 Emission, and Economic Growth Nexus in Nigeria

Onome Louis EMONENA

PG/MGS1405048

DEPARTMENT OF BANKING AND FINANCE
FACULTY OF MANAGEMENT SCIENCES
UNIVERSITY OF BENIN, BENIN CITY
EDO STATE

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DECLARATION

I, Onome Louis EMONENA, a Master of Science (M.Sc.) candidate of the Department of Banking and Finance, Faculty of Management Sciences, University of Benin, Benin City, Nigeria, do hereby declare that this thesis is entirely my work and composition. The work embodied in this thesis has not been submitted in candidature for any degree and it is not concurrently being submitted for any other degree. All references from other works have been duly acknowledged.

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Onome Louis EMONENA **Date**
(PG/MGS1405048)

CERTIFICATION

We, certify that this thesis carried out by **Onome Louis EMONENA** is adequate in scope and quality in partial fulfillment of the requirements for the award of Master of Science (M.Sc.) Finance in the Department of Banking and Finance, Faculty of Management Sciences, University of Benin, Benin City, Nigeria.

______________________ ______________________

Dr. M. G. Ajao **Date**
(Supervisor)

______________________ ______________________

Dr. O. G. Omorokunwa **Date**
(Head of Department)

CERTIFICATION OF THESIS OF NON-PLAGIARISM

We, the undersigned, attest and declare that the thesis of **Onome Louis EMONENA** titled **"Energy Consumption, Co_2 Emission, and Economic Growth Nexus in Nigeria"** has successfully passed the anti-plagiarism test and does not violate any copyright regulation.

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Dr. M. G. Ajao **Date**
(Supervisor)

______________________ ______________________

Dr. O. G. Omorokunwa **Date**
(Head of Department)

ATTESTATION

We, the undersigned, attest and declare that **Onome Louis EMONENA** has successfully carried out all the corrections as recommended by the external and internal examiner in her thesis titled: **"Energy Consumption, Co_2 Emission, and Economic Growth Nexus in Nigeria".**

____________________ ____________________

Dr. M. G. Ajao **Date**
(Supervisor)

____________________ ____________________

Dr. O.G. Omorokunwa **Date**
(Head of Department)

____________________ ____________________

Dr. O. F. Ogieva **Date**
(Internal Examiner)

____________________ ____________________

Dr. N. Ohonba **Date**
(Postgraduate School Faculty Representative)

DEDICATION

I dedicate this thesis to God Almighty, for His love, grace, mercy, and sufficiency towards me during the course of this program.

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ABSTRACT

Energy consumption facilitates economic growth but it is a major source of carbon emission, leading to the dilemma in policy priority between economic growth and pollution reduction. Therefore, this study empirically examined the relationship between energy consumption, carbon emissions and economic growth in Nigeria using cointegration and dynamic causality analysis, with annual time series data for the period 1981 to 2021. A good number of econometric techniques were conducted, which include; descriptive statistics, correlation coefficient, unit root test, granger causality test, optimal lag selection criteria test and co-integration test using Autoregressive Distribution Lag (ARDL) Bound Test and ARDL model Approach. Granger long-run dynamic analysis were conducted using error correction model (ECM) framework to explore the causal relationships between the variables. The study revealed evidence of relationship between energy use, electricity consumption, CO_2 emission and economic growth in Nigeria. A positive but insignificant relationship exist between energy use and economic growth, electricity consumption and economic growth, while a negative and insignificant relationship between CO_2 emission and economic growth in the long-run during the study period. During the lagged period, CO_2 emission and economic growth showed positive and significant relationship in the long-run. The study also revealed that a unidirectional causality exists from economic growth to energy use, electricity consumption to economic growth in the long run, while a bidirectional long-run causality exists between CO_2 emission and economic growth. An important policy implication is that energy consumption has positive influence on economic growth in Nigeria, thus as higher energy consumption also means higher pollution in the long-run, policymakers should diversify and explore alternative energy sources for meeting up the increasing energy demand and reducing the effect of carbon on her citizens.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The rapid growth in population, industrialization, energy consumption, and carbon emission over the last decades have increased the threat of global warming in the world at large. Environmental concerns in developed and developing countries have become of significant importance among economists and environmental experts. These concerns which are based on environmental sustainability emanated from both natural factors and human activities of economic growth and expansion. The prevailing opinion by global economic expert is that economic expansion is highly dependent on energy consumption, given its core role in facilitating productivity, promoting economic growth and development, and enhancing income generation and employment in any economy (Iorember, Goshit & Dabwor, 2020). Thus, energy consumption for the production of economic growth is associated with rising level of carbon emission which is harmful to human health and the environment.

The causality link between energy consumption, carbon emission and economic growth is widely debated and discussed since the seminal work of Kraft and Kraft (1978) on the relationship between energy consumption and economic growth. There exists a good number of literatures on the causal relationship between energy consumption and economic growth in the case of developing economies across the world. Most empirical studies take either or both electricity consumption and kilogram of oil equivalent as a proxy for energy consumption, which is based on the energy sources of respective countries. However, empirical evidence in this regard is mixed and goes from unidirectional or bidirectional causality to non-causality. Evidences vary across different countries, because it probably depends on the country's development path, development stage, the sources of energy used, energy policies applied, energy consumption level, institutional arrangements and so on (Alam, Begum, Buysse & Huylenbroeck, 2012). This shows that the relationship between energy consumption and economic growth in the world at large remain a matter of debate and of great significance to policymakers in developed, developing and undeveloped countries of the world.

It is crystal clear that global warming is predominantly caused by greenhouse gases (GHG) from household, commercial, industrial and transportation activities. Every economy of the world desires a certain level of economic growth and sustainable development, but environmental issues such as climate change and global warming in this modern age poses threat for the realization of this objective. This is due to the fact that a reasonable proportion of energy consumption in the world is met through fossil fuels. Thus, the rise in world trade and rapid growth in economic activities around the world have led to a significant increase in carbon dioxide (CO_2) emission. As energy consumption and other related natural resources cause environmental degradation, likewise increase in the amount of greenhouse gas emissions such as carbon dioxide emission harms the environment as well as inflicting irremediable damages on the atmosphere. This causes adverse climate changes such as floods, drought, rising sea levels, reversing ocean currents, and heightened storm intensity. There are a good number of empirical studies on the relationship between carbon emission and economic growth in an economy. Empirical evidences on this regard are mixed in relation to developed, developing and underdeveloped economies and goes from positive emission-growth relationship to negative emission-growth relationship (Mapapu & Phiri, 2018). Two main streams of empirical literature have investigated carbon emission and economic growth relationship. The first stream evaluated the causal direction between carbon emission and economic growth. Evidence shows a significant support for bi-directional causal relationship against one-way causality which is often implied by most bi-variate and multi-variate approach, while one-way causality is affirmed in some cases. The second stream of empirical literature, studied the presence of an inverted-U relationship between carbon emission and economic growth on the basis of Environmental Kuznet Curve (EKC) hypothesis, with evidences refuting and affirming the hypothesis (Olubusoye & Dasauki, 2020).

Nigeria is one of the underdeveloped countries in the world based on Human Development Index (HDI) characterized by a widespread of adverse poverty and less economic growth and development (World Population Review, 2022). The term underdeveloped country is regarded as an unofficial term. Thus, according to the United Nations, countries that would qualify as underdeveloped are broadly classified as least developed countries (LDCs) or developing countries, of which Nigeria is considered as one of the developing countries in the world with a Human Development Index of 0.538 in 2019, 0.535 in 2020, with a negative HDI change from 2019 of -0.003, and an unchanged HDI of 0.535 in 2021 from 2020 (United Nations Development Programme, 2022). In 2020, the real GDP per capita of Nigeria was $2,396, and $2,421.6 in 2021 after adjusting for inflation, while the nominal GDP per capita and GDP per capita Purchasing Power Parity were $2,097.1 and $5,186.4 in 2020, and $2,085 and $5,459.2 in 2021 respectively (World Bank, 2022). Nigeria ranking 161st in 2020, with a Human Development Index of 0.535, and a similar HDI of 0.535 in 2021, struggled to leverage the country's vast wealth in oil (fossil fuels) in order to minimize adverse poverty that affects the populace (United Nations Development Programme, 2022).

The utilization of fossil fuel causes carbon dioxide emission, likewise the manufacturing of cements, energy consumption, solid liquid consumption, gas fuel consumption, gas flaring produce carbon emission which are indicators for environmental degradation. In 2018, 2019, 2020, and 2021, 114.5, 120.3, 120.3, and 127 million tonnes of carbon dioxide emissions respectively were recorded (Knoema, 2022). In 2018, Nigeria had the highest gross domestic product (GDP) of $397.2 billion in Africa with 109,890 kilo tons of carbon dioxide emission which was its highest in history (World Bank, 2020). This could indicate a relationship between energy consumption, carbon dioxide emission and economic growth in Nigeria.

1.2 Statement of the Research Problem

Energy consumption from burning of fossil fuels and carbon emissions are global concerns which have generated considerable interest among researchers especially the adverse effect of emissions of carbon gas on the environment. Research on the relationship between energy consumption, carbon emission and economic growth has been a hot issue to ascertain the causal direction between the variables and formulation of policies to minimize fuel-based carbon dioxide emission and maximize economic growth.

The need to ascertain the relationship that exist between energy consumption, CO_2 emission and economic growth has led to a plethora of empirical investigation across various countries. In Nigeria context, the relevant empirical studies are Akpan and Akpan (2012), Saibu and Jaiyeola (2013), Shuaibu and Oyinlola (2013), Chindo, Abdulrahim, Waziri, Huong, and Ahmad (2014), Alege, Adediran and Ogundipe (2016), Lin and Atsagli (2016), Rafindadi (2016), Aiyetan and Olomola (2018), Deekor, LeeLee and Aziaka (2020), Esan and Hassan (2020), Iorember, Goshit and Dabwor (2020), and Ushie and Aderinto (2021). Their studies reveal energy issues as they relate to economic growth in Nigeria, and the possible impacts on the environment. Environmental issues in Nigeria are characterized by soil erosion, high population pressure compounded by unplanned growth, and increasing problems of both domestic and industrial waste disposal and pollution (Isife, 2012). Since 1980s, human-related activities, particularly in the development projects of the oil and gas sector have led to increased loss of topsoil and deforestation, loss of habitat, species and biodiversity, and degradation of wetlands (NEST,1992).

In Nigeria, the primary energy consumption comes from oil which is fossil fuel and liquid hydrocarbon, and hydropower. In 2013, Nigeria total energy consumption was 142,953 kilo tonnes of oil equivalent most of which comes from fossil fuels and hydropower. According to Energy Information Administration (EIA) in 2013, Nigeria energy consumption is expected to increase by 56% in 2040 as a result of rapid growth in population (Aiyetan & Olomola, 2018). In 2020, Nigeria total energy consumption was 162,842 kilo tonnes of oil equivalent and 120.3 million tonnes of carbon dioxide emission, while in 2021, total energy consumption was 172,902 ktoe, and 127 million tonnes of carbon dioxide emission, which is expected to increase further as population and industrial activities increase (Enerdata, 2022; Knoema, 2022).

In 2020, electricity generated was approximately 30 billion kilowatt-hours, and 31 billion kilowatt-hours in 2021 (EIA, 2022). Nigeria is targeting to increase the amount of kilo watt-hours of electricity generation in order to meet electric need in the nearest future. The paucity of electric supply in Nigeria has led to intense burning of fossil fuels to generate more electric power to meet both individual and industrial needs. This action could have increased the level of carbon emission and environmental degradation in Nigeria. Nevertheless, energy consumption that drives carbon dioxide emission is indispensable for economic growth (Bosupeng, 2016). Future economic growth depends on the availability of energy. The production activities that lead to economic growth cannot be in isolation of energy consumption (Deekor & Aziaka, 2020). Thus, given this sensitive relationship between carbon emission and economic growth, and the need to optimize growth and minimize carbon emission and environmental degradation in Nigeria calls for this study.

Over the past one decade, the average rate of growth of the Nigerian economy is about 6%. In 2019, the economy grew at 2.208% with CO_2 emission (metric tons per capita) of 0.57, exceeding the 1.923% of 2018 with CO_2 emission of 0.56, and in 2020, there was an observed decrease in growth at -1.794%, and a CO_2 emission of 0.58, while in 2021, there was an increase in growth at 3.6%, couple with an increase in CO_2 emission per capita of 0.60 (World Development Indicator, 2022; Knoema, 2022). However, there was improvement in the generation, transmission and distribution of electricity in Nigeria. Nigeria electricity production is reported on a quarterly basis. Accordingly, the estimated average electricity generation for the fourth quarter of 2020 rose to 3,744.95 Mega Watt-hour, portraying a 6.1% and 6.6% increase, compared with the levels in the fourth quarter of 2019 and third quarter of 2020 respectively. At 3,264.49 MW/h, the estimated average electricity consumption for the review quarter increased by 5.2% and 1.0%, compared with the levels recorded in the fourth quarter of 2019 and third quarter of 2020 (CBN, 2020). In 2021, the average electricity generation was 4,379.11 MW/h in the fourth quarter, indicating an increase of 11.2% in comparison with the preceding quarter, while the average electricity consumption in that same (fourth) quarter of 2021 was 3,408.65 MW/h, signifying an increase of 5.6% relative to the preceding (third) quarter (CBN, 2021). This trend is worrisome, given the relationship between empirical data on carbon dioxide emission, annual growth rate and energy consumption in Nigeria, hence the need for this study.

The empirical studies on the relationship between energy consumption, CO_2 emission and economic growth in Nigeria are relatively many with conflicting findings on the causal link between the variables which are yet to be resolved. The conflicting findings may be attributed to difference in scope, variables used, or methodological issues. Therefore, using energy use of oil equivalent and electric power consumption to capture total energy consumption in Nigeria, this study seeks to answer the question of what relationship exit between energy consumption, CO_2 emission and economic growth through cointegration and dynamic causality framework, using autoregressive distributed lag and error correction model techniques.

1.3 Research Questions

In view of the foregoing issues, the question of what is the nexus between energy consumption, CO_2 emission and economic growth in Nigeria is pertinent to this research. The specific research questions arising from the broader question include;

i. What is the relationship between energy use (of oil equivalent) and economic growth in Nigeria?

ii. What is the existing relationship between electricity consumption and economic growth in Nigeria?

iii. What relationship exit between CO_2 emission and economic growth in Nigeria?

1.4 Objectives of the Study

The main objective of this research study is to examine the nexus between energy consumption, CO_2 emission and economic growth in Nigeria. The specific objectives are to:

i. Determine the relationship between energy use (of oil equivalent) and economic growth in Nigeria.

ii. Evaluate the relationship between electricity consumption and economic growth in Nigeria

iii. Examine the relationship between CO_2 emission and economic growth in Nigeria.

1.5 Hypotheses of the Study

In order to achieve the objectives of this study, the following hypotheses are stated in the null form to serve as guides in finding answers to the research questions:

H_{O1}: There is no significant relationship between energy use (of oil equivalent) and economic growth in Nigeria.

H_{O2}: There is no significant relationship between electricity consumption and economic growth in Nigeria.

H_{O3}: There is no significant relationship between CO_2 emission and economic growth in Nigeria.

1.6 Scope of the Study

This study examines energy consumption, CO_2 emission and economic growth nexus in Nigeria using annual time series data spanning from 1981 to 2021. The choice of the time period captures the Fourth National Development Plan between 1981 and 1985, during which the oil boom increased energy demand growth rate by 10% (Quadri & Bukola, 2022). Since 1981, except for some few drips, energy demand has been on the increase even until 2021.

Since the study is based on aggregate annual time series data of Nigeria, a census sampling technique is used in which population size equals sample size.

The preference for the variables of interest is informed by their relevance in capturing the totality of energy consumption and carbon emissions with respect to industrialization process as outlined in the literature, as well as their supposed role in stimulating economic growth in developing economies, such as Nigeria.

1.7 Significance of the Study

The importance of energy consumption to economic growth has been outlined in the literature. It is argued that energy plays a relevant role in human lives and in the daily activities of the economy, both as a scale of social and economic development and as a fundamental humanitarian need. Thus, it is argued that energy consumption per capita of a country is an important indicator of economic growth and development. Although, energy consumption is crucial to economic activities, the alarming threat and attendant consequence of generating energy from burning of fossil fuels which increases the emission level of carbon dioxide have made the relationship between energy consumption, CO_2 emission and economic growth a contentious issue. This study will therefore be of great benefit to the followings:

Researchers and Academicians: This research contributes significantly to existing literature, therefore benefitting global research community on environmental sustainability by replicating the work done in Bangladesh by Alam et al. (2012) on the nexus between energy consumption, CO_2 emission and economic growth: Cointegration and Dynamic Causality Analysis within the context of Nigeria.

Policy Makers: By shedding light on the relationship between energy consumption, CO_2 emission and economic growth, this study benefits policy makers as it identifies a possible channel of policy action of improving economic growth, reducing carbon emission and outlining alternative energy sources to meeting energy demand for economic growth and simultaneously ensuring environmental sustainability.

Economic Experts: The outcome of the study will also benefit economic experts, as it will offer insight on the causal link that exist between energy consumption, CO_2 emissions, and economic growth in Nigeria.

1.8 Limitation of the Study

The study is limited to the extent of the data obtained from secondary sources, such as World Development Indicators published by World Bank, Enerdata (Nigeria Energy Information), Energy Information Administration, and World Data Atlas by Knoema. Accordingly, likely errors from the sources are possible, though the integrity of those sources minimizes such. Nevertheless, the data are carefully scrutinized to ensure accuracy, dependency, and reliability spanning from 1981 to 2021. The study is limited to the number of variables of interest, and could accommodate more exogenous variables, however, total energy use and electric power consumption are used to capture aggregate energy consumption in Nigeria. In addition, appropriate methods of analysis are employed to ensure that the result is not spurious.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter covers the review of issues surrounding energy consumption, carbon emission and economic growth nexus in Nigeria. The issues discussed in this chapter include conceptual issues relevant to the study, a review of related theoretical literature, and empirical studies by various researchers.

2.2 Conceptual Review

2.2.1 Concept of Economic Growth

Industrialization has brought about permanent changes in human and economic activities at large. Some economist and analysts are of the opinion that industrialization has a significant role to play in the economic growth and development of any country. Economic growth is a reflection of the level of goods and services produced in any country. Economic growth refers to the increase or improvement of the national income per capita, especially in quantitative terms. In a wider sense, it involves the increase in gross domestic product (GDP), gross national product (GNP) and national income (NI). It is expressed in absolute size, relative size, per capita and also encompassing the structural modification of any economy (Haller, 2012). Economic growth is a long-term rise in the economic capacity to increasingly supply of differing economic goods and services to its population, this resulting growing capacity based on advancing technology and adjustment to institution and ideology that it demands (Kuznets, 1973). It is the steady or constant process by which the economic productive capacity increases overtime to bring about increase in the level of national output and income (Todaro, 2005). Also, economic growth is the process of increasing the levels of national outputs and macro-economic indications especially gross domestic product per capita (GDP per capita), with positive impact on economic-social sector (Haller, 2012). Economic growth can be positive, zero or negative. A positive economic growth occurs when the annual average pattern of macro-economic indicators, particularly GDP, are greater than the average growth of the population. When the annual average movement of macro-economic indicators are equal to the average population growth, it is a zero economic growth. It becomes negative economic growth when annual average macro-economic indicators are less than the average population growth.

Economic growth is obtained by the efficient and effective utilization of available natural resources and by increasing the productive capacity of goods and services of a country. However, a country clamoring for economic growth must have basic resources like energy and other naturally endowed resources. In order to ensure the sustainability of economic growth and development in the long run, resources such as energy supply must be readily available, affordable and used in a way that there is ample energy for the contemporary generation as well as the future generation to consume.

In Nigeria, economic growth is predicated on the exploration of crude oil which is the major driver of its growth. Nigeria, a considerable producer of oil, is likewise rich in other energy sources such as wood, coal, gas, tar sands, and hydro power. The rate of production and consumption of these energy sources has changed overtime due to the increase in the demand for energy. The growing rate of energy demand has led to an alternative source of power, which requires the burning of fossil fuels. This trend is discomforting given the colossal detrimental effect of pollutant emissions on Nigeria environment especially in the south-south region of the country (Godson, 2011).

Economic growth that is for the future, must be environmentally sustainable. In order to reduce the adverse effect of pollutant emission in the process of meeting energy needs and achieving sustainable economic growth, many economies are embracing low carbon technologies and energy conservative strategies. In a healthy economy, growth and environmental sustainability must be seen as complement, not substitute (Ogbonna, Ojeaburu & Ehilegbu, 2019). This is not the case in Nigeria as carbon emissions and environmental degradation are rampant in the course of achieving economic growth.

2.2.2 Concept of Energy Consumption

Over the years, there has been a focus on the role of the energy consumption in economic growth. Among the widely used indicators of energy consumption is the energy use per capital of oil equivalent (Alam et al. 2012; Esan & Hassan 2020). Energy use of oil equivalent of a country refers to the use of primary energy before it is transformed into other end-used fuels, which is equal to all indigenous production in addition to import and stock changes, subtracting all exports and fuels supplied to ships and aircrafts involve in international transport. Energy use is the use of primary energy before transformation into other or different end use fuels (end products), which is equal to indigenous production plus (+) imports and stock changes, minus (-) exports and fuels supplied to aircrafts and ships engaged in international transportation (Knoema, 2014). Kilogram of oil equivalent (kgoe) per is a unit measurement of energy. Thus, energy use per capita of oil equivalent measures the energy use per average person in a country which is equivalent to the approximate amount of energy which can be extracted from a single (one) kilogram of crude oil in a country. Energy consumption captures all energy used to carry out an action by residential, commercial, transportation and industrial sectors of the economy. Energy consumption in the residential sector represents a crucial part of the total energy consumed in an economy. Household energy consumption may include gas, electricity and any other source of energy used. In the industrial sector, the total energy consumption can be measured by taking a look at how much energy a production process consumes. Energy consumption for commercial and transportation sectors may include the amount of gasoline or diesel used for commercial activities and movement from one place to another.

Energy is accountable for a minimum of half the industrial growth in a contemporary economy while representing below one tenth of the actual cost of industrial production (Barney & Franzi, 2002). Energy is an important source of economic growth due to the fact that many production and consumption activities use energy as a basic input and important input for economic development (Zahid, 2008). Many empirical studies indicate that energy consumption has a positive relationship with economic growth. Whether energy consumption improves economic growth or economic growth takes precedence over energy consumption have been investigated in a number of studies yet empirical result is mixed and conflicting.

Energy consumption and energy efficiency are intrinsically connected. Energy efficiency is using less energy supply to produce and provide the same number of services required (Saibu & Jaiyeola, 2013). Efficient, clean, sustainable, affordable and reliable energy services are essential for international prosperity (Olatinwo & Adewunmi, 2012). The energy efficiency report 2021, focused on the importance of energy efficiency in accomplishing net zero carbon emissions in the energy sector globally by 2050, incorporating the relevance of efficient appliances, equipment, digital innovations and how digitalization is enlarging the scope and scale of energy efficiency in the international market (IEA, 2021).

2.2.3 Concept of Electricity Consumption

Electricity consumption is one of the forms of energy consumption that uses electric energy. Electricity consumption is based on calculated consumption; this equals the electricity supplied less transmission and distribution losses. Electric power consumption per capita measures the amount of electricity consumed over a given period of time, and it is usually measured in kilowatt-hour(kwh). Electricity has been tipped as the fulcrum of economic prosperity and progress. Electricity facilitates manufacturing process, serve as a complement to both capital and labor, and shortage of it hinders economic growth (Pinson & Madsen, 2014; Jaiyesimi, Osinubi, & Amaghionyeodiwe, 2017; Shahbaz, Chaudhary, & Ozturk, 2017).

The importance of electricity is huge to both residential and industrial sectors of the economy. Electricity is an essential factor of production (Stern, Burke, & Bruns, 2017), and a major facilitator of capital formation (Lechthaler, 2017). Electricity has the capacity to reduce air pollution emanating from household activities (Lim, Vos, Flaxman, Danaei, Shibuya, Adair-Rohani, & Aryee, 2012), and also increase the hours spent by labor on industrial activities (Salmon & Tanguy, 2016).

Regardless of the various importance of electricity, access to electricity has been a major challenge. According to World Development Indicator (2017), about one billion persons in developing countries did not have access to electricity in 2014, accordingly, Nigeria in that same year had about 40% of the populace lived without access to electricity (Best & Burke, 2018). Electricity demand is increasing daily and there are many factors accountable for the global increase in electricity demand and consumption. Population increase, economic growth, urbanization are the chief factors among others causing a surge in electricity demand.

Electric power consumption per capita has been rising since 1981 except for some few drips. Between the year 1981 and 1985, during the Fourth National Development Plan, the oil boom increased power demand growth rate by 10% (Quadri & Bukola, 2022). Since 1981, electricity per capital increase from 50.901 kwh/person to 144.525kwh/person in 2014 (WDI, 2021). Economic growth on the other hand has followed an irregular trend alternating between high and low figures even until 2021 measured by real GDP per capita (2015 US$) Nigeria. Be that as it may, there are still no general consensus on either the direction or magnitude of the causal relationship between electricity consumption and economic growth. Some Studies have attributed the variation of findings to institutional factors, policies, variations in climate, time period considered for the study and differences in the stages of development (Payne, 2010; Ozturk, 2010; Alola, 2019).

2.2.4 Concept of Carbon dioxide (CO_2) Emissions

The concern for environmental sustainability globally is seemingly increasing, and the development strategy depends largely on whether economic growth leads to environmental degradation or whether such economic growth is sufficient to recompense for the environmental cost of production. Carbon dioxide emission refers to those emissions emanating from the burning of fossil fuels and the manufacturing of cement (World Bank, 2021). Carbon dioxide emissions are produced during the consumption of liquid and solid fuel, gas fuel, and gas flaring. Carbon dioxide emissions account for the largest portion of greenhouse gases, which are strongly associated with global warming. Greenhouse gases include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFCs), sulphur hexafluoride (SF_6), perfluorocarbon (PFCs) and carbon dioxide (CO_2). All other greenhouse gases are converted to carbon dioxide equivalent, making it possible to analyze them and ascertain their individual and total contributions to global warming.

Anthropogenic carbon dioxide emissions primarily arise from the combustion of fossil fuels and manufacture of cement. During combustion, different fossil fuels emit different amounts of carbon dioxide into the atmosphere for the same level of energy utilized. Oil releases about 50% carbon dioxide more than natural gas, while coal releases twice as much of carbon dioxide. The manufacturing of cement emits about half a metric ton of carbon dioxide for each metric ton of cement manufactured. Data available for carbon dioxide emissions consist of gases from the combustion or burning of fossil fuels and manufacturing of cements, but excludes carbon dioxide emission from land use such as deforestation. The burning of carbon-based fuel since the industrial revolution has swiftly intensify the concentration of atmospheric carbon dioxide, thereby raising the level of global warming. This activity has overtime indicated an adverse effect on the health of humanity and increased environmental degradation. The environmental effects of carbon dioxide emissions are of significant interest to the world at large.

Nigeria is less industrialized including some other Sub-Saharan states in Africa and thus contribute little portion to the total global emission annually (Ogbonna et al., 2019). In industrialized economies, large amount of greenhouse gases is emitted from factories during production process. Countries like China, United States, Japan, Germany among others are industrialized countries with high industrialized output in the world. China for example was the biggest emitter of fossil fuel carbon dioxide in 2020, responsible for 30.64% of global emission (Tiseo, 2021). For this reason, over time, researchers seek to examine the relationship, cause and effect of carbon emissions and economic growth. Empirical findings on this research problem have been mixed and conflicting. Other empirical literatures argue that in a company's financial statement, pollutant gasses such as carbon dioxide emissions are not accounted for due to lack of international and local designated standards for treating hazardous elements in the statement of financial position (Ogbonna et al., 2019).

2.2.5 Relationship Between Energy Consumption, Carbon-dioxide Emissions, and Economic Growth in Nigeria

Energy is majorly classified into renewable and non-renewable energy. Renewable energy is also referred to as clean energy. It is the energy that comes from natural sources that are continually replenished such as biomass, hydropower, geothermal, wind and solar. Non-renewable energy comes from sources that will eventually run out or not replenished. Its supply is usually finite. Non-renewable energy sources are mostly fossil fuels such as coal, gas and oil.

Energy sources can also be grouped into primary energy sources and secondary energy sources. Primary energy sources may include fossil fuels (such as natural gas, coal and oil), nuclear energy and other sources of renewable energy. Secondary energy sources include electricity which is generated from primary energy sources.

From Nigeria perspective, primary energy consumption comes majorly from fossil fuels (coal, gas, and oil), biofuels and waste, wind, solar and hydropower (IEA, 2019). It is no longer disputable in Nigeria that the demand for energy is growing faster than its supply (generation). Nigerian energy consumption is expected to increase by 56% in 2040 due to its growth in population and industrial activities (Aiyetan & Olomola, 2018). This forecast has necessitated efforts by the government to boost energy supply in order to meet growing energy demand by various sectors in the country. Nigeria is a country that is heavily dependent on oil and the biggest oil producing country in Africa. Oil is a very powerful source of energy and it produces high energy output. Oil is a fossil fuel, and the burning of fossil fuels to generate energy releases CO_2 into the atmosphere, causing atmospheric pollution or in general environmental degradation.

Aside from oil (crude oil), Nigeria is also blessed with coal, natural gas and renewable energy resources such as hydropower, solar, wind, biomass etc. Energy plays a key role in the economy. Energy generation and consumption that causes CO_2 emissions is crucial for economic growth (Bosupeng, 2016), and production activities that engender economic growth cannot be separated from energy consumption (Deekor & Aziaka, 2020). However, the over-reliance on fossil fuels burning to generate energy in order to meet the surge in energy demand in Nigeria is worrisome. In 2017, according to EIA's analysis, most of Nigeria primary energy consumption was derived from oil (petroleum), natural gas and other liquids, constituting 97% of the whole, while traditional biomass and waste, coals and renewables accounted for only 3%. In November, 2021, it was stated that fossil fuels accounted for 60% of Nigeria government revenue and 90% of foreign exchange earnings (Ziady, 2021). As an oil-dependent economy, and an economy that depends highly on the burning of fossil fuels to generate energy for economic growth, it is well established that extracting of oil and burning of fossil fuels generate CO_2 emissions which adversely affects the environment. Overall, total (primary) energy consumption has been increasing due to increase in population and industrial activities, but the annual growth rate of total energy consumption (measured in kg of equivalent per capita) has been fluctuating since 1981until 2021. In spite of the fluctuations in total energy consumption per capita, real GDP per capita has continued to experienced significant growth over the years, while CO_2 emissions metric tons per capita fluctuates.

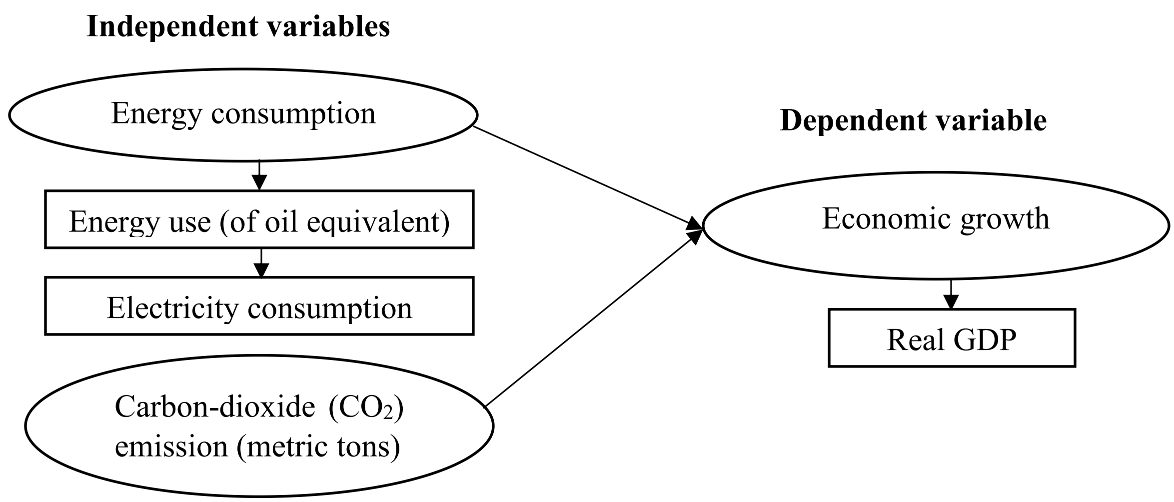
Electricity supply is one of the crucial factors required for rapid and sustainable growth in an economy. Therefore, the supply of an adequate, accessible, affordable, reliable and sustainable electric power is key to the achievement of the broad goals of industrialization, optimum productivity as well as improved standard of living. Nigeria is endowed with abundance of resources, still the country is unable to generate enough electric power to meet demands of residential and industrial sectors. Despite the numerous importance of electricity, access to electricity has been a major challenge in Nigeria. In 2021, the World bank approved the sum of $500 million to assist Nigerian government in order to improve its electricity distribution sector. The essence for this project was to help boost electricity access, by improving the performance of Electricity Distribution Companies (DISCOs) in Nigeria. As a result of this challenge, in 2020, 85 million Nigerians did not have access to grid electricity, representing 43% of the Nigerians population without access to electricity, which made Nigeria the country with the largest energy-access deficit in the world (World Bank, 2021). The approximately 57% of the population with access to grid electricity still experience erratic power supply and often rely on back-up generators which have negative environmental consequences. The non-availability of electricity to a portion of the entire population, poor quality, and unreliable nature of electric power supply in Nigeria has resulted in the increasing use of standby generators of different sizes and shapes (Nkalo & Agwu, 2019). The generators used as back-up depend on petroleum products, such as fuel, diesel etc., and their combustion bye-products emitted are major contributors to climate change, environmental degradation and global warming at large (Modi, Singh & Verma, 2017). Furthermore, the need for Nigeria to increase electric power generation in order to improve access to grid electricity has led to the burning of fossil fuels such as oil, natural gas and coal. The burning of fossil fuels causes CO_2 emission. The more burning of fossil fuels to generate electricity, the more CO_2 emissions released to the environment.

In Nigeria, fossil fuel energy consumption (% of total energy consumption) was 18.88% as of 2014, its highest value between 1971 and 2014 was 22.84% in 1992, while the lowest value was 5.97 in 1971 (World Bank, 2014). After 2014, fossil fuel consumption skyrocketed in Nigeria. In

2015, total electricity produced was 30.806 billion kilowatt hours (kwh), of which 81.5% came from fossil fuels and 18.5% from hydroelectricity and other renewable sources, while electricity net consumption was 25.942 billion kwh (EIA, 2020). In 2017, non-renewable (fossil fuels) energy consumption was 97% of total energy consumed, while renewable and nuclear energy consumption accounted for only 3%. In that same year, Nigeria's electricity generation was 12,664 megawatts (Mw), of which 10,522 megawatts (83%) was from fossil fuels, 2,110 megawatts (17%) was from hydroelectricity, and 32 megawatts (1%) was from wind, solar, and biomass and waste (EIA, 2020). In 2019, 31.6471 billion kilowatts of electricity were generated, of which 23.155 billion kilowatts (79%) was from fossil fuels, and the remaining 21% was from hydroelectricity and other renewable sources, while electricity net consumption was 26.7 billion kilowatts (EIA, 2022). In 2020, 81% of energy produced was derived from fossil fuels and 19% from hydroelectric source (Alves, 2021). In 2021, total electricity produced was 31.4579 billion kilowatt hours (kwh), of which 74.4% came from fossil fuels and 25.6% from hydroelectricity and other renewable sources, while electricity net consumption was 27 billion kwh (EIA, 2022). This trend shows that Nigeria energy generation and consumption, and electric power generation and consumption currently depend more on the burning of fossil fuels compare to other energy sources.

Improving energy generation and access to electric power supply is crucial to reduce poverty and unlock economic growth. The lack of adequate energy and power supply is a significant constraint to both citizens and businesses in Nigeria, resulting to an annual estimated loss of $26.2 billion (₦ 10.1 trillion) which is approximately 2% of the Nigeria gross domestic product (World Bank, 2021).

Figure 2.1: Conceptual Framework



Source: Author's Construction (2022).

As a result of the foregoing, two independent variables are proposed: energy consumption and carbon emission. In order to capture the aggregate energy consumption, two variables, which are energy used (of oil equivalent) and electricity consumption are identified. The independent variables stated may have a relationship with economic growth (dependent variable) in Nigeria. This study therefore examines the nexus between energy consumption, carbon dioxide emission and economic growth in Nigeria

2.3 Theoretical Review

There exist four major theoretical points of view in existing literature that attempt to link energy consumption to economic growth. The theories in energy-growth nexus are; growth hypothesis, feedback hypothesis, conservative hypothesis and neutrality hypothesis. The growth hypothesis suggests that economic growth of a country is strongly related to energy consumption, while the neutrality hypothesis postulated by the neoclassical school of thought suggests that there is no causal relationship between energy consumption and economic growth. Feedback hypothesis postulates that there exists a bidirectional causal relationship between energy consumption and economic growth (Adams, Klobodu & Opoku, 2016), while conservative hypothesis suggests a unidirectional causal relationship running from economic growth to energy consumption (Pao & Fu, 2013). However, global warming problems and the increasing concerns of the scarcity of energy sources on the one hand, and the new idea on green economy on the other hand, the causal relationship between economic growth and environmental pollution due to carbon-dioxide emission has become relevant among researchers and policy makers. The emission of carbon dioxide is a major cause of global warming. Thus, there is a need to examine whether energy consumption and economic growth lead to environment pollution and degradation. The well-known theories that link economic activities and environmental pollution are; Environmental Kuznets Curve (EKC) hypothesis, limit to growth model and pollution haven hypothesis, endogenous growth theory among others.

2.3.1 Environmental Kuznets Curve (EKC) Hypothesis

The Environmental Kuznets Curve is named after Simon Kuznets (1955), who proposed the inverted U-shaped theory relationship between various indicators of environmental pollution/degradation and per capita income. According to Simon Kuznets, income inequalities rise first and then fall as economic growth and developments proceed. Emissions of various pollutants, such as carbon dioxide, methane, sulphur, and nitrogen oxides emissions, are tightly coupled with the use of energy. Thus, Environmental Kuznets Curve is a model of the nexus among energy use, economic growth and the environment. It proposed that in the early stages of economic growth, pollution emissions rise and environmental quality falls, but beyond certain level of per capital income (which will differ from different indicators) the trend or pattern reverses, so that at high income levels, economic growth facilitates environmental improvements.

This means that environmental effects or emissions per capital are an inverted U-shaped function of per capital income. In other words, at the inception of economic transformation, per capita income is attributed to low environmental quality, but at a given peak of economic growth, pollution emissions decrease and income going upward. The idea behind EKC hypothesis is that as a country's industrialization activity increases, extraction and exploration of resources increases as income increases, thus raising the level of environmental pollution. As income continues to increase overtime, people will become more conscious and aware of environmental quality and more willing to embrace cleaner energy, thus reducing environmental pollution.

This EKC hypothesis was justified by Grossman and Krueger, (1991), Shafik and Bandypadhyay, (1992), and Panayotou (1993), pointing out the existence of an inverted U-shaped relationship between environmental degradation and economic growth. The policy implications of such findings are crystal clear denoting that in the long-run economic growth is compatible with environmental quality/improvement as countries by virtue of continues growth bring themselves out of environmental problem.

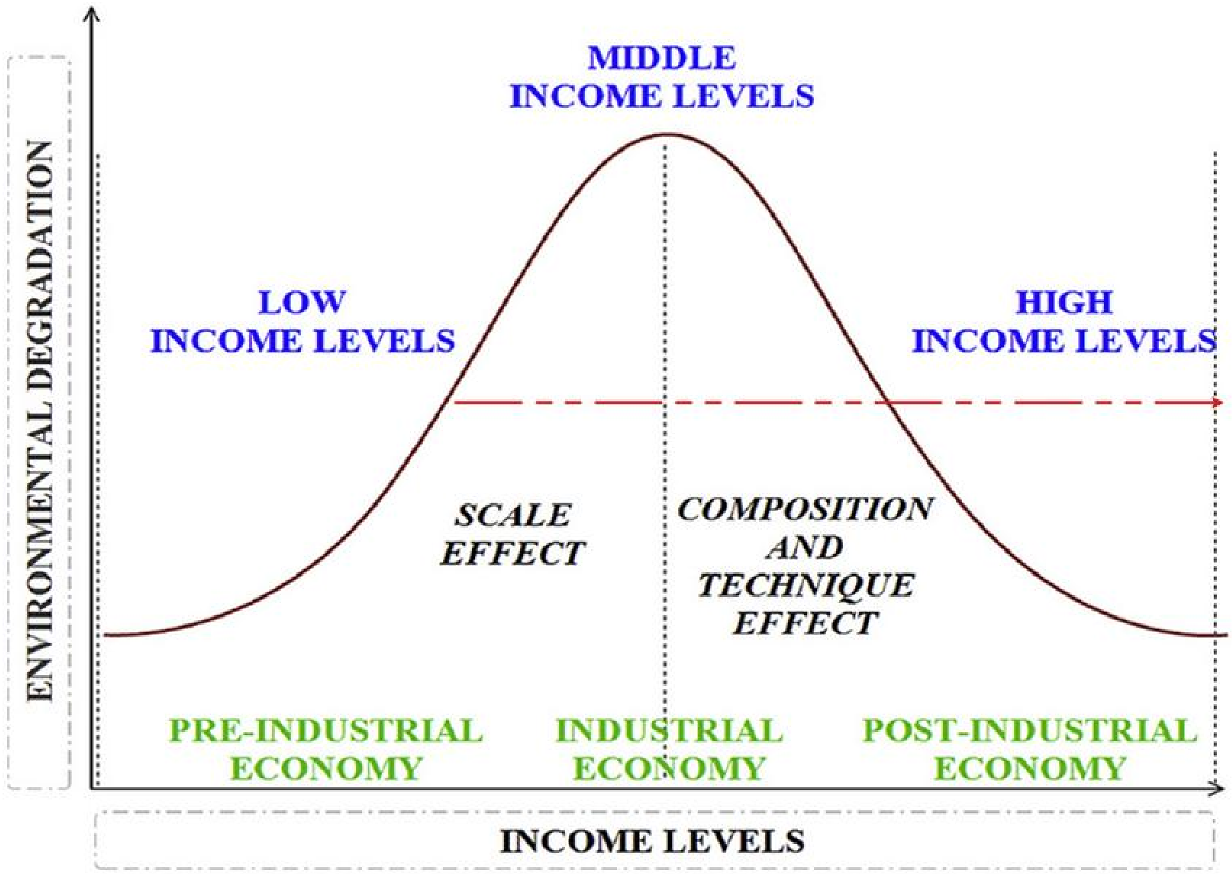


Figure 2.2: Environmental Kuznets Curve

Source: Sarkodie and Strezov (2018).

At the theoretical level, several reasons have been stipulated to justify the existence of an inverted U-shaped path for environmental quality in the long term. These arguments relate to;

(i) the anticipated structural changes in economic output composition as the country develops

(ii) changing technology and input mix

(iii) increased environmental awareness and willingness to embrace a cleaner environment at higher income level

(iv) establishment of stronger institutions and capacity to enforce environmental laws at higher level of income.

More succinctly, the channels through which the inverted U-shaped curve is anticipated to emerge for environmental quality and at a higher level of per capita income is grouped into three;

(i) scale effect

(ii) composition effect

(iii) and the technique effect (Groosman & Krueger, 1991; Stern, 2004; Akpan & Chukwu, 2011).

It is argued that economic growth will at first worsen environmental quality through the "scale effect" as economic production is raised at a given factor-input ratio, output mix and technology. However, as the structure, which is the output mix of the economy changes to a more resource intensive industrialization, pollution increases with growth. At the later stage of economic growth, environmental quality is expected to improve as the economic structure (output mix) moves towards services and light industrialized activities which are expected to generate lesser emission per unit of output, thus, referred to as the "composition effect". The "technique effect" encompasses the expected improvement in productivity and adaptation of a cleaner technology resulting in improvement in environmental quality.

On the basis of this argument, it is expected that environmental pollution is to increase in less developed countries and reduce in more developed countries. If EKC is empirically justified as true in any economy, it indicates that environmental damage is inevitable consequence of economic growth. Therefore, any attempt or strategy to overcome or eradicate such damage at the early stage of economic growth, might be considered as a futile effort.

2.3.2 Limit to Growth Model

The limit to growth model is attributed to Jay Forester of Massachusetts Institute of Technology (MIT) who in his book "World Dynamics" published in 1971 coined a model that examines the interplay of five basic highly aggregated variables such as world population, Industrial world production, food supply, pollution and natural resources in the world. Using "system dynamics methodology" of Forester, the authors of Limits to Growth crafted a world elaborate computer model. This model was crafted to predict the future development of five crucial interrelated variables, which are; population, industrial production, food production, pollution and non-renewable resources. The predictions of the model are hinged on its basic thesis that "continuous economic growth leads to infinite quantities that do not fit into a finite world". The basic thesis suggested that future world population, food production and industrial production will grow exponentially first, become highly unmanageable and then fall during the 21th century. The fall is as a result of the world economy reaching its physical limits in term non-renewable resources, agricultural land and earth's capacity to accommodate or absorb excessive pollutions on the environment which are finite. Thus, high accumulation of pollution reduces the absorbing capacity of the environment. If, in addition, industrial production continues to rise, it will lead to disastrous results. If the current growth trends in the population of the world, industrial level, pollution levels, food problem and resource depletion continue unchanged, the limit to growth in the world will occur and the most probable results will be a sudden and uncontrollable decline in both population and industrial capacity. Since technological advancement or progress does not expand physical resources (non-renewables) infinitely, it will be prudent to put limits on future growth rather than wait for a devastating decline in growth. This devastation can be avoided by controlling output and population growth rate, reducing pollution rate and therefore achieving an equilibrium with zero growth.

2.3.3 Endogenous Growth Theory

Paul Romer in the early 1980s began working on economic growth, and developed the endogenous growth theory. A conventional view among economist was that growth in productivity cannot be influenced by anything in the rest of the economy. As in Solow (1956), economic growth was basically exogenous. Several models developed in the 1960s failed to capture the widespread interest. Paul Romer developed the endogenous growth theory, stated that technological change is the result of effort by researchers and entrepreneurs who respond to economic activities (Jones, 2019). Any factor that affects their efforts, such as research findings, education and tax policy can potentially impact the long-run growth of the economy. The endogenous growth theory was modelled as a reaction to the deficiencies in neoclassical growth model of Solow-Swan. It is a new growth model which explains long-run economic growth rate on the basis of endogenous factors rather than exogenous factors of Solow-Swan. The endogenous growth theory highlights technical progress resulting from investment rate, capital stock size, and human capital stock. Romer's model of endogenous technical change pinpoints a research sector specializing in ideas production. This sector, implores human capital as well as existing stock of knowledge to develop new knowledge. According to Paul Romer, new ideas are more significant than natural resources. Romer cited Japan as an example, which has limited or few resources but it was open to new ideas and technology. He assumes that economic growth emanates from technological change, technological change is basically endogenous, incentives especially market incentives play a significant function in making technological change available, invention of new ideas and designs require specific amount of human capital, and the aggregate supply of human capital is fixed in the economy.

2.3.4 Externalities Theory

The concept of externalities or spillover effect is credited to two British economists, Henry Sidgwick (1838-1900) and Arthur Piguo (1877-1959). Henry Sidgwick is credited with first articulating the concept, while Arthur Piguo is credited with formalizing the concept of externalities. Arthur Pigou in his book "The Economics of Welfare" 1920, developed the concept of externalities by Alfred Marshall, as costs imposed or benefits conferred on others that are not taken into consideration by the person taking the action (Pigou, 1920). Arthur argued that the presence of externalities is cogent reason for government intervention. If someone is causing negative externalities on the environment such as pollution, he is engaging in too much of such activities that resulted in that externalities. Pigou suggested a tax should be imposed on that activity to discourage them. If someone is creating positive externalities, such as education that add to the value of the society, Pigou, suggested subsidies for such activities that create positive externalities. Pigou's idea was embraced until 1960, when Ronald Coase laid out that taxes and subsidies are not that relevant if the people creating it and people affected by the externalities can reason together and bargain. Nevertheless, most economist still advocate Pigovian taxes a very effective measure to curb pollution in the economy.

Thus, this study will adopt the Environmental Kuznets Curve (EKC) hypothesis because it hypothesizes the relationship between the various indicators of environmental degradation and per capita income.

2.4 Review of Empirical Literature

A review of empirical literature shows the most of studies that have examined the relationship between energy consumption, carbon dioxide emission and economic growth. This section robustly examines the empirical literature on the nexus between energy consumption, carbon dioxide emission and economic growth.

2.4.1 Empirical Studies in other Countries

Ang (2007) examines the dynamic causal relationship between CO_2 emissions, energy consumption, and output in France using cointegration and vector error-correction modelling techniques for the period 1960–2000. The empirical results show a strong long-run relationship between carbon emission, energy consumption and output level. The causality result shows a long-run causality from economic growth to energy consumption, then to carbon emission. It also reveals a short-run unidirectional causality running from energy used to output level in France.

Zhang and Cheng (2009) investigate energy consumption, carbon emissions, and economic growth relationship in China using a multivariate model. The empirical results for the period of time 1960 to 2007 show a unidirectional causality from GDP to energy consumption in the long-run. It also reveals a unidirectional causality running from energy consumption to carbon emissions in the long-run. Result shows that carbon emission nor energy consumption causes economic growth. The study recommends the pursuit of energy conservative and carbon emission reduction policy in China.

Menyah and Wolde-Rufael (2010) examine the relationship between energy consumption, pollutant emissions and economic growth in South Africa from 1965 to 2006 in multivariate framework, using the bound test approach and granger causality test. The empirical results show a short-run and long-run relationship among the variables. The results show a positive and a unidirectional causal relationship running from pollutant emissions to economic growth. A unidirectional causality running from energy consumption to economic growth exist, likewise from energy consumption to CO_2 emission all without feedback effects. The study suggests that South Africa may sacrifice economic growth in order to reduce pollutant emissions or reduce pollutant emissions by developing alternative energy sources such as coal to meet energy need and economic growth in the long-run.

Acaravci and Ozturk (2010) investigate energy consumption, CO_2 emissions and economic growth relationship in Europe from 1961 to 2005, using annual time series data for the nineteen European countries and ARDL bound test approach for analysis. The bound test shows a relationship between per capita carbon emissions, per capita energy consumption, real gross domestic product per capita and square of real GDP per capita for Switzerland, Portugal, Italy, Iceland, Greece, Germany, and Denmark only in the long-run. There is evidence of long-run positive elasticity estimate of carbon dioxide emissions in relation to energy consumption in Portugal, Italy, Greece and Germany at 1% significant level. In Denmark and Italy, at 1% and 5% significant level respectively, a long-run positive elasticity estimate is recorded of carbon dioxide emissions in relation to real GDP and a long-run negative elasticity estimate is found for carbon emission relative to square of real GDP per capita. The study validates the Environmental Kuznets Curve for Italy and Denmark among other countries in Europe.

Ozturk and Acaravci (2010) investigate the nexus between CO_2 emission, energy consumption, economic growth and employment ratio in Turkey from 1968 to 2005 using ARDL bound test for data analysis. The empirical findings suggest the evidence of a long-run relationship among the variables of interest at 5% significance level. The income elasticity of per capita carbon emission and energy consumption are 0.606 and 1.375 respectively. The results show that neither per capita carbon emissions nor per capita energy consumption granger causes per capita GPD, but employment ratio granger causes per capita GDP in the short-run. The Environmental Kuznets Curve hypothesis using linear logarithm model is not valid in Turkey. The study therefore recommends energy conservation policies, indicating no adverse effect on the real output growth in the long-run for Turkey.

Chang (2010) investigates the causality test of carbon dioxide emissions, energy consumption and economic growth in China, using multivariate cointegration causality test on the annual data spanning between 1981 and 2006. The results show a bidirectional causality running from GDP to CO_2 emission from crude oil and coal consumption. A bidirectional causality running from electricity consumption to GDP exists. Growth in GDP and energy consumption stimulates CO_2 emission. Electricity consumption is positively correlated GDP. Coal consumption and CO_2 emission exhibit bidirectional causality with a feedback effect.

Wang, Zhou, Zhou, and Wang (2011) study the nexus between CO_2 emissions, energy consumption and economic growth in China, using panel cointegration and panel vector error correction model based on the panel data for 28 provinces over the period 1995–2007. The empirical result shows cointegration between the variables. It also reveals a bidirectional causal relationship between CO_2 emission and energy consumption, and likewise between energy consumption and economic growth. In the long run, energy consumption and economic growth causes CO_2 emissions, and also CO_2 emissions and economic growth causes energy consumption. The study recommends that at the micro-level, government should strengthen energy and carbon management in order to facilitate energy efficiency, minimize energy waste and reduce avoidable CO_2 emissions.

Tiwari (2011) investigates energy consumption, CO_2 emission and economic growth in India by utilizing granger approach (vector error correction model framework) for the annual data spanning from 1971 to 2005. the result shows that carbon dioxide granger-causes gross domestic product, energy consumption does not granger-cause gross domestic product, gross domestic product does not granger-cause carbon dioxide, energy consumption granger-causes carbon dioxide emissions, and carbon dioxide emissions granger-causes energy consumption, but gross domestic product does not granger-causes carbon dioxide emissions. The study recommends that India should settle for policies that ensures energy conservation and efficient utilization of energy.

Hossain (2011) investigates CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of 9 newly industrialized countries using time series data for the period 1971 to 2007. The study employs panel unit test, Johansen Fishers cointegration and granger causality. The study shows no presence of long-run causal relationship, but there is the presence of unidirectional short-run causality running from economic growth and trade openness to CO_2 emissions, from urbanization to economic growth, and from trade openness to urbanization. The result also shows a (1.2189) long-run elasticity of CO_2 emissions in relation to energy consumption is higher than (0.5984) short-run elasticity. The study recommends that newly industrialized countries need to embark on energy conservation policies and strict environmental and energy policies.

Pao and Tsai (2011) examine the relationship betweeniCO_2 emissions, energy consumption, and economic growth in Brazil during 1980 to 2007. The empirical result reveals an inverted U-shaped relationship between carbon emission and income as well as energy consumption and income, meaning that both environmental degradation and energy consumption firstly increase with income, then stabilize, and eventually fall. The result indicates a bidirectional causality between income, energy consumption and carbon emission. The study recommends a dual strategy of increasing investment in energy infrastructure and development of energy conservation policies in Brazil.

Alam, Begum, Buysse, Rahman, and Huylenbroeck (2011) examine the causal relationship between energy consumption, CO_2 emissions and economic growth in India from 1971 to 2006, using innovation accounting method. The empirical results show the existence of granger causal bidirectional relationship between energy consumption and CO_2 emissions in the long run, but neither energy consumption nor CO_2 emission causes change in real income in the long run. There is no existence of directional causal relationship between energy consumption and income in the long-run, thus India could develop and follow energy conservative and efficiency polices without impeding its long run growth as recommended by the study.

Alam et al. (2012) examine energy consumption, carbon emissions and economic growth nexus in Bangladesh using cointegration and dynamic causality framework. The study uses Johansen bivariate cointegration model, ARDL and Granger causality with vector error correction model. The empirical results show a short-run and long-run unidirectional causality running from energy consumption to economic growth, while a strong long-run bidirectional causality exists between electricity consumption and economic growth but no evidence of short-run causal relationship. A short-run unidirectional causal relationship running from energy consumption to CO_2 emissions, but there exists feedback causality in the long-run. The results also show that in both short-run and long-run cases, CO_2 granger causes economic growth. The study recommends that policy makers should steer up the use of alternative energy sources to meet the rapid increase in energy demand in Bangladesh.

Sebri and Ben-Salha (2014) investigate the causal relationship between economic growth, renewable energy consumption, CO_2 emissions and trade openness in BRICS countries over the period from 1971 to 2010 using a multivariate framework. The study employs ARDL bound test and Vector Error Correction Model to determine the causal relationship between the variables. The empirical results show the existence of long-run equilibrium relationships among the variables (ARDL). The vector error correction model analysis shows a bidirectional granger causality between economic growth and renewable energy consumption, indicating a feedback effect. This explains the significant role renewable energy plays in stimulating growth in BRICS countries.

Alshehry and Belloumi (2014) investigate energy consumption, carbon dioxide emission and economic growth causal relationship in Saudi Arabia from 1971 to 2010 using Johansen multivariate cointegration approach. The results show the existence of a long-run relationships between the energy consumption, carbon dioxide emissions, energy price and economic growth. A long-run unidirectional causality running from energy consumption to carbon dioxide emissions and economic growth exists. A long-run unidirectional causality exists from energy price to carbon dioxide emissions and economic growth, and a short-run unidirectional causal relationship running from carbon dioxide emissions to energy consumption and output level. There exists a short-run unidirectional causality running from energy price to carbon dioxide emissions. The study validates the energy led growth hypothesis, and identifies energy price as the most significant factor that influences economic growth in Saudi Arabia. The study recommends that investing in renewable energy sources will help reduce fossil fuel consumption in Saudi Arabia.

Begum, Sohag, Abdullah, and Jaafar (2015) investigate the impact of economic growth, energy consumption, population growth on CO_2 emission in Malaysia from 1970 to 2009 using ARDL bound test, dynamic ordinary least square and Sasabuchi Lind Mehlum U (SLM U) tests. The empirical results show that from 1970 to 1980, carbon emission per capita decreases as GDP per capital increases, while carbon emission per capita increases sharply and GDP per capita increases from 1980 to 2009. The results also show that environmental Kuznets curve (EKC) hypothesis is not valid in Malaysia. The study also shows that energy consumption per capita and GDP per capita have a positive impact on carbon emission per capita in the long-run, but population growth has no significant effect on carbon emission per capita. However, in the long-run, the study suggests an adverse effect of economic growth on carbon emission. The paper recommends transformation renewable energy sources and energy efficiency as major strategies to sustain long-run economic growth in Malaysia.

Saidi and Hammami (2015) study the effect of CO_2 emissions and economic growth on energy consumption in 58 countries using a dynamic panel model. Generalized Method of Moment (GMM) was used to estimate the data for the period 1990 to 2012. The 58 countries were categories into various global panels. Empirical result reveals a statistically significant and positive impact of CO_2 emissions on energy consumption, and a significant positive impact of economic growth on energy consumption for the four global panels.

Ahmad, Zhao, Shahbaz, Bano, Zhang, Wang, and Liu (2016) carry out aggregate and disaggregate analysis of the Indian economy on the relationship between carbon emissions, energy consumption and economic growth during 1971 to 2014. The study employs ARDL and vector error correction model. The empirical results show a long-run cointegration relationship between the variables and that the Environmental Kuznets Curve hypothesis is considered valid in both aggregated and disaggregated level. In addition, energy consumption and carbon emission have positive relationship and a feedback causal effect exist between economic growth and carbon emission. The study recommends the use of energy efficient technologies for domestic production in order to reduce carbon emission at both aggregated and disaggregated levels.

Shahbaz, Mahalik, Shah, and Sato (2016) investigate the nexus between CO_2 emissions, energy consumption, and economic growth nexus for next 11 countries for the period spanning from 1972 to 2013. The study employs a time varying granger causality. The study finds that economic growth granger causes CO_2 emission in both Bangladesh and Egypt. In Philippine, Turkey and Vietnam, economic growth granger causes energy consumption, but in South Korea, feedback effect exists between energy consumption and economic growth. A unidirectional time varying granger causality exists in Indonesia and Turkey running from economic growth to CO_2 emissions and therefore validate the presence of Environmental Kuznets Curve hypothesis.

Stamatiou and Dritsakis (2017) investigate the causal relationship between energy consumption, Co_2 emission and economic growth in Italy. The authors employ dynamic modeling using Johansen's cointegration test and vector error correction model (VECM) to analyze the annual data covering the period of 1960 to 2011. The empirical findings show a short-run unidirectional causal relationship between economic growth and CO_2 emissions, with the direction of causality from economic growth to CO_2 emissions. It also reveals a unidirectional relationship between economic growth and energy consumption and a short-run bidirectional causal relationship between energy consumption and CO_2 emissions. The study recommends alternative renewable sources of energy. These measures will ensure the realization of growth expectation and adherence to EU's plan for climate change.

Kahouli (2018) examine the causal link between energy electricity consumption, CO_2 emissions, R&D stocks and economic growth in Mediterranean counties using SUR, 3SLS and GMM. The study covers the period 1990 to 2016. The empirical results show the presence of strong feedback effect between the variables (SUR). The results confirm the presence of unidirectional causality between electricity and R&D stocks (3SLS). Unidirectional causality between R&D stocks and economic growth, likewise between R&D stocks and CO_2 emissions (GMM). The study recommends the use of energy efficient technologies to reduce environmental degradation and to meet the escalating energy demands in Mediterranean countries.

Mardani, Streimikiene, Nilashi, Aranda, Loganathan, and Jusoh (2018) examine using the adaptive neuro-fuzzy inference system to predict the relation between energy consumption, economic growth, and CO_2 emissions in G20 countries from 1960 to 2016. The experimental result reveal that the proposed model is well capable of predicting CO_2 emissions based on energy consumption and economic growth for some G20 countries. The fuzzy rule system results show that by increasing economic growth and energy consumption in some G20 countries, CO_2 emissions level rise.

Jauhari, Dewata, Ridho, and Miskiyah (2018) examine the relationship between renewable energy, CO_2 emissions and economic growth in Indonesia for the annual time series data beginning from 2000 to 2016, using Johansen cointegration, Granger causality approach and Vector Autoregression model. The results show the absence of one or two-way causal relationship between economic growth, renewable energy consumption and CO_2 emissions. There is one-way causality running from the consumption of renewable energy to CO_2 emissions only. There is no evidence of one or two-way causal relationship between consumption of renewable energy and oil prices inithe world as it relates to Indonesia.

Mensaha, Sun, Gao, Omari-Sasu, Zhu, Ampimah, and Quarcoo (2019) examine the nexus of economic growth, fossil fuel energy consumption, CO_2 emissions and oil price in 22 African countries from 1990 to 2015 using PMG panel ARDL approach. The empirical results show a short-run and long-run bilateral causal relationship between fossil fuel energy consumption and growth, and also between fossil fuel energy consumption and carbon emission. A short-run and long-run unilateral causal relationship exists running from carbon emissions to economic growth for non-oil producing countries in Africa, and a long-run bilateral causal relationship for oil exporting countries in Africa. It also shows a short-term and long-term unilateral cause and effect relationship running from oil prices to economic growth, fossil fuel energy consumption and carbon emissions for both non-oil exporting and oil exporting countries in Africa.

Nugraha and Osman (2019) examine the relationship between CO_2 emissions, economic growth, energy consumption, and household expenditure in Indonesia from 1975 to 2014. The study employs cointegration and granger causality based on vector error correction model. The empirical result reveals that CO_2 emissions and energy consumption have mutual effect and an increase in CO_2 emissions tend to cause a greater effect on energy consumption. CO_2 emissions, energy consumption, value added of the industry sector, and the expenditure of household final consumption have significant Impact on the value added of both the agricultural sector and service sector. A cointegration relationship occurs in the long term when energy consumption, household final expenditure, value added of the industry sector, value added of the agriculture sector, and value added of the service sector, respectively, are ascertained as the dependent variables in the model.

Akadiri, Bekun, Taheri, and Akadiri (2019) investigate the link between carbon emissions, energy consumption and economic growth in Iraq, apply bounds test for cointegration and Toda-

Yamamoto for Granger causality test using annual data covering the period 1972 to 2013. The study findings show unidirectional causality running from economic growth to energy consumption, as well as a unidirectional causality running from carbon emission to energy consumption in the long-run. In Iraq, there is no feedback causal relationship between economic growth, carbon emissions and energy consumption. The study recommends based on findings that Iraq should exercise energy conservative measure, as such measure will not retard growth in the long-run.

Odugbesan and Rjoub (2020) consider the relationship among economic growth, energy consumption, CO_2 emission, and urbanization in MINT (Indonesia, Mexico, Nigeria, and Turkey) countries using ARDL bound test model for the annual from 1993 to 2017. The study reveals a unidirectional causality from energy consumption to economic growth for Nigeria and Indonesia, while a bidirectional causality for Mexico and Turkey. The study also reveals that all there is a long-run relationship from economic growth, energy consumption, and CO_2 emissions to urbanization for all the MINT countries. The study recommends the development of energy conservative policies, reduction in urbanization level to ensure sustainable urbanization and formulation of relevant policies to minimize CO_2 emissions.

Awodumi and Adewuyi (2020) investigate non-renewable energy consumption role in economic growth and carbon emission from oil producing economies in Africa from 1980 to 2015. The study utilizes non-linear autoregressive distribution lag for data analysis. The paper reveals the presence of asymmetric effect of per capita consumption of both petroleum and natural gas consumption on economic growth and carbon emission per capita in all selected countries except Algeria. Positive change in the non-renewable energy consumption slow down growth and thus reduces emission in Nigeria. High consumption of these energy products in Gabon promotes growth and improves environmental quality. In Egypt, the consumption of these energy products has negative impact on environment as it enhances economic growth. Positive change in the consumption of non-renewable energy products contributes to economic growth in Angola, the effect on carbon emission is mixed across time and energy type. The negative change effect in petroleum and natural gas consumption is the same to those of positive change in Egypt and Nigeria. The study recommends that policymakers in oil producing economies (in Africa) must explore the avenues available to invest in and promote carbon-reducing technology in production processes in their course of realizing economic growth.

Adebayo and Akinsola (2020) examine the causal relationship between Co_2 emission, energy consumption and economic growth in Thailand for the time series data starting from 1971 to 2020 using wavelet coherence approach, conventional Granger and the Toda-Yamamoto causality model. The study results show that economic growth causes CO_2 emissions at different frequencies between the study period. A bidirectional causal relationship exists between CO_2 emissions and energy consumption in Thailand. In both short-run and long-run cases, a positive relationship exists between CO_2 emissions and energy consumption, and likewise between GDP growth and CO_2 emissions. The study recommends an initiative towards energy efficiency and policies to minimize energy waste in Thailand.

Etokakpan, Solarin, Yorucu, Bekun, and Sarkodie (2020) examine the nexus between natural gas consumption, capital formation, globalization, CO_2 emissions and economic growth in Malaysia for data starting from 1980 to 2014 in a multivariate framework, utilizing cointegration test and Granger causality analysis. The study results show a long-run equilibrium relationship between the variables of interest. The results show the existence of growth-energy driven hypothesis over the study period. The study recommends a cleaner energy and alternative energy sources that are environmentally friendly, of which both private and public sectors must embrace in Malaysia.

Thongrawd and Kerdpitak (2020) investigate the nexus between energy consumption, CO_2 emissions and economic growth in four ASEAN countries (Indonesia, Malaysia, Singapore and Thailand) from 1980 to 2018 using Vector Error Correction Model framework for data analysis. The study finds a significant positive relationship between the variables of interest for the four ASEAN countries. In the long-run CO_2 emissions and per capita GDP form a non-linear EKC relationship. The causality results show a unidirectional causal relationship running from energy consumption and CO_2 emission to economic growth, and a short-run unidirectional causal relationship running from CO_2 emission to energy consumption.

Adebayo, Ayobamiji, Kirikkaleli, Akinsola, and Mwamba (2021) examine if CO_2 emissions and energy consumption determine the economic performance of South Korea using a time-series analysis. The study utilized autoregressive distribution lag for annual time series data from 1965 to 2018. The result of autoregressive distribution lag bound test shows a long-run connection between the variables of interest, and energy consumption causes economic growth. The study recommends a change in the energy mix in South Korea to a renewable energy, and South Korea cannot embark on energy conservation policies.

Gao, Ge, Lu, Wang, and Zhang (2021) investigate provincial energy related CO_2 emissions from economic growth in China and its convergence. The study covers the period from 1995 to 2017. The study applied Tapio decoupling model, Logarithmic Mean Divisia Index model with the Cobb-Douglas production function for data analysis. The empirical result shows that CO_2 emission-economy decoupling has primarily been relying on economic activities decoupling from energy consumption for the period under consideration. There is variation in provincial emissions and the forces that drives it. Nevertheless, CO_2 emission-economy decoupling pattern may assume to converge as one club, implying a low carbon progress throughout the provinces. The study recommends developmental strategies for the provinces that will engender significant focus on technological innovation, especially technologies with low carbon emissions, rather than expanding labor and capital inputs.

2.4.2 Empirical Studies in Nigeria

Akpan and Akpan (2012) investigate the nexus between electricity consumption, CO_2 emissions and economic growth in Nigeria for annual time series data starting from 1970 to 2008, utilizing a multivariate vector error correction framework. The empirical results show a long-run relationship of economic growth to increasing carbon emission, while an increasing consumption of electricity causes increase in carbon emissions. Electricity consumption has a positive relationship with carbon emission, while carbon emission has a negative impact on the environment. In Nigeria, the study refutes the Environmental Kuznets Curve hypothesis. A unidirectional causal relationship running from economic growth to carbon emission exits, while no causal relationship exists between electricity consumption and economic growth in Nigeria. The study therefore recommends the pursuit of emission reduction policies and investment in electricity infrastructures to obtain neutrality hypothesis between electricity consumption and economic growth in Nigeria.

Nnaji, Chukwu, and Moses (2013) study electricity supply, fossil fuel consumption, CO_2 emission and economic growth relation in Nigeria for the annual time series data beginning from 1971 to 2009, using a multivariate framework. The study employs bound test approach and Granger causality. The empirical results reveal a positive relationship between electricity supply and CO_2 emissions in Nigeria. Economic growth in Nigeria is related with increasing CO_2 emission. The causality test reveals that electricity supply does not have significant impact on economic growth in Nigeria. The study recommends that to drive economic growth, there is need for proper energy planning such as developing alternatives to fossil fuel burning and consumption, and significant investment in energy infrastructures in Nigeria.

Saibu and Jaiyeola (2013) study the relation between energy consumption, carbon emission and economic growth and its implications for energy policy and climate protection in Nigeria between 1970 and 2011, using ARDL and Granger causality framework. The study reveals that economic growth in Nigeria is significantly influenced by investment growth rate, growth rate change in investment, growth rate in crude oil production, growth rate in crude oil consumption, growth rate change of carbon monoxide emissions from gas flaring, carbon emission growth rate from gas flaring and economic growth rate. The study concludes that carbon emission causes impediment to sustainable economic in Nigeria, since there exists a causal relationship among the variables of interest.

Shuaibu and Oyinlola (2013) investigate the causal relationship between energy consumption, CO_2 emissions and economic growth in Nigeria from 1970 to 2011, using Gregory-Hansen cointegration test and Toda and Yomamoto Granger non-causality test analysis. The study findings show that energy consumption, CO_2 emissions and economic growth are cointegrated with a break point in 1991 and 1992. Due to probable structural shift, there is no evidence of causality running from CO_2 emissions and energy consumption to economic growth in Nigeria. There is a time varying effect of CO_2 emissions and energy consumption on economic growth before, between and after the structural break point in 1991 and 1992. The study recommends renewable energy consumption and alternative energy sources that are environmentally friendly in the long-run.

Chindo et al. (2014) investigate the relationship that exist between energy consumption, CO_2 emissions and GDP in Nigeria from 1970–2010 using ARDL for cointegration. The study results show presence of a long run relationship between the variables in Nigeria. CO_2 emissions, both in short and long-run have a positive significant impact on GDP. In the short-run, energy consumption has a negative effect on GDP. The study recommends a renewable energy source exploration such as solar and wind, and other alternative energy sources in Nigeria. This will result to the reduction of CO_2 emissions in the atmosphere.

Alege et al. (2016) examine the relationship between pollutant emission, energy consumption and economic growth in Nigeria using annual time series data from 1970 to 2013. The study employs Johansen cointegration test and Wald exogeneity Granger causality. The results indicate that fossil fuel enhances carbon emissions, while clean energy sources like electricity reduces the concentration of carbon dioxide emissions in the atmosphere. A unidirectional causality running from fossil fuel to carbon dioxide emissions and gross domestic product exists in Nigeria. The study recommends a sustainable environment and economic growth based on clean energy sources for fossil fuel consumption.

Lin and Atsagli (2016) study the nexus between energy consumption, inter-fuel substitution and economic growth in Nigeria from 1980 to 2012 by adopting Translog production function and Ridge regression due to the presence of multicollinearity to analysis the possibility for inter-factor and inter-fuel substitution among the variables of interest. The study findings show that all input pairs of interest are substitutes, thus the initiation of price ceiling, competitive pricing policies and elimination of petroleum subsidies would lead to the incremental use of electricity by industries and thus increase the intensity of both capital and labor in the sector. The study also reveals a convergence in technical progress relatively among the paired input factors with electricity scoring the fastest rate of progress. The study concludes that in the future there is tendency for petroleum to lose its dominance among the energy mix in Nigeria.

Rafindadi (2016) carry out the study to know whether economic growth impacts energy consumption and CO_2 emissions in Nigeria, using innovation account test to validate analysis. The study employs time series data from 1971 to 2011, and ARDL bound test, Bayer–Hanck cointegration and VECM model for analysis. The results indicate energy demand stimulation by financial development, but reduction in CO_2 emissions. Economic growth reduces the demand for energy but increases emission of carbon dioxide. The study shows that trade openness increases the consumption of energy, but enhances environmental quality. A significant impact on CO_2 emissions by energy consumption exists. The causality test shows a bidirectional causal relationship between financial development and energy consumption, as well as between financial development and CO_2 emissions in Nigeria. The study supports trade led energy hypothesis and confirms the existence of a feedback effect between economic growth and CO_2 emissions. The study recommends investments in the financial sector in Nigeria, which will in turn lead to investment in sustainable renewable energy sources to meet energy needs.

Aiyetan and Olomola (2018) investigate environmental degradation, energy consumption, population growth and economic growth in Nigeria. They seek to know if Environmental Kuznets Curve matter in Nigeria. The study employs autoregressive distributed lag bounds test approach with structural breaks and Toda-Yamamoto non-granger causality approach for data during the period 1980 to 2012. The study findings reveal the presence of strong unidirectional causal relationship running from carbon dioxide emission, energy consumption and economic growth to population growth and no evidence of unidirectional causal relationship running from carbon dioxide emissions and energy consumption and economic growth in Nigeria. Energy consumption and population growth have strong positive impact on carbon dioxide emission in both short-run and long-run cases, while economic growth has a weak negative impact on carbon dioxide emission in the short-run. The study supports Environmental Kuznets curve in Nigeria with a turning point of 4.87 in its inverted U-shaped curve analytically. The study recommends the increase of environmental tax rate so as to reduce the rate of fossil fuel consumption by individuals, which will in turn reduce carbon dioxide emissions per capita.

Deekor et al. (2020) investigate the role energy consumption in carbon dioxide emissions and economic growth in Nigeria from 1970 to 2016, using ARDL approach. The study findings show a probable cointegration between energy consumption, CO_2 emissions and economic growth. The findings show that EKC hypothesis is not valid in the Nigerian economy. There is a monotonically increasing relationship between carbon dioxide emissions and per capita gross domestic product. The study also shows a different energy mix response between CO_2 emission and energy consumption in Nigeria.

Esan and Hassan (2020) examine the nexus that exists between carbon dioxide emissions, energy consumption and economic growth in Nigeria from 1980 to 2018, using Granger block exogeneity (wald test) and Vector Autoregressive approach. The study results show a relationship between GDP and increasing carbon emission, while a positive relationship between primary energy consumption and carbon emissions in Nigeria. In the long-run, the shock to the variables of interest is not evident. The study recommends investment in the Nigeria energy sector, in order to engender diversification in energy generation and reduction in carbon dioxide emissions. It also encourages the adoption of energy conservative measures in order to achieve efficient use of energy in the country Nigeria.

Iorember et al. (2020) investigate the nexus between renewable energy consumption and environmental quality as it relates to broad based financial development in Nigeria as well as re-examining the EKC hypothesis from 1990 to 2016, using ARDL and VECM granger causality test approach. The results reveal that renewable energy consumption enhances environmental quality, while broad based financial development hurts the environment. The study validates the inverted U-shaped Environmental Kuznets Curve in Nigeria. The study indicates a long-run impact of the independent variables on carbon dioxide emissions. The short-run causality test shows a mix of both bidirectional and unidirectional causal relationship between the variables of interest. The study recommends policy formulation by policy makers that will ensure environmental sustainability given the role of renewable energy and financial development.

Ushie and Aderinto (2021) investigate the nexus between energy consumption, economic development and environmental degradation in Nigeria, testing the Environmental Kuznets Curve hypothesis for the annual time series data from 1981 to 2019 using ARDL method. The empirical results show the existence of short-run and long-run relationships among the variables of interest. In Nigeria, energy consumption has a positive impact on CO_2 emissions in short-run and long-run cases. In the short-run, without any significant impact noticed in the long-run, energy consumption is the only variable in the three lagged period observed has a positive association with ecological footprints. The study validates the U-shaped EKC hypothesis in relation to environmental degradation to economic development in Nigeria, while there is no U-shaped EKC evidence for ecological footprints. The study recommends an increase in the usage of alternative energy sources that are free from pollution emissions in Nigeria.

2.5 Summary Table of Empirical Literature Reviewed

S/N	Author/ Year	Location	Variables of Interest	Methods	Periods	Findings
	Studies in other countries					
1	Ang (2007)	France	CO_2 emissions metric tons per capita, commercial energy use kilogram of oil equivalent (kgoe) per capita, Real Gross Domestic Product (RGDP) per capita, and square of RGDP per capita	Cointegration and Vector Error Correction Model	1960 - 2000	The study shows a long-run causal relationship from economic growth to energy consumption, then to carbon emission. It also reveals that in the short-run, unidirectional causality running from energy used to output level exist.
2	Zhang and Cheng (2009)	China	RGDP, Gross Fixed Capital Formation (GFCF), Energy Consumption (EC) kilotons of standard coal equivalent (ktce), CO_2 emissions, and Urban Population (UP)	Granger Causality Test	1960 - 2007	The study reveals unidirectional Granger causality running from GDP to energy consumption, and from energy consumption to carbon emissions in the long run. Evidence shows that neither carbon emissions nor energy consumption leads economic growth.
3	Menyah and Wolde-Rufael (2010)	South Africa	EC**,** CO_2 emissions, Labor and Capital	Bound test Cointegration and Granger Causality Test	1965 - 2006	The study shows the evidence of unidirectional causality running from pollutant emissions to economic growth, from energy consumption to economic growth, and from energy consumption to CO_2 emissions. All without feedback.
4	Chang (2010)	China	Fossil fuel, Electricity billion Kilowatts hour (kwh), CO_2	Multivariate cointegration causality test	1981 - 2006	The result shows the presence of a bidirectional causal relationship running from

			emissions million metric tons, and GDP.			GDP to CO_2 emission emanating from crude oil and coal consumption. A bidirectional causal relationship running from electricity consumption to GDP. Growth in GDP and energy consumption stimulates CO_2 emission.
5	Ozturk and Acaravci (2010)	Turkey	RGDP, CO_2 emissions kg metric tons, Energy use (EU) kg of oil equivalent, Total labor force and Total population	Autoregressive Distributed Lag bounds testing approach.	1968 - 2005	The result reveals that neither carbon emissions per capita nor energy consumption per capita cause real GDP per capita, but employment ratio causes real GDP per capita in the short run.
6	Acaravci and Ozturk (2010)	Europe	CO_2 emissions metric kg per capita, EU (kgoe), RGDP per capita, and Square of RGDP per capita	ARDL bound test approach	1961 - 2005	The study shows a relationship between per capita carbon emissions, per capita energy consumption, real gross domestic product per capita and square of real GDP per capita for Switzerland, Portugal, Italy, Iceland, Greece, Germany, and Denmark only in the long-run
7	Alam et al. (2011)	India	RGDP, Total commercial energy consumption kilotons of oil equivalent (ktoe), CO_2 emissions, total labor forces and GFCF	Granger Causality test and Generalized Impulse Response Function (GIRF)	1971 - 2006	The study shows that in the long-run, there exist a bi-directional causality between energy consumption and CO_2 emissions but neither CO_2 emissions nor energy consumption causes movements in real income.
8	Pao and Tsai (2011)	Brazil	CO_2 emissions, EC, and RGDP	Grey prediction model (GM) and Autoregressive Integrated Moving Average	1980 - 2007	The results show the presence of a bidirectional strong causal relationship running between income, energy consumption and emissions.

				(ARIMA)		
9	Hossain (2011)	9 Industrialized countries	CO_2 emissions metric tons (mt) per capita, EC per capita, RGDP per capita, % of export and import value of GDP, and % UP of the total	Johansen Fisher panel cointegration and Granger Causality test	1971 - 2007	The results show the absence of long-run causal relationship, but there is the evidence of unidirectional short-run causal relationship from economic growth and trade openness to carbon dioxide emissions. Also, from economic growth to energy consumption, from trade openness to economic growth, from urbanization to economic growth and from trade openness to urbanization.
10	Tiwari (2011)	India	CO_2 emissions per capita, electricity consumption per capita, and GDP per capita	Granger Approach	1971 - 2005	The result shows that CO_2 Granger-causes GDP, while energy consumption does not Granger-cause GDP. GDP does not Granger-cause CO_2 while energy consumption Granger-causes CO_2 emissions. CO_2 emissions Granger-causes energy consumption.
11	Wang et al. (2011)	China	CO_2 emissions (mt) per capita, EC kg of coal equivalent (kgce) per capita, RGDP per capita, and Square of RGDP per capita	Panel cointegration and panel vector error correction	1995 - 2007	The study results show that CO_2 emissions, energy consumption and economic growth are cointegrated. It reveals a bidirectional causal relationship between CO_2 emission and energy consumption, and likewise between energy consumption and economic growth. In the long run, energy consumption and economic growth causes CO_2 emissions. Also, CO_2 emissions and

						economic growth causes energy consumption.
12	Alam et al. (2012)	Banglad-esh	RGDP per capita, EC (kgoe) per capita, Electricity consumption kwh, and CO_2 emissions (mt) per capita	Johansen bi-variate cointegration model and Granger Causality test	1972 - 2006	The study results indicate a unidirectional causality from energy consumption to economic growth both in the short and long-run, while a bi-directional long-run causality between electricity consumption and economic growth but no causal relationship exists in short- run. A unidirectional causality runs from energy consumption to CO_2 emission for the short-run but feedback causality exists in the long-run. CO_2 Granger causes economic growth both in short and long-run.
13	Sebri, and Ben-Salha (2014)	BRICS countries	RGDP per capita, Combustible renewables and wastes in 1000 mtoe per capita, CO_2 emissions (mt) per capita, Sum of import and export divided by GDP per capita	ARDL bounds testing approach to cointegration and vector error correction model (VECM)	1971 - 2010	The study shows a bi-directional Granger causality between economic growth and renewable energy consumption, supporting the feedback hypothesis.
14	Alshehry, and Belloumi (2014)	Saudi Arabia	EC (kgoe) per capita, GDP per capita, Crude oil consumer price index, and CO_2 emissions per capita	Johansen multivariate cointegration approach	1971 - 2010	The study reveals a long-run unidirectional causality running from energy consumption to carbon dioxide emissions and economic growth. A long-run unidirectional causality exists from energy price to carbon dioxide emissions and economic growth. A short-run unidirectional

						causal relationship running from carbon dioxide emissions to energy consumption and output level. A short-run unidirectional causality running from energy price to carbon dioxide emissions. The study validates energy led growth hypothesis.
15	Begum et al. (2015)	Malaysia	CO_2 emissions (mt) per capita, GDP per capita, EC (kgoe) per capita, and population growth	Dynamic Ordinary Least Squared (DOLS) and the Sasabuchi–Lind–Mehlum U (SLM U test) tests.	1970 - 2009	The findings reveal that in the long-run, both per capita energy consumption and per capita GDP has positive impact on per capita carbon emissions, but population growth rate has no significant impacts on per capita CO_2 emission.
16	Saidi and Hammami (2015)	58 countries	EC per capita, Domestic credit as a share of GDP, growth rate GDP, CO_2 emissions, Population, and Capital stocks per capita	Generalized Method of Moments (GMM)	1990 - 2012	The study reveals a positive impact of CO_2 emissions on energy consumption. Economic growth has a positive impact on energy consumption
17	Shahbaz et al. (2016)	Next 11 Countries	EC (ktoe) per capita, RGDP per capita, Square of RGDP per capita, and CO_2 (mt) per capita	Novel approach i.e., time-varying Granger causality	1972 - 2013	The study reveals that economic growth granger causes CO_2 emission in Bangladesh and Egypt. In Philippine, Turkey and Vietnam, economic growth granger causes energy consumption. In South Korea, feedback effect exists between energy consumption and economic growth. A unidirectional time varying granger causality exists in Indonesia and Turkey running from

						economic growth to CO_2 emissions. The study validates the presence of Environmental Kuznets Curve hypothesis.
18	Ahmad et al. (2016)	India	CO_2 emissions per capita, EC per capita, RGDP per capita, and RGDP square	Autoregressive Distributed Lag and Vector Error Correction Model	1971 - 2014	The study results show a long-run cointegration relationship between the variable and that Environmental Kuznets Curve is valid at the aggregated and disaggregated levels. There exists a feedback causality between economic growth and carbon emission. Energy consumption and carbon emission are positively related.
19	Stamatiou and Dritsakis (2017)	Italy	CO_2 emissions per capita, EU per capita, Income per capita, Trade openness, and Square of trade openness	Johansen's cointegration test and vector error correction model (VECM)	1960 - 2011	The study reveals a unidirectional causality relationship between economic growth and CO_2 emissions with running from economic growth to CO_2 emissions, as well as a unidirectional causality relation running from economic growth to energy consumption in the short-run. It also reveals a short-run bidirectional causality relation between energy consumption and CO_2 emissions.
20	Kahouli (2018)	Mediterra-nean Countries (MCs)	RGDP, Energy electricity consumption per capita, CO_2 emissions per capita, R&D stocks, FDI, Trade, Real Capital and Labor	SUR, 3SLS and GMM	1990 - 2016	The study reveals the presence of strong feedback effect between the variables (SUR). There exists a unidirectional causality between electricity and R&D stocks (3SLS). A

			force			unidirectional causality between R&D stocks and economic growth, likewise between R&D stocks and CO_2 emissions (GMM).
21	Jauhari et al. (2018)	Indonesia	Real Gross National Product (RGNP), Renewable energy, CO_2 emissions (mt) per capita, and World oil price	Johansen co-integration, Granger's causality, and VAR Model	2000 - 2016	The study reveals there exist no one or two-way causality relationship between economic growth, consumption of renewable energy and CO_2 emissions. There exists one-way causality between renewable energy consumption and CO_2 emissions but not vice versa, and there is no evidence of one or two-way causality between consumption of renewable energy and world oil prices.
22	Mardani et al. (2018)	G20	CO_2 emissions (mt) per capita, GDP per capita, and EC (kgoe)	Adaptive Neuro-Fuzzy Inference System (ANFIS) model	1962 - 2016	The study reveals that economic growth and energy consumption are positively related to CO_2 emissions, and causes CO_2 emissions to increase.
23	Akadiri et al. (2019)	Iraq	CO_2 emissions (mt) per capita, EU kilo equivalent per capita, and GDP per capita	Bound test and Toda-Yamamoto Granger causality test	1972 - 2013	The study shows a unidirectional causality from economic growth to energy consumption, as well as from carbon emission to energy consumption in the long-run. There is no feedback relationship between economic growth, carbon emissions and energy consumption.
24	Nugraha and Osman (2019)	Indonesia	CO_2 emission, EC, Value added of agricultural sector, industry sector,	Cointegration and Error correction model	1975 - 2014	The study finds that CO_2 emission and energy consumption have a mutual impact. An

			service sector, and Household final expenditure			increase in CO_2 emissions causes greater effect on energy consumption.
25	Mensaha et al. (2019)	22 African countries	Fossil fuel, CO_2 emissions, Oil price, RGDP, Capital stock and Labor	PMG panel ARDL approach	1990 - 2015	The study reveals a bilateral causal link flanked by fossil fuel energy consumption and economic growth as well as fossil fuel energy consumption and carbon emissions in long and shot-terms for all panels. A unilateral causality from carbon emissions to economic growth in long-term and short-term for non-oil exporters nonetheless a bilateral causal relationship only in long-term for oil exporting countries. A unilateral cause-and-effect link from oil prices to economic growth, energy consumption (fossil fuel) and carbon emission across all country groups in long and short-terms.
26	Thongrawd and Kerdpitak (2020)	ASEAN Countries	CO_2 emissions (mt) per capita, Electricity consumption million kwh per capita, RGDP per capita and RGDP square	Vector Error Correction Model (VECM)	1980 - 2018	The study reveals a positive significant relationship among energy consumption, CO_2 emissions and economic growth. A unidirectional causal relationship running from energy consumption and CO_2 emission to economic growth, and a short-run unidirectional causal relationship running from CO_2 emission to energy consumption exist.
27	Adebayo	Thailand	CO_2 emissions, EC,	Wavelet	1971 -	Changes in economic

	and Akinsola (2020)		and GDP	coherence approach, Conventional Granger and the Toda-Yamamoto Causality techniques	2018	growth led to changes in CO_2 emissions. Bidirectional causal relationship between CO_2 emissions and energy consumption. Positive correlation among variables in the short and long-run.
28	Awodumi and Adewuyi (2020)	Oil producing countries in Africa	RGDP per capita, Financial Development, CO_2 emission per capita, Trade openness, and EC per capita	Non-linear Autoregressive Distributed Lag (NARDL) technique.	1980 - 2015	The study reveals evidence of asymmetric effect of per capita consumption of both petroleum and natural gas consumption on economic growth and carbon emission per capita in all the selected countries except Algeria.
29	Odugbesan and Rjoub (2020)	MINT Countries (Mexico, Indonesia, Nigeria, and Turkey)	UP, GDP per capita, CO_2 emission per capita, and EU (kgoe) per capita	ARDL Bounds test approach	1993 - 2017	The study reveals a unidirectional causality energy consumption to growth was true for Nigeria and Indonesia, whereas Mexico and Turkey followed the feedback hypothesis, which indicates a bidirectional relationship. All the MINT countries have a long-run relationship from economic growth, energy consumption, and CO_2 emissions to urbanization.
30	Etokakpan, et al. (2020)	Malaysia	CO_2 emissions, RGDP, Gross Capital Formation (GCF), Globalization index and Natural gas	Cointegration and Granger causality	1980 - 2014	The study shows the existence of growth-energy driven hypothesis over the study period.
31	Adebayo et al. (2021)	South Korea	GDP per capita, CO_2 emissions per capita, % of GCF, UP, and Primary	Autoregressive distributed lag (ARDL)	1965 - 2018	The study reveals a long-run positive relationship between CO_2 emission, energy consumption and

			energy consumption			economic growth
32	Gao et al. (2021)	China	CO_2 emissions from fossil fuel, GDP, and EC.	Tapio decoupling model	1995 - 2017	The study reveals that emissions-economy decoupling has been primarily dependent on decoupling of economic activities from energy consumption.
	Studies in Nigeria					
1	Akpan and Akpan (2012)	Nigeria	CO_2 emissions millions (mt), Electricity consumption, Real income per capita, and Real income per capita square	Multivariate Vector Error Correction Model (VECM)	1970 - 2008	The study findings show that in the long run, economic growth is associated with increase carbon emissions, while an increase in electricity consumption leads to an increase in carbon emissions. A unidirectional causal relationship running from economic growth to carbon emission exits, while no causal relationship exists between electricity consumption and economic growth.
2	Shuaibu and Oyinlola (2013)	Nigeria	GDP, Working population, GFCF, and CO_2 emissions	Granger non causality test	1970 - 2011	The study reveals cointegration between variables and due to structural shift, no causal relationship from energy consumption and Co_2 emission to economic growth.
3	Nnaji et al. (2013)	Nigeria	Electricity consumption, Fossil fuel consumption, RGDP, and CO_2 emission in million (mt)	Bound test approach and Granger causality test	1971-2009	The study findings reveal a short-run and long-run positive and statistically significant relationship between CO_2 emissions and fossil fuel consumption. Economic growth is associated with increased CO_2 emissions

						while a positive relationship exists between electricity supply and CO_2 emissions. Electricity supply has not impacted significantly on economic growth.
4	Saibu and Jaiyeola (2013)	Nigeria	RGDP, Oil production, CO_2 emissions from gas flaring, Oil consumption, and Investment	Autoregressive Distributed Lag (ARDL) bounds testing framework and Granger causality test	1970 - 2011	The study reveals that economic growth is significantly influenced by growth rate change of carbon monoxide emissions from gas flaring, carbon emission growth rate from gas flaring and economic growth rate.
5	Chindo et al. (2014)	Nigeria	GDP per capita, Employment rate, CO_2 emissions, and Fossil fuel consumption	ARDL	1970 - 2010.	The study findings reveal a long run relationship between energy consumption, CO_2 emissions and GDP. Both in the long run and short run, CO_2 emissions has been found to have a significant positive impact on GDP. On the other hand, energy consumption has a significant negative impact on GDP in the short-run.
6	Alege et al. (2016)	Nigeria	CO_2 emissions (kt), GDP per capita, Fossil fuel energy consumption, Human capital, Electric power consumption, and Institution	Johansen cointegration technique	1970 - 2013	The study reveals the existence of unidirectional causality running from fossil fuel to CO_2 emissions and gross domestic product (GDP) per capita.
7	Lin and Atsagli (2016)	Nigeria	Outputs, Electricity consumption, GCF, Labor, and Petroleum consumption	Translog Production Function	1980 - 2012	The study shows that all inputs employed except petroleum consumption are positively and significantly related to

						the Nigerian economy.
8	Rafindadi (2016)	Nigeria	EC (kgoe) per capita, Real credit to private sector per capita, Real trade per capita, and RGDP per capita	Innovation account test, ARDL bound test, Bayer–Hanck cointegration and VECM model	1971 - 2011	The study shows a bidirectional causality between financial development and energy consumption. A bidirectional causality also exists between financial development and CO_2 emissions. The study supports the trade led energy hypothesis as well as the existence of a feedback effect between economic growth and CO_2 emissions.
9	Aiyetan and Olomola (2018)	Nigeria	CO_2 emissions per capita, RGDP per capita, Population growth, and EU (kgoe)	ARDL and Toda-Yamamoto non-granger causality approach	1980 - 2012	The study reveals the evidence of unidirectional causality running from CO_2 emissions and energy consumption to economic growth. A strong unidirectional causality running from CO_2 emissions, energy consumption and economic growth to population growth.
10	Esan and Hassan (2020)	Nigeria	CO_2 emission (mt) per capita, Primary energy consumption (kgoe) per capita, and RGDP per capita	Granger blocked exogeneity (wald test) and Vector Autoregressive approach	1980 - 2016	The empirical findings reveal GDP is associated with increase in carbon emission, while primary energy consumption and emissions are positively related.
11	Iorember et al. (2020)	Nigeria	CO_2 emission per capita, Renewable energy, Financial Development Index, and GDP per capita	Autoregressive Distributed lag (ARDL) and Vector Error Correction Model (VECM) Granger causality tests	1990 - 2016	The results validate an inverted U-shaped association between economic growth and environmental degradation in Nigeria. The short-run causality test shows a mix of both bidirectional and unidirectional causal

						relationship between the variables of interest, and a long run impact of the independent variables on CO_2 emissions.
12	Deekor and Aziaka (2020)	Nigeria	GDP per capita, Fossil fuel energy consumption, and CO_2 (mt) per capita	ARDL	1970 - 2016	The study estimation results refute the Environmental Kuznets Curve (EKC) in the context of the Nigerian economy. The relationship between carbon dioxide (CO_2) emissions and Gross Domestic Product (GDP) per capita is monotonically increasing. The response of CO_2 emission to energy consumption to vary for different energy-mix.
13	Ushie and Aderinto 2021	Nigeria	EC, GDP per capita, Ecological footprint, GDP per capita square, CO_2 emissions, and GFCF	ARDL	1981 - 2019	The study shows a short run and long run positive impact of energy consumption on carbon emission. The study validates EKC hypothesis.

Author's compilation (2021).

2.6 Gaps in Empirical Literature

This study investigates the nexus between energy consumption, CO_2 emissions and economic growth in Nigeria between 1981 to 2021. Knowing the relationship that exist between environmental degradation and economic growth will enable informed policy formulation and implementation. This is because the findings will reveal which of the environmental related variables has a causal relationship with economic growth. Many studies have been carried out to examine the nexus between energy consumption and economic growth, electricity consumption and economic growth, and CO_2 emissions or carbon footprints and economic growth in Nigeria. The above tabular review of empirical literature reveals a good number of studies have been done on the nexus between energy consumption, carbon emission and economic growth in Nigeria. With regards to the studies reviewed in Nigeria, no study has combined total or aggregate energy used and electricity consumption as proxy for energy consumption. The unique aspects in this study are the extension to total energy consumption instead of only electricity consumption as proxy for energy consumption and the use of an alternative econometric approach for estimating the dynamic causal relationships between the variables of interest.

Thus, this study intends to fill the gap by extending the work of Alam et al. (2012) done in Bangladesh by utilizing total energy use per capita and electricity consumption per capita as proxy for energy consumption, CO_2 emissions per capita for carbon dioxide emissions and real GDP per capita for economic growth in the case of Nigeria from 1981 to 2021. In addition, Alam et al. (2012) mainly used Johansen Jesulius approach. This study will employ ARDL bound test to test for cointegration between energy consumption, CO_2 emissions and economic growth in Nigeria.

This study differs from the work of Alam et al. (2012) in terms of scope, location and econometric approach.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter discusses the method that will be used in estimating the nexus between energy consumption, carbon emission and economic growth in Nigeria. The chapter has eight subdivisions which comprise: the research design, population and sample size, sources of data, theoretical framework, model specification, a-priori expectation, measurement of variables, and method of data analysis.

3.2 Research Design

The study uses an ex-post factor research design. This is due to the fact that study data already existed overtime, therefore the researcher cannot meddle with them, because they are inherently not manipulable. The data collected, will be analyzed to explain the causal relationship between the energy consumption, carbon emission and economic growth in Nigeria.

3.3 Population and Sample Size

Since this study is based on annual aggregate data, thus, a census sampling technique in which population equals sample size is used. Hence, every carbon emission, energy consumption and economic growth cases as documented by the World Bank, World Development Indicator (WDI), Enerdata, Energy Information Administration (EIA), and Knoema spanning from 1981 to 2021 with respect to Nigeria is used. The choice of this period (1981 to 2021) was informed because it captures the relevant energy consumption, carbon emissions and economic growth issues as it relates to Nigerian economy.

3.4 Sources of Data

The study uses secondary data which will be sourced from World Development Indicator (WDI), Enerdata, Energy Information Administration (EIA), and Knoema (World Data Atlas) from 1981 to 2021. The total gross domestic product (GDP) will be converted to per capita real GDP. This indicator serves as proxy for economic growth. Also, the per capita data on energy consumption will be measured as kilograms of oil equivalent, electricity consumption will be measured as kilowatt hour (KWh) and CO_2 emission will be measured in metric tons (as a proxy of environmental pollution).

The data nomenclatures are indicated as follows:

PY - per capita real GDP

ENU - per capita energy use (of oil equivalent)

ELC - per capita electricity consumption

CO_2 - per capita CO_2 emissions.

3.5 Theoretical Framework

This study is based on Simon Kuznets (1995) Environmental Kuznets Curve hypothesis. The theory seeks to establish an inverted U-shaped relationship between environmental degradation/pollution and per capita income. It asserts that at the early stage of economic growth and development, environmental degradation/pollution increases at an increasing rate, but after a threshold of economic growth and developments, the co-movement between economic growth and environmental degradation reverses at higher level of economic progress with fall or decline in environmental degradation. For an economy to achieve a high level of development, there is need to employ natural resources which will in turn have some residual effects on the environment. Growth in income and its residual effect on the environment can be transmitted in three channels; the scale effect, composition effect and technique effects (Grossman, 1995). Economic growth is likely to be associated with environmental degradation at low-income levels, but as income increases, the demand and need for environmental protection tends to rise, leading to a development path that is characterized with improvement in both economic growth and environmental quality (Ante & Heidebrink, 1995).

3.6 Model Specification

This study adapted the functional model of Alam et al. (2012), to include the pertinent variables used in their study. They studied energy consumption, co_2 emission and economic growth nexus in Bangladesh using cointegration and dynamic causality analysis. The model functional form is expressed as follows;

$Y = f(EN, EL, CO_2)$ ………………………………………………………………… (1)

Where;

Y is per capita real GDP, EN is per capita energy consumption, EL is per capita electricity consumption and CO_2 is per capita CO_2 emissions.

The null hypotheses that aggregate the entire inquiry in this study stating that 'There is no significant relationship between energy consumption, carbon emission and economic growth in Nigeria' will be tested. As earlier enunciated in the theoretical framework, the model will assume the Environmental Kuznets Curve (EKC) theory. This study will modify the model used by Alam et al. (2012) using the same variables to investigate the objectives of this study. Therefore, the study includes; PY for Per capita real GDP, ENU for Per capita energy use (of oil equivalent), ELC for Per capita electricity consumption, and CO_2 for per capita carbon emission (proxy for environmental pollution). The modified model will be subjected to Autoregressive Distributed Lag Model (ARDL) in explicit form as specified below to investigate the long run relationships:

Model 1: Energy use and economic growth

$$\Delta ENU_t = \mu + \sum_{i=i}^{q_1} \beta_i \, \Delta ENU_{t-1} + \sum_{j=i}^{q_2} \beta_j \, \Delta PY_{t-1} + \alpha_1 \, ENU_{t-1} + \alpha_2 \, PY_{t-1} + \varepsilon_1, t \; ...(2)$$

$$\Delta PY_t = \emptyset + \sum_{i=i}^{q_1} \beta_i \, \Delta ENU_{t-1} + \sum_{j=i}^{q_2} \beta_j \, \Delta PY_{t-1} + \alpha_1 \, PY_{t-1} + \alpha_2 \, ENU_{t-1} + \varepsilon_2, t \; ...(3)$$

Model 2: Electricity consumption and economic growth

$$\Delta ELC_t = \mu + \sum_{i=i}^{q_1} \delta_i \, \Delta ELC_{t-1} + \sum_{j=i}^{q_2} \delta_j \, \Delta PY_{t-1} + \alpha_1 \, ELC_{t-1} + \alpha_2 \, PY_{t-1} + \varepsilon_1, t \; ...(4)$$

$$\Delta PY_t = \emptyset + \sum_{i=i}^{q_1} \delta_i \, \Delta ELC_{t-1} + \sum_{j=i}^{q_2} \delta_j \, \Delta PY_{t-1} + \alpha_1 \, PY_{t-1} + \alpha_2 \, ELC_{t-1} + \varepsilon_2, t \; ...(5)$$

Model 3: Carbon (CO_2) emissions and economic growth

$$\Delta CO_{2_t} = \mu + \sum_{i=i}^{q_1} \lambda_i \, \Delta PY_{t-1} + \sum_{j=i}^{q_2} \lambda_j \, \Delta CO_{2_{t-1}} + \alpha_1 CO_{2_{t-1}} + \alpha_2 PY_{t-1} + \varepsilon_1, t \; ...(6)$$

$$\Delta PY_t = \mu + \sum_{i=i}^{q_1} \lambda_i \, \Delta PY_{t-1} + \sum_{j=i}^{q_2} \lambda_j \, \Delta CO_{2_{t-1}} + \alpha_1 PY_{t-1} + \alpha_2 CO_{2_{t-1}} + \varepsilon_2, t \; ...(7)$$

3.6.1 Granger causality in the error correction modelling (ECM) framework

The moment cointegration relationship is ascertained from ARDL bound test approach, the granger causality will be conducted using vector error correction mechanism. This ECM equation will represent the short run analysis of the long run ARDL model earlier specified in equation (2) to (7). The presence of cointegration in the bi-variate relationship indicates long-run Granger causality at least in a single direction which under specific restrictions can be tested through the use of Wald test (Mosconi & Giannini, 1992; Dolado & Lutkepohl, 1996). If the α matrix in the cointegration rank matrix (Π) has a complete column of zeros, no long run causal relationship exists, this is because no cointegrating vector surfaces in that particular block. For the purpose of acknowledging the short-run and the long-run causal relationship between energy consumption, CO_2 emission, and economic growth, the equation (2) can be re-specified in the case of bi-variate model of energy use (of oil equivalent) and economic growth as the key variables of interest in the explicit form below:

$$\Delta ENU_t = \mu + \sum_{i=i}^{q_1} \beta_i \ \Delta ENU_{t-1} + \sum_{j=i}^{q_2} \beta_j \ \Delta PY_{t-1} + \alpha_1 \ ECT_{t-1} \ + \ \varepsilon_1, t \ ...(8)$$

$$\Delta PY_t = \emptyset + \sum_{i=i}^{q_1} \beta_i \ \Delta ENU_{t-1} + \sum_{j=i}^{q_2} \beta_j \ \Delta PY_{t-1} + \alpha_1 \ ECT_{t-1} \ + \ \varepsilon_2, t \ ...(9)$$

Where;

PY	= Per capita real GDP
ENU	= Per capita energy use (of oil equivalent)
ELC	= Per capita electricity consumption
CO_2	= per capita carbon emission (proxy for environmental pollution)
ECT_{t-1}	= denotes error correction term, while t is time
α_1	= is the coefficient of ECT in the short run
α_1/α_2	= co-efficient in the long-run
$\mu/\emptyset$	= constant/intercept
ε	= error term/stochastic disturbance
β_i / β_j	= co-efficient in the short

3.7 *A priori* Expectation

The a-priori expectation for a standard (inverted U) EKC relationship between environmental degradation and economic growth are β_i and $\beta_j > 0$ in the short run, denoting an initial increase in environmental degradation/pollution as economic growth increases, and α_1 *and* $\alpha_2 < 0$ in the long-run, denoting an inverse relationship between variables.

3.8 Measurement of Variables

Table 3.1: Description of Variables

S/N	Variable Type	Variables names	Variables Description	Source	Data Source
	Dependent Variables:				
1	PY	Per capita real GDP (proxy for economic growth)	It determines the share of GDP accruable to a citizen per year	Alam et al. (2012)	World Development Indicator, 2022.
	Independent Variables				
1	ENU	Per capita energy use	Showing the share of energy used by an individual in a country	Alam et al. (2012)	World Development Indicator 2022, and Enerdata, 2022.
2	ELC	Per capita electricity consumption	Denotes the amount of electricity rate consumed by individual in Nigeria	Alam et al. (2012)	World Development Indicator, 2022, and Energy Information Administration (EIA), 2022.
3	CO_2	Per capita carbon emission (proxy for environmental pollution)	Indicates the portion of pollutions experienced by individual in Nigeria	Ben (2011); Alam et al. (2012)	World Development Indicator, 2022, and Knoema, 2022.

Source: Researcher's compilation (2021).

3.9 Method of Data Analysis

Owing to the linearity of the models formulated to investigate the energy consumption, carbon (CO_2) emission (proxy for environmental pollution) and economic growth nexus in Nigeria, descriptive statistics, correlation matrix, co-integration, Autoregressive Distributed Lag (ARDL) model method of estimation technique will be adopted in obtaining the estimates of the parameters in the models. The objectives of the study shall be accomplished by analyzing the models with the help of ARDL estimation to determine the cointegration using Bound test approach and Granger causality technique using vector error correction mechanism (VECM) through the aid of E-views 10 Statistical Software Package for Windows.

3.9.1 Unit Root Test

In order to avoid the spurious regression problem, with its related non-stationary pattern of variables, differencing has become a significant method of bringing non-stationary series to stationary. Non-stationary in the data implies that the regression coefficients may be spurious (Phillips, 1986).

If a variable is stationary without differencing, then, it is of order zero, i.e. I(0). If a variable is stationary after differencing once, it is said to be integrated of order one, i.e. I(1) and if it is stationary after differencing twice, then, it is said to be integrated of order two, i.e. I(2). In this study, stationarity shall be ascertained by adopting the Augmented Dickey-Fuller (ADF) test and the Phillip-Perron test which are widely acceptable to test whether the data are difference stationary or trend stationary and to determine the number of unit roots at their level.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter addresses the presentation of data and analysis of results based on the model postulated which depicts the relationship between energy consumption, carbon emission and economic growth in Nigeria. The following econometrics analyses were conducted: pre-test, estimation, and post-test analysis. The pre-test analysis include: descriptive statistics, correlation coefficient, unit root test, granger causality test, optimal lag selection criteria test and co-integration test using ARDL Bound Test Approach. The main estimation was conducted using Autoregressive Distributed Lag ARDL model while the post-test include: R-Square test, Adjusted R-Square test, Durbin Watson test, F-statistics test, Heteroskedascity test and stability test.

Having carried out the aforementioned analyses, the results was would be interpreted and implication of findings would be discussed accordingly in this chapter. See Appendix IX (page 113 and 114) for the data used.

4.2 Results of Descriptive Statistics

Descriptive statistics is conducted to assess the adequacy of the elements of the variables adopted in this study and to determine whether or not there is issue in normality condition, dispersion and volatility in the variables employed. The Table 4.1 below depicts descriptive statistics test thus.

Table 4.1: Descriptive Statistics

	CO_2	ELC	ENU	PY
Mean	0.728537	106.5964	729.6063	1887.532
Median	0.740000	100.8850	721.8140	1685.201
Maximum	0.980000	156.7970	817.8900	2688.267
Minimum	0.500000	50.90100	671.9070	1388.535

Std. Dev.	0.132562	27.66239	43.43960	470.7625
Skewness	-0.006953	0.128359	0.356966	0.444242
Kurtosis	1.673858	1.880722	1.807535	1.542199
Jarque-Bera	3.004695	2.252757	3.299939	4.979085
Probability	0.222607	0.324205	0.192056	0.082948
Sum	29.87000	4370.454	29913.86	77388.83
Sum Sq. Dev.	0.702912	30608.31	75479.95	8864693.
Observations	41	41	41	41

Source: (Author's computation using E-views 10 version (2023)

From Table 4.1 above, the descriptive statistics is exhibited crucial results. The mean of per capita carbon emission (CO_2) (proxy for environmental pollution), per capita electricity consumption (ELC), per capita energy use (ENU) and per capita real gross domestic product (PY) are 0.728537, 106.5964, 729.6063, and 1887.532 respectively.

Kurtosis which measures the peakedness or flatness of the series is shown for each of the variables. It should be noted that the normal distribution for the Kurtosis is 3. Where the kurtosis exceeds 3, the distribution is peaked (leptokutic) relative to the normal. Meanwhile, if the kurtosis is less than 3, the distribution is flat (playkurtic) relative to the normal. The result above indicates that per capita carbon emission (CO_2) (proxy for environmental pollution), per capita electricity consumption (ELC), per capita energy use (ENU) and per capita real gross domestic product (PY) could be described as flat (playkurtic) as their respective distribution falls below 3 which is a normal distribution.

Looking at the Jarque-bera result in Table 4.1, Jarque-Bera is a statistical test for whether the series is normally distributed or not. The decision rule under Jarque-Bera statistics is that the null hypothesis is rejected where its probability is less than 5% vice-versa. The probability of Jarque-Bera indicates that null hypotheses for per capita carbon emission (CO_2) (proxy for environmental pollution), per capita electricity consumption (ELC), per capita energy use (ENU) and per capita real gross domestic product (PY) should be accepted in that they are more than 5%. There are 41 observations in all after adjustment.

4.3 Results of Correlation Matrix

Correlation coefficient was used to evaluate the relationship between variables adopted in this study and below is the result in table 4.2**.**

Table 4.2: Correlation Coefficient Analysis

Correlation Probability	CO_2	ELC	ENU	PY
CO_2	1.000000			

ELC	-0.856877	1.000000		
	0.0000	-----		
ENU	-0.795740	0.871916	1.000000	
	0.0000	0.0000	-----	
PY	-0.835661	0.881636	0.905327	1.000000
	0.0000	0.0000	0.0000	-----

Source: Author's computation using E-views 10 version (2023)

The correlation matrix on Table 4.2 is explained based on the relationship between dependent variable of model and independent variables. From Table 4.2, the correlation coefficient result shows that per capita real GDP (PY) has a positive relationship with energy use (ENU) and electricity consumption (ELC) and the result are statistically significant, except with carbon emission (CO_2) which indicates negative but significant relationship. The result indicates that there is no multicollinearity issue in this analysis.

4.4 Stationarity Test

It is important to ensure that the variables to be used for analysis do not contain unit root otherwise the results obtained therefrom would not reliable and might be misleading as the results would be spurious and would neither be fit for forecasting nor decision making. In this wise, it is pertinent to guard against non-stationarity of variables. Thus, Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test would be used to determine stationarity of variables adopted in this study. The decision rule is that the ADF/PP test statistic value must be greater than the Mackinnon critical value at 5% and at absolute value. The Table 4.3, Table 4.4, Table 4.5 and Table 4.6 below show the summary of unit root test conducted on the parameter at level and first difference using ADF/PP.

4.4.1 Unit root test using Augmented Dickey-Fuller (ADF)

Table 4.3: ADF-Unit root test at level

Variables	ADF Test Statistic Value	Mackinnon critical Value at 5%	Prob.	Remark
CO_2	-3.3629	-3.5266	0.0710	Non-stationary
ELC	-2.5840	-3.5266	0.2892	Non-stationary
ENU	3.1233	-3.5266	0.1149	Non-stationary
PY	-2.2591	-3.5403	0.4442	Non-stationary

Table 4.4: ADF-Unit root test at first Difference

Variables	ADF Test Statistic Value	Mackinnon critical Value at 5%	Prob.	Remark
CO_2	-7.8318	-3.5330	0.0000	$I(_1)$
ELC	-7.7290	-3.5297	0.0000	$I(_1)$
ENU	-6.0180	-3.5297	0.0001	$I(_1)$
PY	-3.6898	-3.5297	0.0351	$I(_1)$

Source: *(Author's computation using E-views 10 version (2023)*

4.4.2 Unit root test using Phillips-Perron (PP)

Table 4.5: PP-Unit root test at level

Variables	ADF Test Statistic Value	Mackinnon critical Value at 5%	Prob.	Remark
CO_2	-3.4791	-3.5266	0.0554	Non-stationary
ELC	-2.5806	-3.5266	0.2906	Non-stationary
ENU	-2.7124	-3.5266	0.2373	Non-stationary

PY	-2.8061	-3.5266	0.2035	Non-stationary

Source: *(Author's computation using E-views 10 version (2023)*

Table 4.6: PP-Unit root test at first Difference

Variables	ADF Test Statistic Value	Mackinnon critical Value at 5%	Prob.	Remark
CO_2	-13.8006	-3.5297	0.0000	$I_{(1)}$
ELC	-12.4578	-3.5297	0.0000	$I_{(1)}$
ENU	-7.8711	-3.5297	0.0000	$I_{(1)}$
PY	-3.6898	-3.5297	0.0350	$I_{(1)}$

Source: *(Author's computation using E-views 10 version (2023)*

The computations in Table 4.3, Table 4.4, Table 4.5 and Table 4.6 showed the results of unit root test for Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) as indicated above. It could be deduced that both ADF and PP produced the same trend of results. From Table 4.3, 4.4, 4.5 and 4.6, the ADF and PP reported that none of the variables were stationary at level until after first difference for both ADF and PP. Thus, at first difference all the variables became stationary as they have ADF/PP statistics greater than Mackinnon Critical value at 5%.

Since virtually all the variables were stationary after first difference with their ADF/PP statistics greater than their Mackinnon critical value at 5% and thus their season variations had been corrected and they are now fit for regression analysis which can produce dependable results.

4.5 Optimal Lag Selection

The optimal lag selection indicates the appropriate lag length to choose while estimating Autoregressive Distributed Lag (ARDL) model as the unit root test points to the choice of ARDL in our estimation. This is obtained using vector autoregressive (VAR) model. The optimal lag length for the variables is stated below in Table 4.7.

Table 4.7: Appropriate lag length for dependent variables:

Dependent Variables	Lag Length Criteria

PY	2
CO_2	3
ENU	0
ELC	1

Source: *(Author's computation using E-views 10 version (2023)*

From Table 4.7, the appropriate lag length to be selected are stated when each of the variables is specified as dependent variable based on the causality model highlighted in chapter three of this study. The per capita real GDP should take 2 as lag length while carbon emission, energy use, and electricity consumption should take 3, 0 and 1 respectively. The selection procedure was based on the AIC (Akaike information criterion) as displayed below in Table 4.8.

Table 4.8: AIC (Akaike Information Criterion).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-236.9998	NA	18903.57	12.68420	12.85658	12.74553
1	-207.0176	52.07429*	4115.356	11.15882	11.37429*	11.23549
2	-205.3487	2.810845	3977.476*	11.12362*	11.38218	11.21561*
3	-205.3124	0.059182	4191.087	11.17434	11.47600	11.28167

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

4.6 Co-integration Test

In this sub-section, the Autoregressive Distributed Lag (ARDL) model bound test approach is adopted to evaluate whether or not long run relationship exists among the variables. It should be noted that before any meaningful conclusion could be made as touching the long run relationship between the series, it is crucial that co-integration must first exist among the variables.

4.6.1 ARDL Bounds Co-integration Test

From Table 4.3, 4.4, 4.5, and 4.6, some of the variables were stationary at level, while some were stationary after first difference. The result from unit root test informed the decision to choose ARDL bounds co-integration test to analyse the variables' long run relationship in this study. Below in Table 4.9, the ARDL bounds co-integration test was carried out.

Table 4.9: F-Bounds Test (see Appendix 5 for Robust Result)

	ARDL Model	
Bound significance	I(0)	I(1)
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61
F-Statistics	4.592415	
D.F	3	

Source: *(Author's computation using E-views 10 version (2023)*

F-Bound test could be used to evaluate co-movement among the variables.

Decision Rule: at 5% Significance value

If F-Statistics (BT) < Lower Limit Bound ↔No Long-run relationship exist

If Lower Limit < F-Statistics (BT) > Upper Limit ↔ Long-run relationship exist

If F-Statistics (BT) > Upper Limit (I_1) ↔ Long-run relationship exist

- Where Bounds Test (BT) is less than lower limit, accept null hypothesis of no long run relationship exist.

- ➢ Where BT is greater than lower limit but less than upper limit, reject null hypothesis of no long run relationship exist.
- ➢ Where BT is greater than upper limit, reject null hypothesis of no long run relationship exist.

NB: Any reasonable level of significance can be chosen depending on the researcher margin of confidence. Here, 5% level of significance is chosen as margin of safety or confidence.

Table 4.9 indicates that there is a long run relationship among the variables as F-Bound test conducted attest to this fact with the F-statistics result of 4.592415. This indicates F-statistics comes above the Lower Limit Bound I(1) even at 1% level of significance. This portrays the model has a long run relationship among the variables, thus variables are jointly co-integrated in the same level and there is existence of long-run relationship.

4.7 Presentation of Results

4.7.1 Auto-Regressive Distributed Lag (ARDL) Model Results

This section presents the regression result of the models earlier specified to achieve the stated objectives of the study.

In order to achieve the objective of this study, an ARDL estimation technique is postulated to conduct an empirical analysis. The reason for the choice of this estimation technique is informed from the result of unit root test conducted where some variables are stationary at level or I(0), and others are stationary after first difference or I(1).

Table 4.10: ARDL Long-Run and Short-Run Results for Model

Dependent Variable: PY (Proxy for per capita real gross domestic product)							
Short-Run Estimation				**Long-Run Estimation**			
Variable	**Coefficient**	**t-Statistic**	**Prob**	**Variable**	**Coefficient**	**t-Statistic**	**Prob**
*PY(-1)	0.960488	5.234086	0.0000	D(PY(-1))	0.232812	1.687501	0.1015
PY(-2)	-0.232812	-1.687501	0.1015	D(CO_2)	-	-1.455122	0.1557

					260.084220		
CO_2	-260.0842	-1.455122	0.1557	**D(CO_2(-1))	457.360893	2.582779	0.0147
CO_2(-1)	-2.437081	-0.011627	0.9908	D(ENU)	0.311253	0.567833	0.5742
**CO_2(-2)	-457.3609	-2.582779	0.0147	D(ELC)	1.380585	1.397941	0.1721
ENU	0.311253	0.567833	0.5742	*ECM(-1)	-0.272324	-3.834100	0.0006
ELC	1.380585	1.397941	0.1721				
C	673.8802	1.677253	0.1035				

Source: *(Author's computation using E-views 10 version (2023)*
**implies significant at 1%, **implies significant at 5%*

Table 4.11: Statistical Properties and Post Diagnostic Results for the Model

Statistical Properties		Post Diagnostic Test Results	
R-Squared	0.989098	B-G Serial Correlation LM (F-Statistics)	0.659501
Adj R-squared	0.986636	B-G Serial Correlation LM Prob F (1, 28)	0.5250
F-statistics	401.1786	BPG Heteroskedasticity (F-stat)	1.220833
Prob(F-statistcis)	0.000000	BPG Heteroskedascity Prob(20, 9)	0.3223
Durbin Watson Statistics	2.177417	Jarque-Bera	1.211409
Akaike Info Criterion		JB Prob	0.545690
Model Selection	1		
ARDL Best Model	(2, 2, 0, 0)		

Source: *(Author's computation using E-views 10 version (2023)*

4.7.1.2 Interpretation of Results

The implication of findings when autoregressive distributed lagged model – ARDL is applied to analyse the relationship between per capita real GDP (PY) (dependent variable) and other explanatory variables such as carbon emission (CO_2), energy use (ENU), and electricity consumption (ELC) are discussed in turns thus:

On examining the relationship between per capita real GDP (PY) and carbon emission (CO_2) in the short run, the CO_2 has an associated adverse influence on the PY (proxy for per capita real gross domestic product). This implies that there is negative relationship between carbon emission and per capita real gross domestic product in Nigeria within the period of review. The coefficient result of CO_2, at current and when lagged one and two periods, of 260.0842, 2.437081 457.3609 imply that 1% increase in the carbon emission will stimulate 26008.42%, 243.7081% and 45736.09% respective in per capita real GDP (PY) at current and when lagged in one- and two-year periods respectively. The results are statistically insignificant with the probability value of 0.1557and 0.9908 at current and when lagged one period. However, P-value is statistically significant when lagged two periods at 0.0147.

On the long run, the carbon emission (CO_2) has an adverse influence on RGDP per capita at current period but positive influence when lagged a period. The coefficient value of CO_2 of 260.084220 and 457.3600893 at current and when lagged after a period connote that 1% increase in the CO_2 will lead to 26008.4220% decline in per capita real GDP (PY) at current period and 45736.00893% incline in per capita real GDP (PY) when lagged one period. The result is statistically insignificant at current level with the probability value of 0.1557 while it is significant when lagged one period with probability value of 0.0147. The result tallies with a priori expectation when carbon emission is lagged a period whereas it is not at the current period. The finding agrees with the work of Gao et al. (2021) and Adebayo et al. (2021).

Looking at electricity consumption (ELC) in the short run, it has an associated positive influence on the per capita real GDP within the period of investigation. The coefficient value of 1.380585 implies that 1% increase in ELC will stimulate 138.0585% boost in the RGDP per capita. The result agrees with a priori expectation as a positive outcome is anticipated in this study. This portrays that the government should endeavor to make light (electricity consumption) available for Nigerians, as this will definitely better their lot and increase the opportunities at their disposal. The government may not be able to create jobs but the government should try and create enabling environment for the people which will foster apple opportunities and hence induce job creation for all. In doing this, the marginal contribution by a citizen will witness a boost and thus increase their living standard and enable everyone to enjoy better life. The finding is consistent with the work of Odugbesan and Rjoub (2020).

Electricity consumption, on the long run, has a positive influence on the RGDP per capita. The coefficient value of 1.380585 indicates 1% increase in the electricity consumption will induce 138.0585% boost in the RGDP per capita within the period of review. The result is statistically insignificant with the P-value of 0.1721. The a priori expectation remains positive on the long run which has been anticipated. The finding agrees with the work of Aiyetan and Olomola (2018); Esan and Hassan (2020) and Iorember et al. (2020).

Also, in the short run, energy use (ENU) has an associated positive influence on the per capita RGDP (proxy for PY) within the period of investigation. The coefficient value of 0.311253 indicates that 1% increase in the ENU will induce 31.1253% increase in the RGDP per capita within the period of investigation. The result agrees with the a priori expectation as a positive relationship is projected in this study. The economic implication of this result implies that the energy use, if it should be made available for individuals by the government, will stimulate the living standard of every citizen. Hence, the government has a lot to do in terms of energy generation for her citizens as this will stimulate and cause opportunities for them and reduce the rate of citizens' migration in seeking greener pasture outside the shore of Nigeria. This is because energy use has direct link to productivity, investment and economic growth both in the short and long run. The finding agrees with the work of Rafindadi (2016).

In the long run, energy use has a positive influence on the RGDP per capita within the period of investigation. The coefficient value of 0.311253 portrays that 1% increase in the energy use will induce 31.1253% increase in the RGDP per capita although the result is statistically insignificant with the probability value of 0.5734 which is far above 5%. The finding is consistent with the work of Mardani et al. (2018).

The constant has a turning point as it has an associated favorable relationship with per capita real GDP within the period of review both in the short run and long run. The result is statistically insignificant with the p-value of 0.1035.

The error correction mechanism (ECM) which measures the speed of adjustment is rightly signed with the negative sign. The ECM(-1) result of - 0.272324 indicates that error in the previous period could be corrected in the subsequent period with speed of adjustment of 27.2324%. Thus, any shock in the economic probably as a result of pandemic, financial meltdown, economic recession, global financial crisis or any global menace could be reverted to equilibrium with the speed of 27.2324%. The influence is statistically significant with the probability value of 0.0006. This result looks impressive and technically balance in boosting RGDP per capita especially in Nigeria. The finding is actually consistent with the work of Aiyetan and Olomola (2018), Chindo et al. (2014) and Saibu and Jaiyeola (2013).

4.8 Granger Causality Checks and Interpretation

Table 4.12: Granger Causality Checks

Null Hypothesis	F-statistics	Prob	Test Conclusion	Remarks
ELC does not Granger Cause CO_2	2.86764	0.0707	No granger causality	Accept null hypothesis
CO_2 does not Granger Cause ELC	2.01405	0.1491		
ENU does not Granger Cause CO_2	5.03523	0.0122	ENU granger causes CO_2	Reject null
CO_2 does not Granger Cause ENU	4.49730	0.0185	CO_2 granger causes ENU	
PY does not Granger Cause CO2	3.30553	0.0488	PY granger causes CO_2	Reject null
CO_2 does not Granger Cause PY	6.60234	0.0038	CO_2 granger causes PY	
ENU does not Granger Cause ELC	1.58900	0.2189	No granger	Accept null

ELC does not Granger Cause ENU	0.08806	0.9159	causality	hypothesis
PY does not Granger Cause ELC	9.30244	0.0006	Causality exist	Reject null
ELC does not Granger Cause PY	2.58105	0.0905	No causality	Accept null hypothesis
PY does not Granger Cause ENU	6.37628	0.0045	Causality exist	Reject null
ENU does not Granger Cause PY	2.29972	0.1157	No causality	Accept null hypothesis

Source: *Author's computation using E-view 10 (2023)*

The decision rule here is:

Accept Null hypothesis if Probability Value (Prob) is greater than 5% indicating no granger causality in existence between the variables. Reject if otherwise.

That is, Null > 5% Accept

Null < 5% Reject

From the Table 4.12 above, the result of causality check using pairwise test is presented. The submission from the result is highlighted thus below in Table 4.13.

Table 4.13: Granger causality highlight

Variables	Directions of causality
ELC $\rightarrow$ CO_2	No causality
ENU $\rightarrow$ CO_2	Bi-directional causality
PY $\rightarrow$ CO_2	Bi-directional causality
ENU $\rightarrow$ ELC	No causality
PY $\rightarrow$ ELC	Unidirectional causality
PY $\rightarrow$ ENU	Uni-directional causality

Source: Author's computation using E-view 10 (2023)

From Table 4.13, it could be deduced that electricity consumption (ELC) does not granger cause carbon emission (CO_2), *vice versa*. Hence, there is no existence of causality between the two variables.

Energy use (ENU) has a bi-directional causality relationship with the carbon emission (CO_2) and hence causality exists between the variables indicating that ENU granger causes CO_2, vice versa.

The finding agrees with the work of Rafindadi (2016), Gao et al. (2021) and Adebayo et al. (2021).

Per capita real gross domestic product (PY) has bi-directional causality relationship with carbon emission (CO_2). This indicates that PY granger causes CO_2, vice versa. This finding is consistent with the work of Rafindadi (2016).

On the other hand, energy use (ENU) does not granger cause electricity consumption (ELC), vice versa. The finding agrees with the work of Hossain (2011).

Per capita real gross domestic product (PY) has uni-directional causality relationship with electricity consumption (ELC). Per capita real gross domestic product (PY) granger causes electricity consumption but electricity consumption does not granger cause Per capita real gross domestic product (PY), therefore it is consistent with the work of Kahouli (2018). The same issue applies to PY and ENU. PY granger causes ENU while ENU does not granger cause PY. Hence, uni-directional relationship exists between PY and ENU. The finding is consistent with the work of Stamatiou and Dritsakis (2017) and Tiwari (2011).

4.9 Post-Diagnosis Test

Table 4.14: Post-Diagnosis Test Result

Diagnostic Test	**Statistics**	**P-Value**
Heteroskedasticity Test: Breusch-Pagan-Godfrey	1.220833	0.3223
Jarque- Bera test	1.211409	0.545690
Breusch-Godfrey Serial Correlation LM Test	0.659501	0.5250

Source: Author’s computation using E-view 10 (2023)

It is relevant here to examine some of the post diagnostic results for the model specified in this study. Table 4.11 and Table 4.14 reported the post diagnostic results. The coefficient of determination (R-Squared) of 0.989098 indicates that the explanatory variables are able to give about 98.90% information as regards variation in the carbon emission, energy consumption and electricity consumption on per capita real gross domestic product in Nigeria. The outcome is supported by the adjusted R square with 98.66. This is an indication that the model might be free from wrong specification and omission of vital variables as attested by the adjusted R square.

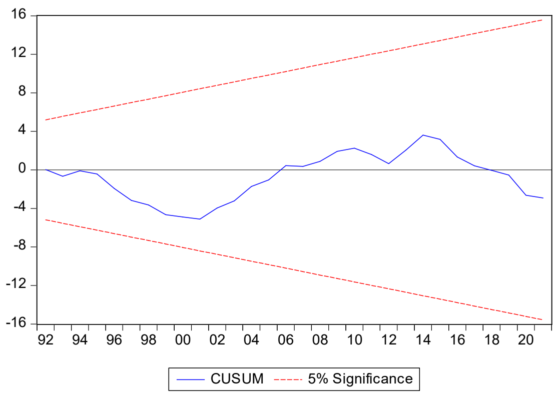
The Durbin Watson result of 2.177417 indicates that there might not be presence of autocorrelation problem in the study. Meanwhile, the F-statistics test result of 401.1786 with the probability value of 0.000000 connotes that the entire regression analysis is statistically significant.

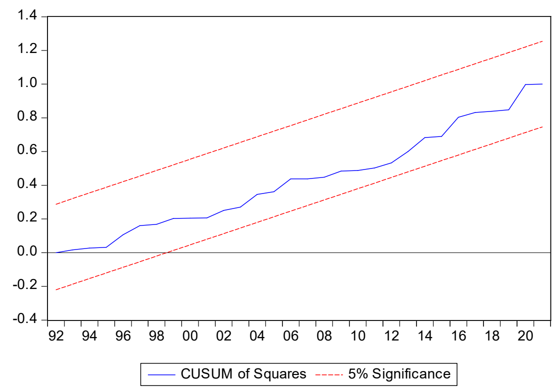
Breusch-Godfrey Serial Correlation Lagranger Multiplier (LM) test is used to test for higher order Autoregressive Moving Average (ARMA) errors and it can be used to determine whether or not there are lagged dependent variables of serial correlation. The B-G tests the null hypothesis of no serial correlation against the alternative hypothesis of serial correlation. The Breusch-Godfrey's serial correlation LM probability result of 0.5250 is greater than 5% indicating the acceptance of the null hypothesis of no serial correlation connoting that the model is free from higher order correlation.

The Breusch-Pagan Godfrey (BPG) test assists in ascertaining whether or not there is presence of heteroskedasticity in the regression result. The BPG probability value of 0.3223 is greater than 5% indicating that there is no presence of heteroskedasticity in the regression result.

4.9.1 Stability Test

Graph 4.1: CUSUM result **Graph 4.2: CUSUM of Squares result**





Graph 4.1 and Graph 4.2 depicted the cusum and cusum of squares test results at 5% significance level respectively. The cusum test and cunsum of squares test conducted showed the relative stability of the regression as it falls within the acceptable region at 5% significance level. In summary, every crucial post diagnostic test conducted and examined are enough to corroborate the validity and reliability of the model postulated in this study.

4.10 Test of Hypotheses

This section deals with the authentication and validation of hypotheses coined from the objectives of this study. The model postulated had hypotheses waiting to be tested so as to give clear direction for inferences from the analysis conducted as indicated in Table 4.10. The t-statistics and probability value would be used to test the hypotheses from Table 4.10 in both long run and short run.

Hypothesis One: *There is no significant relationship between energy use and economic growth in Nigeria.*

Energy use, in the long run, with the t-statistics value of 0.567833 negates the rule of thumb of (t-statistics > 2) and hence, the hypothesis that there is no relationship between energy use and economic growth cannot be rejected. This is attested to by the probability value of 0.5742 which is greater than 5%. In the short run, the energy use takes the same trend indicating that the hypothesis of there is no relationship between energy use and economic growth cannot be rejected. Hence, energy use has no significant relationship with economic growth.

Hypothesis Two: *There is no significant relationship between electricity consumption and economic growth in Nigeria*.

Regarding electricity consumed and economic growth in the long run, the electricity consumed with the t-statistics value of 1.397941 also negates the rule of thumb of (t-statistics > 2) indicating that the hypothesis of there is no relationship between electricity consumed and economic growth per capita cannot be rejected. The result is statistically insignificant with the probability of 0.1721 validating the t-statistics. Hence, there is no significant relationship between electricity consumed and economic growth per capita within the period of review. In the short run, the result takes the same trend indicating that the hypothesis of there is no relationship between electricity consumed and economic growth cannot be rejected as its t-statistics is 1.3979 which is less than 2.

Hypothesis Three: *There is no significant relationship between CO_2 emission and economic growth in Nigeria.*

In the long run, t-statistics value of carbon emission (CO_2) at current period of 1.455122 is less than 2 indicating that null hypothesis of there is no significant relationship between carbon emission and economic growth per capita cannot be rejected. The rule of thumb is that if t-statistics is greater than 2, the null hypothesis can be rejected. If otherwise, null hypothesis cannot be rejected. This can be corroborated by the probability value which must be less than or equal to 5%. From the result of probability value of 0.1557 for CO_2, the null hypothesis cannot be rejected. Hence, carbon emission has no significant value and relationship with economic growth per capita. However, in the long run, carbon emission when it is lagged a period, that is,

CO_2 (-1) with t-statistics value of 2.582779 fulfils the rule of thumb of (t-statistics > 2) indicating that the hypothesis of there is significant no relationship between carbon emission and economic growth per capita can be rejected. Thus, there is significant relationship between carbon emission (CO_2 (-1)) and economic growth. The result is statistically significant with the probability value of 0.0147 substantiating and validating the t-statistics. However, in the short run, the carbon emission with the t-statistics value of 1.4551 is less than 2 indicating that the hypothesis of there is no relationship between carbon emission and economic growth cannot be rejected. The result is statistically insignificant with the P-value of 0.1557.

4.11 Discussion of Findings

The fantastic inferences deduced from the findings in this study are that carbon emission has significant relevance with economic growth within the lagged period. However, energy use and electricity consumed have no significant relevance with the economic growth per capita within the period of review in this study.

Energy use has positive influence on the economic growth although the result is not statistically significant with the probability value of 0.5742 both in the long run and short run. This suggests that energy consumption or use has direct link with economic development. Hence the government should mobilize concerted efforts to boost the megawatt of power to be generated in the coming years to decentralize this energy making it cost effective and bearable to the average Nigerians. The study is consistent with the work of Shuaibu and Oyinlola (2013), and Ushie and Aderinto (2021). No one can do without energy which can be in form of solar, kinetic, charcoal, etc.

Electricity consumption has a positive relationship with the economic growth though not statistically significant within the period of review. The probability value of 0.1721 indicates that the hypothesis of there is no significant relationship between electricity consumption and economic growth cannot be rejected. Thus, the study portrays the fact that Nigerian economy largely dependents on electricity consumption as it fosters rapid growth and development. This electricity issue, if properly addressed, will take care of poverty laden people in the country. Electricity consumption drives the economic, production, service sector and most other vital industries and sectors in Nigeria. The finding is consistent with the work of Deekor and Aziaka (2020); Ushie and Aderinto (2021); Iorember et al. (2020) and Esan and Hassan (2020).

Carbon dioxide emission has adverse and relationship with economic growth within the period of review. However, when it is lagged a period, it has a positive and significant relationship with economic growth in the long-run. The implication of this finding is that CO_2 emission should be addressed with serious actions in that it has significant influence on economic growth. The finding agrees with the work of Ang (2007) from France which submitted that carbon emission in metrics tons have significant influence on the economic growth. Shahbaz et al (2016) found that CO_2 granger caused economic growth and economic growth granger caused CO_2 in Bangladesh and Egypt. However, the study does not agree with the work of Ozturk and Acaravci (2010). Ozturk and Acaravci (2010) found that carbon emission does not have significant influence on economic growth in Turkey and neither does CO_2 granger cause economic growth. In an attempt to protect the global community and nature, the global Sustainable Developmental Goal (SDG) was developed to eliminate or reduce the carbon emission to zero by 2025 (Gao et al., 2021).

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter deals with summary of findings, conclusion and recommendations. Also, the suggestions for further studies are highlighted in this section. This study examined the relationship between energy consumption, carbon dioxide emission and economic growth in Nigeria. Carbon finance is a trending concept in the field of finance. Moreover, energy and electricity consumption portray the real issues facing Nigeria presently.

5.2 Summary of Findings

This study examined the relationship between energy consumption, carbon dioxide emission and per capita real gross domestic product in Nigeria. Using aggregate annual data covering 1981 to 2021, a cointegration and dynamic causality framework were devised for the study. The result showed that there is a long run relationship among the variables as indicated by the co-integration using ARDL Bound test. ARDL in the long run and short run respectively was conducted as indicated in Table 4.10 with impressive outcomes. Specifically, the following were the findings made:

i. Energy use (of oil equivalent) has a positive relationship with economic growth in both the short-run and long-run. There is a unidirectional causal relationship between energy use and economic growth. The causal link runs from economic growth to energy use (of oil equivalent).

ii. Electricity consumption has a positive relationship with economic growth, both in the short-run and long-run. Electricity consumption has a unidirectional causal relationship with economic growth, running from economic growth to electricity consumption.

iii. CO_2 emission has a negative relationship with economic growth, both in the short-run and long-run. However, a positive and significant relationship exist between CO_2 emission and economic growth during the lagged period in the long-run. There is a bidirectional causal relationship between CO_2 emission and economic growth.

5.3 Conclusion

This study examined the relationship between energy consumption, carbon dioxide emission and economic growth in Nigeria. By applying cointegration and dynamic causality analysis, the study investigated the relationship and dynamic linkages between energy use (of oil equivalent) and economic growth, electricity consumption and economic growth, and CO_2 emission and economic growth. The results show a positive influence of energy use and electricity consumption on economic growth, and a causality effect running from economic growth to both energy use and electricity consumption in Nigeria. Carbon dioxide emission shows an adverse influence on economic growth within the period of investigation in this study. However, when carbon dioxide emission is lagged a period (CO_2 (-1)), it has a positive significant influence on economic growth in the long-run. Meanwhile, the direction of causality between CO_2 emission and economic growth bi-directional.

This study therefore conclude that aggregate energy consumption positively influences economic growth, while CO_2 emission adversely influences economic growth in Nigeria, with a unidirectional and bidirectional dynamic causality relationship respectively. However, when CO_2

emission is lagged a period, it has a positive and significant influence on economic growth in Nigeria.

5.4 Recommendations

Based on analytical findings, the following recommendations are, thus, given below:

i. Given that energy consumption has a positive influence on economic growth, the government should ensure that the rate or cost of energy is affordable for all income classes in the country. This will increase energy consumption and in turn facilitate economic growth in the long-run.

   Also, given a unidirectional causality link moving from economic growth to energy consumption, government should diversify and explore alternative energy sources in order to meet up with the rising energy demand as the economy grows.

ii. Electricity consumption positively drives the Nigerian economy. It has the capacity to attract foreign investors, hence, the government should re-strategize investment into the power sector and strengthen institutions and agencies saddled with the responsibility of generating, transmitting, and distributing electricity in Nigeria.

iii. CO_2 emission has a negative influence on the economic growth within the study period, thus the government should initiate clean energy plans with the aim of shifting from non-renewable energy sources to clean/renewable energy sources, so to avoid decrease in economic growth and eradicate CO_2 emission in the long-run.

   However, during the lagged period, CO_2 emission has a positive and significant influence on economic growth, therefore in order not to sacrifice economic growth for low level CO_2 emission, the government should implement energy conservation policy aim at achieving energy efficiency. The use of less energy to achieve the same task, will reduce CO_2 emission per capita and improve economic growth and environmental quality in the long-run.

5.5 Contributions to Knowledge

This study investigated the nexus between energy consumption, CO_2 emissions and economic growth in Nigeria between 1981 to 2021. Knowing the relationship that existed between environmental degradation and economic growth would enable informed policy formulation and implementation. This is because the findings would reveal whether environmental related variables have a causal relationship with economic growth. Thus, this study has contributed to knowledge in the following ways:

i. Many studies have been carried out to examine the nexus between energy consumption and economic growth, electricity consumption and economic growth, and CO_2 emissions, or carbon footprints and economic growth in Nigeria. The review of empirical literature revealed a good number of studies have been done on the nexus between energy consumption, carbon emission and economic growth in Nigeria. With regards to the studies reviewed in Nigeria, no study has combined total or aggregate energy use and electricity consumption as proxy for energy consumption. The unique aspect in this study was the extension to total energy consumption instead of only electricity consumption as proxy for energy consumption in Nigeria.

ii. The study also used an alternative econometric approach such as ARDL and ECM for estimating cointegration and dynamic causal relationships between the variables of interest, thus, it filled the gap in methodology.

5.6 Suggestions for Further Studies

This study examines the relationship between energy consumption, CO_2 emission, and economic growth in Nigeria. However, the study has highlighted areas on which further studies would be beneficial.

i. The study uses CO_2 emission, which is one among the available greenhouse gas emissions, thus there is need to incorporate more exogenous variables to proxy green-house gases in order to boost the robustness of the result.

ii. This study focuses on the economic growth of Nigeria in relation to energy consumption and CO_2 emission, however, the performances of various sectors in Nigeria such as the banking sector, manufacturing sector, etc., can be ascertained in relation to the amount of energy consumed and CO_2 emitted.

iii. Further studies could determine the relationship between energy consumption, CO_2 emission and economic growth beyond the economy of Nigeria, such as sub-Saharan countries, Ecowas countries, West African Countries etc.

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Appendix I

Pairwise Granger Causality Tests
Date: 02/04/23 Time: 16:58
Sample: 1981 2021
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ELC does not Granger Cause CO_2	39	2.86764	0.0707
CO_2 does not Granger Cause ELC		2.01405	0.1491
ENU does not Granger Cause CO_2	39	5.03523	0.0122
CO_2 does not Granger Cause ENU		4.49730	0.0185
PY does not Granger Cause CO_2	39	3.30553	0.0488
CO_2 does not Granger Cause PY		6.60234	0.0038
ENU does not Granger Cause ELC	39	1.58900	0.2189
ELC does not Granger Cause ENU		0.08806	0.9159
PY does not Granger Cause ELC	39	9.30244	0.0006
ELC does not Granger Cause PY		2.58105	0.0905
PY does not Granger Cause ENU	39	6.37628	0.0045
ENU does not Granger Cause PY		2.29972	0.1157

Source: World Development Indicator, Enerdata, Energy Information Administration (EIA), and Knoema (2022)

Appendix II

VECM

Dependent Variable: PY
Method: ARDL
Date: 02/06/23 Time: 09:35
Sample (adjusted): 1983 2021
Included observations: 39 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (1 lag, automatic): CO_2 ENU ELC
Fixed regressors: C
Number of models evalulated: 16
Selected Model: ARDL(2, 1, 0, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
PY(-1)	1.048154	0.195668	5.356806	0.0000
PY(-2)	-0.285618	0.148036	-1.929388	0.0626
CO_2	-187.7501	191.5332	-0.980249	0.3343
CO_2(-1)	-283.8737	194.2651	-1.461269	0.1537
ENU	0.520057	0.588226	0.884111	0.3832
ELC	1.520237	1.069916	1.420895	0.1650
C	255.5318	398.9292	0.640544	0.5264

R-squared	0.986752	Mean dependent var	1894.983
Adjusted R-squared	0.984268	S.D. dependent var	481.3963
S.E. of regression	60.38080	Akaike info criterion	11.20037
Sum squared resid	116666.9	Schwarz criterion	11.49896
Log likelihood	-211.4072	Hannan-Quinn criter.	11.30750
F-statistic	397.2354	Durbin-Watson stat	2.227153
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Appendix III

VAR Lag Order Selection Criteria
Endogenous variables: PY
Exogenous variables: C CO_2 EGYU ELPCO
Date: 01/31/23 Time: 22:39
Sample: 1981 2021
Included observations: 38

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-236.9998	NA	18903.57	12.68420	12.85658	12.74553
1	-207.0176	52.07429*	4115.356	11.15882	11.37429*	11.23549
2	-205.3487	2.810845	3977.476*	11.12362*	11.38218	11.21561*
3	-205.3124	0.059182	4191.087	11.17434	11.47600	11.28167

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix IV

ARDL Cointegrating And Long Run Form
Dependent Variable: PY
Selected Model: ARDL(1, 3, 0, 0)
Date: 01/31/23 Time: 22:43
Sample: 1981 2021
Included observations: 38

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO_2)	-133.214758	195.383779	-0.681811	0.5006
D(CO_2(-1))	250.858117	223.238748	1.123721	0.2700
D(CO_2(-2))	273.386979	208.130483	1.313536	0.1990
D(EGYU)	0.171130	0.566438	0.302117	0.7646
D(ELPCO)	1.982556	0.877484	2.259365	0.0313
CointEq(-1)	-0.310444	0.068859	-4.508379	0.0001

Cointeq = PY - (-2608.8600*CO_2 + 0.5512*EGYU + 6.3862*ELPCO + 2762.6226)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO_2	-2608.859966	657.280351	-3.969174	0.0004
EGYU	0.551245	1.777785	0.310074	0.7586
ELPCO	6.386204	2.722294	2.345890	0.0258
C	2762.622627	1594.442953	1.732657	0.0934

Appendix V

ARDL Bounds Test
Date: 01/31/23 Time: 22:44
Sample: 1984 2021
Included observations: 38
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	4.650201	3

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Test Equation:
Dependent Variable: D(PY)
Method: Least Squares
Date: 01/31/23 Time: 22:44
Sample: 1984 2021
Included observations: 38

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO_2)	-162.2346	205.8737	-0.788030	0.4369
D(CO_2(-1))	639.0135	212.7207	3.004002	0.0053
D(CO_2(-2))	361.4671	212.1746	1.703631	0.0988
C	1008.120	468.7455	2.150677	0.0397
CO_2(-1)	-949.2456	237.9913	-3.988573	0.0004
EGYU(-1)	0.225496	0.665939	0.338614	0.7373
ELPCO(-1)	1.171095	1.017610	1.150829	0.2589
PY(-1)	-0.309037	0.087915	-3.515186	0.0014

R-squared	0.386273	Mean dependent var	25.82726
Adjusted R-squared	0.243070	S.D. dependent var	68.09963
S.E. of regression	59.24785	Akaike info criterion	11.18600
Sum squared resid	105309.2	Schwarz criterion	11.53075
Log likelihood	-204.5340	Hannan-Quinn criter.	11.30866
F-statistic	2.697383	Durbin-Watson stat	1.384437
Prob(F-statistic)	0.027116		

Appendix VI

BGP HETER

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.220833	Prob. F(7,30)	0.3223
Obs*R-squared	8.424818	Prob. Chi-Square(7)	0.2966
Scaled explained SS	3.664017	Prob. Chi-Square(7)	0.8176

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 01/31/23 Time: 22:45
Sample: 1984 2021
Included observations: 38

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1744.456	24072.70	0.072466	0.9427
PY(-1)	4.591376	3.560069	1.289687	0.2070
CO_2	5294.457	10101.47	0.524127	0.6040
CO_2(-1)	12985.33	11869.95	1.093966	0.2827
CO_2(-2)	7246.803	11541.59	0.627886	0.5348
CO_2(-3)	-13119.06	10760.48	-1.219189	0.2323
EGYU	-25.61509	29.28523	-0.874676	0.3887
ELPCO	19.61216	45.36648	0.432305	0.6686

R-squared	0.221706	Mean dependent var	2460.916
Adjusted R-squared	0.040104	S.D. dependent var	2946.209
S.E. of regression	2886.528	Akaike info criterion	18.95816
Sum squared resid	2.50E+08	Schwarz criterion	19.30291
Log likelihood	-352.2050	Hannan-Quinn criter.	19.08082
F-statistic	1.220833	Durbin-Watson stat	2.070632
Prob(F-statistic)	0.322254		

Appendix VII

B-PLM SERIAL

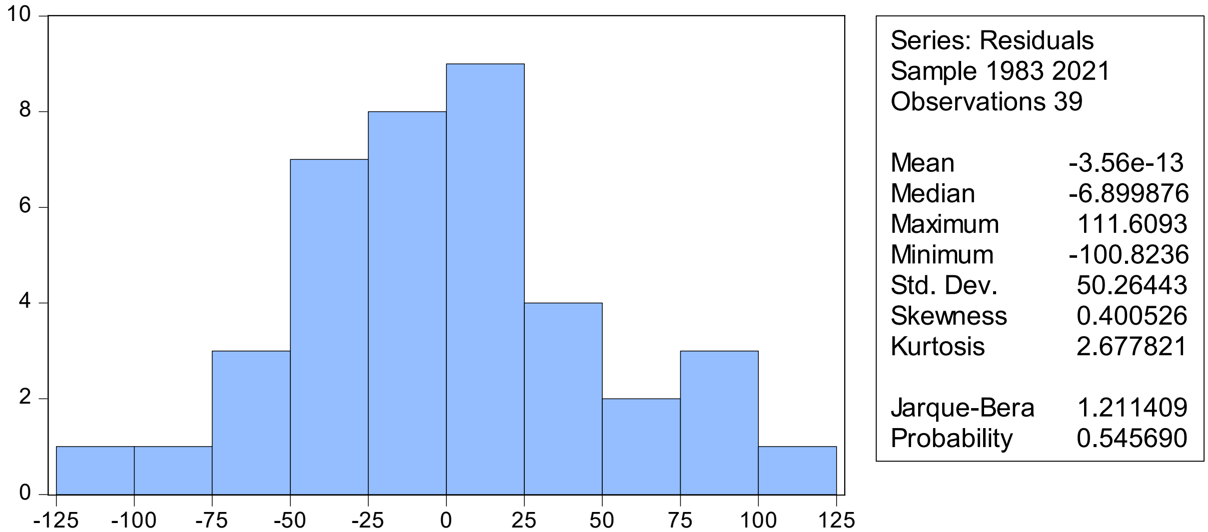
Breusch-Godfrey Serial Correlation LM Test:

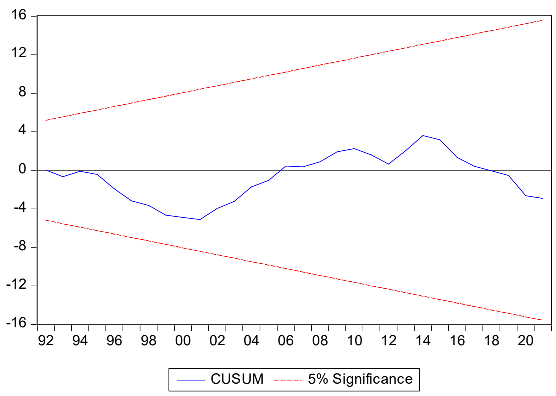
F-statistic	0.659501	Prob. F(2,28)	0.5250
Obs*R-squared	1.709542	Prob. Chi-Square(2)	0.4254

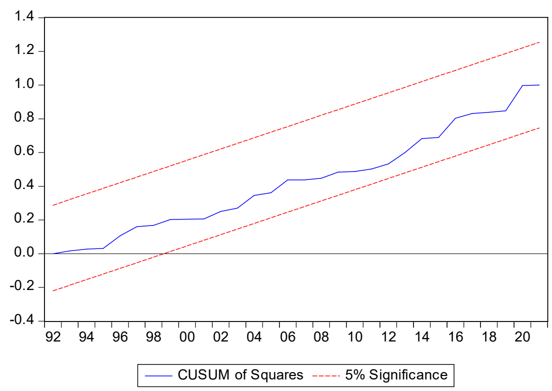
Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 01/31/23 Time: 22:46
Sample: 1984 2021
Included observations: 38
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PY(-1)	-0.009905	0.070486	-0.140523	0.8893
CO_2	8.784165	212.5865	0.041320	0.9673
CO_2(-1)	-58.42105	254.5852	-0.229475	0.8202
CO_2(-2)	-5.246265	227.2760	-0.023083	0.9817
CO_2(-3)	-78.53667	236.2710	-0.332401	0.7421
EGYU	-0.121859	0.626538	-0.194496	0.8472
ELPCO	-0.326931	0.949813	-0.344206	0.7333
C	241.1176	563.9935	0.427518	0.6723
RESID(-1)	0.217593	0.200561	1.084921	0.2872
RESID(-2)	0.092847	0.255572	0.363290	0.7191

R-squared	0.044988	Mean dependent var	-7.65E-14
Adjusted R-squared	-0.261980	S.D. dependent var	50.27352
S.E. of regression	56.47622	Akaike info criterion	11.12645
Sum squared resid	89307.77	Schwarz criterion	11.55739
Log likelihood	-201.4026	Hannan-Quinn criter.	11.27978
F-statistic	0.146556	Durbin-Watson stat	1.946001
Prob(F-statistic)	0.997537		


Series: Residuals
Sample 1983 2021
Observations 39
Mean -3.56e-13
Median -6.899876
Maximum 111.6093
Minimum -100.8236
Std. Dev. 50.26443
Skewness 0.400526
Kurtosis 2.677821
Jarque-Bera 1.211409
Probability 0.545690


CUSUM
5% Significance


CUSUM of Squares
5% Significance

Appendix VIII

Dependent Variable: PY
Method: ARDL
Date: 02/08/23 Time: 04:26
Sample (adjusted): 1983 2021
Included observations: 39 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (3 lags, automatic): CO_2 ENU ELC
Fixed regressors: C
Number of models evalulated: 128
Selected Model: ARDL(2, 2, 0, 0)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
PY(-1)	0.960488	0.183506	5.234086	0.0000
PY(-2)	-0.232812	0.137963	-1.687501	0.1015
CO_2	-260.0842	178.7371	-1.455122	0.1557
CO_2(-1)	-2.437081	209.5988	-0.011627	0.9908
CO_2(-2)	-457.3609	177.0809	-2.582779	0.0147
ENU	0.311253	0.548141	0.567833	0.5742
ELC	1.380585	0.987585	1.397941	0.1721
C	673.8802	401.7761	1.677253	0.1035

R-squared	0.989098	Mean dependent var	1894.983
Adjusted R-squared	0.986636	S.D. dependent var	481.3963
S.E. of regression	55.65084	Akaike info criterion	11.05675
Sum squared resid	96007.50	Schwarz criterion	11.39800
Log likelihood	-207.6067	Hannan-Quinn criter.	11.17919
F-statistic	401.7785	Durbin-Watson stat	2.177417
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

ARDL Cointegrating And Long Run Form
Dependent Variable: PY
Selected Model: ARDL(2, 2, 0, 0)
Date: 02/08/23 Time: 04:28
Sample: 1981 2021
Included observations: 39

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PY(-1))	0.232812	0.137963	1.687501	0.1015
D(CO_2)	-260.084220	178.737113	-1.455122	0.1557
D(CO_2(-1))	457.360893	177.080929	2.582779	0.0147
D(ENU)	0.311253	0.548141	0.567833	0.5742
D(ELC)	1.380585	0.987585	1.397941	0.1721
CointEq(-1)	-0.272324	0.071027	-3.834100	0.0006

Cointeq = PY - (-2643.4814*CO_2 + 1.1430*ENU + 5.0697*ELC +

2474.5575)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO_2	-2643.481380	713.455763	-3.705179	0.0008
ENU	1.142953	1.887067	0.605677	0.5491
ELC	5.069651	3.186674	1.590891	0.1218
C	2474.557504	1676.855580	1.475713	0.1501

Appendix IX

Data Presented (USED)

Data Trend of Energy use per capita, Electric power consumption per capita, CO_2 emissions per capita, and Real GDP per capita in Nigeria from 1981 to 2021.

Period	Energy use (kgoe) per capita	Electric power consumption (kwh per capita)	CO_2 emissions (mt) per capita	Real GDP per capita
1981	676.764	50.901	0.98	1826.201
1982	692.186	81.896	0.91	1658.28
1983	693.97	81.735	0.88	1440.164
1984	678.173	62.064	0.87	1388.535
1985	683.232	80.454	0.88	1433.434
1986	671.907	90.886	0.84	1397.456
1987	677.268	89.304	0.77	1404.804
1988	679.269	87.14	0.86	1468.68
1989	684.864	97.071	0.85	1458.269
1990	697.613	87.079	0.76	1588.502
1991	712.676	89.6	0.84	1554.12
1992	722.402	90.054	0.92	1585.603
1993	715.863	100.885	0.84	1514.932
1994	681.111	95.561	0.74	1450.808
1995	682.669	91.488	0.80	1414.101
1996	694.18	85.905	0.91	1437.216
1997	700.052	82.004	0.87	1443.063
1998	687.508	76.969	0.76	1443.889
1999	694.561	75.767	0.73	1416.516
2000	703.637	74.491	0.80	1450.784
2001	720.446	75.57	0.81	1498.523
2002	725.009	104.661	0.72	1685.201
2003	747.019	101.925	0.77	1763.694
2004	748.746	123.632	0.73	1878.151
2005	758.365	129.327	0.71	1948.048
2006	744.941	111.752	0.62	2012.845
2007	751.178	138.909	0.55	2089.777
2008	753.249	127.245	0.58	2172.794
2009	721.814	120.635	0.50	2285.735
2010	756.347	136.426	0.57	2403.645
2011	778.844	150.198	0.58	2464.345
2012	798.63	156.797	0.57	2500.641
2013	780.14	142.729	0.63	2597.009
2014	763.632	144.525	0.65	2688.267

2015	795.931	143.217	0.59	2687.48
2016	803.43	145.031	0.60	2575.455
2017	783.62	146.492	0.57	2529.385
2018	759.96	131.209	0.56	2512.192
2019	784.804	122.467	0.57	2502.652
2020	789.96	120.646	0.58	2396.036
2021	817.89	125.807	0.60	2421.6

Source: *Author's computation 2022 extracted from World Bank, World Development Indicators; Enerdata (Nigeria Energy Information); Energy Information Administration (EIA); and Knoema (World Data Atlas).*