STRUCTURAL BREAKS AND ASYMMETRIC ANALYSES OF CO_2 EMISSIONS, ENERGY CONSUMPTION AND ECONOMIC GROWTH NEXUS IN NIGERIA

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CERTIFICATION

We certify that this work, being the effort of Akeem Olabanji OLASUNKANMI (Matric number: 187544) of The Centre for Petroleum, Energy Economics and Law, University of Ibadan, was carried out under our supervision.

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DEDICATION

This study is dedicated to the memory of

ALHAJI RAIMI OLAOGUN OLASUNKANMI & ALHAJA MORINAT OLAOGUN OLASUNKANMI

I pray that Almighty Allah the Most Merciful and the Most Benevolent be pleased with their souls.

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ABSTRACT

Energy consumption is a leading cause of carbon dioxide (CO_2) emissions. Previous studies have addressed either the link between economic growth and energy consumption or economic growth and CO_2 emissions and largely ignored the investigation of both relationships in a single framework. Also, the structural break and asymmetric effects of the relationship at the disaggregated level remained largely unexplored. This study was therefore designed to investigate the structural breaks and asymmetric nature of economic growth and energy consumption on CO_2 emissions in Nigeria at the aggregate and disaggregated level in a single framework.

The Environmental Kuznets Curve hypothesis provided the framework. It considered the dynamic effects of economic growth, energy consumption on the emissions from aggregate CO_2 and the disaggregated components of coal, natural gas and petroleum products emissions using annual data between 1970 and 2017. Data were sourced from the World Bank World Development Indicator. The Dickey-Fuller with Generalised Least Squares detrending (DFGLS) and Ng-Perron (NP) tests were utilised to investigate the order of integration of the variables. The auto-regressive distributed lag (ARDL) and the Non-linear Auto-regressive Distributed Lag techniques (NARDL) that took cognisance of short and long run relationships were employed. The analysis employed structural break unit root test and the multiple break date regression test to reflect the potentials of the structural shift. The asymmetric effects of economic growth and energy consumption on CO_2 emissions were analysed by differentiating between the partial sums of positive and negative shocks using the Wald tests (W_{SR} and W_{LR}). The coefficients were analysed at $\alpha \leq 0.05$.

The DFGLS and NP stationarity tests revealed a mixed order of integration of the variables. While some variables were stationary at levels, others were found stationary at first difference. The symmetric result showed that higher economic activities were responsible for higher CO_2 emission in the short run (α=0.21) and long run (α=0.71), while energy consumption increased emission only in the short run (α=0.24). There was significant and increasing impact of economic growth on emissions from coal in the short run (α=1.60) and long run (α=2.96). The asymmetric result showed that economic growth was responsible for higher CO_2 emission in the short run (α=0.59) and long run (α=2.24), while energy consumption increased emission in the short run (α=1.87) and long run (α=5.24). However, economic decline was responsible for reduced CO_2 emission in the short run (α=0.86) and long run (α=2.74). There was significant and increasing impact of economic growth on emissions from coal only in the short run (α=1.54). Accounting for structural break, economic growth increased CO_2 emission in the short run (α=0.15) and long run (α=0.24). The Wald test revealed the presence of asymmetries in the aggregate economic growth, energy consumption and CO_2 emission nexus (W_{SR}=4.74; W_{LR}=3.21) and coal emission (W_{SR}=5.39).

Economic growth and energy consumption exhibited significant asymmetric and structural breaks on CO_2 emission at the aggregate and disaggregated level in Nigeria. Appropriate domestic policies and institutional arrangements are required to reduce carbon emission in the production process.
Keywords: Carbon dioxide emission, Economic growth in Nigeria, Energy consumption, Carbon Reduction.

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List of Acronyms and Abbreviations

2SLS	Two Stage Least Squares
ADF	Augmented Dickey-Fuller
ARDL	Auto-Regressive Distributed Lag
CBN	Central Bank of Nigeria
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DOLS	Dynamics Ordinary Least Squares
ECN	Energy Commission of Nigeria
ECN	Energy Corporation of Nigeria
EKC	Environmental Kuznet Curve
ENU	Energy Use
EPC	Electricity Power Consumption
EPIC	Electrical Power Implementation Committee
EPSRA	Electricity Power Sector Reform Act
FD	Financial Development
FDI	Foreign Direct Investment
FEPA	Federal Environmental Protection Agency
FME	Federal Ministry of Environment
FMOLS	Fully Modified Ordinary Least Squares
FMWR	Federal Ministry of Water Resources
GCC	Gulf Cooperation Council
GDP	Gross domestic product
GHG	Greenhouse Gas
GMM	Generalized Method of Moments
IAE	International Energy Agency
ICAO	International Civil Aviation Organisation
IIPs	Integrated Power Producers
IPCC	Intergovernmental Panel on Climate Change
IV	Instrumental Variables
Kg	Kilogram
KPSS	Kwiatkwoski-Phillips-Schmidt-Shin

Kt	Kilowatt
LAC	Latin America Countries
LASEPA	Lagos State Environmental Protection Agency
MENA	Middle East and North Africa
NAPAMA	National Petroleum Assets Management Agency
NAPTIN	National Power Training Institute of Nigeria
NARDL	Nonlinear Autoregressive Distributed Lag
NASPA-CCN	National Adaptation Strategy and Plan of Action for Climate Change Nigeria
NBET	Nigerian Bulk Electricity Trading
NDA	Niger Dam Authority
NEEDS	National Environmental, Economics and Development Study
NEMSA	National Electricity Management Services Agency
NEP	National Energy Policy
NEPA	National Electric Power Authority
NEPP	National Electric Power Policy
NERC	Nigeria Electricity Regulatory Commission
NGMP	Nigerian Gas Master Plan
NNPC	Nigerian National Petroleum Corporation
NOGP	National Oil and Gas Policy
NPD	National Petroleum Directorate
NPI	Nigerian Petroleum Inspectorate
NPRC	National Petroleum Research Center
NREEEP	National Renewable Energy and Energy Efficiency Policy
OGIC	Oil and Gas Sector Reform Implementation Committee
OLS	Ordinary Least Squares
PH	Porter Hypothesis
PHCN	Power Holding Company of Nigeria
POP	Population
PPRA	Petroleum Products Regulatory Authority
R&D	Research and Development
REA	Rural Electrification Agency
REMP	Renewable Energy Master Plan

REPG	Renewable Electricity Policy Guidelines
SIC	Schwarz Information Criterion
TAR	Threshold Autoregressive Model
TCN	Transmission Company of Nigeria
TY-VAR	Toda and Yamamoto Vector Autoregressive
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VAR	Vector Autoregressive
VEC	Vector Error Correction
VECM	Vector Error Correction Model
WDI	World Development Indicators
WE	Western Europe

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Energy is the major means of support of any modern economy. It is a crucial input to nearly all of the goods and services. It is not only the cornerstone of economic development, but also an important strategic resource for a country. The stable supply of energy is vital to improving the current production level and maintaining as well as improving living standards of billions people across the globe (Kulionis, 2013). Energy also fuels productive activities including agriculture, commerce, manufacturing, industry, and mining. Therefore, energy consumption in the process of production is considered as a precondition of sustainable economic development. It is indispensable for economic activity because all production and consumption activities are directly related to energy consumption. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly.

However, the simultaneous rise in the production activities that generate economic growth is also expected to increase carbon dioxide (CO_2) emissions. This is because the productive activities rely on energy consumption. It is therefore expected that economic growth will result in high carbon dioxide emissions. By using the transitive property in mathematics, we can infer that economic growth thrives on energy consumption which in turn drives carbon dioxide emissions (Bosupeng, 2016). Thus, energy consumption plays the dual role of providing the foundation for economic activity and human well-being as well as acting as the driving force for environmental degradation. The growth-driven hypothesis has substantial implications for a developing country to be high carbon dioxide emitters.

For example, the excessive energy consumption has brought dramatic increases in CO_2 emissions that come from the combustion of fossil fuels (coal, oil and natural gas), thereby resulting in global warming and climate change due to the discharge of several potentially harmful gases (Kulionis, 2013; Li, Li and Lu, 2017, Kebede, 2017). Over the last three decades, greenhouse gas (GHG) emissions have increased by an average of 1.6% per year with carbon dioxide emissions from the use of fossil fuels growing at a rate of 1.9% per year.[1] In the absence of additional policy actions, these emission trends are expected to be continued. It is projected that with current policy setting global energy demand and associated supply patterns based on fossil fuels, the main drivers of Greenhouse gas (GHG) emissions will continue to grow. Despite continuous improvements in energy intensities, global energy use and supply are projected to continue to grow, especially as developing countries pursue industrialization (Hossain, 2012).

The GHG emissions not only cause deterioration of the environment but also adversely affect human life. Pollutants being emitted in the air as well as in streams and lakes contaminate the drinking water and affect the local ecosystems directly. When changing the dynamic of an ecosystem, the balance of organisms that provides us with the clean air we breathe and the food we eat gets disrupted. Particularly, emissions from manufacturing plants and other polluting establishments affect humans directly by causing sickness including different types of cancers, inflammations and heart diseases (Pope and Dockery, 2006). In this respect, energy consumption and environmental degradation have gained a large amount of attention worldwide as it is a huge challenge, not only for local areas but for the whole planet on a global scale.

The increasing volume of CO_2 emissions due to expanding and widening of the process of industrialization and the consequences of urbanization all over the world are the determinants of the ascending greenhouse gas threats. Therefore, the research of this aspect is becoming more important for all societies including developing countries and developed countries (Hossain 2012). World population has rapidly increased since the beginning of 20th century. Due to rapidly increasing of world population, the world energy demand has also increased year by year. In this regard, rapidly increasing use of fossil fuels (especially in the energy sector) is considered as an essential reason of environmental degradation (such as air pollution, ozone depletion), climate change and global warming. The reason behind all of them is induced progressive greenhouse gas (GHG) emission (especially carbon dioxide (CO_2)), due to an increasing use of fossil fuels (Erdem, 2010; Toklu, 2013; Bakirtas, Bayrak, Cetin, 2014). Accordingly, the prevailing threat of global warming and climate change has brought the attention on the relationship between economic growth, energy consumption and environmental

[1] A greenhouse gas is a gas in an atmosphere that absorbs and emits radiant energy within the thermal infrared range. Greenhouse gases trap heat and make the planet warmer.

pollution to a new level. Hence, the nature of this link between the growth in economic activity and carbon emissions is a critical question for climate change. Linkage implies that deep emission reductions will constrain economic growth while decoupling implies that deep emission reductions are possible, with little or no effect on growth. The nature of this relationship in Nigeria, like any other developing countries, becomes an important issue in this discuss.

Nigeria is a middle-income, mixed economy and emerging market, with expanding manufacturing, financial, service, communications, technology and entertainment sectors. Prior to the economic recession in 2015, economic growth in Nigeria was on a steady increase. The gross domestic product (GDP) growth rate in Nigeria averaged 5.30 percent between 2010 and 2014, reaching an all-time high of 8.60 percent in the fourth quarter of 2010. It was 6.2% in 2014. The Nigerian economy is ranked 26th in the world in terms of GDP (nominal: 30th in 2013 before rebasing, 40th in 2005, 52nd in 2000), and is the largest economy in Africa (based on rebased figures announced in April 2014). Its re-emergent manufacturing sector became the largest on the continent in 2013, and it produces a large proportion of goods and services for the West African subcontinent (KPMG, 2015).

Given that it is a growing economy, Nigeria has huge energy demands and energy requirements, mostly for electricity generation. Electricity consumption in Nigeria in 2014 was 24.57 billion kWh while primary energy consumption was 1.33 quadrillion btu. Total installed capacity for electricity generation was also 12,232 MW in 2014, the same level recorded in 2013, but showed an increase of 23.1 per cent above the level in 2012 (CBN Annual Reports and Statement of Account, Various Issues, 2012). The average generation capacity of electricity has been oscillating within the range of 2,623.1 MW/hr in 2007 and 3,485.5 MW/hr in 2014 against the estimated demand of 10,000MW per day (Rapu, Adenuga, Kanya, Abeng, Golit, Hilili, Uba, and Ochu, 2015).

As an oil dependent economy, it is well established that all hydrocarbon extraction activities generate CO_2 emissions. One particular by-product of crude oil production is associated gas, the flaring of which generates large amounts of greenhouse gases (Total.com, 2018). On the net calorific value, Nigeria's economy is fueled by unclean and traditional energy, comprising 80.9 per cent of the total consumption. Cleaner and modern energy like gas and electricity comprised only a paltry amount of 11.1 per cent

(Rapu et al., 2015). The sustainability of the energy systems in Nigeria is likely to be vulnerable if the anticipated energy crisis – in particular, the electricity crisis and CO_2 emissions issues – are not addressed appropriately. This is because the country is still highly dependent on fossil fuels such as oil and gas in its productive activities which also represents other main causes of carbondioxide (CO_2) emissions.

Consequently, the CO_2 emissions level has grown significantly. For example, the value for CO_2 emissions from gaseous fuel consumption (kt) in Nigeria increased from 212.69 in 1970 to 7,484.35 in 1990 and peaked at 33,131.34 in 2014 (WDI, 2018). As a percentage of total emission, CO_2 emissions from gaseous fuel consumption increased from 0.99% in 1970 to 19.09% in 1990 and peaked at 34.41% in 2014 (WDI, 2018). Also, the value for CO_2 emissions from liquid fuel consumption (kt) in Nigeria increased from 6410 in 1970 to 29,802 and 32,380 in 2014. It peaked at 39,776 in 2005 (WDI, 2018). In terms of solid fuel consumption (kt), the value for CO_2 emissions in Nigeria increased from 58 in 1969 to 121.01 in 2014 (WDI, 2018). In addition, CO_2 emissions from residential buildings and commercial and public services (% of total fuel combustion) in Nigeria was 2.61 as of 2014. Its highest value over the past 43 years was 17.29 in 1987, while its lowest value was 2.47 in 2012 (WDI, 2018).

Nevertheless, different attempts have been made to reduce the share of emissions in the atmosphere. For example, over the past several decades, the international community has attached great importance to carbon emissions and signed a number of related agreements, such as the Kyoto Protocol in 1997, which aimed to stabilize greenhouse gas levels in the atmosphere at an appropriate level, and the Copenhagen Accord in 2009, which stipulated that all countries should reduce CO_2 emissions according to the sizes of their national GDP (Li, Li and Lu, 2017). The Kyoto Protocol was an agreement negotiated by many countries in December 1997 and came into force with Russia's ratification on February 16, 2005. The goals of Kyoto were to see participants collectively reducing emissions of greenhouse gases by 5.2% below the emission levels of 1990 by 2012. While the 5.2% figure is a collective one, individual countries were assigned higher or lower targets and some countries were permitted increases (Carbonify.com, 2018).

In addition, the Paris Agreement was signed in April 22, 2016 within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions mitigation, adaptation and finance starting in the year 2020.

The Agreement's aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels. It also aims to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.

As part of the global initiatives, Nigeria also adopted several environmental and sectoral policies, strategies, and plans to reduce the CO_2 emission. For example, in 2012, the Federal Executive Council adopted a comprehensive strategy and policy on climate change. The policy is the Nigeria Climate Change Policy Response and Strategy with the objective of promoting low-carbon, high-growth economic development and build a climate-resilient society (London School of Economics and Political Science, 2013; New Climate Institute, 2015; UNFCCC, 2015; Climate Scorecard, 2018). The government, through the Nigerian Civil Aviation Authority (NCAA), has joined the countries that have endorsed the implementation of the CO_2 Emissions Mitigation Measures and Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) by the International Civil Aviation Organisation (ICAO). Others include: institutional strengthening (upgrade of the Department of climate of change); capacity building (public awareness programmes, training of stakeholders as well as beneficiaries both locally and internationally); and execution of projects (largest gas gathering programme in Africa (LNG), mandatory reduction of emissions by 20% of Joint Ventures) (climatechange.gov.ng., 2018). The Federal Government of Nigeria has also established the National Climate Change Trust Fund and the Environmental Sustainability Group to design and attract financing mechanisms for adaptation initiatives (AAP Nigeria, 2016, Climate Scorecard, 2018).

However, despite the initiatives, the International Energy Agency (IEA, 2009) suggests that current trends in energy supply and use are still economically, environmentally and socially unsustainable. This is because the energy-mix supplied to run the global economy in the 2025-2030 time frame will essentially remain unchanged while more than 80% of the energy supply will be based on fossil fuels, with consequent implications for GHG emissions (IPCC, 2007). It is projected that the primary energy demand will increase by 1.5 % per year between 2007 and 2030, with fossil fuels being a dominant energy source. Projections have consistently showed increase in annual world emissions of gases, measured in CO_2-equivalent) of 25–90% by 2030, compared to 2000 (IPCC, 2007). It is expected that because of increasing energy demand the energy-related CO_2 emissions will more than double by 2050 whereas, the increased demand for oil will heighten the concerns over security of energy supplies (IEA, 2009).

Consequently, these concerns therefore raise the following questions: what is the relationship between economic growth and CO_2 emissions in Nigeria? Is the relationship between CO_2 emissions and economic growth in Nigeria linear or non-linear? Is there asymmetric pattern in the relationship between CO_2 emissions, energy consumption and economic growth in Nigeria? Does the impact of energy consumption on CO_2 emission vary across its components? To what extent do other factors such as foreign direct investment and financial development contribute to CO_2 emission in Nigeria? To what extent does structural and/or policy shift matters in the CO_2 – economic growth relationship? What is the health implication of continuous CO_2 emission? These questions will constitute the main research focus of this study.

1.2 Objectives of the Study

The main objective of this study is to analyse CO_2 emission, energy consumption and economic growth in Nigeria. More specifically, the objectives are to:

1. empirically analyze the effects of economic growth, energy consumption on CO_2 emissions at the aggregate and disaggregated level in Nigeria;
2. empirically establish the asymmetric effects of economic growth, energy consumption on CO_2 emissions;
3. determine the extent to which structural breaks and policy shift influence carbon emission and –economic growth relationship in Nigeria; and
4. empirically evaluate the health effect of carbon emission in Nigeria.

1.3 Justification for the Study

The relationship between energy consumption and economic growth, and environmental pollution has been the subject of intense research in the energy-economic literature (Acaravci and Ozturk, 2010). However, the empirical evidence remains controversial and ambiguous to date. The existing literature reveals that empirical studies differ substantially in terms of methods of data analysis and are not conclusive to present policy recommendation that can be applied across countries. While there is an extensive amount of research looking at the linkage between economic growth and energy consumption (Stern, 2004; Ozturk , Aslan , Kalyoncu, 2010; Belke, Dobnikad, Dregerb, 2011; Ahmad, Ayat, Hamad, Lukman, 2012; Pirlogea and Cicea, 2012; Esen, 2017) on the one hand, and between economic growth and environmental pollution (Venu 1974; Galeotti 2006; Halkos and Tzeremes 2011; Yang, Yuan, Sun, 2012; Yali 2014; Taylor, Elisha, Denkyirah, 2018) on the other, there is a dearth of empirical studies that investigate both relationships in one framework for Nigeria and at the disaggregated level. Therefore, the aim of this study is an attempt to fill this gap.

Also, the health effects of CO_2 emission have been neglected in the literature (Balan, 2016; Ghorashi and Rad, 2017). For example, the impacts of environment degradation on human health affect the society, both in terms of loss of quality of life and expenditure on health care. Therefore, health care expenditures due to environmental degradation are substantial and the studies examining the impact of CO_2 emissions. Greater carbon dioxide emissions are associated with more air pollution, which leads to health issues involving the lungs, heart and cardiopulmonary system (Davidson 2003). Countries with higher levels of carbon dioxide emissions would also likely tolerate higher levels of other harmful chemicals and pollutants, further increasing the risk of health problems among their citizens. As a result, this study therefore considers the health dimension of CO_2 emission. There is no known study that has attempted this for Nigeria.

Previous research studies on the nexus among energy consumption, CO_2 emissions, and economic growth mainly focused on exploring the overall relationships among variables and leaves out the composition of the carbon emission. The main driver of carbon dioxide emissions is energy consumption, given that the bulk of African economies utilize fossil fuels for energy production. Additionally, automobiles use fossil fuels such as gasoline during internal combustion, which adds to carbon dioxide emissions. Unlike these past studies, this study disaggregates the total carbon emission into CO_2 emissions from the consumption of coal, CO_2 emissions from the consumption and flaring of natural gas, and CO_2 emissions from the consumption of petroleum products. This has not been carried out in the Nigerian literature on economic growth, energy consumption and CO_2 emission. Thus, as a way of improving on past studies, this study attempts a disaggregated analysis. Disaggregating emission will aid our understanding on the interaction between emissions, energy use and growth in the domestic economy. In addition, the turning point at which the level of income per capita changes and emissions start declining is calculated for Nigeria. This has not been done for Nigeria.

With respect to the methodological contribution, the majority of the previous studies suffer from five major weaknesses; namely, (i) the use of a bivariate causality test, which may lead to the omission-of-variable bias; (ii) the choice of OLS techniques that suffer from the problem of endogeneity which may result, when there is correlation between the regressor and the error term (iii) the use of cross-sectional data, which does not satisfactorily address the country-specific effects; (iv) the use of the maximum likelihood test based on Johansen (1988) and Johansen and Juselius (1990), which has been proven to be inappropriate when the sample size is too small (Narayan and Smyth, 2005) and when the order of integration is mixed; (v) relying on linear cointegration techniques, while a nonlinear cointegration approach should have been employed (vi) the choice of unit root tests and cointegration techniques which fail to consider structural breaks.

It is against this backdrop that the current study attempts to examine the inter-temporal causal relationship between CO_2 emissions, energy consumption and economic growth, using the auto-regressive distributed lag (ARDL) and the newly developed non-linear ARDL (NARDL) bounds testing approach. With respect to the health implication of CO_2 emission, a multivariate causality model between CO_2 emissions and health indicators was adopted. On the possible role of structural shift in the CO_2 –economic growth relationship, the study explored structural break unit root test and also the regression based multiple break date test to reflect the potentials of the structural shift endogenously. In addition, the study also analysed the relationship between income per capita and CO_2 emissions per capita to know whether there is no relationship, a monotonically increasing or linear relationship, a monotonically decreasing relationship, an inverted-U-shaped relationship, a U-shaped relationship, an N-shaped relationship, or an inverted-N-shaped relationship.

In view of the above, this study contributed to the literature on carbon dioxide, energy consumption and economic growth relationship by using different but complementary statistical approaches. However, a more precise investigation of the relationship between economic growth and environment effects requires the study of the single country characteristics underlying the importance of the specific historical experience.

To the best of our knowledge, there has been no systematic study that has focused exclusively on the contribution of economic growth and energy consumption to CO_2 emissions in Nigeria (at the aggregate and disaggregated level), and particularly how this has changed over time. Hence, this thesis intends to fill the gap by investigating the role of energy consumption and economic growth on CO_2 emission while controlling for other determinants. The results will be particularly important in policy decisions in order to act on the level of emissions while pursuing economic growth objectives.

1.4 Scope of the Study

The study covered a period of forty-six years for Nigeria. This is between 1970 and 2015. The choice of the period and country (Nigeria) was on the basis of data availability on CO_2 emissions and the relevant macroeconomic variables. The period was also chosen in order to have sufficient data to enable the separation of the effects into the short run and the long run horizon. In addition, the choice of the period corresponds to the significant rise in CO_2 emission in Nigeria.

1.5 Organization of the Study

Following the introductory chapter, the literature was reviewed in chapter two. A detailed analysis of the trend in economic growth and CO_2 emissions in the selected African countries was undertaken. Thereafter, a review of policy issues and institutional frameworks was conducted. The relevant theoretical, methodological and empirical literature was also reviewed in chapter two. The theoretical foundation on which the models are predicated is developed in chapter three. The empirical specification of the equations as well as the estimation technique was also highlighted in the chapter. Empirical results were discussed in chapter four while the summary, conclusion and recommendations were presented in chapter five.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter presents the background and Theoretical framework work to the study. The trend analysis of major indicators of carbon emission, energy consumption and economic growth are presented. In addition, developments in policies and institutions relating to carbon emissions are discussed.

2.2 Trend Analysis of Key Variables

A cursory look at Figure 2.1 shows that CO_2 emission from liquid fuel consumption[2] was at its lowest in 1970 but thereafter increased after witnessing some slight fluctuations between1988 and 2014. The mainstay of the Nigerian economy is crude-oil which explains the reason behind the upward trend of her CO_2 emission from liquid fuel consumption. The volatility in the volume of CO_2 emissions from liquid fuel consumption could be attributed to either of these two reasons: unstable prices of liquid fuel or irregular production/exploitation of liquid fuel. The former is however more likely. In addition, owing to the fluctuation of oil price in the international market, there is bound to a corresponding fluctuation in output and export because price of products is an important determinant of export. Put differently, export is affected by a change in prices of products. Moreover, the prices of most primary products for export are exogenously determined.

In addition, a cursory look at Figure 2.1 shows that CO_2 emission (kt)[3] and total greenhouse gas (GHG) emission[4] moved in the same direction for most of the period under review such that when one increases, the other also increases and vice versa.

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[2]Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source.

[3]Carbon dioxide emissions (kt) are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

[4]Total greenhouse gas emissions in kt of CO_2 equivalent are composed of CO_2 totals excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peat lands), all anthropogenic CH_4 sources, N_2O sources and F-gases (HFCs, PFCs and SF_6).

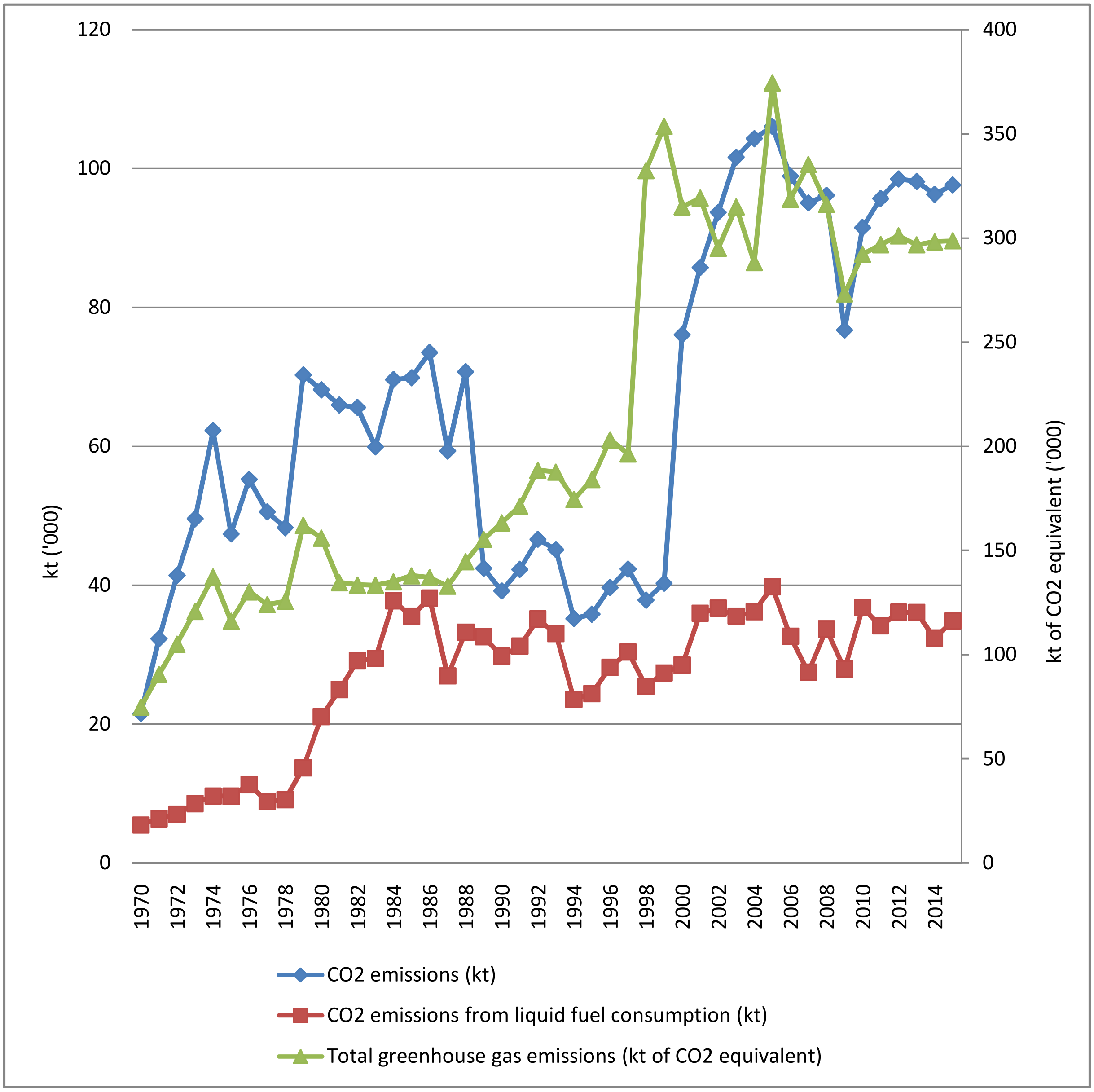

Figure 2.1: CO_2 Emissions (kt), CO_2 Emissions from Liquid Fuel Consumption (kt) and Total Greenhouse Gas Emissions (kt of CO_2 Equivalent) in Nigeria.
Source: Author's Computation from World Development Indicators (WDI), 2017.

Nevertheless, the volume of the total greenhouse gas (GHG) emission is greater than the CO_2 emission (kt) throughout this period. Nigeria discovered crude oil in commercial quantities in 1970 and has continuously been exploring this natural resource which necessitates gas flaring thereby contributing to the CO_2 emissions and the greenhouse gas emissions. This trend accounts for the upward trend of the CO_2 and total greenhouse gas emissions in Nigeria. Furthermore, the increasing demand for cement in the domestic construction activities led to its high production which obviously leads to higher emissions. In addition, burning of fossil fuel has been on the increase overtime and it has significant contribution to the volume of CO_2 and greenhouse gases emitted in Nigeria. Thus, Nigeria is confronted with the crucial issue of producing more energy resources to meet her energy requirements, while at the same time grappling with the issue of reducing greenhouse gas (GHG) emissions.

Figure 2.2 shows that CO_2 intensity[5]in Nigeria rose significantly from 0.97 in 1971 to 1.68 in 1974 before falling to 1.23 in 1975. Similarly, it can be observed from Figure 2.2 that CO_2 intensity (kg per kg of oil equivalent energy use) and CO_2 emission (metric tons per capita) have the same trend throughout the between 1970 and 2015 such that when the CO_2 intensity increases, the CO_2 emission also increases and vice versa. The increase in these two indicators highlights the increased contribution of coal to the total national output, while the converse is true for a decline in these emissions. Put differently, the trend signifies the importance of coal to the Nigerian economy as a source of energy, foreign exchange and government revenue. It also indicates the rate of exploration and utilization of this natural resource. However, despite the great potentials of coal in contributing to national output and since the discovery of oil in commercial quantities as well as the oil boom in the 1970s in Nigeria, it has been widely regarded as a dirty form of energy. Whereas CO_2 intensity reached its peak in 1974, it plummeted afterwards thereby giving credence to the fact that its importance declined subsequently. This accounts for the volatile trend of these emissions indicating that the contribution of coal to the Nigerian economy has been unstable overtime.

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[5]CO2 intensity (kg per kg of oil equivalent energy use) is the carbon dioxide emissions from solid fuel consumption and refers mainly to emissions from use of coal as an energy source.

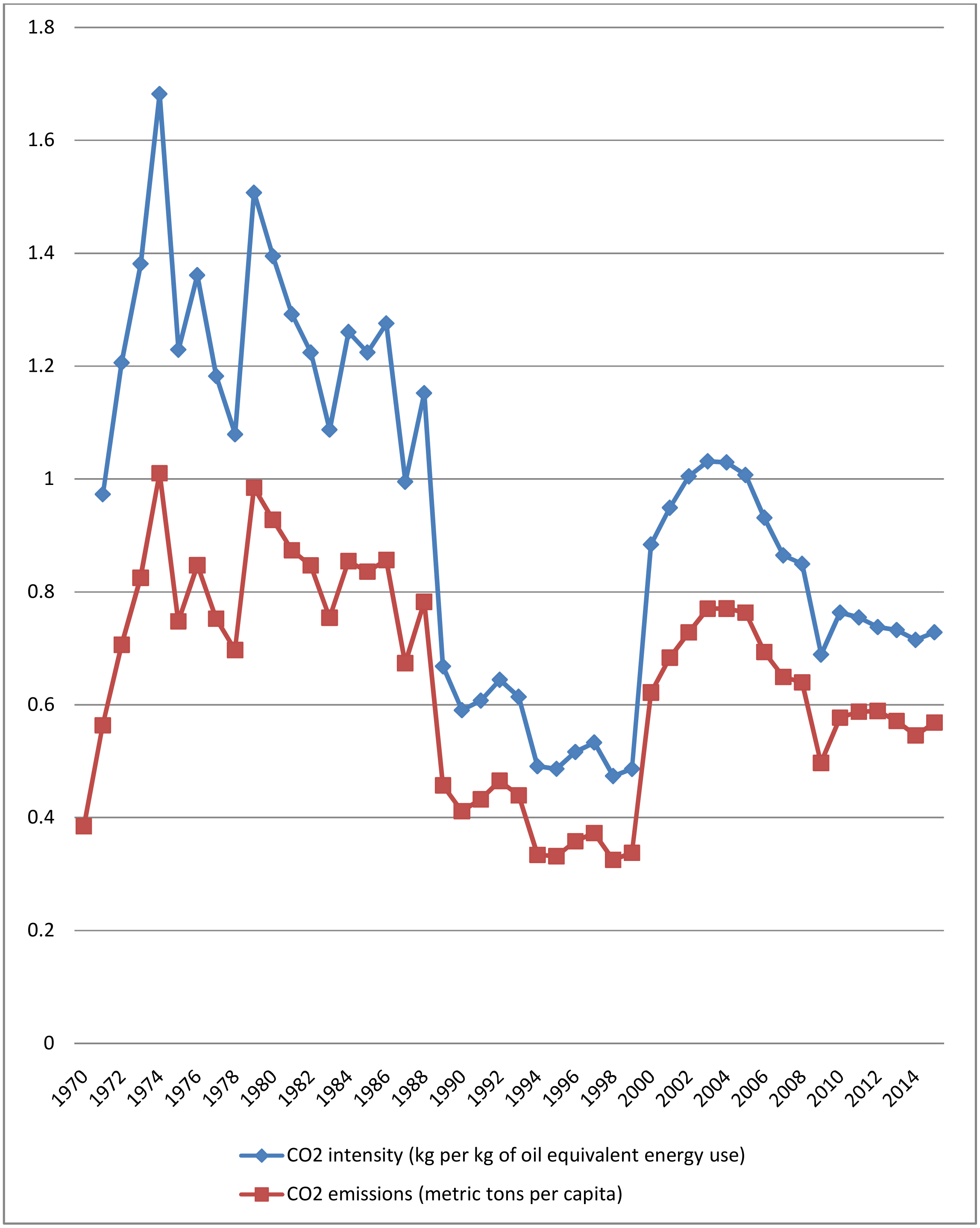

Figure 2.2: CO_2 Intensity (kg per kg of Oil Equivalent Energy Use) and CO_2 emissions (metric tons per capita) in Nigeria.
Source: Author's Computation from World Development Indicators (WDI), 2017.

Figure 2.3 shows that energy use[6]increased steadily from 1970 to 1984 after which it became relatively stable throughout the period under review. The abundant presence and exploration of crude-oil deposits accounts for the observed trend of energy use. This trend is indicative of the fact that the sum of indigenous production plus imports and stock changes far outweighs that of exports and fuels supplied to ships and aircraft engaged in international transport. Energy use is directly related to CO_2 emission (Lin et al, 2015) and has a positive relationship with export (Li, 2010). These relationships have implications for economic growth as economic growth will tend to increase when energy use increases.

Similarly, it is apparent that combustible renewables and waste (% of total energy)[7] has been very high over time, indicating that it takes the bulk share of the total energy. This trend shows that the economy is highly dependent on crude-oil whose proceeds serve as a major source of government revenue and foreign exchange. In the same vein, fossil fuel energy consumption (% of total)[8] increased steadily from 1970 till 1982 and has been relatively stable afterwards. Pal *et al.* (2011) and Jones and Sands (2013) opined that the level, extent and nature of economic activities affect the amount of greenhouse gas emissions, including CO_2 emissions. In other words, the increase in emissions is instigated by increase in economic activities with regards to the extraction of natural resources.

Figure 2.4 shows that CO_2 emissions from manufacturing industries and construction[9] declined steadily from 1974 to 2002 and have been volatile afterwards. This is indicative of the state of the manufacturing and construction sector of Nigeria. On the average, it is clear that the contribution of the manufacturing and construction sector to total national output is low as depicted by the share of CO_2 emission in the sector to total emissions. Put differently, the manufacturing and construction sector of Nigeria is not the booming sector of the Nigerian economy and as such is not a major driver of growth in Nigeria. The expectation is that an increase in the productive activities in the manufacturing and construction will lead to an increase in the CO_2 emission of the sector.

[6]Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.
[7]Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use.
[8]Fossil fuel comprises coal, oil, petroleum, and natural gas products.
[9]CO_2 Emissions from manufacturing industries and construction are from the generation of electricity and/or heat. It also includes emissions from coke inputs into blast furnaces.

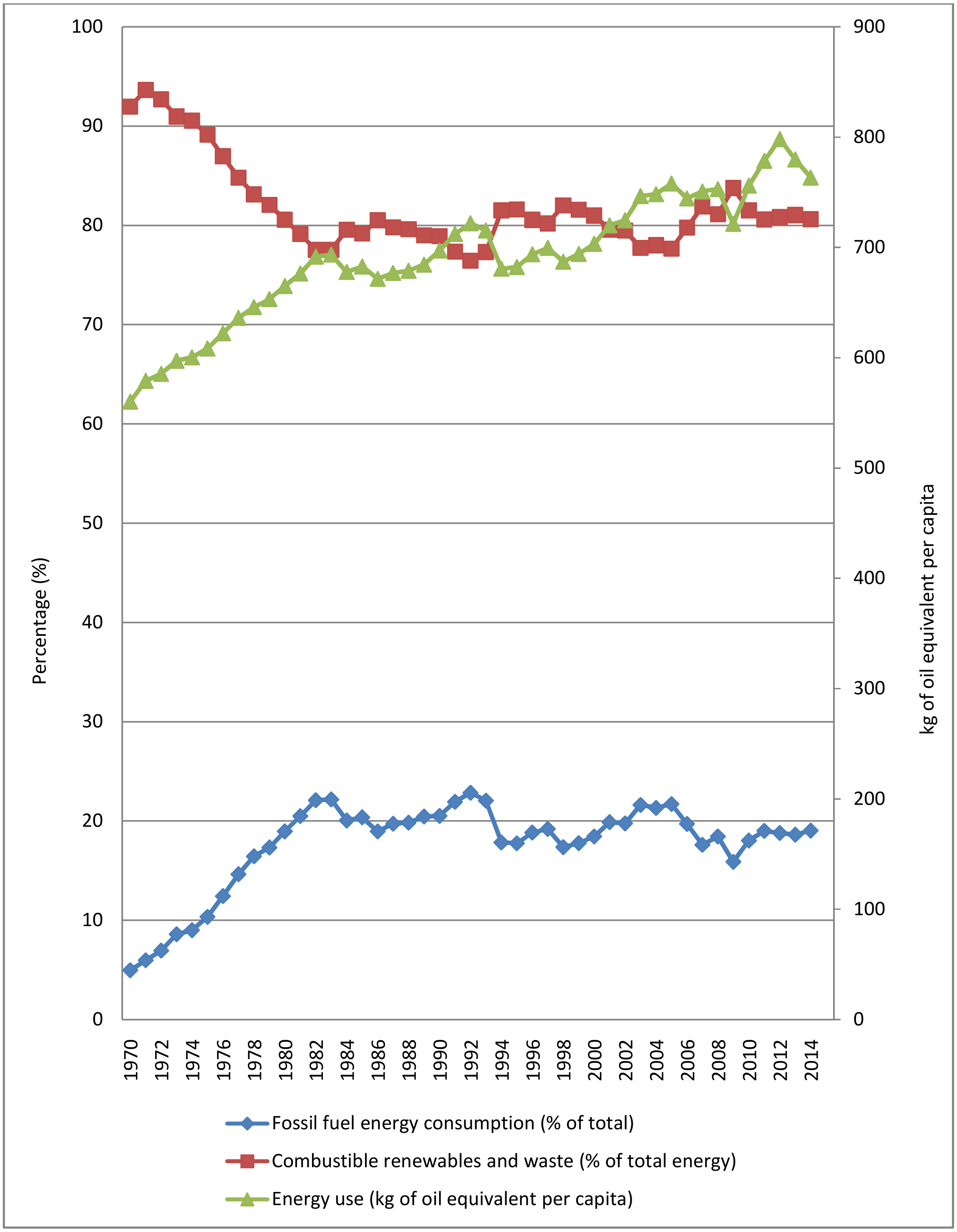

Figure 2.3: Fossil Fuel Energy Consumption, Combustible Renewables and Waste and Energy Use in Nigeria

Source: Author's Computation from World Development Indicators (WDI), 2017.

In view of this, the trend of the CO_2 emission from manufacturing industries and construction shows that Nigeria has not yet tapped fully into the potentials of her manufacturing and construction sector. The situation which might be responsible for the high unemployment rate, high incidence of poverty and slow growth of the economy. Rather than invest maximally in the manufacturing sector thereby producing intermediate or finished goods, most African countries, including Nigeria, concentrate on the extraction and export of primary products which emits CO_2 and whose prices are often exogenously determined.

Figure 2.4 further shows that CO_2 emission from transport[10] has been high (between 40 and 60 percent) throughout the period except from 2010 to 2014 when it fell below 40 percent (WDI, 2017. Again, this shows the state of the transport sector of Nigeria, its contribution to national productivity as well as the volume of activities in the sector, among others. The high CO_2 emission from transport could also be attributed to the high rate of pipelines vandalism, lack of good road networks, underdeveloped or non-functional rail networks as well as high volume of activities in the aviation sector, among others.[11] This implies that Nigeria should adopt clean energy technologies which emits little CO_2.

Figure 2.5 reveals that CO_2 emission from solid fuel consumption increased markedly between 1970 and 1972 from 172.35kt in 1970 to 550.05kt and 858.08kt in 1971 and 1972 respectively before it started declining until it reached a record low of 7.33kt in 2000 and 2001 but it has since grown steadily to 121.01kt in 2014. This shows that Nigeria gradually neglected the use of coal as a source of energy until 2000 and 2001 and had since started using it but not as she did in the 1970s. Instead, Nigeria gave more priority to the exploitation of crude-oil as the country exports it in exchange for foreign currency.

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[10]CO2 emissions from transport contain emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation. This includes domestic aviation, domestic navigation, road, rail and pipeline transport.

[11] Given the challenges associated with CO_2 emission, it would have been proper for government to use other effective means of transporting crude oil products.

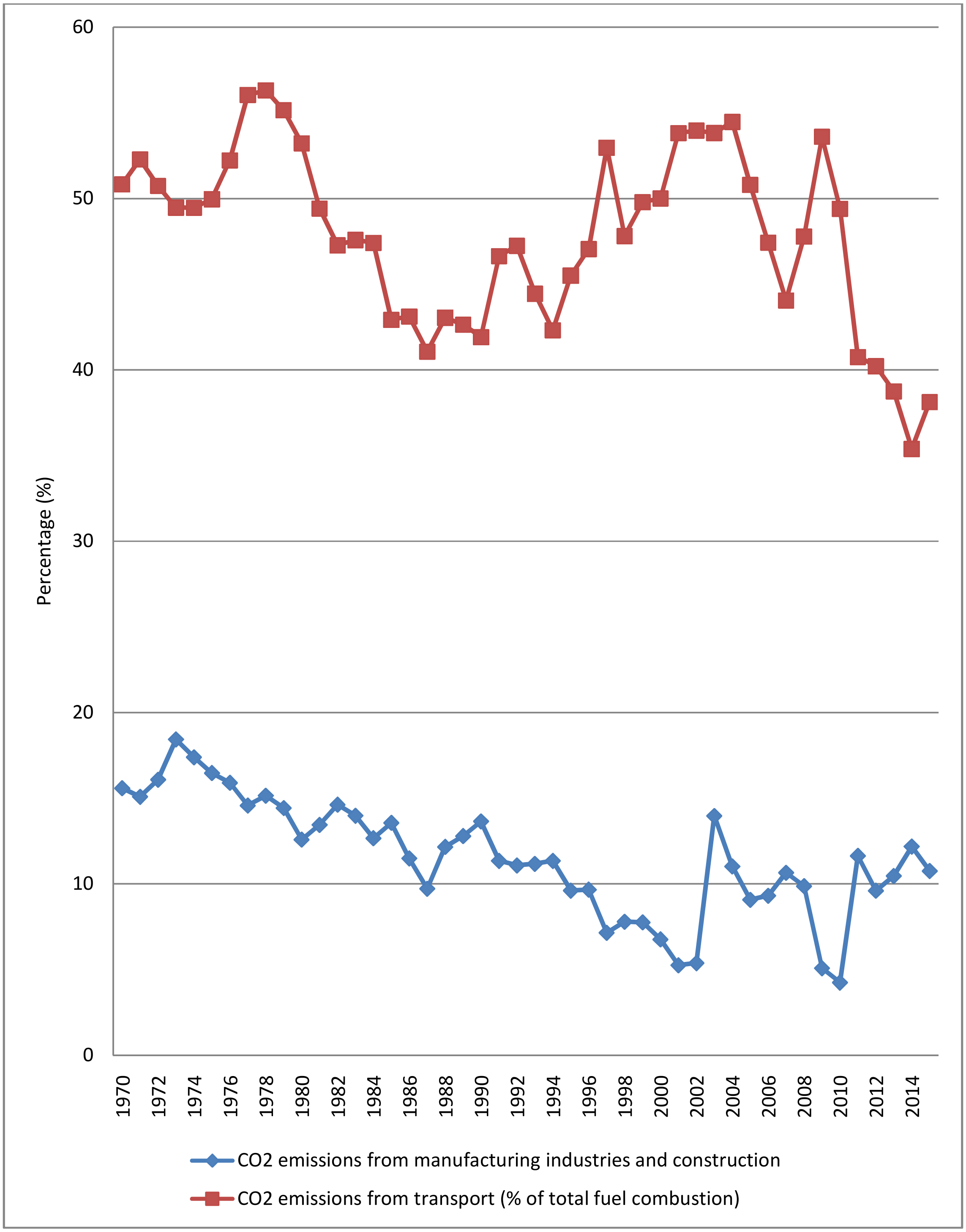

Figure 2.4: CO2 Emissions from Manufacturing Industries and Construction and CO2 Emissions from Transport in Nigeria.
Source: Author's Computation from World Development Indicators (WDI), 2017.

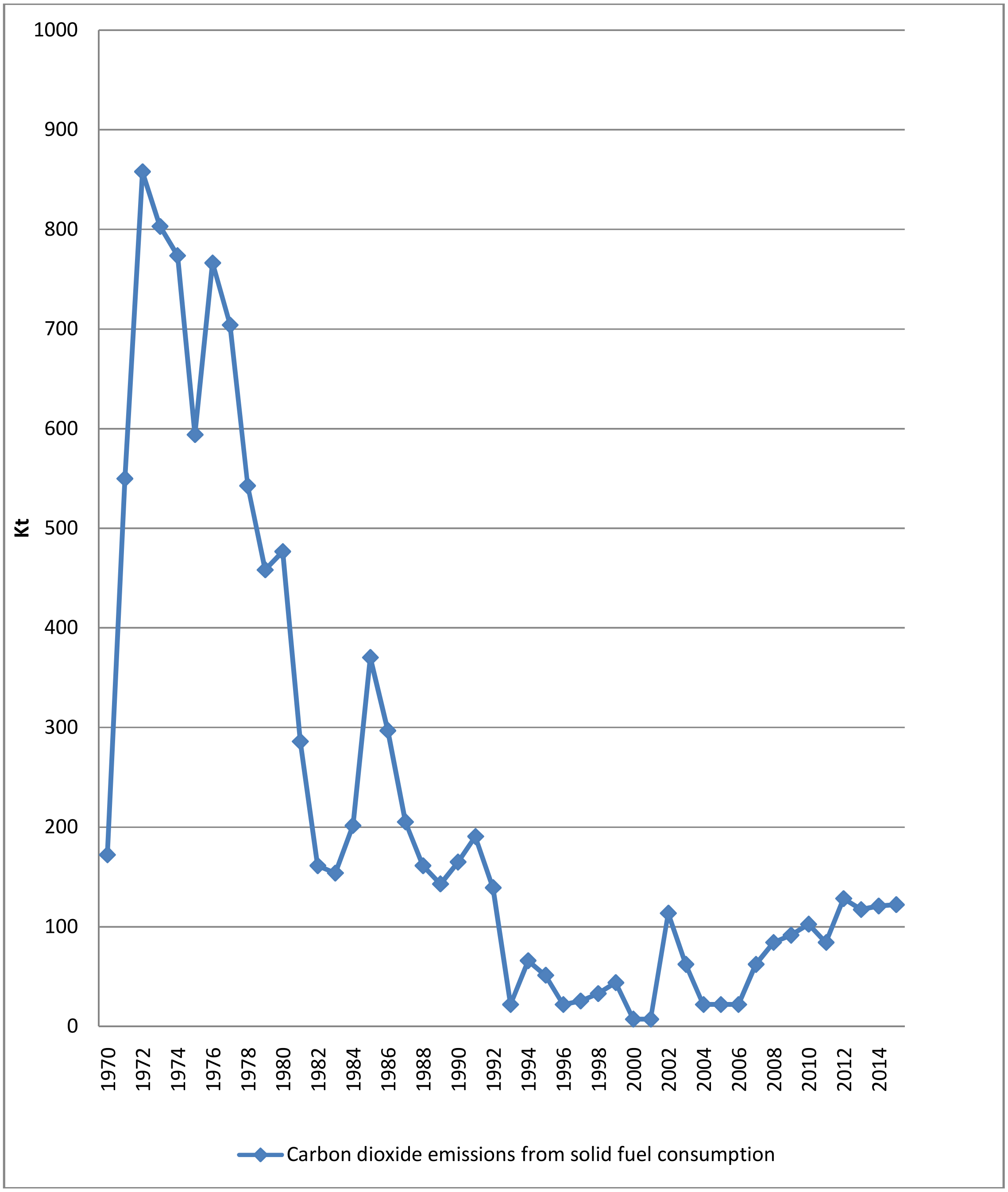

Figure 2.5: Carbon dioxide emissions from solid fuel consumption (kt)
Source: Author's Computation from World Development Indicators (WDI), 2017.

The World Bank estimated the 2015 population of Nigeria to be about 181 million people with a land area of 923770 sq. km., a ratio which gives Nigeria's population density as 226 per km^2 (586 people per mi^2). Figure 2.6 shows that there has been an upward trend in the population density of Nigeria, indicating that there has been significant growth in the population of Nigeria given that land area is fixed in supply. This could imply either of these: the birth rate is higher than the death rate in Nigeria and/or immigration rate is higher than emigration rate in Nigeria. Nigeria is said to be the most populous country in Africa even though her land area is less than that of some African countries. Population growth is expected to increase the pressure on the available resources and also increase economic activities which may in turn lead to an increase in CO_2 emission (Pal et al. 2011; Jones and Sands 2013). Population density could also, therefore, affect CO_2 emission. This is clear from the upward trend of both population density and CO_2 emission in Nigeria. Furthermore, it has been proven that a positive relationship exists between population density and CO_2 emissions (Lin et al, 2015 and Amuakwa-Mensah and Adom, 2017).

Similarly, Figure 2.6 shows an upward trend in urban population between 1970 and 2015. The upward trend in both population density and urban population are caused by either of these possibilities: the birth rate in the urban area is greater than the rural areas or there is high rural-urban migration, the latter being most likely. The high rate of industrial development and the presence of modernity as well as social amenities account for why cities such as Lagos, Kano and Port Harcourt, among others, are densely populated. Theoretically, there is a positive relationship between population and urban population[12] (urbanization rate) such that when population increases, urban population (urbanization rate) also increases and vice versa.

Since, a direct relationship has been established between population density and urbanization rate in Nigeria as well as a positive relationship between population density and CO_2 emissions, then, it is expected that CO_2 emissions would be an increasing function of urbanization rate such that CO_2 emissions would increase as urbanization rate increases and vice versa. Hence, the upward trend in urbanization rate in Nigeria also accounts for the increase in CO_2 emissions in the country.

[12]Urban population refers to people living in urban areas as defined by national statistical offices.

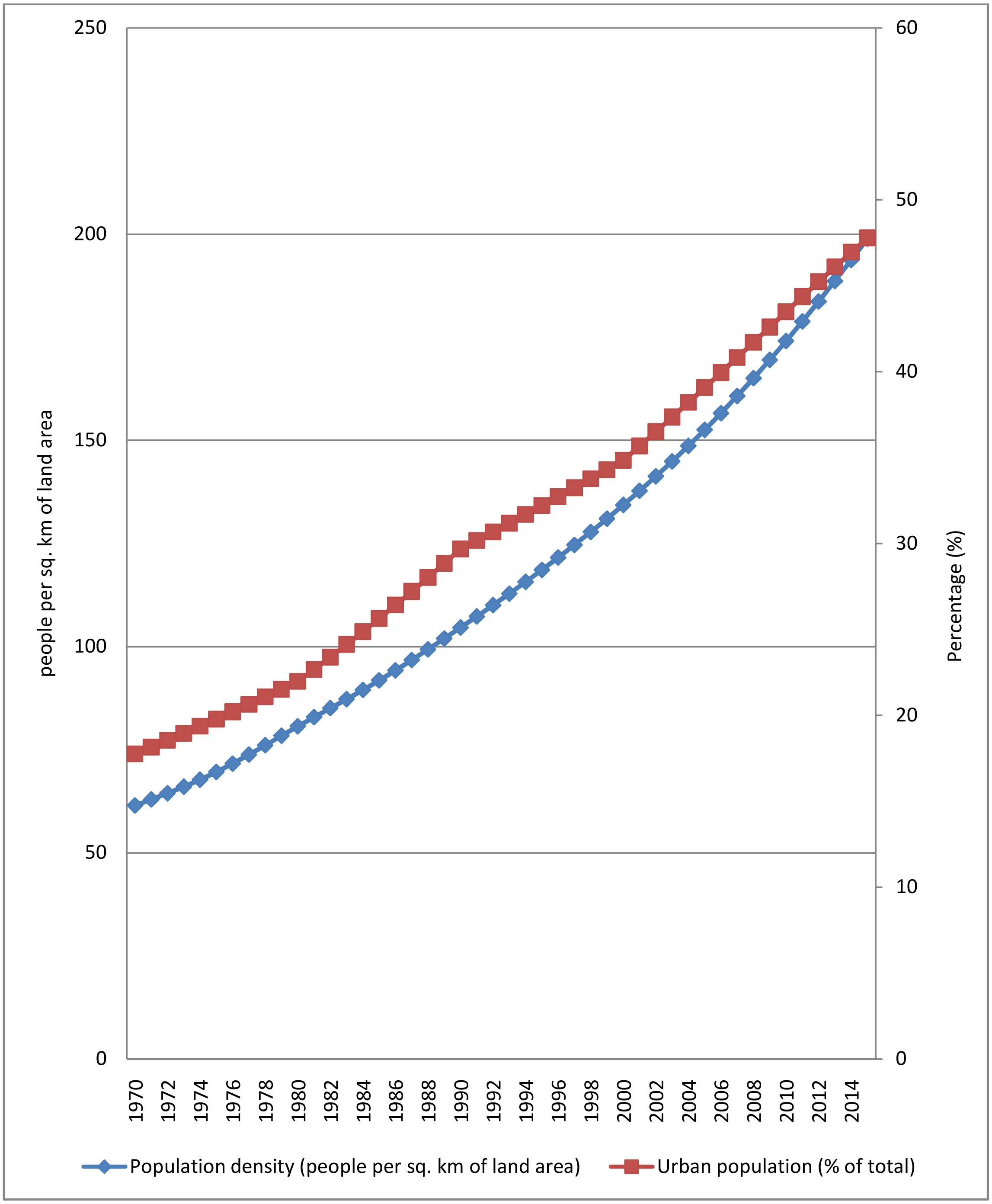

Figure 2.6: Population Density (People per sq. km of land area) and Urban Population (% of Total) in Nigeria

Source: Author's Computation from World Development Indicators (WDI), 2017.

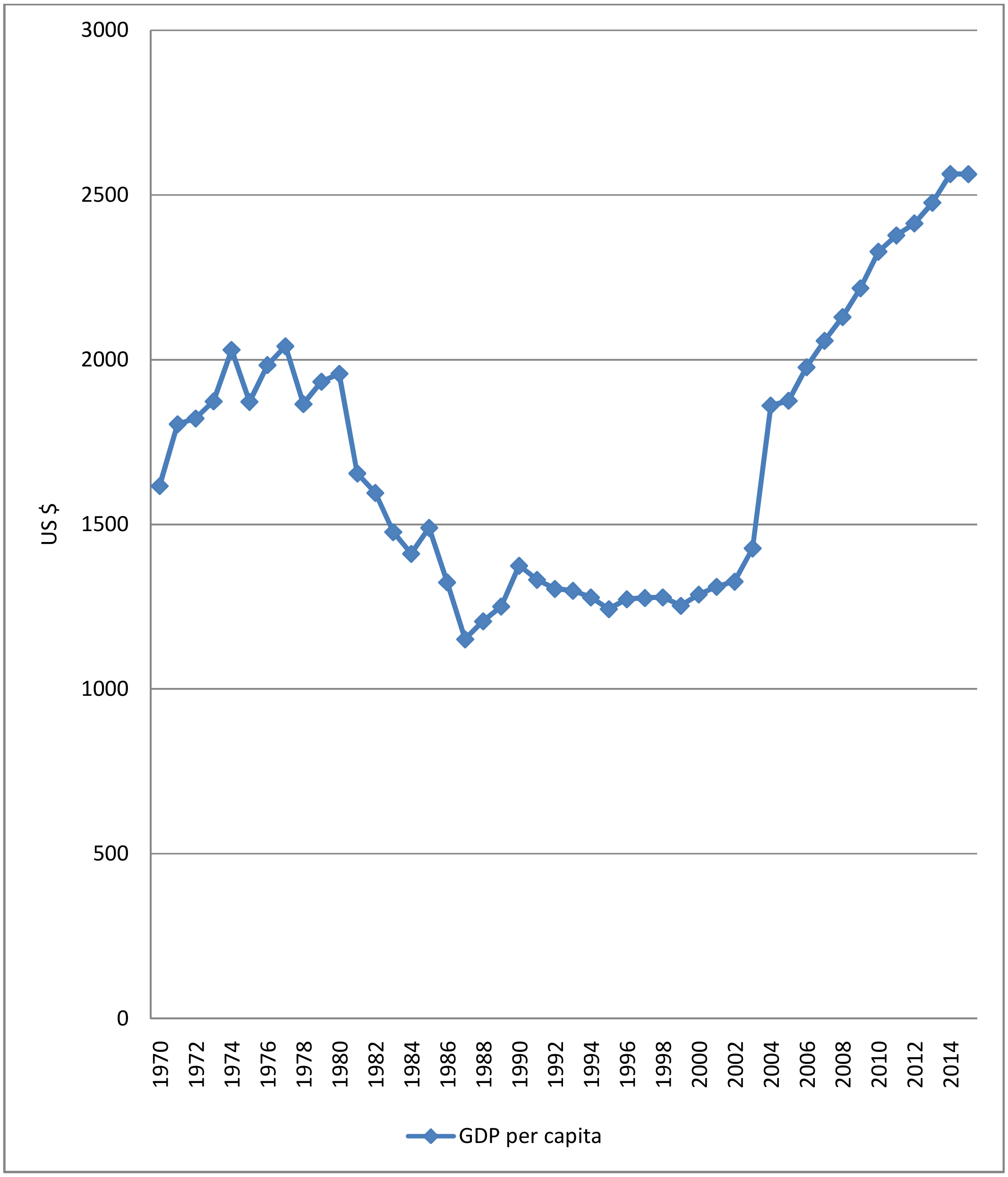

Figure 2.7: GDP Per Capita in Nigeria (US$)
Source: Author's Computation from World Development Indicators (WDI), 2017.

The GDP per capita[13] is usually used to measure the welfare of citizens of a country. Figure 2.7 reveals that GDP per capita in Nigeria is relatively volatile between 1970 and 1990, indicating that the growth rate in GDP is not proportionate with population growth rate during this period. However, it is apparent that GDP per capita was relatively stable from 1990 to 2002, after which it recorded significant positive growth, thereby indicating that GDP growth rate in Nigeria from 1990 outweighs population growth rate. This implies that the populations of Nigeria and income/output have been increasing overtime. It is observed that growth in GDP per capita is accompanied by growth in CO_2 emission thus; the upward trend in both CO_2 emissions and GDP per capita could mean that GDP per capita is an important driver of CO_2 emissions. Moreover, Lin et al (2015) and Amuakwa-Mensah and Adom (2017) argued that GDP per capita and CO_2 emissions have a significant direct relationship.

In summary, it can be observed from the trend analysis that CO_2 emissions from different sources have been persistently increasing overtime. Some of the likely causes of this trend are: export growth, GDP per capita growth, high population density and high urbanization rate, among others. It was also observed that CO_2 emissions from manufacturing industries and construction have been low, indicating Nigeria does not process her natural resources before exporting them, and that her manufacturing sector is not well developed, thus, hampering forward and backward linkages in the economy. The disaggregation of the CO_2 emission by sector/products gave an insight into the contribution of each sector/product to total national output and exports.

It was observed that CO_2 emissions in the primary sector (coal exploitation and other primary energy sources) are more than that of the secondary sector (manufacturing and construction) and the tertiary (services) sector (transportation). This is a similitude of the rate of contribution of each sector to aggregate national output and gives credence to the fact that the level, extent and nature of economic activities affect the amount of greenhouse gas emissions, including CO_2 emissions (Pal *et al.* 2011; Jones and Sands 2013). This also shows that the primary sector is still the main driver of economic growth in Nigeria.

The upward trend in CO_2 emissions from different sources implies that the cost attached to an increase in energy consumption, economic growth and diversification of the economy is a corresponding increase in CO_2 emission, which is detrimental to

[13]GDP per capita is gross domestic product divided by midyear population.

human health and welfare. In other words, given the recent realities in the Nigerian economy, it may be impossible to increase export, utilize energy consumption to industrialize and increase GDP per capita without increasing environmental pollutions because most of the products for exports are primary products, some of which instigate carbon emissions. This implies that the clarion call for expansion of national output in Nigeria has a trade-off (the welfare of the people which will be affected by environmental pollutions).

2.3 Policy Development on Carbon Emission

This section focuses on the various policies initiated across the globe and Nigeria to regulate CO_2 emission as well as boost energy consumption over time.

2.3.1 Global Perspective on Carbon Emission

The subsection provides information on global perspective on carbon emission, by discussing a few conventions held in the past to address ozone layer and climate change issues, which are offshoots of carbon emissions.

Vienna Convention for the Protection of the Ozone Layer (1985)

In 1985, the Vienna Convention for the Protection of the Ozone Layer was adopted, which is an environmental agreement. Thus, the agreement acts as an international agenda targeted towards the protection of the ozone layer. The objectives of the Convention were to encourage cooperation by means of systematic observations, research and information exchange on the effects of human activities on the ozone layer and to agree upon legislative or administrative measures against activities that could strengthen the adverse impacts on the ozone layer (Sand, 1985). The activities of the Convention are financed through the Trust Fund for the Vienna Convention and Trust Fund for research and Systematic Observations.

The United Nations Framework Convention on Climate Change (UNFCCC)

In 1992, under the United Nations Framework Convention on Climate Change, countries joined an international treaty that brought forth agenda for international cooperation. The treaty aimed to combat climate change by limiting average world temperature and the resulting climate change, and coping with adverse effects that were, by then, inevitable. Furthermore, Kyoto Protocol was adopted in 1995, through intensive negotiations among member countries to strengthen global responses to climate changes. In the Kyoto developed country Parties were legally binds to set emission reduction targets (UN Framework Convention Climate Change, 1997).

The most recent UN climate change course towards combating the climate change is the Paris Agreement. The Agreement was adopted in Paris in 2015. This agreement seeks to advance and intensify efforts towards the realisation of a sustainable low carbon future. This is reflected in its objective of strengthening the global response to the threat associated with climate change by ensuring that the global temperature rises below 2 degree Celsius as well as strengthens the capacity of countries to deal with the adverse effects of climate change (Rogelj, et al., 2016). The agreement, unlike previous ones, places premium on sustainable development as well as individual planned strategies. It is believed that the new agreement will promote transparency of action through the development of a robust transparency framework.

2.3.2 Carbon Emission Policy Development in Nigeria

As observed in other developing countries, the government of Nigeria in 2012 adopted the Nigeria Climate Change Policy Response and Strategy in order to ensure an effective national response to the significant and multi-faceted impacts of climate change. Thus, the deliberate goal of the Nigeria Climate Change Policy Response and Strategy was to foster low-carbon, high growth economic development and build a climate resilient society through implementing mitigation measures that will stimulate low carbon as well as sustainable and high economic growth; augment national capacity to adapt to climate change; raising climate change-related science, technology and R&D to a new level that will allow the country to better participate in international scientific and technological cooperation on climate change; intensifying public awareness and involve private sector participation in addressing the challenges of climate change as well as strengthening national institutions and mechanisms to establish a suitable and functional framework for climate change governance.

Furthermore, National Adaptation Strategy and Plan of Action for Climate Change Nigeria (NASPA-CCN) targeted at reducing the vulnerability and at the same time enhance the resilience and adaptive capacity of all economic sectors and of all people – particularly women, children, and resource-poor men – to the adverse effects of climate change, while also utilizing the opportunities that might arise as a result of climate change (Nigeria-INDC, 2017). Therefore, the goal of the plan is to articulate actions towards adaption to climate change by decreasing the country's vulnerability to climate change consequences and to improve the resilience and sustainable wellbeing of all Nigerians. In addition, NASPA-CCN aims to minimize risks through enhancing existing adaptive capacity, leveraging on new opportunities and strengthening collaboration within and outside the country. Towards the actualisation of the above-mentioned objectives, a set of thirteen sector-specific strategies, policies, programmes and measures have been articulated.

The National Policy on Climate Change addresses concerns on the adverse effects of climate change in Nigeria, given its likely impacts on poverty eradication and the actualisation of sustainable development (NEEDS-Climate change, 2010). Thus, the policy aims at achieving the goal of low carbon, high growth and resilient socio-economic system for equitable and sustainable socio-economic and environmental development despite the challenges facing the nations as a whole. The challenges include: ensuring stability and sustainability of the environment, institutional and human resources capacity inadequacy, unavailability of adequate resources to address mitigation and limited adaptation initiatives to address climate change. This then implies that the accomplishment of economic growth, resource management and climate change mitigation and adaptation can all happen simultaneously through the enactment of a national policy on climate change.

Another relevant policy in Nigeria is the National Forest Policy. This policy is centred on ensuring sustainable forest management, promoting the participatory process of development, facilitating private sector through adopting an integrated approach to forestry development (NEEDS-Climate change, 2010). Under the guidance of the African Union Commission, Nigeria has embarked option the *Green Wall Initiative* in which a *green wall* of trees (40 million trees annually in the next 10 years) was expected to be planted across the dry-land area of Nigeria. The initiative intended to push back deforestation and secure agriculture and livelihoods across the Sudano-Sahelian zone of the country, and also to enhance the carbon sequestration of biological diversity resources, thus serving as a climate change mitigation strategy.

Furthermore, energy policy arises out of the need to bring about a new Nigeria that is peaceful and prosperous through extensive support to renewable energy. In the same vein, it contributes to the country's efforts to keep green household gases at barest possible level through expanding access to energy services, reduction in environmental degradation and health risks, and the provision of a guideline on the realisation of a substantial share of the national energy supply mix that compromises of renewable energy, thereby facilitating the attainment of an optimal energy mix (NEEDS-Climate change, 2010).

In 2010, the National Environmental, Economic and Development Study (NEEDS) for Climate Change in Nigeria was developed to avoid the negative concerns of climate change on the nation's realization of its developmental plan. Thus, the policy initiative, therefore, aims at providing innovative solutions with a view to upholding sustainability as a key principle in her quest for growth. On the effectiveness of CO_2 regulations in mitigating CO_2 emissions in Nigeria, the results presented in Figure 2.5 suggests that post-2000, annual CO_2 emissions have increased, especially between 2000 and 2007. It should be pointed out that the implementation of the climate change policies has limited the rate of growth in CO_2 emission.

2.3.3 Energy Policy Development in Nigeria

This section covers the review of the key reforms in the Nigerian energy sector. Specifically, the review focused on the oil sector, gas sector, and the electricity sector.

National Oil and Gas Policy (NOGP)

The NOGP emanated from the Oil and Gas Sector Reform Implementation Committee (OGIC), which was set-up on 24 April 2000. The policy was anchored on the need to separate the commercial institutions in the oil and gas sector in Nigeria from the regulatory and policy-making institutions (Iledare, 2008). One of the outcomes of this policy is the unbundling of the current National Petroleum Corporation (NNPC). However, due to the inability NOGP to translate into the desired effect, in 2007, the then president of Nigeria, Umaru Yar'Adua, appointed Dr Riwlanu Lukman to chair a reconstituted OGIC with a mandate to transform the broad provisions in the NOGP into functional institutional structures that are legal and practical for the effective management of the oil and gas sector. With the Lukman's report on the initial NOGP, the functional responsibilities of the various institutional structures are well spelt out. These institutional structures are National petroleum directorate (NPD), Nigerian Petroleum Inspectorate (NPI), Petroleum Products Regulatory Authority (PPRA), Nigerian National Petroleum Company (NNPC), National Petroleum Assets

Management Agency (NAPAMA), and National Petroleum Research Center (NPRC) (Iledare, 2008).

National Electric Power Policy (NEPP)

This policy is an outcome of the recommendation of the Electrical Power Implementation Committee (EPIC). The performance of the sector over the years has been adjudged to be inefficient, mostly attributed to the monopolistic market structure, poor regulatory framework and inadequate infrastructural. EPIC was set-up in 1999 with the objective of designing reforms and transforming the Nigeria power sector (Emodi, 2016). In 2001, NEPP was established, precisely two years after EPIC was set-up. The policy was designed to reform the Nigerian power sector. It comprises of three core stages. The first stage of the reform entails the privatization of the National Electric Power Authority (NEPA) and the introduction of the Integrated Power Producer (IPPs) of electricity. The second stage of the policy involves intensifying the level of competition among participants in the market. Thus, the second stage of the policy centered on removing subsidies. The third stage of the policy centred on ensuring that the pricing associated with supply is full cost-reflective. Following the above-identified stages, the policy is expected to increase investment of the private sector, the establishment of an independent regulatory agency, and the establishment of a Rural Electrification Agency (REA) (Emodi, 2016).

National Energy Policy (NEP)

The Energy Commission of Nigeria (ECN) in corroboration with United Nation Development Programme (UNDP) in 2003 developed the first comprehensive energy policy in Nigeria called National Energy Policy (NEP), thus serving as the roadmap to a better national energy future (Ajayi and Ajayi, 2013). The policy targeted at creating energy security through the development of a robust energy supply mix by diversifying the energy supply and energy carriers, which is framed on the principle of an energy economy (Emodi, 2016). According to this principle, the share of renewable energy in total energy consumption should increase as well as the level of access to energy. Thus, the policy was geared towards facilitating the realisation of sustainable development and environmental conversation. The initial policy was revised in 2006, with the view to address the shortcoming of the policy. The policy was again revised in 2013 to incorporate the development in the energy sector (NEP 2003, 2006, and 2013). Despite the existing policy action on renewable energy, Ajayi and Ajayi (2013) pointed out that the country is yet to generate electricity from wind or biomass.

Renewable Energy Master Plan (REMP)

This plan was developed by the Energy Commission of Nigeria in collaboration with the United Nations Development Programme (UNDP) in 2005. The plan centred on intensifying the importance of renewable energy towards making sustainable development a reality (Ajayi and Ajayi, 2013; Emodi, 2016). As a result, the plan advances the cause for the need to incorporate the idea of renewable into the construction of buildings, electricity grids, and off-grid electrical systems.

National Renewable Energy and Energy Efficiency Policy (NREEEP)

In 2014, the Federal Ministry of Power developed the National Renewable Energy and Energy Efficiency Policy (NREEEP) with the intention of increasing the use of renewable energy and energy efficiency in Nigeria (Emodi, 2016). Hence, the policy set out strategies towards mitigating challenges associated with inclusive access to modern and clean energy resources, improved energy security, and climate change.

Electricity Power Sector Reform Act (EPSRA)

This Act was enacted in 2005 following the 2001 NEPP as well as the need for a legal and regulatory framework for the power sector. Thus, the Act facilitated the liberalisation of the Nigerian power sector, which is in line with the goal of increasing private sector investment in the sector as set out in the NEP. The following are the key provisions of the Act: creation of the initial Power Holding Company of Nigeria (PHCN); unbundling of PHCN into successor companies; privatisation of the successor companies; establishment of the Nigeria Electricity Regulatory Commission (NERC) and Rural Electrification Agency and Fund; the development of the power consumer assistance fund; introduction of a well-functional market organ (Nigeria Bulk Electricity Trader); and an effective investment vehicle (the Multi-Year Tariff Order) (Rapu, et al, 2015). Hence, the Act is expected to create a conducive investment atmosphere for potential investors as well as pave the way to the privatisation and the unbundling of the Nigerian power sector. Sadly, one decade after enacting the Act, electricity production and accessibility in the country is yet to improve significantly (Ohiare, 2015).

Renewable Electricity Policy Guidelines (REPG)

The Renewable Electricity Policy Guidelines (REPG) was established by the Nigerian Federal Ministry of Power and Steel in December 2006 with the core objective of ensuring that the share of renewable electricity is at least 5% of the total electricity production (REPG, 2006). Other objectives include the co-ordination of the establishment of independent renewable electricity systems in areas not currently covered by the electricity grid, increase rural areas access to electricity through the development of an innovative, cost-effective and practical approach, and broadening national development goals and contributing to the ongoing global efforts in mitigating climate change. The roadmap for the realisation of the REPG was set-out in the Renewable Electricity Action Programme, which was also developed by the Nigerian Federal Ministry of Power and Steel in 2006 (REAP, 2006).

Gas sector reforms

In February 2008, the Nigerian Gas Master Plan (NGMP) was implemented. The Plan was designed in response to the government intention of being among the key players in the international gas market (Emodi, 2016). The plan is designed to provide a framework that would ensure the realisation of maximum value from the country's gas resource. Thus, the plan is expected to facilitate timely and cost-effective gas production to meet domestic demands by converting the huge waste associated with gas flaring as well as promote effective use of the nation's abundant gas reserves. Furthermore, under the power sector recovery programme, the government introduced the Gas to Power Initiatives. This was targeted at ensuring uninterrupted electricity supply for both industrial and domestic use, by reducing gas flaring as well as promoting efficient utilisation of the country's abundant gas reserves (Rapu, et al. 2015). While natural gas constituted more than 75 percent of the country's power generation base, the realisation of the initiative objective depends on the availability and reliability of domestic gas supply at all time.

In summary, this section provided a detailed review of CO_2 regulations, from both global and National level. An overreaching findings from this review is that the Nigerian government is making tremendous efforts towards mitigating the adverse effects of climate change by institutionalising policies that could assist in minimising CO_2 emissions arising from production and non-production activities Similarly, the series of energy policies adopted over the last two decades suggest that the government is serious about improving the energy situation in the country, although, the evidence available proof otherwise.

2.4 Institutional Development

The aim of this section is to review the activities of the various institutions responsible for the management of carbon emissions in the five selected African countries: Nigeria, South Africa, Tunisia, Kenya and Cameroon.

2.4.1 Institutions Development on CO_2 Emission in Nigeria

Nigeria is one of the countries that are signatory to many agreements on climate change, particularly the UNFCCC which it signed on June 1992 and ratified later in August 1994 with the protocol enforced in 2005 (UNFCCC, 2015). Due to crucial nature of the climate change, the Federal Government of Nigeria, under the Federal Ministry of Environment (FME), established Department of Climate Change which serves as an anchor for national climate change efforts. Since the establishment of the department in the FME, it has embarked on several programmes, policy prescriptions and documentations as well as drumming legislative support for climate change matters (Federal Ministry of Environment, 2016). To provide a legal support for climate change operation in Nigeria and to deepen the understanding of Nigerian authority's commitment to the Paris Agreement through the legislative, the FME, the officials of the Climatic Change Department of the FME and other international agencies, such as the United Nations Development Programme, met with lawmakers in both houses of assembly with the objective to equip them with required need for the legislative support for the climatic agenda (Federal Ministry of Environment, 2016).

Besides seeking support of the lawmakers, the FME has been engaging in the different policies formulation geared towards keeping to the agreements that it was part of the signatory. The foremost of these policies is documented in the 1999 constitution of the Federal Republic of Nigeria in which the State is mandated and empowered to pursue the protection and improvement as well as safeguarding the water, air, land, forest and wildlife in Nigeria (Constitution of the Federal Republic of Nigeria, 1999, pg. 29). Prior to the 1999 constitution, Nigeria had put in place the Environmental Impact Act in 1992 (EIA Act of 1992). which provided that the public and private sectors of the economy should not embark on any project without prior consideration for the impact on the environment. Other laws and regulations promulgated to safeguard the Nigerian environment include: Federal Environmental Protection Agency Act of 1988 (FEPA

Act 1998), Human Wastes Act of 1988 (Harmful Waste Act), Environmental Guidelines and Standards for the Petroleum Industry in Nigeria 2002, among others.

In a bid to reduce gas emission, government, through FEPA in collaboration with FME, has been engaged in institutional strengthening, capacity building and execution of projects such as GHG inventory system, CDM projects, largest gas gathering programme in Africa and mandatory reductions of emissions by 20% JVs (Federal Ministry of Environment, 2016). The FEPA Act also empowered each state and local government in the country to set up its own environmental protection body for the protection and improvement of the environment within the State. The states are also empowered to make laws to protect the environment within its jurisdiction. Consequently all states have environmental agencies and state environmental law including the Federal Capital Territory, Abuja. For instance, Abuja has Environmental Protection Board Regulations 2005 controlling the solid waste disposal in Abuja. In Lagos, the state government established the Lagos State Environmental Protection Agency LASEPA through the enactment of Lagos State Environmental Protection Agency Law. The LASEPA's obligatory duties include monitoring and controlling of disposal waste in Lagos State and advising the state government on all environmental management policies include the climate change policy.

Apart from the engagement of FME and that department of climate in the ministry on the fulfilment of climate agreement, the Federal Government of Nigeria also introduced another agency or authority surnamed Presidential Implemental Committee on Clean Development Mechanism (CDM). The authority is saddled with responsibility of seeing to the organisation of CDM activities in Nigeria, particularly in the areas where government intervention and activities on CDM are needed or expected. Apart from government institutions or agencies established to see to the climate change issues, other non-governmental agencies such as the general republic and private sectors particularly are getting engaged in environmental issues so as to mitigate the excruciating impact of climate change. One of these private organisations in Nigeria is the Nigerian Conservation Foundation. The Nigerian Conservative Foundation is the Nigeria foremost Non-Governmental Organisation established in 1980. It became registered in 1982 as a Charitable Trust under the Land Act of 1961. Since its registration, the NCF has been collaborating with both local and international agencies, particularly the FME on the issues related to the environment and climate change policies. In specific, the vision of NCF is to preserve the full range of Nigeria's biodiversity such as species, ecosystems and genetic biodiversity; promote the sustainable use of natural resources for the benefit of present and future generations, and advocate actions for the minimisation of the activities that give birth to pollution and wasteful utilisation of renewable resources.

2.4.2 Institutions or Agencies Dealing with Electricity Supply and Consumption in Nigeria

Historically, Federal Government and its ministry, parastatal and agency were responsible for generation, transmission and distribution of electricity in Nigeria. However, due to inefficiency that characterised the operations of these agencies, government undertook several reforms, particularly during the current democratic dispensation so as to allow the private sector organisation to participate, particularly transmission and distribution of electricity in Nigeria.[14] Consequent upon this, this subsection is devoted to examine the operational activities of the institutions or agencies that are saddled with responsibility of managing electricity generation, transmission and distribution in Nigeria.

Federal Ministry of Power

Although the Federal Ministry of Power has been collapsed with Ministry of Work and Housing to form Ministry of Power, Work and Housing in the current administration of the President Muhammad Buhari, the ministry still has sole responsibility of guaranteeing the power sector that meets the electricity needs of Nigeria from different sources of energy. Specifically, the ministry has overriding objective or goal to initiate, formulate, coordinate and implement broad range of policies as well as programmes geared towards the development of electricity generation in Nigeria. Besides, the FMP sees to maintenance or management of power sector infrastructure in the country. Moreover, the ministry also sees to the implementation of renewable energy programmes or initiatives such as Solar, Wind, Biomass and hydro and supervision of policy matters relating to research and development in the power sector. The ministry participates in local and international conferences related to power sectors and on behalf of government of Nigeria, it represented, signs bilateral or multilateral agreements or relations affecting the power sector (FMP, 2011).

[14]Specifically, government undertook three major reforms-Nigerian Electricity Power Policy 2001/2002 (NEPP, 2001/2002), Electricity Power Sector Reform Act 2005 (EPSRA, 2005) and Nigerian Electricity Management Services Agency Act 2015 (NEMSA 2015).

To meet the need of both urban and rural area, the ministry is devoted to ensure the utilisation of renewable energy for power generation in the areas, that is, rural and urban area. Several agencies and parastatals are under the supervision of the Federal Ministry of Power. These agencies or parastatals include Power Holding Company of Nigeria (PHCN), Transmission Company of Nigeria (TCN), Nigerian Electricity Regulatory Commission, (NERC) Nigerian Bulk Electricity Trading Company (NBET), National Power Training Institute of Nigeria (NAPTIN), National Electricity Liability Management Ltd, Rural Electrification Agency (REA), Presidential Task Force on Power, among others. These agencies are saddled with one responsibility or the other to ensure efficient generation, transmission and distribution of electricity to meet the development needs of the country. Despite the laudable roles played by the ministry, it is bedevilled with many challenges that have limited its ability to fulfill its mandates.

In almost all parts of the country, power infrastructural faculties are under constant threat due to vandalism. This has rendered almost the operation of the ministry ineffective. Other challenges facing the ministry include non-payment of bills/affordability, illegal bye-passing and manipulation of installed meters and stealing of installed meters, misunderstanding of the ministry operational activities by the consumers of electricity as well as lack of investible funds or adequate investment in the power sector (FMPWH, 2016). Apart from the Ministry of Power, Works and Housing, there are other federal ministries which are indirectly related through their activities and operation to the provision of electricity in Nigeria. These ministries include Federal Ministry of Environment (FME) and Federal Ministry of Water Resources (FMWR). Although the statutory responsibility of FME is to protect the natural environment resources against all sorts of degradations and pollutions as well as preservation or conservation of environment through campaign for climate change, the ministry also sees to promotion of renewable energy usage in an efficient way in the country. With regards to the Federal Ministry of Water Resources, its statutory duty revolves around the provision of sustainable access to safe and sufficient water with the purpose to meet the water needs of Nigerians. However, the ministry is also responsible for the management of hydropower generating plant that powers turbine which generates electricity power. Through its Department of Dams and Reservoir Operations, the ministry involves in many renewable energy and rural electrification activities (FMWR 2015).

National Electric Power Authority (NEPA)/Power Holding Company of Nigeria (PHCN)

Combing the literature shows that around the 50s, colonial master in Nigeria established Energy Corporation of Nigeria (ECN) through the ECN ordinance No. 15 of 1950s with the main objective to provide in an effective manner the electricity in Nigeria. Coupled with this is the establishment of Niger Dam Authority (NDA). The two organisations were merged together in 1972 to form National Electric Power Authority (NEPA), saddled with responsibility to develop and maintain effective and efficient electricity supply throughout the country. Since its establishment as an agency of government, NEPA maintained the monopoly of generating, supplying and distributing the electricity in commercial quantity throughout the federation.

However, despite the tremendous efforts made by the parastatal in ensuring the supplying of electricity and the huge sum expended by government over the years, the parastatal's operations are characterised by inefficiency, which often results in incessant power outage. Due to these weakness and poor state of the parastatal, government undertook several reforms, particularly Nigerian Electric Power Policy 2001/2002 and Electric Power Sector Reform Act 2005. Through these reforms, government established Power Holding Company of Nigeria which began its operation in 2005 to replaced defunct National Electric Power Authority. The PHCN's statutory responsibilities include construction and engineering of power generation units, maintenance and servicing of power grids, dam operations and water management for power generation and many more. However, in 2013, through privatisation exercise, the PHCN was unbundled to allow for competitiveness in the energy sector. While the government still retains the transmission grid as a public unit through the Transmission Company of Nigeria, the generation of electricity rests on GENCOs companies and the distributions companies are called DISCOs (KPMG 2013). Both GENCOs and DISCOs are under the regulation of the Nigerian Electricity Regulatory Commission.

Nigerian Electricity Regulatory Commission (NERC)

In order to regulate energy industry in Nigeria, Federal Government established, an independent regulatory agency, known as Nigerian Electricity Regulatory Commission through the EPSR Act of 2005. The statutory duties of NERC are derived from the same Act. According to the EPSR Act 2005, the major statutory responsibilities of NERC include:

- Creating, promoting and preserving efficient electricity industry and market structures and ensuring the optimisation of available resources for the provision of electricity services.
- Maximising access to electricity services through the promotion and facilitation of consumer connections to distribution systems in both rural and urban areas
- Ensuring an adequate supply of electricity is available to consumers
- Ensuring that the prices charged by licenses are fair to consumers and also allow the licenses to cover their finances and make reasonable earnings for effective and efficient operation
- Monitoring and investigating energy markets
- Administer accounting and financial reporting regulations and conduct of regulated companies
- Ensuring the safety, security, reliability and quality of service in the production and delivery of electricity to consumer
- Ensuring that regulation is fair and balanced for licenses, consumers, investors and other stakeholders related to electricity matters in Nigeria (EPSRA, 2005).

Nigeria Bulk Electricity Trading PLC (NBET)

Part of the outcomes of reforms in electricity industry in Nigeria is the establishment of Nigerian Bulk Electricity on 29th July, 2010. NBET is completely owned by the Federal Government of Nigeria. It was established under the license granted by National Electricity Regulation Commission. The statutory responsibility of NBET is to engage in purchasing and supplying of electricity power and other ancillary services from the independent power producers in the country. The main objectives of establishing NBET include:

- To create confidence for new investors into the electricity market in Nigeria, by ensuring fair allocation of risks on the basis of parties best able to manage them through the Power Purchasing Agreements, and providing incentive for investments in power generation by bearing off-take market and payment of default risks.
- Purchasing of electricity from the Generating Companies through PPAs and selling it to the distribution companies through vesting contracts.
- Management and administration of the financial flows for the physical supplies on the network

- Operation of a competitive market that encourages efficient value discovery for commodity and capacity
- Formulation and advisory on policies for efficient system settlement and least possible cost incentive for maintaining transportation network within it acceptable energy, frequency responses and voltage tolerances (National Council on Power, 2014).

Transmission Commission of Nigeria

Transmission Commission of Nigeria was established in 2005, to replace the defunct National Electric Power Authority. However, the transmission license was given to the commission in July 2016. The TCN is empowered to see to the transmission of electricity, system operation and electricity trading in Nigeria.

Rural Electrification Agency of Nigeria (REA)

Under section 88 of Electric Power Sector Reform Act of 2005, the Rural Electrification Agency of Nigeria was established with the purpose of providing low cost electricity to rural areas across the breath and length of the country. According to EPSRA (2005) subsection 13 of section 88, the purpose of establishing REA are itemised as follows:

- To promote, support and provide rural electrification programmes through public and private participation.
- To achieve more equitable regional access to electricity
- To maximise the economic, social and environmental benefit of rural electrification subsidies
- To promote expansion of the grid and development of off grid electrification
- To stimulate innovative approaches to rural electrification

National Electricity Management Services Agency

The National Electricity Management Services Agency (NEMSA) was established in 2015 by the NEMSA Act of 2015. The Act provides structural operational mechanisms and the financing of NEMSA towards achieving the following objectives:

- To carry out electrical inspectorate service for the electricity supply industry in Nigeria
- To enforce all statutory technical electrical standards and regulations as published by NERC and all other relevant statutory bodies.

- To collaborate with SON and other relevant agencies of government in order to ensure that all the major electrical materials and equipment used in Nigeria are of high quality standards.
- To ensure that the power systems and networks put in place have been properly executed before use, to ensure that such systems are capable of delivering safe, reliable and sustainable supply to customers nationwide.
- To enforce compliance with technical standards for all electrical installations, electrical plants, including power plants and anxilliary systems, electric networks and connectivity to the grid.
- To enforce compliance with safety requirements for construction, operation and maintenance of electrical power plants, transmission system, distribution networks and electric installations.
- To enforce the conditions of installation of meters for transmission systems, distribution networks and supply of electricity among others.

2.5 Theoretical Review

This section presents the review of theoretical literature on the relationship between economic growth and CO_2 emission. The possible theoretical relationship between economic growth, energy consumption and CO_2 emission in the literature include the Environmental Kuznets curve (EKC), the Porter Hypothesis and the Pollution Haven Hypothesis. These theories are reviewed in order to identify the most suitable for the economic growth, energy consumption and environment linkage.

2.5.1 Environmental Kuznet Curve (EKC)

Discussions of the Environmental Kuznets Curve (Cole 2004; Grossman and Krueger 1991 Shafik 1994; Soytas et al. 2007; Ang 2007) are central to the literature on the intersection of trade and the environment. Kuznets (1955) first published the theory that as countries increase in wealth, economic inequality would increase at first and then begin to decrease after reaching a certain stage of development (or turning point).

The environmental Kuznets curve hypothesized relationship among various indicators of environmental degradation and income per capita. The theory of the EKC is based on the effects of the transition from agricultural production in rural areas to industrial production in urban areas. As the industrial production becomes more intensive, pollution increases. With time, and higher income levels, the industrial-heavy production is phased out in favour of a more high-technological and service-centralized production. This development is expected to counteract the increase in pollution and eventually cause the pollution levels to drop. This implies that at early stages of economic growth, degradation and pollution increase, but beyond some level of income per capita (which will vary for different indicators) the trend reverses, so that at high income levels of economic growth, the environment qualities will improve (Stern, 2004).

The effects of a high-technological and production-effective economy is thought to contribute to the decrease in pollution, as well as a higher demand for a clean climate from consumers and higher political interests in the wellbeing of the environment (Cederborg and Snöbohm, 2016; Dinda, 2004). Environmental Kuznets curve (EKC) posits a quadratic relationship between economic growth and environmental degradation. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita (Figure 2.8).

There are different aspects of the EKC hypothesis. The initial increase in environmental degradation as economies grows is called *the scale effect*. Economic growth implies increased pollution levels simply due to increased output. Increased output requires increased input and therefore more natural resources are used and pollution levels rise. The pollution is expected to increase to scale with economic growth (Grossman and Krueger, 1991). The shape of the EKC indicates the existence of other mechanisms offsetting the scale effect. These mechanisms added together acts as the decreasing effect of environmental degradation as the economies grow. The mechanisms thought to counteract the scale effect and ultimately offsetting it completely are described as the technological effect, the composition effect, effects of international trade, increased demand for a clean environment and strengthened regulations. If the scale effect dominates the *technological*, *composition*, and *regulation* effects in the early stages of economic growth, pollution will be monotonic in relation to output. If, at some point, the latter effects dominate the former, pollution may begin to decrease with continual increases in output. This scenario typifies the EKC relationship.

The technological effect describes the effects of technological improvements and a more effective production. The incentives for new technology is usually not based on environmental concerns on firm-level, but the environmental benefits of a more effective production can still be utilized. As basic economic theory tells us, a competitive market puts pressure on firms to sell products and services at a low price. In order to maximize profits, firms try to make production cheaper by investing in both existing effective technology and in developing new technology internally. Richer countries can afford investments in R&D and thus technological development goes hand in hand with economic development (Komen *et al.*, 1997). A more effective production requires less input, which is thought to create a diminishing effect on pollution levels.

When an industry-heavy economy moves towards a more service-intensive economy, the relative change in the composition of goods and services produced is called *the composition effect*. Governments and firms increase their consumption in services when the economy grows, which could be explained by the increased need for R&D, as well as an increased need for practices of the law, teachers, doctors and other professions essential in a modern society. The population increase their consumption of household related services as their income increases as well. These are examples of actions that increase per capita GDP without increasing pollution levels. In other words, the pollution levels may not increase to scale with economic growth if the composition of output is changed (Vukina, et al., 1999).
When richer countries invest more in R&D, use high-technology equipment and operate in a more service-centralized economy, it creates large differences in the preconditions of *trade* between developed and developing countries. Basic trade theory implies economies specialize in products they are relatively effective producers of, in other words have a comparative advantage in. As developed countries have a high-technology intensive production and developing countries have a low-technology intensive production, the results of international trade divides the global production into *dirty* production with high pollution levels in developing countries and *green* production with lower pollution levels in developed countries (Jänicke et al., 1997; Stern et al., 1996). The displacement hypothesis describes this displacement of dirty industries from developed to developing countries. The pollution is not thought to decrease globally; its intensity is simply moved from one part of the world to another. Additional underlying factors behind the creation of *Pollution Havens* are the differences in regulations and costs of production (Dinda, 2004). Another effect of international trade is the increase in market size. As the market increases in size, so

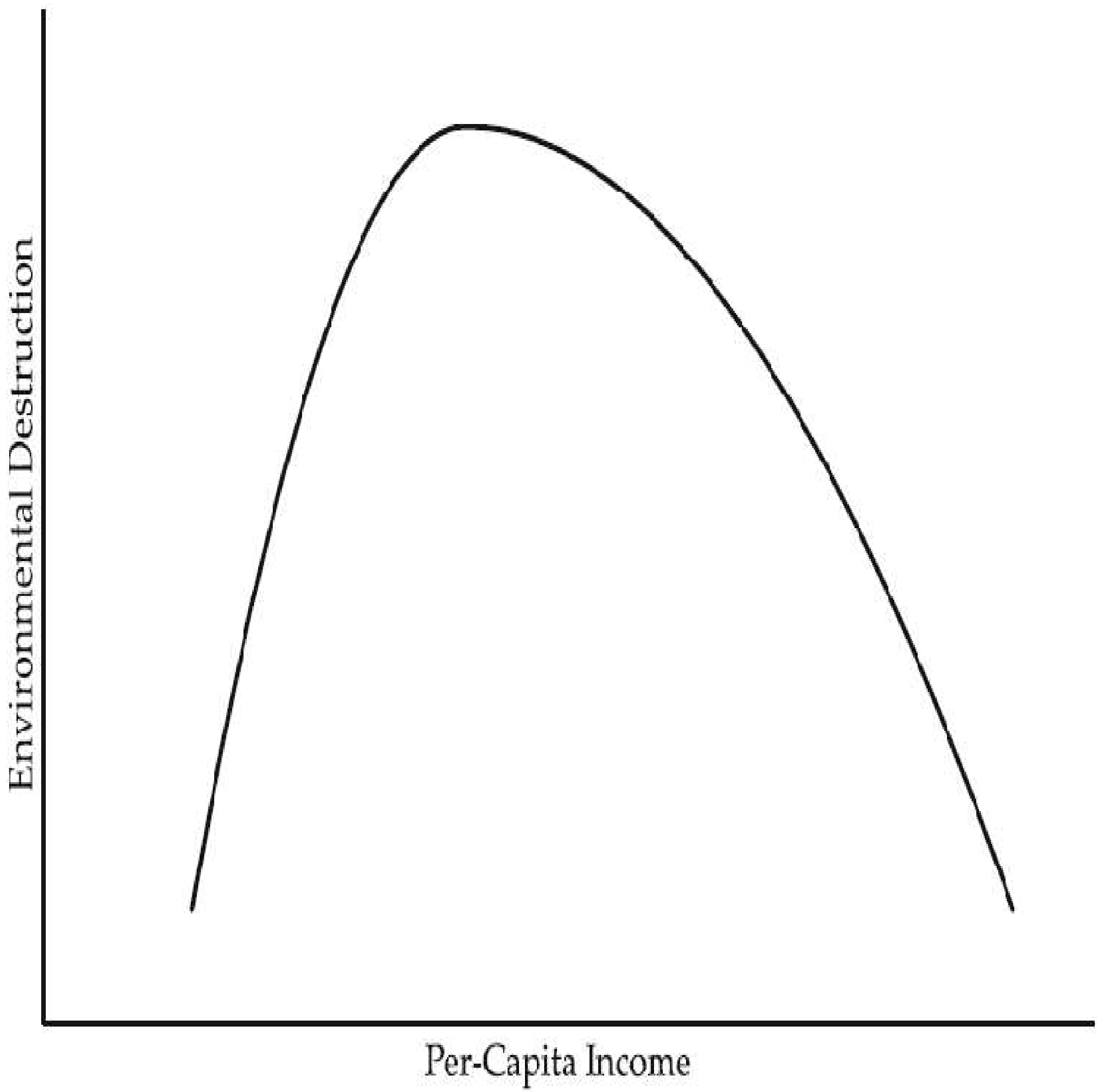

Figure 2.8: Environmental Kuznets Curve
Source: Kebede (2017)

does the competitive pressure to increase investments in R&D. This could have a decreasing effect on pollution levels. However, another point made about the greater market is that there is nothing you cannot buy – the availability for all kinds of goods increase and people might buy more unnecessary products, which increases the production volume and thus the pollution (Dinda, 2004).

Another mechanism argued to play a role in the decrease of environmental degradation is *the increased demand for a clean planet*. As income increases, so does the willingness to pay for a clean environment. At some point, the willingness to pay for a clean planet increases relatively more than the increase in income (Roca, 2003). Consumers express this through choices of less environmentally damaging products, donations to environmental organizations and voting for environmentally friendly political parties (Beckerman, 1992; McConnell, 1997). Hettinge et al. (2000) states that pollution grows unless *environmental regulation* is strengthened. Different types of regulations that is used to decrease pollution levels include emission charges and subsidies, emission standards and property rights (Cunningham and Sinclair, 1998). Regulations are decided by politicians, and so the question is whether economic growth motivates politicians to introduce additional environmental regulations. Since people have a higher demand for a clean environment when income grows, the median voter theorem could shed some light to our case (given the state in question is a democracy). The median voter theorem, introduced by Black (1948), states that politicians adopting their politics to the median voter should maximize the number of votes in their favour. This could explain why politicians in countries with growing incomes tend to strengthen environmental regulations - to gain voters.

Many theorists have extended this logic to environmental concerns and posit the existence of an Environmental Kuznets Curve (EKC). However, empirical studies of the EKC have produced mixed results. Frankel and Rose (2005) claim evidence of an EKC for local air pollutants. Investigations of EKC patterns for other environmental indicators, such as concentrations of pathogens in water and discharged heavy metals and toxic chemicals, have proven less conclusive (Borghesi 1999; Harbaugh et al. 2002). Nevertheless, the scale of investigation, both geographic and temporal, is important. Despite the model specification difficulties, evidence has been found that developing countries are adopting environmental standards much earlier than their predecessors (Stern, 2004), thus altering the turning point. More recently, Lee, Chiu, and Sun (2009) found statistically significant evidence for various cohorts of nations, but question the universal applicability of the EKC. Hence, the latest empirical evidence on the EKC has thus tended to narrow its applicability to specific regions and pollutants (Emerson, et al., 2010).

2.5.2 Pollution Haven Hypothesis

Pollution haven hypothesis suggests that, under free trade condition, pollution-intensive industries or countries will relocate to countries with less stringent environmental regulations (Copeland and Taylor, 2004). The premise is intuitive: environmental regulations raise the cost of key inputs to goods with pollution-intensive production, and reduce jurisdictions' comparative advantage in those goods. The pollution haven hypothesis suggests that environmental regulations affect exports, but the reverse may also be true: exports may affect regulations. If trade increases incomes, and environmental quality is a normal good, trade could increase voters' demand for strict environmental regulations. Alternatively, increased pollution caused by trade could increase local demand for strict environmental regulations.

The hypothesis assumed unequal distribution of income and treat environmental quality as normal goods. According to this hypothesis, multinational firms transfer pollution-intensive industries to those countries with lower environmental regulations to circumvent costly regulatory compliance in their home countries (Eskeland and Harrison, 2003; Copeland and Taylor, 2004). Therefore, developing countries become pollution-havens and suffer more environmental pollution. Conversely, the pollution haven hypothesis poses that multinational firms diffuse their clean technology in developing/hosting countries through the export of modern technologies.

However, literature linking trade to environmental qualities predicted that differences in rigidity of pollution regulation among countries are the main factor of comparative advantage. Thus, in the presence of free trade, less developed countries with weaker environmental policy, become dirtier as they will specialize in dirty-goods production. There are three major reasons for developing countries to have weaker environmental policy and thus, lower standards. Firstly, the costs of monitoring and exerting pollution standards are relatively higher because of the high costs of implementing new pollution standards, difficulty of obtaining modern equipment. Second, countries with high incomes generate a larger demand for clean environment compared with developing countries. This second point is because growth in developing countries comes from the diversification of the production base of the economy from agriculture to manufacturing production. This diversification is accompanied by associated increases in investment in the form of urban infrastructure; which raises the pollution intensity. In developed countries, however, growth implies a shift from manufacturing to services, which leads to a decrease of pollution intensity (Brunnermeier and Levinson 2004).

The first generation of empirical work on the pollution haven hypothesis used cross sections of data and made no attempt to control for unobserved heterogeneity or simultaneity. Most of them found small insignificant effects of environmental regulations, a few found counter-intuitive positive effects, and none found robust significant support for the pollution haven hypothesis. This early literature is summarized in Jaffe et al. (1995) which argued that there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness. However, an important caveat is that the findings are positive, or descriptive, rather than normative.

These tests of the pollution haven hypothesis merely measure whether industry relocates to less stringent jurisdictions; they have no welfare implications. Given the difficulties in measuring both regulatory stringency and trade barriers, and the likely endogeneity of both, few studies have attempted to estimate this indirect effect of trade liberalization on pollution havens. Nevertheless, it is important to be clear that the basic empirical estimates of the pollution haven effect do not address this more complex extension. A second concern related indirectly to the pollution haven hypothesis is that governments will engage in inefficient competition to attract polluting industries by weakening their environmental standards. A welfare-maximizing government should set standards so that the benefits justify the costs at the margin.

2.5.3 Porter Hypothesis

Porter Hypothesis asserts that through technical change, policies mandating strict environmental compliance have the potential to make firms and industries more competitive (Thurow and Holt, 1997). Assuming that firms are set out to maximize profits thus, any profitable opportunities to improve environmental performance will be automatically undertaken. Any regulations requiring more environmental performance, therefore, can come only at a cost. Specifically, Porter and van der Linde (1995) take the issue with the idea that pollution is only inefficient if it can be prevented for less expenditures than what it costs a firm to deal with it once it is created. They point to cases where innovation offsets–cost reductions due to technological change in response to environmental regulations–have resulted in *win-win* situations where both profits and environmental performance have improved.

Porter Hypothesis (PH) suggests the mechanisms through which stringent environmental policies in the home country can actually lead to increased efficiency and innovation, a net reduction in costs and an improved comparative advantage for domestic industries. Sinclair-Desgagne (1999) and Gabel and Sinclair-Desgagne (2001) provide a theoretical analysis in which they suggest that well-designed environmental regulation could force firms to seek innovations that would turn out to be both privately and socially profitable. Xepapadeas and de Zeeuw (1999) also argues that downsizing and modernization in firms subjected to stringent environmental regulations increases their average profitability, thus having a positive effect on the marginal change of profitability and environmental performance. They further analyzed in their model the reaction of firms in terms of the type and the quantity of equipment that firms invest in as a response to production cost changes. Mohr (2002) argued that environmental regulation in form of a tax, increases productivity and reduces the environmental externality if an unused technology is available, which is always more efficient than the one currently used, when environmental policy favors the unused but more efficient technology.

It must be noted however, that with regard to theoretical consideration about Porter hypothesis, strict environmental regulations translate into a long-run competitive advantage of national industries. The basic argument made is that although regulations have an economic cost, properly constructed environmental standards may, whilst imposing costs, spur innovations, which offset some or all of the spending on pollution abatement. Even if regulation leads to innovation offsets, which reduce the cost of compliance and produce competitive advantages for products and production processes, and simultaneously increase social welfare by reducing environmental externalities, this may not be an optimal choice.

Nevertheless, the hypothesis has generated considerable debate, while Porter and van der Linde (1995) contend that these innovation offsets are likely to be common and large, others have disagreed (Gardiner and Portney, 1994; Palmer, Oates, and Portney, 1995; Thurow and Holt, 1997; Jaffe and Palmer, 1997). For example, Palmer et al. (1995) noted that there are strong dispute with the Porter hypothesis; they argue that environmental regulation does indeed involve tradeoffs, but that the cost of regulation will be neither negligible nor non-existent. More importantly, studies employing the Porter hypothesis to-date have exclusively focused on the process of innovation, and how R&D expenditures affect output (Ferrante, 1998; Jaffe and Palmer, 1997).

2.6 Methodological Review

Various estimation techniques have been employed in examining the link between CO_2 emissions, energy consumption and economic growth. Prominent techniques include the uses of Ordinary Least Square (OLS), Autoregressive Distributed Lags (ARDL), structural decomposition analysis and use of instrumental variables (such as 2SLS and GMM) among others. The pioneer set of studies in this area of research employed the Ordinary Least Square (OLS) method. Some of these studies include Xinpeng (1999), Lee and Chang (2007), Douglas and Nishioka (2010), Fang (2011), Abanda et al., (2012), Bajona and Kelly (2012), Islam et al. (2012) and Bernhard (2013), among others. The ordinary least squares (OLS) estimates the unknown parameters in a linear regression model, with the goal of minimizing the sum of the squares of the differences between the observed responses in the given dataset and those predicted by a linear function of a set of explanatory variables (Greene, 2003). However, OLS estimation technique is only appropriate in situations where there is no problem of perfect multi-collinearity and heteroscedasticity (unequal Variance).

Some other studies have employed some other techniques such as the Vector autoregressive (VAR) and Vector error correction-(VEC) based Model, Granger Causality (Yoo and Kim, 2006; Caraiania et al., 2015, and Menegaki, 2015), Toda and Yamamoto granger causality (Wolde-Rufael, 2010), panel co-integration and Vector error correction-based Granger Causality (Al-Iriani, 2006; Sadorsky, 2009, Sadorsky, 2011; Chang, 2010; Lee et al., 2008; Lean and Smyth, 2010, War and Ayres, 2010; Chen et al., 2007; Pao and Tsai, 2011; Chandran and Tang, 2013; Khan et al., 2014; and Yuan et al., 2008), Other variants of combined estimation techniques employed include Granger Causality-error correction model-ECM (Abosedra, 2009), Threshold Autoregressive Model (Lee and Chang, 2007) and Instrumental variables (such as 2SLS and the generalized method of moments (GMM)).

However, the challenges of omitted-variable bias in modeling which results from the data generating process, especially when the process is not directly measurable or no good proxies can results into problem of endogeneity. That is, there can be correlation between the regressor and the error term. To correct for this problem and estimate a consistent model, the instrumental variables (IV) methods are often employed, as the most widely known solution to endogenous regressors. The IV methods provide a way to nonetheless obtain consistent parameter estimates. To use the IV approach with endogenous regressors, x_i, there is need for observable variable, z_i, that is not in the original equation regression that satisfies two conditions. First, z_i, must be uncorrelated with the error term; that is the $\mathrm{Cov}(z_i, \varepsilon) = 0$. This condition is known as the exclusion restriction. Secondly, the estimate of z_i, must be non-zero-that is z_i is correlated with the endogenous variable. A typical example of the IV methods is the two stage least square (2SLS) and GMM estimate. We can also state that the OLS is a class of IV where the instruments are also the regressors.

The Generalized Method of Moments (GMM) is an estimation procedure that allows economic models to be specified while avoiding often unwanted or unnecessary assumptions, such as specifying a particular distribution for the errors (Greene, 2003). This lack of structure means GMM is widely applicable, although this generality comes at the cost of a number of issues, the most important of which is questionable small sample performance. Generalized Method of Moments (GMM) extends the classical setup in two important ways. The first is to formally treat the problem of having two or more moment conditions which have information about unknown parameters.

It allows estimation and inference in systems of equations with *P* unknowns, P ≤ Q. The second important generalization of GMM is that quantities other than sample moments can be used to estimate the parameters. GMM exploits laws of large numbers and central limit theorems to establish regularity conditions for many different *moment conditions* that may or may not actually be moments. These two changes produce a class of estimators that is broadly applicable. The advantage of GMM over 2SLS is that if heteroscedasticity is present, the GMM estimator is more efficient than the simple IV estimator (2SLS), whereas if heteroscedasticity is not present, the GMM estimator is no worse asymptotically than the IV estimator.

Some studies also used static panel data technique for a group of countries (Narayan, et al 2010; Narayan and Smyth, 2009; Lee and Chang, 2008; Al-mulali and Sheau-Ting, 2014; Khan, et al., 2014; Al-mulali, et al., 2013; Sadorsky, 2011; Hamit-Haggar, 2012; Komal and Abbas, 2015). A couple of them also utilized the dynamic panel data analysis (Al-mulali, et al 2014; Ozturk and Bilgili, 2015), and heterogeneous panel data analysis (Apergis and Payne, 2009 and 2011; Dedeoglu and Kaya, 2013), while study such as Narayan and Smyth (2008) combined both fully modified and dynamic OLS (FMOLS and DOLS). The following techniques are also used in the literature; logistic regression (Arabatzis, 2012), generalized method of moment model (GMM), Tobit and Heckman regression (Arabatzis and Melesios, 2011), Structural time series model (Javid and Qayyum, 2014), Grey incidence analysis (Yuan, et al 2010), Grey prediction and Granger causality (Pao and Tsai, 2011).

Moreover, more recent studies have used Autoregressive distributed lags (ARDL). This approach corrects for the problem of multi-collinearity and heteroskedasticity that are associated with the use of regression equation such as the OLS. The use of the ARDL has advantages over other times series estimation methods because it enables the co-integration relationship to be estimated by the ordinary least square (OLS) after determining the lag order of the model. Also, the model can accommodate regressor that are stationary at either levels I(0) or after first difference I(1). In addition, the long run and short run parameters of the models can be simultaneously estimated (Pesaran et al, 2001). Studies that have employed the uses of autoregressive distributed lag (ARDL)-based cointegration and Granger causality include the work of Shahbaz et al., 2013; Shahbaz and Lean, 2012; Ozturk and Acaranci, 2011; Jayanthakumaran et al., 2012; Tang and Tan, 2013; Acaranci and Ozturk, 2010, Azhar et al., 2005; Akpan and Chuku, 2011; and Halicioglu, 2011, among others.

In summary, while these previous techniques are useful, they all however, assumed symmetric effects for the relationship between energy consumption, economic growth and carbon emission. It is possible there are non-linear relationships among the variables (potential asymmetries). In that case, the ARDL will no longer be appropriate to address the issue. Hence, the non-linear ARDL will be the most suitable. Consequently, this study complements the previous studies by looking at both the long run and short run symmetric and asymmetries effect of carbon emissions on energy consumption and economic growth (at the aggregated and disaggregated level) in

Nigeria. The models of ARDL and NARDL enable researchers to capture both symmetric and asymmetric effect in the energy consumption-economic growth-carbon emission relationship in both short run and long run.

2.7 Empirical Review

There exists a large body of empirical literature on the relationship between economic growth, energy consumption and environmental pollutants. In particular, studies that focus on growth, energy consumption and environmental pollutants are quite many, with different results across countries and regions of the world. Essentially, there are three research strands in the literature on the relationship between economic growth, energy consumption and environmental pollutants. The first strand focuses on the relationships between economic growth and energy consumption, while the others focus on environmental pollutants–growth nexus and growth, energy and pollution nexus. Given this strands in the literature, the study approach this section of the study by reviewing each of the nexus in turn and then creating a new separate section for studies extensions and identified literature in Nigeria.

2.7.1 Output – Energy Literature

The first strand of the empirical literature focuses on the nexus between growth and energy consumption (Acaravci and Ozturk, 2010a; Alkhathlan and Javid, 2013; Jafari, Ismail, Othman, and Mawar, 2015; Baek and Kim, 2011). The literature is extensive at single-country, multi-country and regional levels on the nexus between economic growth and energy. The findings of the existing studies have however largely remained inconclusive given the scope and dimension of issues addressed and methodological approaches adopted. At the single-country level, Yuan et al (2008), using Johansen co-integration and vector error correction model (VECM), investigated the existence and direction of causality between output growth and energy use. They discovered short run bi-directional causality between energy consumption and output in China (but no causality between electricity consumption and output) during 1990 - 2006 period.

This finding was supported by Chang (2010) who, in the study, combined Granger causality with ECM for the period of 1981 to 2006. He found that energy consumption in China produced efficiency gains over the period with bi-directional causality between energy consumption and output. In the same vein, Pao et al (2009) reported a bi-directional relationship using VECM for Russia during 1990 to 2011. Also, Pao and Tsai (2011), employed similar methods and equally reported bi-directional causality for

Brazil for the period 1980 – 2007, while Shahbaz and Lean (2012) combined ARDL with VECM to obtain the same result for Pakistan.

Some studies have also indicated uni-directional causality between energy consumption and output or economic growth. However, findings have been mixed, with evidences that causality either runs from energy to output or from output to energy. For instance, Abosedra (2009) assessed the relationship among temperature and humidity, energy import, electricity consumption and output using Granger causality and error correction model (ECM) for Lebanon. He found that electricity consumption granger causes output without any long–run relationship between them. Also, Warr and Ayres (2010) combined Granger Causality with ECM to study the United States, and found that causality moved from energy consumption to economic growth while OLS results used by Fang (2011) showed that renewable energy has positive on economic growth for the case of China. Alternatively, Pao (2009) employed VECM to show that both in the short and long run, causality runs from economic growth to electricity consumption in Taiwan for the period 1980-2007. Similarly, Yoo and Kim (2006), adopted granger causality approach and indicated that the same result is valid for the case of Indonesia. Also, Komal and Abbas (2015), used GMM approach to examine the relationship among financial development, agricultural output, real GDP and energy consumption, and showed that economic growth has positive impact on energy consumption in Pakistan.

Acaravci and Oztturk (2010) examined the relationship between economic growth and CO_2 emission among European countries. They show evidence for a positive long run relationship between carbon emission and output growth. Pao and Tsai (2010) and Apergis and Payne (2009) also reported a similar result for BRIC countries and Central America respectively. In a cross country analysis, Jayanthakumaran et al. (2012) compared the long run relationship between growth and CO_2 emission. They concluded that emission was influenced by per capita income, structural changes and energy consumption in China. Several other studies showed positive relationships between output growth and CO_2 emission. Studies in this category include the work of Lau et al., (2014) for Malaysia, Jalil and Muhammed, (2009) for China; Dritsaki and Dritsaki (2014) for Greece, Spain and Portugal. Other studies include those of Turkey (Halicioglu 2009); China (Zhang and Cheng, 2009); France (Ang, 2008); US (Soytas et al 2007).

A number of studies were not able to establish either linear or nonlinear relationship between energy and economic growth. For example, Lee and Chang (2007) revealed that there is no linear relationship between energy consumption and economic growth in Taiwan, though the Ordinary Least Square (OLS) and the Threshold Autoregressive Model (TAR) showed that changes in energy consumption contribute to output growth. Javid and Qayyum (2014) applied the structural time series model to data covering the period 1972-2012 and revealed an upward slope relationship for electricity usage in commercial, agricultural and residential sectors in Pakistan with no particular energy–output relationship. Also, Hamit-Hagger (2012) used FMOLS to examine the relationship among Greenhouse gas emissions, energy consumption and economic growth in Canada during 1990 to 2007. His results showed no evidence of causality between economic growth and energy consumption in the long run, though there seems to be weak uni-directional causality from economic growth to energy consumption in the short run.

The findings from multi-country investigations are similar to those of the single country. Wolde-Rufael (2010) used Toda and Yomamoto Granger causality to assess the link between coal consumption and output. His study found that causality runs from coal consumption to output in India and Japan; and from output to coal consumption in China and South Korea; and bidirectional causality in South Africa and the United States. Apergis and Payne (2011), using heterogeneous panel co-integration test and error correction model for 16 emerging economies, revealed that causality runs from output to renewable energy consumption, while output and non-renewable energy have bi-directional causality in the short run. In the long run, both renewable and non-renewable energy reflects bi-directional causality.

Applying the same method to investigate causality between coal consumption and economic growth in 15 emerging market economies, Apergis and Payne (2010) found bi-directional both in the short run and the long run. In the same vein, Chandran and Tang (2013) used panel co-integration and granger causality approach and found a bi-directional causality between output and coal consumption; output and CO_2 emissions for China both in the short run and the long run while the same relationship exist for India only in the short run. For the G7 countries, Narayan and Smyth (2008) used the fully modified OLS for heterogeneous panel (FMOLS) to examine the nexus between energy consumption, real gross fixed capital formation and economic growth. They discovered that causality is positive and bi-directional between energy consumption and economic growth.

Al-Mulali et al (2013) investigated the relationship between renewable energy, energy consumption and output in high income, upper middle income, lower middle income and low income countries using FMOLS. They reported that 79 percent of the countries have positive long run bi-directional causality between energy consumption and economic growth; 19 percent showed no long run relationship while only 2 percent revealed unidirectional causality from economic growth to renewable energy. However, Al-Iriani (2006) examined the case of the 6 countries of the Gulf Cooperation Council (GCC) using panel VECM and GMM, and reported that causality runs from economic growth to energy consumption. Based on the FMOLS, Khan et al, (2014) showed that gross domestic product (GDP) per capita has positive impact on energy consumption in low income countries, middle income countries, South Africa and MENA. However, in high income OECD and non-OECD regions, no significant relationship was found. They also showed that FDI has significant impact on increased energy demand in middle income, high income OECD and non-OECD regions.

According to Sadorsky (2009), results of panel co-integration and error correction model estimated for 18 emerging economies revealed that increase in output has positive and significant impact on renewable energy. In the same vein, Narayan et al (2010) applied FMOLS to selected 93 countries categorised under Western Europe (WE), Asia and Latin America (LAC) and Middle East and Africa (MENA), and found that 60 percent of the countries showed positive relationship between energy consumption and economic growth. Similarly, based on ARDL bound testing, employed by Jayanthakumaran et al (2012), revealed that CO2 emissions were influenced by economic growth, structural changes and energy consumption in China while similar causal connection cannot be established in the case of India. Their results however showed no evidence of causal relationship between energy consumption and economic growth.

Regional analysis has equally shown mixed results. Thus, Caraiani et al (2015) assessed the causality between energy consumption and economic growth and revealed that emerging European countries exhibited bi-directional causality between economic growth and energy consumption. According to Apergis and Payne (2009), this finding is valid both in the short run and long run for six Central American countries using heterogeneous panel co-integration and ECM. Also, Apergis and Payne (2011) employed similar estimation techniques to obtain similar result between renewable energy and economic growth for the six Central American countries. Lee et al (2008) investigates 22 OECD countries during the 1960-2001 period using FMOLS and found a bi-directional relationship between energy consumption and between real gross fixed capital formation and output but no causality between energy consumption and output.

Adopting FMOLS and VECM for 6 South American countries, Apargis and Payne (2011) argued that causality runs from energy consumption to economic growth, while Ozturk and Bilgili (2015) used dynamic panel OLS to shows that output is affected by biomass consumption in the Sub-Saharan African countries. Al Mulal et al (2014) also used dynamic panel OLS to show that renewable energy and non-renewable energy have long run positive effect on economic growth in the 18 LACs considered.

In contrast, Chen et al (2007) applied panel co-integration and ECM to examine causality between electricity consumption and output for 10 Asian countries. The result revealed that causality runs from output to electricity consumption in the short run but bi-directional in the long run. Lee and Chang (2008), applying FMOLS to 16 Asian countries, explained that no short run, but long run, causal relationship exists between energy consumption and output. Abanda et al (2012) examined the link between renewable energy production and gross domestic product among oil blocks in Africa using OLS and correlation analysis. Their results showed that while correlation between renewable energy production and GDP was positive for all the blocks except the Southern Africa block, the direction of causality could not be determined.

2.7.2 Output – Pollution Relationship

The second strand of the literature focused on the relationship between output and environmental pollution. These studies are closely related to testing the validity of the so-called environmental Kuznets curve (EKC) hypothesis which postulates an inverted U-shaped relationship between the level of environmental degradation and income growth. This implies that environmental degradation increases with per capita income during the early stages of economic growth, and then declines with per capita income after arriving at a threshold (Acaravci and Ozturk, 2010). Pioneer empirical work on testing the EKC hypothesis started with the seminal working paper of Grossman and Krueger, (1991) and later by the work of Shafik and Bandyopadhyay (1992) and Panayotou (1993). The common identified point of these studies is that the environmental quality declines at the early stages of economic growth and subsequently improves at the later stages. Literature reviews by Lapinskienė and Peleckis (2017), Stern (2004) and Dinda (2004) assert that previous EKC studies have failed to provide clear and inclusive findings on the inverted U-shaped relationship between the environment and economic growth. Moreover, Stern (2004) and Narayan and Narayan (2010) noted that most of the EKC literatures are econometrically weak.

Growth and CO_2 emission studies have also been conducted. For example, Ru, Chen, Liu, and Su, (2012) investigated the driving forces of carbon dioxide emissions, and found that with the evolutionary process of carbon dioxide emissions driven by technical advances over time, decoupling phenomenon in carbon dioxide emissions intensity, carbon dioxide emissions per capita, and total carbon dioxide emissions would appear in turn. In term of causality, a unidirectional causality was found between economic growth and CO_2 emission in the following studies Chandran and Tang (2013) for Malaysia; Govindaraju and Tang (2013) for China and India, Menyah and Wolde-Rufael (2010) for South Africa, Zhang and Cheng (2009) for China and Soytas et al (2007) for USA.

Studies such as Kohler (2013), Tiwari et al (2013), and Shahbaz et al (2012) found a bi-directional causality between per capita GDP and CO_2 emissions for South Africa, India and Pakistan respectively. Uddin and Wadud (2014) focused on the causal relationship between CO_2 emissions and economic growth in seven SAARC countries using time series data for the period of 1972-2012. They found co-integration relationship between environmental pollution and economic growth and their results show that the estimated coefficients of emissions have positive and significant impacts on GDP. Hossain (2012) showed that short-run unidirectional causalities are found from energy consumption and trade openness to carbon dioxide emissions, from trade openness to energy consumption, and from carbon dioxide emissions to economic growth. He also found evidence for long run relationship among variables.

Behnaz, Jamalludin and Saidatulakmal (2012) examined the relationship between economic growth and carbon dioxide (CO_2) emissions for Malaysia. They found evidence for long-run relationship between per capita CO_2 emissions and real per capita GDP with inverted-U shape relationship between CO_2 emissions and GDP in both short and long-run. In that paper, there was no evidence of causality between CO_2 emissions and economic growth in the short-run while demonstrating unidirectional causality from economic growth to CO_2 emissions in the long-run. Tiari (2011), in an attempt to re-examine the relationship between energy consumption, CO_2 emissions and economic growth in India, found that energy consumption, capital and population Granger-cause economic growth and that CO_2 emission has positive impact on both energy use and capital but negative impact on population and GDP.

Parikh et al. (2009) investigate the CO_2 emissions of the Indian economy based on Input–Output (IO) table and Social Accounting Matrix (SAM) for the year 2003–2004 that distinguishes 25 sectors and 10 household classes. According to them, total emissions of the Indian economy were estimated to be 1217 million tons (MT) of CO_2, of which 57% is due to the use of coal and lignite. Some authors have also examined the linearity or non-linearity of the relationship between economic growth and CO_2 emission. Results from these studies are mixed and census has not yet emerged in terms of their findings. Shafik (1994) and Azomahou et al. (2006) found a linear relationship between CO_2 emissions and economic growth, while Lean and Smyth (2010) and Saboori et al. (2012) reported an inverted U-shaped relationship.

2.7.3 Output – Energy – CO_2 Nexus

The third strand of the literature combines the above mentioned lines of research in order to capture the inter-temporal linkages in economic growth, energy use and pollution in the same framework. These studies include: Apergis and Payne (2010b), Apergis and Payne (2014), Bella, Massidda and Mattana (2014), Alkhathlan and Javid (2013), Yang and Zhao (2014), Saboori and Sulaiman (2013), Alam et al. (2016), Rafindadi (2016), Youssef, Hammoudeh, and Omri (2016), among others. However, these studies modeled carbon emissions as a function of income, income squared in addition to other explanatory variables; thus, established a common problem of collinearity or multicollinearity in the series (Alkhathlan and Javid, 2013).

In their cross countries study, (Al-mulali and Sheau-Ting, 2014) reported a long run positive impact of energy consumption on trade as well as between trade and CO_2. In a similar vein, Acaranci and Ozturk (2010) found a positive relationship between CO_2 and energy consumption in all the countries except in Iceland and Switzerland. GDP and energy consumption was found to exert a significant influence on CO_2 in MENA (Chandran and Tang, 2013) and in China (Jayanthakumaran et al, 2012) but the same cannot be established in the case of India.

Yet other studies involved exploring the link between economic growth, energy consumption and trade (Dedeoglu and Kaya, 2013; Sadorsky, 2012; Halicioglu, 2011; Lean and Smyth, 2010). In their different methodologies and studies, Dedeoglu and Kaya (2013) reported a bi-directional causality between energy consumption and GDP as well as between energy consumption and trade (export and import) in OECD. Similar result was also reported by Sadorsky (2012) for South American countries. In a specific country study, Halicioglu (2011) found a long and short run bi-causal relationship between export and energy consumption and also between economic growth but reported a uni-directional relation between export and GDP. Lean and Smyth (2010) also showed a bi-directional relationship between electricity consumption and economic growth for Malaysia.

Another area of research has established connections among CO_2, energy consumption, GDP as well as FDI (Pao and Tsai, 2011; Pao et al., 2011). In a country specific analysis, Pao and Tsai (2011) and Pao et al. (2011) reported bi-directional causality between CO_2 and economic growth in Brazil and Russia respectively. However, CO_2 appears to be inelastic with energy and GDP in the case of Brazil but elastic in the case of Russia. Studies have also been carried out on the relationship between economic growth, energy consumption, financial development, international trade and CO_2 (Shahbaz et al, 2013). The study revealed a bi-directional causality between economic growth and CO_2 as well as between FDI and CO_2.

2.7.3.1 Extensions of Output – Energy – CO_2 Nexus

The literature has further been extended to capture the inter-temporal linkages in economic growth, energy use-pollution and other macroeconomic series like Foreign Direct investment (FDI), trade openness and financial development in a single framework. Studies such as Tamazian et al (2009), Ozturk and Acaravci (2013), Smarzynska and Wei (2001), Pao and Tsai (2011), Al-mulali (2012), Lee (2009) and Hitam and Borhan (2012) are prominent, among others.

In terms of empirical findings, Tamazian et al (2009) showed evidence that higher degree of financial development reduces environmental degradation among BRIC countries. Menyah et al. (2014) reported unidirectional causality between financial development, trade openness and CO_2 emission for 21 African countries. Ozturk and Acaravci (2013) found evidence of short run unidirectional relationship between financial development and per capita CO_2 emission. The nexus between FDI and CO_2 emissions has long been debated. Empirical evidence of the association between FDI and CO_2 emissions remain inconclusive. Most studies have used multi-country analyses, and the results varied by country. One conclusion is that FDI has a positive influence on CO_2 emissions.

Smarzynska and Wei (2001) analyzed 24 transition economies in Europe. Finding reveals that FDI inflows increase CO_2 emissions in host countries. Pao and Tsai (2011) investigated the dynamic relationships between CO_2 emissions, FDI, energy consumption and growth for BRIC countries and concluded that FDI has positive impact on CO_2 emission. Al-mulali (2012) found that FDI net inflows longitudinally increase CO_2 emissions in 12 Middle Eastern countries. Another conclusion is that a negative relationship exists between FDI and CO_2 emissions. For instance, Lee and Brahmasrene (2013) found a negative nexus between FDI and CO_2 emissions in the European Union countries. Al-mulali and Tang (2013) found that FDI contributes to decreased CO_2 emissions in Gulf Cooperation Council Countries.

Mielnik and Goldermberg (2002) found similar results in 20 developing countries. Other studies suggest that inward FDI has no influence on CO_2 emissions. For example, Perkins and Neumayer (2009) found that FDI inflows have no influence on CO_2 efficiency in developing countries. Hoffinann et al (2005) reported similar finding for high-income countries while Atici (2012) for Japan-ASEAN countries and Lee (2013) for Malaysia. Also, Lee (2009) and Hitam and Borhan (2012) found that FDI significantly determined pollution and that increased FDI will raise CO_2 emissions in Malaysia. Acharyya (2009) also found that FDI has a large positive impact on CO_2 emission in India. However, List et al. (2000) found that FDI in the United States contributed to improved energy efficiency but reduced CO_2 emissions.

Shahbaz et al. (2013) established that globalization had an inverse impact on CO_2 emissions in Turkey because FDI contributes to the transfer of energy-efficient technologies to domestic firms. Sbia et al. (2014) found that FDI helped reduce energy consumption and CO_2 emissions in the UAE and Merican et al (2007), while taking a study of Indonesia, obtained similar result. Omri et al (2015) examined the relationship for 12 Middle East and North Africa (MENA) region and their finding reveals that financial development reduces the level of environmental quality. Tamazian and Rao (2010) showed that financial development, in addition to foreign direct investment is capable of reducing CO_2 emissions for transition economies. Sadorsky's (2010) study focused on 22 developing economies, found that overall financial development in these countries causes energy consumption to increase, which in turn leads to more CO_2 emission.

Similarly, Shahbaz and Hye (2013) studied the link among economic growth, energy consumption, financial development, trade openness and CO_2 emission for Indonesian economy. Applying both ARDL and VECM, they found that while economic growth and energy consumption granger cause CO_2 emissions, there exists no causality between economic growth and energy consumption. In summary, the literature review suggests that various studies have been conducted, relating different types of energy, output, FDI and export with CO_2 emission. It is evident that majority of the studies focused on China and other developed countries while, limited studies exist for African countries and Nigeria in particular.

2.7.4 CO_2 Emission, Energy Consumption and Economic Growth in Nigeria

The literature is replete with studies on the relationship among carbon emission, energy consumption and economic growth as different studies have been devoted to examining the nexus among these economic variables. However, the empirical evidence on this nexus is mixed as there exists conflicting results on this subject matter. Some studies argued in favour of a unidirectional relationship where one variable causes the other; the feedback hypothesis where there is a bidirectional relationship between the variables; and the neutrality hypothesis which implies no relationship between the variables. The differences in these findings can be attributed to the sources of data, time period and econometric methods used in estimating the specified equations, among others.

In their study, Chindo et al (2014) examined the energy consumption, carbon dioxide emissions and economic growth nexus in Nigeria and found the existence of a long run relationship among carbon emission, energy consumption and economic growth in Nigeria. It was also found that carbon emission has a significant positive relationship with economic growth both in the short and long run, indicating that the former is an important driver of the latter in Nigeria. On the other hand, it was found that energy consumption is inversely related to economic growth in the short run. Adedokun and Tajudden (2016) used annual time-series data for the period, 1970-2012 to investigate the relationship among carbon emissions, energy consumption and economic growth in Nigeria. The cointegration test result shows the existence of a long-run relationship among the variables. The empirical result shows strong evidence of the existence of the Kuznets curve hypothesis in Nigeria for the period under review.

Essien (2011) contributed to the literature on the impact of CO_2 emissions and economic growth by disaggregating energy consumption into components according to their source. The study investigated the impacts of electricity per capita, GDP per capita, crude oil per capita, natural gas per capita, and fuel woods per capita on the trend of emission in Nigeria. The study found that there is a long-run relationship among the various macroeconomic variables used in the study. The empirical result showed that, in the short run, carbon emissions patterns in Nigeria significantly affect the level of economic growth. The result also supports the existence of the neutral hypothesis in the long run. In addition, it was found that gas and electricity consumption are important drivers of economic growth in Nigeria both in the short and long run while only fuel woods drive economic growth in the long run. The result further showed that natural gas and fuel woods drive CO_2 emissions in the long and short run respectively.

Using annual time-series data over the period of 1970 to 2013, Alege (2011) assessed the direction of causality among CO_2 emissions, energy consumption and economic growth in Nigeria. The result of the cointegration test depicts the existence of a long-run relationship among the variables. The empirical result shows that whereas fossil fuel aids carbon emissions, clean energy source inhibits the atmospheric concentration of carbon emissions. In addition, a unidirectional causal relationship running from fossil fuel to GDP per capita and CO2 emissions was found. It was also found that non-fossil energy leads to a more proportional change in GDP per capita even though a causal link between carbon emissions and electricity could not the established by the result.

Ejuvbekpokpo (2014) sourced for annual time series data from 1980 to 2010 from the Central Bank of Nigeria (CBN) statistical bulletin to assess the extent of influence carbon emissions have on economic growth in Nigeria. Variables like emissions from fossils fuel, solid fuels, liquid fuels and gas fuels were used to proxy carbon emissions while gross domestic product is used to proxy economic growth. The result of the estimated equation reveals that carbon emissions negatively impact economic growth in Nigeria.

Using a multivariate framework by incorporating capital and labour in the causality analysis and secondary data for the period of 1980-2011, Mustapha and Fagge (2015) re-examined the causality between energy consumption and economic growth in Nigeria. The results of the causality test showed the non-existence of a causal relationship between energy consumption and economic growth while the result of the variance decomposition revealed that capital and labour are more important in affecting economic growth than energy consumption. Applying a multivariate Vector Error Correction (VECM) framework to estimate annual time-series data from 1970 to 2008, Akpan and Akpan (2012) assessed the long run relationship and causation among carbon emissions, electricity consumption and economic growth in Nigeria. The empirical findings show that while carbon emission is an increasing function of Nigeria's economic growth in the long run, electricity consumption stimulates carbon emissions. The implication of these findings is that Nigeria's growth process is pollution-intensive and electricity consumption is an important driver of carbon emissions in Nigeria. The study did not support the existence of the environmental Kuznets curve (EKC) in Nigeria. The Granger causality analysis shows unidirectional causation running from economic growth to carbon emissions while no causal relationship was found to exist between electricity consumption and economic growth. The study attributes this neutrality hypothesis between electricity consumption and economic growth to inefficiency in developing electricity infrastructures in the country.

Given the energy crisis facing the Nigerian economy, Rafindadi (2016) empirically examined whether the nexus among economic growth, financial development, energy consumption, trade openness and carbon emissions in Nigeria could provide a clue as to whether Nigeria can simultaneously experience sustainable economic growth and carbon emission reduction. Estimating annual time-series data for the period, 1971-2011, it was found that, whereas financial development and trade openness stimulate energy demand but lowers carbon emissions, economic growth lowers energy demand but raises carbon emissions. Furthermore, the result reveals a significant positive relationship between energy consumption and carbon emissions. The Granger causality test results showed bidirectional causation between financial development and both energy consumption. In addition, the result revealed that the trade-led energy hypothesis and feedback effect between CO_2 emissions and economic growth hold in Nigeria. Adenikinju (2005) noted that there is a positive relationship between energy consumption in Nigeria and growth. For Akinlo, (2008) energy consumption is co-integrated with economic growth in Cameroon, Cote d'Ivoire, Gambia, Ghana, Senegal, Sudan and Zimbabwe. In another study by Adewuyi and Awodumi, (2017),there is a significant interactive relationship (feedback effects) exists among GDP, biomass consumption and carbon emission Nigeria, Burkina Faso, The Gambia, Mali and Togo.

2.7.5 CO_2 Emission and other Macroeconomic Variables

In the literature, studies have also been extended to cover relationship between carbon emission and other macroeconomic variables like health, FDI and financial development (Chen and Ching 2000, Berger and Messer, 2002, and Jerrett et al. 2003). These set of studies underscore the possible impact of environment pollution on economic and social variables among countries. In terms of empirical findings, Chen and Ching (2000) investigated the effects of both economic and life expectancy at birth for 146 countries. They found that life expectancy is positively correlated to GNP per capita, population growth, fertility, enrollment and access to safe water, but negatively correlated to AIDS, tuberculosis, forest and woodland percentage and rate of deforestation. Jerrett et al. (2003) examined the link between environmental quality and health care spending using cross-sectional data for 49 counties. The study concluded that counties with higher pollution have higher per capita health expenditures and counties with more environmental budget, significantly pay lower health expenditures.

Another study by Narayan and Narayan (2008) found that carbon monoxide emissions and sulphur oxide emissions have positive effect on health expenditure, while Declercq et al. (2011), advised that life expectancy would increase up to 22 months if the major European cities can reduce air pollutions. Assadzadeh et al. (2014) found that increases in carbon dioxide emissions increases health expenditures, while a rise in life expectancy at birth decreases health expenditures in short-run. Yazdi et al. (2014) examined the role of environmental quality and income in determining health expenditures (1967 to 2010) in Iran. Their study showed evidence that income, health expenditures and the pollutants such as sulphur oxide emissions and carbon monoxide emissions are co-integrated in long-run. Moreover, their empirical findings showed that income and the pollutants are correlated with health expenditures in both short run and long-run.

Also, Odusanya et al. (2014) studied the effect of per capita carbon dioxide emission on real per capita health expenditures in Nigeria (1960 to 2011). They concluded that carbon dioxide emission increases health expenditures significantly in both long-run and short-run. Similarly, Jaba et al. (2014) analyzed the relationship between the dynamics of the inputs and the outputs of healthcare systems. Applying panel data analysis for 175 countries from 1995 to 2010, the authors found that health expenditures as an input of the healthcare system have a significant positive impact on the health outcome, namely on life expectancy at birth.

In summary, several studies have been reported on the relationship between carbon emission, growth and energy consumption, while scanty studies are found investigating the link between health and carbon emission. Up till date, the only known studies linking environmental pollution, growth and energy consumption in Nigeria is Odusanya et al. (2014). However, the study by Odusanya et al. (2014) did not account for other possible determinant factors like FDI, financial development and possible externalities that characterized the Nigerian energy sector. This study, therefore, focused on the effect of CO_2 on health, financial development and FDI. Thus, this study helps to fill a gap by aiding the design of policies for dealing with the negative environmental externalities that characterized the Nigerian energy sector. Additional summary of the literature is provided in Table 2.1.

Table 2.1: Summary of Literature

S/N	Author & Year	Country (s) & scope	Methodology		Findings
			Variables	Estimation Techniques	
Single-country Studies					
1	Chang (2010)	China (1981-2006)	Y, ECC, NG, CO &EL	VECM Granger causality Approach	1. ECC in China produced efficiency gains over the period. 2. ECC↔Y
2	Lee and Chang (2007)	Taiwan (1955-2003)	Y, K, L, X & ECC	OLS and Threshold Autoregressive Model (TAR)	Changes in ECC contributed to Y, but the relationship is not linear
3	Pao and Tsai (2011)	Brazil (1980-2007)	CO_2, ECC & Y	Grey prediction and VECM	In the long run, CO_2 appears to be both ECC & Y inelastic. Y ↔ ECC ↔ CO_2
4	Pao et al, (2009)	Russia (1990-2007)	CO_2, ECC & Y	VECM	In the long run, CO_2 appears to be ECC elastic and Y inelastic. Y↔ECC↔CO_2
5	Pao (2009)	Taiwan (1980-2007)	Y & EL	Johansen Co-integration and Error Correction Models	In the Short and long run, Y→EL but not vice versa
6	Komal and Abbas (2015)	Pakistan (1972-2012)	FD, UR, real Y and ECC	GMM	+ & significant impact of Y & UR on ECC. FD + affected ECC through Y.
7	Shahbaz and Hye (2013)	Indonesia (1975Q1-2011Q4)	Y, ECC, FD, TO and CO_2	ARDL and VECM	In the short-run ECC, Y, FD↔CO_2; Y & ECC →CO_2 (+); FD & TO →CO_2 (-). In the long-run, ECC→FD
8	Javid and Qayyum (2014)	Pakistan (1972-2012)	EL, Y, EP & ECC	Structural time series model (STSM)	An upward slope relationship for electricity usage in commercial,, agricultural and residential sectors, EL→Y
9	Abosedra (2009)	Lebanon, monthly data	M, EL, and TEM	Granger-type causality test	1.EL→Y 2. Absence of a

		from January 1995 to December 2005		with a lagged error correction term (VECM)	long-run equilibrium relationship between EL & Y.
10	Shahbaz and Lean	Pakistan (1972-2009)	Y, ECC, L & K	ARDL & VECM	ECC↔Y
11	Fang (2011)	China (1978-2008)	RE, ECC & Y	OLS	RE→Y
12	Warr and Ayres (2010)	US (1946-2000)	ECC, Y, K, L & energy efficiency	Granger causality and VECM	ECC→Y
13	Yoo and Kim (2006)	Indonesia (1971-2002)	EL & Y	Co-integration and Hsiao version of the Granger-causality method	Y→EL
14	Yuan et al (2008)	China (1985-2007)	Y, ECC, EL & CO	Johanson co-integration and VECM	In the short run, EL↔ECC↔Y. No causality between CO, ECC & Y. Also, Y↔ECC; CO↔ECC but no causality between Y & EL.
15	Hamit-Hagger (2012)	Canada (1990-2007)	ECC, GH & Y	FMOLS	In the Short run, ECC → GH, Y→GH and a weak GH→ECC; Y→ECC. In the long run, a weak ECC→GH, Y→GH
Multi--country Studies					
16	Narayan et al (2010)	93 countries, categorized under Western Europe, Asia, Latin America, Middle East and Africa (1980-2006)	ECC & Y	Panel – Fully Modified Ordinary Least Squares (PFMOLS)	In the long run, 60% of the countries considered showed ECC + Y while 40% has relationship either negative or statistically insignificant. Also, ECC→Y in 59% of the countries and Y→ECC in 41% of the countries
17	Wolde-Rufael (2010)	India, Japan, China, South	CO &Y	Toda and Yomamoto	CO→Y in India & Japan; Y→CO in

		Africa, South Korea and United States (1965-2005)		Granger causality	China and South Korea; Y↔CO South Africa and United States
18	Ozturk and Acaranci (2011)	11 MENA countries (1971-2006)	Y &EL	ARDL bound testing approach	No relationship between EL & Y
19	Jayanthakumaran, et al. (2012)	China and India (1971-2007)	RE, Y, TO, ECC & CO_2	ARDL bound testing approach	In china, CO_2 were influenced by Y, structural changes & ECC. A similar causal connection cannot be established for India.
20	Sadorsky, (2009)	18 emerging economies (1994-2003)	RE & Y	FMOLS, DOLS & OLS	Increases in Y have + significant impact on RE.
21	Al-Iriani, (2006)	6 Countries of the Gulf Cooperation Council (GCC)	ECC & Y	Panel VECM and GMM	Y→ECC in the GCC countries
22	Apergis and Payne (2011)	16 emerging economies (1990-2007)	RE, NRE, EL, Y, K & L	Heterogeneous panel co-integration test, panel error correction model	1.In the short-run, Y→RE & Y↔NRE 2. In the long-run, RE↔Y & NRE↔Y
23	Apergis and Payne (2010)	15 emerging market economies (1980-2006)	Y, RE, NRE, K & L	Heterogeneous panel co-integration	In the short-run and long run, CO↔Y
24	Pao and Tsai (2011)	Brazil, Russia, India and China (1980-2007)	CO_2, FDI, Y & ECC	VECM and Grey prediction	CO_2 ↔FDI, Y→FDI; ECC→FDI
25	Khan et al (2014)	Low income, middle income, high income, non-OECD, high income OECD, South Africa, MENA (1975-2011)	ECC, Y, FDI, relative prices and FD	FMOLS	Y + impact on ECC in low income, middle income, South Africa and MENA; FDI & FD→ECC in both middle & high income countries; in low income countries Y&FD→ECC(+); FDI & relative prices→ECC (-)

26	Narayan and Smyth, (2008)	G7 countries	K, ECC, & Y	FMOLS	K, ECC, & Y are co-integrated with K & ECC↔Y + in the long run
27	Al-mulali et al (2013)	High income, upper middle income, lower middle income and low income (1980-2009)	RE, ECC & Y	FMOLS	79% of the countries have a + long run RE↔ECC↔Y, 19% showed no long run relationship and 2% showed Y →RE
Regional Studies					
28	Lee et al., (2008)	22 OECD countries (1960–2001)	ECC, K & Y	Panel co-integration & VECM	ECC↔K↔Y. K plays a critical role in realizing the dynamic relationship between ECC & Y
29	Acaravci and ozturk (2010)	Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland (1960-2005)	CO_2, ECC & Y	ARDL bound testing approach	In the long-run ECC, Y →CO2in Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland. In the short-run, Y→ECC in Greece and Italy; Y↔ECC in Switzerland.
30	Abanda et al., (2012)	Africa (Oil &Non-oil producing block, West, East, North, Southern and central Africa)	RE & Y	OLS & correlation analysis	The correlation between RE production and GDP was positive for all the blocks except the Southern Africa block. The direction of causality between RE & Y could not be determined.
31	Lee, and Chang, (2008)	16 Asian countries(1971-2002)	ECC, Y, K & L	FMOLS	No short run causal relationship. Long-run ECC→Y
32	Apergis and Payne (2009)	6 central American countries (1980-2004)	Y, ECC, K & L	Heterogeneous panel co-integration and ECM	ECC↔Y in short run & long run

33	Al-mulali et al (2014)	18 LAC (1990-2011)	L, K, trade in goods & services, ECC & CO_2	Panel dynamic OLS (DOLS)	ECC, L, K & total trades have long run + effect on Y
34	Caraiani et al (2015	Emergiing European countries (1980-2013)	ECC & Y	VECM	ECC ↔Y
35	Ozturk and Bilgili, (2015)	51 Sub-Sahara African Countries (1980-2009)	Y, biomass consumption, TO & POP	Dynamic panel OLS	BC, TO, & POP →Y.
36	Apergis and Payne, (2011)	6 Central American countries (1980–2006)	Y, RE, K, & L	The heterogeneous panel co-integration and FMOLS	RE↔Y in both the short and long-run.

Source: Compiled by the Author

Note: GDP = Y; Energy Consumption of crude oil or energy use = ECC; Energy intensity = EIN; Industrial development = ID; Energy prices = EP; Natural gas = NG; Coal consumption = CO; Trade ratio = TR; Greenhouse gas emission = GH; Electricity consumption = EL; Temperature and humidity = TEM; positive relationship between = + ; Fully modified OLS for heterogeneous panel = FMOLS; Negative relationship between = -; X = energy Exports; Energy Import = M; Agricultural output = AGR; Population = POP, Biomass consumption=BC; Labour = L; Investment = I; Real gross fixed Capital formation or Capital = K; Renewable energy = RE; Non-renewable energy = NRE; Urbanization = UR; CO2 emissions = CO2 ; Trade openness = TO; Bi-directional causality = ↔; Uni-directional causality = → ; Financial development = FD; Western Europe = WE, Asia, Latin America = LAC, Middle East and Africa = ME

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This chapter presents the methodology and estimation related issues in relation to the objectives of the study. The theoretical framework is also developed in this chapter. The equations are specified and the estimation technique is discussed. The sources of data are also highlighted.

3.2 Theoretical Framework

Following the approach of Lanzt (2000), we develop a theoretical model of a competitive economy that is capable of explaining the EKC within the context of scale, composition, technological, and regulation effects. It is assumed in the model that there are two sources of inefficiency in the economy. Firstly, regulators do not have enough information to price polluting sources at their socially efficient levels. The competitive economy, therefore, exhibits a pollution externality that is not fully internalized by regulatory policy. As such, the regulator may not generate sufficient revenues for abating pollution, and individuals may unduly suffer from the negative effects that pollution has on their utility. A second source of inefficiency in the economy concerns the use of regulation revenues. It is assumed that al1 such revenues are invested in pollution abatement activities. The maintenance of this restriction may be justified by observing the current view toward pollution taxes. In order to maintain public support for such regulations, current governments may be required to earmark revenues.

The scale effect is captured in the model through transitionary capital accumulation and a neutral technological change parameter. In the standard neoclassical growth model, an economy that starts with low initial levels of capital will accumulate capital and grow toward a steady-state. This growth increases the demands for all factors of production (both polluting and non-polluting), and is referred to in this study as the transitionary *scale* effect. Additionally, a technological advance may stimulate economic growth (via the Solow residual) and add to the increased demand for all production factors. This effect is referred to in this paper as a long-run scale effect. This type of scale effects are often the explanations given for why pollution levels increase with output.

The technological change parameter accounts for a technological effect in the model through the assumption that the energy input in the production process may become more efficient and less polluting. A technological innovation in energy inputs can come about in two ways. First, there may be intra-energy substitution as producers substitute for higher grades of an existing energy source.[15] Second, there may be inter-energy substitution, where producers substitute for more efficient energy sources.[16] In addition to becoming more efficient, intra and inter-energy substitution typically causes fewer pollution emissions per unit of energy used. For example, soft coal is less energy efficient and emits more pollution per unit burned than hard coal, and oil is more efficient and emits less pollution per unit burned than coal. These technological effects are often cited as having a negative effect on pollution levels as economic growth continues in the later stages of the development process.

Government revenue generated from pollution regulation of energy is used to improve the assimilative capacity of the environment. Therefore, energy regulation could be interpreted as an energy tax or abatement technology standard (both are equivalent in this analysis). In the first case, the revenue generated from the tax would be used to fund government projects aimed toward abating pollution. An example of such a project includes the creation of wetlands to absorb and assimilate the pollutant. In the second case, the producer would be required to purchase abatement technologies (with the same amount of revenue as in the case of the tax). An example of such a private project includes the installation of end-of-pipe pollution abatement equipment. The reason for specifying the regulator's role in this manner is to introduce a particular regulation effect in the economy. If environmental regulations were to increase, firms would have incentive to utilize the most up-to-date technologies in order to minimize their production costs. As well, the assimilation of pollution into the environment would improve through such government projects as creating more wetlands and installing pollution abatement equipment. This regulation effect may add to the technological effect in diminishing pollution levels in the later stages of development (Lanzt, 2000).

The study adopts the Lanzt (2000) model which builds on the Ramsey (1927) competitive market framework. In the economic environment of the model, the population of the economy, N(t), grows at an exogenously given rate q. Individuals are

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[15] An example includes substituting to higher grades of coal which have higher BTUs per tonne used.
[16] An example of this includes substituting oil for coal since oil has more BTUs per tonne used.

endowed with capital, and labour, which are used by firms to produce output. While individuals inelastically supply their labour services and receive a wage w(t), they must decide how much capital to save or consume. They can save by accumulating capital for which they receive a rental price, r(t). The per capita law of motion on capital is given in equation (3.1) as:

$$\dot{k}(t) = (r(t) - \delta - q)k(t) - c(t) + w(t) \tag{3.1}$$

where, $\dot{k}(t) = \frac{\partial k(t)}{\partial t}$, k(t) and c(t) are per capita capital and consumption, respectively, and ∂ is the depreciation rate of capital. Individual are assumed to be identical and infinitely-lived. Their preferences are represented by the following utility integral in equation (3.2):

$$U = \int_0^\infty e^{-\beta t} U(c(t))dt \tag{3.2}$$

where c(t) represents per capita consumption, U(c(t)) is assumed to be concave, and β is the rate of time preference. The individual solves the following optimization problem, taking prices as given in equation (3.3):

$$\max_{<c(t),k(t)>} \left\{ U = \int_0^\infty e^{-\beta t} U(c(t))dt \right\} \tag{3.3}$$

s.t $\dot{k}(t)^s = (r(t) - \delta - q)k(t)^s - c(t) + w(t), k(0)^s \, given, t \in [0, \infty]$

There are many identical firms using the per capita labour, l(t), and capital, k(t), supplied by individuals to produce per capita output (the price of output is normalized to equation (4.1)). The aggregate production function for output is given in equation (3.4) as:

$$Y(t) = F(K(t), L(t)) \tag{3.4}$$

where Y(t), K(t) and L(t) are aggregate output, capital, and labour, respectively, K(t)=k(t)L(t), and the production function is assumed homogeneous of degree 1. Each firm has the following per capita costs of production in equation 3.5:

$$co(t) = r(t)k(t) + w(t).....(5) \tag{3.5}$$

where co(t) represents per-capita production costs.

The firm chooses per-capita capital, k(t), to maximize period profits, taking factor prices as given. The firm's problem is formalized in equation (3.6) as:

$$\max_{<k(t)^d>} \left\{ \Pr ofit = y(t) - r(t)k(t)^d - w(t) \right\}$$
$$s.t.\, y(t) = f(k(t)^d) \qquad (3.6)$$

where y(t) is per capita output. The competitive equilibrium in the model consists of prices $\{r(t),\, w(t)\}_{t=0}^{\infty}$, an allocation for the representative consumer $\{c(t),\, \mathrm{k}(t)\}_{t=0}^{\infty}$, and an allocation for the representative firm $\{\mathrm{k}(t)\}_{t=0}^{\infty}$ such that the following holds:

(1) $\{c(t),\, \mathrm{k}(t)\}_{t=0}^{\infty}$ solves the consumer's optimization problem as specified in equation (4.3). The (current value) Hamiltonian function associated with this problem is given in equation 3.7 as follows:

$$H = U(c(t)) + \lambda(t)\dot{k}(t)^s \qquad (3.7)$$

where $\lambda(t)$ is the marginal value, as of time t, of an additional unit of capital at time *t.* The Maximum Principle yields the following:

$$U_c(c(t)) - \lambda(t) = 0 \qquad (3.8)$$

$$\dot{\lambda} = \lambda(t)\left[\beta - r(t) + \delta + q\right] \qquad (3.9)$$

$$\dot{k}(t) = [r(t) - \delta - q]k(t)^s - c(t) + w(t).....(10) \qquad (3.10)$$

(2) $\{\mathrm{k}(t)\}_{t=0}^{\infty}$ solves the firm's optimization problem as specified in equation (3.6). The solution gives the following first-order conditions for firms in equation (3.11):

$$f_k(k(t)^d) = r(t).....(11)$$
$$f(k(t)^d) - f_k(k(t)^d)k(t) = w(t) \qquad (3.11)$$

(3) Markets clear such that demand for capital equals its supply.

The following system of equations describes the equilibrium:

$$\dot{c} = -\theta(c(t))c(t)(f_k(k(t) - \delta - q - \beta) \qquad (3.12)$$

$$\dot{k} = f(k(t)) - (\delta + q)k(t) - c(t) \qquad (3.13)$$

where $\theta(c(t)) = \dfrac{U_c(c(t))}{U_{c,c}(c(t))c(t)}, \dfrac{1}{\theta(c(t))}$ is known as the elasticity of marginal utility with respect to consumption.

Equation (3.12) indicates that the optimal flow of consumption will change if and only if the net marginal product of capital differs from the subjective discount rate of consumption (Leonard and Van Long, 1992, Lanzt, 2000). Equation (3.13) indicates the optimal path of capital. Together, these two equations ultimately determine the equilibrium path of aggregate output over time, as defined in equation (3.4). This Ramsey growth model has become a standard framework for explaining economic growth in modern times. Extensions that have incorporated elements such as technological change and regulations have provided further insights into the factors that affect economic development. In the model build up, pollution is then defined as a by-product of energy-use that negatively affects consumer's aesthetic values.

In the neo-classical growth pollution model, consumers are identical to that described in the Ramsey growth model with the exception of additively separable preferences over consumption and pollution emissions in equation (3.15):

$$U(c(t), x(t)) = U_1(c(t)) + U_2(x(t)) \tag{3.15}$$

where *x(t)* is the per capita stock of pollution in the economy in period *t*, U_1 is assumed to be increasing in consumption, *c(t)*, U_2 is assumed decreasing in pollution, *x(t),* and both U_1 and U_2 are assumed to be concave. The consumer faces the same budget constraint and choice variables as in the Ramsey model. In this case, pollution is not within the choice set for consumers since they do not own the input that produces pollution. Hence a pollution externality is expected.

In addition, firms in this economy are identical to those in the Ramsey model. However, they now produce output using per capita capital, *k(t)*, and energy, *e(t)*. In addition, neutral and biased technological change is included in the analysis. The following specifies the production technology in equation 3.16:

$$y(t) = Af(k(t), ae(t)) \tag{3.16}$$

where A denotes a neutral technological parameter (or the Solow residual), and *ae(t)* represents efficiency units of energy. The production function is strictly concave, twice continuously differentiable, and increasing in both inputs. The signs on the cross derivatives are strictly positive and production are bounded in the limit when increasing any single input. Firms have the following costs of production as highlighted in equation (3.17):

$$co(t) = r(t)k(t) + \varepsilon ae(t) + w(t) \tag{3.17}$$

where ε is the price paid per efficiency unit (tonne of oil-equivalent is typically used) of energy used in the production process. The total price of energy may include energy taxes, the cost of energy extraction, and other factors (such as oligopoly pricing as in the case of the OPEC cartel in the early 1970s). However, these latter costs (which may create short-run energy price fluctuations) are left out in other to simplify the analysis. Specifically, by assuming that energy is a renewable resource that is priced in a competitive market, it is possible to focus the analysis on the long-run impacts of energy regulation. Consequently, the firm chooses capital, k(t), and efficiency units of energy, *ae(t)*, to maxirnize profits each period, taking factor prices as given in this environment.

Technology enters into the production function in two ways. First, neutral technology is measured by the Solow residual, A. If a new production process is invented, a neutral technological advance may occur, causing A to increase. This permanent shock therefore represents a long run *scale* effect**.** The second way in which technology enters the production function is through its effects on energy efficiency. This factor is defined as biased technology, or *a*. A new technique of refining energy or a new energy source is assumed to make each unit of energy more effective in the production process. An improvement in the amount of BTUs stored in a particular energy source (intra-energy substitution) or a change of energy sources (inter-energy substitution) makes each unit of energy more efficient. This process, occurring over time path of an economy, describes the *technique* effect.

This specification of energy efficiency can be interpreted as an improvement in the quality of energy. This characterization is similar to that of the human capital literature concerning economic growth (Lucas, 1988). The human capital analysis effectively endogenizes technological change by suggesting that labourers can become more productive with increased education and knowledge. However, since the firms do not choose the level of biased technology change in this model, energy quality is not endogenous. The law of motion on pollution is defined in equation 3.18:

$$\dot{x} = N(t) - (\gamma + q)x(t) - \ell(t) \qquad (3.18)$$

where $\dot{x}$ is the rate of change in the per capita stock of pollution. This rate accounts for new emissions from the production process, N(t), the environment's natural emissions assimilative capacity, $0 < \gamma < 1$, the growth rate of labour, *q*, and man-made additions to the natural rate of pollution assimilation $\ell(t)$.

The government's role in this competitive economy is to regulate the price of energy and utilize the regulation revenue for projects aimed toward improving the pollution assimilative capacity of the environment above its natural rate. Such man-made pollution projects include creating wetlands (government projects) and installing pollution abatement equipment on production sites (technological standards enforced at the firm level). Investment in man-made pollution assimilation is described in equation (3.19):

$$\ell(t) = (\varepsilon ae(t)^{n}\varphi(x(t)) \qquad (3.19)$$

where $\ell(t)$ denotes man-made additions to the environment's assimilative capacity, $0 < n < 1$, is a parameter describing the returns to pollution abatement investments, and $\varphi(x(t))$ is a function describing the effectiveness of regulation revenue in the assimilation of pollution. The assumption is that $0 < n < 1$ indicates that the returns to pollution abatement investments are decreasing. That is, for a given abatement technology, each dollar invested in pollution abatement becomes less and less effective. Although there are some circumstances where increasing returns may exist, most pollution abatement investments will exhibit decreasing returns in the long run.

In addition, the assumption is that $\varphi(x)$ is increasing in *x*. When there is a lot of pollution in the environment, the marginal cost of abating that pollution is relatively small (as such man-made abatement efforts are relatively effective). At lower levels of pollution, the marginal cost of abating pollution increases (and man-made abatement efforts become less effective). The marginal cost associated with abating the last few units of pollution may be infinite (and so man-made abatement efforts become ineffective). In this analysis, the marginal abatement costs can be expressed as MAC = $\left[\frac{1}{\varphi(x(t))}\right]^{\frac{1}{n}}$.[17]

It is assumed here that the regulator chooses to charge some price to firms for energy-use in order to compensate the individual. Given the above assumptions, the regulator chooses some price, ε, and given some level of *ae(t)*, and *n* determines the amount of (effective) dollars invested in pollution abatement. Multiplying this by $\varphi(x(t))$ determines the actual amount of pollution abated, $\ell(t)$. With respect to emissions of pollution, it is assumed that the use of energy releases emissions of pollution into the

[17] The relationship between MAC and *x* is similar to the literature in fisheries economics where, as the stock of fish increases, they become easier to catch. In the current context, as pollution increases, man-made efforts become more effective at assimilation.

environment. Additionally, there are other factors that play a role in the actual emissions released in each period as described in equation 3.20:

$$N(t) = N(e(t), a, \varphi(x(t)) \qquad (3.20)$$

where the amount of new pollution emitted into the environment, *N(t)*, is assumed increasing in the energy variable *e(t)*, decreasing in energy efficiency parameter *a*, and increasing in the effectiveness of the policy variable $\varphi(x(t))$. The assumption that *N(t)* is decreasing in parameter *a* can be justified by examining the development of most energy sources over time. For example, coal has been replaced by oil and/or oil has been replaced by natural gas (less polluting sources).

The effectiveness of regulation policy, $\varphi(x(t))$, is assumed to affect the amount of pollution emitted from each efficiency unit of energy. Specifically, as the regulator becomes more effective at abating pollution, each efficiency unit of energy may become more polluting. This assumption can be justified when recognizing that pollution abatement technologies (a capital input) may substitute for polluting energy sources (an energy input). As capital inputs become more capable of assimilating pollution, energy inputs may become more polluting. In the framework, a competitive equilibrium consists of prices $\{r(t), w(t), \varepsilon\}_{t=0}^{\infty}$, an allocation for the representative consumer $\{c(t), k(t)^s\}_{t=0}^{\infty}$, and an allocation for the representative firm $\{k(t)^d, e(t)\}_{t=0}^{\infty}$ such that the following holds:

(1) $\{c(t), k(t)^s\}_{t=0}^{\infty}$ solves the following consumer's optimization problem taking prices as given in equation (3.21):

$$\max_{<c(t),k(t)>} \left\{ U = \int_0^{\infty} e^{-\beta t}[U_1(c(t)) + U_2(x(t))]dt \right\} \qquad (3.21)$$

$$s.t. \quad \dot{k}(t)^s = r(t) - \delta - q)k(t)^s - c(t) + w(t), k(0)^s \; and \; x(0) \; given \; t \in [0, \infty]$$

The Hamiltonian function associated with this problem is given as in equation (3.22):

$$H = U_1(c(t)) + U_2(x(t)) + \lambda(t)\dot{k}(t)^s \qquad (3.22)$$

This is the Maximum Principle. Equations (3.8) - (3.10) hold (with the exception that utility is now defined as $U_{1c}(c(t))$.

(2) $\{k(t)^d, ae(t)\}_{t=0}^{\infty}$ solves the firm's period optimization problem, taking prices as given in equation 3.23:

$$\max_{<k(t)^d, ae(t)>} \left\{ \Pr ofit = Af(k(t)^d, ae(t)) - r(t)k(t)^d - \varepsilon ae(t) \right\} \quad (3.23)$$

The first-order conditions are as follows in equation 3.26 and 3.27:

$$Af_k(k(t)^d, ae(t)) = r(t) \quad (3.24)$$

$$\begin{aligned} &Af(k(t)^d, ae(t)) - Af_k(k(t)^d, ae(t))k(t) - Af_{ae}(k(t)^d, ae(t))ae(t) = w(t) \\ &Af_{ae}(k(t)^d, ae(t)) \end{aligned} \quad (3.25)$$

(3) The law of motion on pollution, man-made abatement investments, and emissions of pollution equations are satisfied according to equations (3.18), (3.19), and (3.20).

(4) Markets clear such that demand for capital equals its supply.

The equilibrium can be expressed as the system of equations (3.25) and the following equations:

$$\dot{c} = -\theta^1(c(t))c(t)(Af_k(k(t), ae(t)) - \delta - \beta - q) \quad (3.26)$$

$$\dot{k} = Af(k(t), ae(t)) - (\delta + q)k(t) - c(t) \quad (3.27)$$

$$\dot{x} = N(e(t), a, \varphi(x(t)) - (\gamma + q)x(t) - (\varepsilon ae(t)^n \varphi(x(t)) \quad (3.28)$$

$$where\, \theta^1(c(t)) = \frac{U_{1c}(c(t))}{U_{1c,c}(c(t))c(t)}, and\ A, e, and\ \varepsilon\ are\, exogenous\ parameters$$

Equations (3.26) and (3.27) have a similar interpretation as equations (3.12) and (3.13), respective1y. Equation (3.25) indicates the efficient path of energy. Together, these three equations determine the equilibrium path of per capita output over time, as defined in equation (3.18). The equilibrium path of energy augments the per capita rate of change of pollution (in equation (3.28)). Since energy utilization is affected by economic growth, it is possible to reveal a direct relationship between capital accumulation, energy use, output, and pollution in the economy over time.

From the above, it is clear that an EKC may exist (within the context of this model) only in some situations. While the model indicates that the *regulation* effect may not play a major role determining whether an EKC exists (since output will decrease with pollution in the steady-state), it indicates that the *technique* effect may be the source of the EKC finding. However, while the *technique* effect may start an EKC trajectory, it may be offset by a *scale* effect. Expectedly, this would lead to the N-shaped relationship between output and pollution. Additionally, periodic *regulation*, *technique*, and *scale* effects may cause the long-run output-pollution trajectory to be continuously fluctuating.

Within this environment, too much pollution may result in the economy (if energy prices do not reflect the true costs of using this polluting input). In attempting to reduce the size of the externality, regulators may decide to minimize pollution at any time by appropriately augmenting the supply of energy. This policy may lead to a Pareto-improving allocation of resources if the pollution externality is reduced. The social cost of pollution is assumed to be sufficiently large to warrant such pollution minimization policy. In order to determine the economic environment under which pollution is minimized in the economy, regulators are assumed to choose energy efficiency units in a way that minimizes the net increase in pollution subject to the market economy being in equilibrium. Regulators are assumed to take equilibrium energy prices as given when making their supply decisions. This specification may occur, for example, when there are a large number of jurisdictions and regulators in an economy and the regulators believe their energy supply decisions will not have an impact on energy prices. However, energy prices will no longer remain constant (or exogenously determined). Instead, they will now be determined in the market for energy. The formalization of the objective of a regulator within each jurisdiction of an economy is given as:

$$\min_{<ae(t)>} \{\dot{x} = N(e(t), a, \varphi(x(t)) - (\gamma + q)x(t) - (\varepsilon(t) ae(t)^n \varphi(x(t))\} \qquad (3.29)$$

where $\varepsilon(t)$ is assumed fixed at its current level.

The solution to equation 3.29 yields the minimum-pollution energy supply rule for the regulator and can be expressed as follows:

$$N_{ae}(e(t), a, \varphi(x(t))) = n\varepsilon(t)^n (ae(t))^{n-1} \varphi(x(t))$$

where $N_{ae}(e(t), a, \varphi(x(t)))$ is determined by first multiplying each element in N by a, and then taking the derivative of the function (the individual chooses efficiency units of energy here). Firms and individuals face the same profit and utility maximization problems as in the poorly-regulated economy, so they have the same first-order conditions. Specifically equations (3.24) and (3.25) hold for producers and equations (3.26)-(3.28) hold for individuals (with the exception that utility is now defined as $U_{1c}(c(t))$. The equilibrium can be expressed as the system of equations (3.26), (3.27), and the following:

$$N_{ae}(e(t), a, \varphi(x(t))) = n(Af_{ae}(k(t), ae(t))^n (ae(t))^{n-1} \varphi(x(t)) \qquad (3.30)$$

$$\dot{x} = N(e(t), a, \varphi(x(t))) - (\gamma + q)x(t) - (Af_{ae}(k(t), ae(t))(ae(t))^n \varphi(x(t)) \qquad (3.31)$$

where A and a are exogenous parameters.

Equation (3.31) is the new efficiency condition for energy. The equilibrium level of energy is now dependent on the level of pollution, the effectiveness of using revenue for pollution abatement, the returns to man-made pollution abatement, and other factors not included in the poorly-regulated economy. This occurs because regulators in each jurisdiction now account for the effects that energy-use has on pollution levels. Specifically, each regulator sets the supply of energy such that pollution is minimized (taking prices as given). Energy prices are now implicitly determined within the model. The rate of change in per capita pollution, equation (3.28), is for the poorly-regulated economy. However, the equilibrium path of energy defined in equation (3.25) now augments the pollution path. Together, equations (3.26), (3.27), (3.29) and (3.30) determine the equilibrium path of output over time, as defined in equation (3.16).

Since energy utilization is affected by both economic growth and pollution levels, it is possible to repeat the procedure of evaluating the stability properties of the steady state, and investigate the role that *scale*, and *technique* effects play on the paths of output and pollution in this minimum-pollution environment. As the economy grows over time, the *regulation* effect will change at a rate dependent on neutral and biased technological change, and the level of capital and energy used in equilibrium. Combining the results for output and pollution, it can be argued that an EKC may exist depending on the realized shocks to *scale* and *technique* parameters at different periods in time in a poorly-regulated economy. Specifically, regulation effects (in the steady-state) do not play a significant role in determining whether or not an EKC exists because they cause both pollution and output Ievels to fall. However, *regulation* effects do play an important role in determining the transition to the steady state and therefore the *height* of the output-pollution trajectory.

In the poorly-regulated economy, the path of the economy is sub-optimal for two reasons: (i) energy is assumed to be priced below where its marginal revenue equals its social marginal cost, and (ii) regulation revenues are earmarked for pollution abatement activities. As a result of the relatively low energy prices in the poorly-regulated economy, output and pollution will be relatively high. By attempting to improve the state of the environment, regulators following a minimum-pollution regulation policy would reduce output and pollution. Thus, the EKC becomes flattened. The results of the mode1 have important implications for policy. They indicate that, if pollution externalities exist within an economy, pollution levels may be too high causing individuals to experience losses in welfare. Regulators may be able to minimize pollution by imposing stricter regulations on polluting sources. However, pollution is expected to have more serious effects on individuals and the economy than what is specified in this model, such as causing respiratory illnesses or acidification of soils. This implies that the model underestimates the extent of the externality arising from pollution. Such a circumstance would emphasize that the EKC is too high in the poorly-regulated economy and should be flattened.

3.3 Empirical Specification of the Equations

The EKC hypothesis postulates an inverted U-shaped relationship between CO_2 emissions and per capita income: emissions per person increase up to a certain threshold level as per capita income go up, after which they start to decrease (Dinda 2004; Müller-Fürstenberger and Wagner 2007; Kaika and Zervas, 2013). Following Storm and Mir (2016), the study estimate a general reduced-form model in which CO_2 emissions per capita is a polynomial cubic function (of degree three) of per capita income:

$$CO_{2t} = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \varepsilon_t \qquad (3.32)$$

Equation (3.32) is our baseline equation where CO_{2t} denotes per capita emissions of carbon dioxide while Y_t denotes per capita income in real terms (measured at levels, quadratic and cubic form). The essence is to determine whether the hypothesis of EKC holds in the case of Nigerian economy and which between the linear, squared/quadratic or cubic is more appropriate for modeling CO_2 emission and economic growth relationship in Nigeria. The CO_2 emission in equation (3.32) would be further disaggregated into different components of carbon dioxide to include emission from solid fuel (COAL), emission from liquid fuel (Petroleum (PET)), and emission from gaseous fuel (GAS). The underlying intuition for disaggregating the CO_2 emission is to determine the extent to which the preference for linear, squared or cubic function is sensitive to whether the CO_2 emission is aggregated or disaggregated. Depending on the empirical outcome of equation (3.32), the preferred model would then be extended to include the role of energy consumption (EC) as shown below.

$$CO_{2t} = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + EC_t + \varepsilon_t \qquad (3.33)$$

The EC in the extended carbon emission function in equation (3.33) will be reflected via different energy-mix earlier defined to include ENC, ENU and EPC. Each of these measures of energy consumption will be captured singly in the extended model. Another version of the extended model as depicted in equation (3.34) captures the role of some fundamentals namely, financial development (FD), foreign direct investment and population growth (POP).

$$CO_{2t} = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + Z_t + \varepsilon_t \qquad (3.34)$$

where the term Z_t represent each of the fundamentals individually in the CO_2 emission function. The variables in the Z_t vector include health outcomes, financial development (FD) and foreign direct investment (FDI). The FD has dual potential of stimulating the increase of carbon emissions as well as promoting its reduction on the other hand. This can be viewed from the FD features of wealth and scale effects. For the wealth effect, the prosperity of the financial market can allow customers to obtain wealth and capital more conveniently, which would satisfy the needs of the customers for energy consumption products and encourage them to purchase more cars, houses and so on, which would obviously increase carbon emissions. Meanwhile, the expansion of financial development and the capital market is beneficial for the expansion of the production scale of enterprises and marketing activities, which encourages the adoption of financing to build new production lines and purchase large-scale equipment to expand production. Thus, the scale effect of financial development on carbon emissions is clear.

The FD can also have a technological and structural effect on carbon emissions because the financial development and prosperity of a capital market can attract more foreign direct investment with high technology and more investment for research and development, promoting technological advancement and curbing carbon emissions in local regions. At the same time, a developed financial market prefers investment in environmentally friendly projects, which can offer more convenient financing and motivation for new projects and facilities that have the advantages of energy conservation and emission reduction or market potential. Therefore, the industry and energy structure can be enhanced, and the structural effect of financial development on carbon emissions is apparent, which could promote the development of a low-carbon economy. Consequently, there is ambiguity in the effect of financial development and CO_2 emission.

Also, FDI is considered as an important driving force of economic development such that rapid FDI inflows are likely to stimulate more productive activities which are likely to bring about higher pollution activities. High population growth (POP) is also predicted as possible of leading to increasing demand for energy and consequently fossil fuel emission. Thus, in addition to economic growth and energy consumption, we will also control for the direct effect of these variables namely, financial development and population growth on CO_2 emissions. Depicted in Table 3.1 are the apriori expectations.

It can be seen that the EKC is only one of various possible numerical outcomes for equation (3.33), namely outcome 4 in Table 3.1, which occurs when we find that $\beta_1>0$, $\beta_2<0$ and $\beta_3 = 0$. Using (4.411), the turning point or threshold level of per capita income can be calculated as (assuming $\frac{dy_i}{dx_i}=0$). $x^* = -\frac{\beta_1}{2\beta_2}$ or in logarithmic term $x^* = e^{\frac{\beta_1}{2\beta_2}}$. For computational purposes, all variables are expressed in logs.

3.4 Estimation Technique

The empirical analysis of the study entails establishing the stationarity of the variables and estimating the long-run demand model for carbon emission using the ARDL and the NARDL model. Thereafter, we will proceed to estimate the long- and short-run elasticities using the ARDL and NARDL with or without the endogenous structural breaks.

3.4.1 The Unit Root

The unit root test is conducted to investigate the order of integration of the variables. The Dickey-Fuller Test with GLS Detrending (DFGLS) and Ng-Perron tests are employed. The DFGLS is a simple modification of the Augmented Dickey-Fuller (ADF) test in which the data are detrended so that explanatory variables are taken out of the data prior to running the test regression. Ng and Perron (2001) construct four test statistics that are based upon the GLS detrended data y_t^d. These test statistics are modified forms of Phillips-Perron MZ_α and MZ_t statistics, the Sargan-Bhargava test statistic (MSB), and the ERS Point Optimal test statistic (MPT). The two unit roots tests are not sensitive to the choice of the lag length.

Table 3.1: A-Priori Expectation

	Values of coefficients β_i	Relationship between income per capita (Y) and CO_2 emissions per capita
1	$\beta_1 = \beta_2 = \beta_3 = 0$	No relationship
2	$\beta_1 > 0 \, and \, \beta_2 = \beta_3 = 0$	A monotonically increasing or linear relationship
3	$\beta_1 < 0 \, and \, \beta_2 = \beta_3 = 0$	A monotonically decreasing relationship
4	$\beta_1 > 0, \beta_2 < 0, \beta_3 = 0$	An inverted-U-shaped relationship (KC)
5	$\beta_1 < 0, \beta_2 > 0, \beta_3 = 0$	A U-shaped relationship
6	$\beta_1 > \beta_2 < \beta_3 > 0$	An N-shaped relationship
7	$\beta_1 = \beta_2 = \beta_3 = 0$	An inverted-N-shaped relationship
8	$\beta_4 > 0$	The higher the choice of fossil fuels in energy consumption, the higher the carbon emission.
9	$\beta_5 < 0$	Higher FDI inflows will require higher energy consumption which generates higher CO_2 emission
10	$\beta_6 > 0$ or $\beta_6 < 0$	There is ambiguity in the effect of financial development on CO_2 emission.
11	$\beta_7 > 0$	Higher POP will require higher energy consumption which generates higher CO_2 emission

Note: $\beta_1 - \beta_7$ are parameters that provide information on the magnitude and direction of impact of the independent variable on the dependent variable.

3.4.2 The ARDL co-integration approach

To examine the long-run relation among the variables, we employ the use of the ARDL bounds test co-integration approach developed by Pesaran and Shin (1999) and further extended by Pesaran *et al*. (2001). The technique is largely preferred by economist and econometricians due to its flexibility, as it permits co-integration modelling even when all variables are stationary in levels [I(0)], after the first difference [I(1)] or a mix of the two. Again, the bounds test co-integration approach provides robust long-run estimates even in the presence of some endogenous variables in the model (Narayan, 2005). Finally, unlike the conventional techniques such as the Johansen co-integration approach, the bounds test is capable of giving robust results even when the sample size is small. Hence, these advantages make the adoption of the ARDL approach suitable in investigating the long-run impact of CO_2 emission, energy consumption and economic growth in Nigeria. Using the bounds test approach, the following unrestricted error correction model will be estimated through OLS method.

$$\Delta \ln CO_{2t} = \alpha + \sum_{i=1}^{p}\lambda_{1i}\Delta \ln CO_{2t-i} + \sum_{i=0}^{q}\lambda_{2i}\Delta \ln Y_{t-i} + \sum_{i=0}^{r}\lambda_{3i}\Delta \ln Y^2_{t-i} + \sum_{i=0}^{r}\lambda_{4i}\Delta \ln Y^3_{t-i} + \sum_{i=0}^{v}\lambda_{5i}\Delta X_{t-i} + \varphi_1 \ln CO_{2t-1} + \varphi_2 \ln Y_{t-1} + \varphi_3 \ln Y^2_{t-1} + \varphi_4 \ln Y^3_{t-1} + \varphi_5 \ln X_{t-1} + \varepsilon_t \quad (3.35)$$

where the parameters, λ_{mi} for m= 1, 2 . . . 5, represent the short-run dynamics in the model while the long-run relationships are given by φ_i. The term X_t is a vector controlling for the different energy-mix and other fundamentals which were estimated singly in the extended model. To determine the long-run relationship between the regressand and regressors, the ARDL bounds test approach requires estimating equation (10) and restricting the parameters of the lag level (long run) variables to zero. Hence we test the null hypothesis (no co-integration) $H_0 : \varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = \varphi_5 = 0$ against the alternative hypothesis of co-integration. The hypothesis is tested using the *F*-test. The computed *F*-statistic is then compared with the Pesaran *et al*. (2001) asymptotic critical value bounds to ascertain the existence of a long-run relationship (co-integration). The null hypothesis of no co-integration is accepted if the computed *F*-statistic is less than the lower bounds and vice versa. The decision, however, remains inconclusive, if *F*-statistics lies between lower and upper critical bounds. Thus, in the event of a level relationship among the variables, the resulting long-run model can be estimated as:

$$\ln CO_{2t} = \phi_0 + \phi_1 \ln Y_{t-1} + \phi_2 \ln Y^2_{t-1} + \phi_3 \ln Y^3_{t-1} + \phi_4 \ln X_{t-1} + v_t \quad (3.36)$$

The concluding step of the bounds test is to estimate the short-run elasticities which is obtained via the error correction framework represented by equation (3.37):

$$\Delta \ln CO_{2t} = \delta_1 + \xi_{ect} ECT_{t-1} + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^{q} \lambda_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{r} \lambda_{3i} \Delta \ln X_{t-i} + \eta_t \quad (3.37)$$

where ECT_{t-1} is the error correction term while ξ_{ect} is the coefficient which captures the speed of adjustment of the model to its long-run equilibrium. In other words, ξ_{ect} captures the rate of correction at time t of deviation from the long-run equilibrium at time $t-1$.

3.4.3 The NARDL co-integration approach

While the ARDL technique enables the evaluation of the long-run and short-run interactions of the variables, they presume symmetric relations between CO_2 emission and its determinants. Recently, Shin et al. (2014) advance a nonlinear ARDL cointegration approach (NARDL) as an asymmetric extension to the well-known ARDL model of Pesaran and Shin (1999) and Pesaran et al. (2001), to capture both long run and short run asymmetries in a variable of interest. Hence, we also adopt this modeling approach for our purpose. To begin, we specify the following asymmetric long-run equation CO_2 emission (Shin et al., 2014):

$$\ln CO_{2t} = \phi_0 + \phi_1 \ln Y_t^{+} + \phi_1 \ln Y_t^{-} + \phi_2 \ln X_t + v_t$$

(3.38)

where the variables are as earlier defined. The variables Y_t^{+} and Y_t^{-} are partial sums of positive and negative changes in Y_t , respectively. They are defined as:

$$Y_t^{+} = \sum_{i=1}^{t} \Delta Y_i^{+} = \sum \max(\Delta Y_i, 0) \quad (3.39a)$$

and

$$Y_t^{-} = \sum_{i=1}^{t} \Delta Y_i^{-} = \sum \min(\Delta Y_i, 0) \quad (3.39b)$$

Consequently, the long run relation as represented by (3.38) reflects asymmetric long-run economic growth pass-through to CO_2 emission. As shown in Shin et al. (2014), equation (3.38) can be framed in an ARDL setting along the line of Pesaran and Shin (1999) and Pesaran et al. (2001) as:

$$\ln CO_{2t} = \alpha + \phi_0 \ln CO_{2t-1} + \phi_1 \ln Y_{t-1}^{+} + \phi_2 \ln Y_{t-1}^{-} + \phi_3 \ln X_{t-1} + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^{q_1} \theta_{2i}^{+} \Delta Y_{t-1}^{+} + \sum_{i=0}^{q_2} \theta_{2i}^{-} \Delta Y_{t-1}^{-} + \sum_{i=0}^{q_3} \lambda_{3i} \Delta \ln X_{t-i} + \mu_t \quad (3.40)$$

where all variables are as defined above, p and q are lag orders and $\gamma_1 = -\phi_1 / \phi_0$, $\gamma_2 = -\phi_2 / \phi_0$ are the aforementioned long run impacts of respectively per capita income increase and per capita income decrease on CO_2 emission. Also, $\sum_{i=0}^{q_1} \theta_{2i}^{+} \Delta Y_{t-1}^{+}$ measures the short-run influences of per capita income increases on CO_2 emission while $\sum_{i=0}^{q_2} \theta_{2i}^{-} \Delta Y_{t-1}^{-}$ measures the short run influences of per capita income decreases on CO_2 emission. Hence, in addition to the asymmetric long run relation, the asymmetric short-run influences of per capita income changes on CO_2 emission are also captured.

Following Katrakilidis and Trachanas (2012), we adopt the general-to-specific procedure to arrive at the final specification of the NARDL model by trimming insignificant lags. In addition, based on the estimated NARDL, we perform a test for the presence of cointegration among the variables using a bounds testing approach of Pesaran et al. (2001) and Shin et al. (2011). This involves the *Wald F* test of the null hypothesis, $\phi_0 = \phi_1 = \phi_2 = \phi_3 = 0$. In the final step, with the presence of cointegration, we can also derive the asymmetric cumulative dynamic multiplier effects of a one percent change in Y_{t-1}^{+} and Y_{t-1}^{-} respectively as:

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial CO_{2t+j}}{\partial Y_{t-1}^{+}}, \quad \sum_{j=0}^{h} \frac{\partial CO_{2t+j}}{\partial Y_{t-1}^{-}}, \qquad h = 0,1,2,\ldots \quad (3.41)$$

Note that as $h \to \infty,\ m_h^{+} \to \phi_3 \ and \ m_h^{-} \to \phi_4$

To account for the potential of structural shift in the CO_2 –economic growth relationship, we extend ARDL model in equation (3.35) to include endogenous structural breaks follows:

$$\Delta \ln CO_{2t} = \alpha + \sum_{i=1}^{p} \lambda_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^{q} \lambda_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{r} \lambda_{3i} \Delta \ln Y_{t-i}^{2} + \sum_{i=0}^{r} \lambda_{4i} \Delta \ln Y_{t-i}^{3} + \sum_{i=0}^{v} \lambda_{5i} \Delta X_{t-i} + \varphi_1 \ln CO_{2t-1} + \varphi_2 \ln Y_{t-1} + \varphi_3 \ln Y_{t-1}^{2} + \varphi_4 \ln Y_{t-1}^{3} + \varphi_5 \ln X_{t-1} + \sum_{r=1}^{k} D_r B_{rt} + \varepsilon_t \quad (3.42)$$

As shown in equation (3.42), the break(s) are captured with the inclusion of $\sum_{r=1}^{k} D_r B_{rt}$ where B_{rt} is a dummy variable for each of the breaks defined as $B_{rt} = 1$ for $t \geq T_{B_r}$, otherwise $B_{rt} = 0$. The time period is represented by t; T_{B_r} are the structural break dates where $r = 1, 2, 3, \ldots, k$ and D_r is the coefficient of the break dummy. All the other parameters have been previously defined.

3.4.4 Toda and Yamamoto Causality

Taking cognizance of the ambiguity regarding the direction of relationship between the health indicators (life expectancy (LE) and death rate (DR)) and CO2 emission, this study further complement the single equation –based techniques explored so far with a multivariate –based estimation technique. Unlike the ARDL or NARDL, the multivariate model namely, vector autoregression (VAR) allows for all variable to be treated as endogenous and therefore, there is no a priori distinction between endogenous and exogenous variables. Essentially, we favour a VAR model with the Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) [TYDL; henceforth] causality testing approach to determine the direction of relationship between CO_2 emission and the health indicators under consideration namely, life expectancy (LE) and death rate (DR).

Greater carbon dioxide emissions are associated with more air pollution, which leads to health issues involving the lungs, heart and cardiopulmonary system (Davidson 2003). Countries with higher levels of carbon dioxide emissions would also likely tolerate higher levels of other harmful chemicals and pollutants, further increasing the risk of health problems among its citizens (Balan, 2016). Thus, we would expect that as carbon dioxide emissions increases, life expectancy will decrease and there is potential of death rate increasing. There is also, the likelihood of healthy population constituting robust economic activity and consequently increasing carbon dioxide. It is this ambiguity of apriori regarding the direction of relationship between CO_2 emission and health issue that motivated our preference for causality testing technique.

Although, there are others approaches to implement causality testing in the literature including a VAR model in the level data; a VAR model in the first difference data (VARD); and a vector error correction model (VECM). But the simulation results by Yamada and Toda (1998) suggests the TYDL is relatively the more stable when compared to these listed alternative causality procedures. The main rationale behind TYDL is to artificially augment the correct VAR order, say *k*, with d_{max} extra lags, where d_{max} is the maximum likely order of integration of the series contained in the system. In the case of this present study however, we follow the TYDL framework and the given lag augmented VAR (k + dmax) for CO_2 emission –economic growth nexus as below.

$$
\begin{aligned}
CO_{2t} &= \alpha_0 + \sum_{i=1}^{k}\alpha_{1i}CO_{2t-i} + \sum_{j=k+1}^{k+d_{max}}\alpha_{2j}CO_{2t-j} + \sum_{i=1}^{k}\beta_{1i}LE_{t-i} + \sum_{j=k+1}^{k+d_{max}}\beta_{2j}LE_{t-j} + \sum_{i=1}^{k}\lambda_{1i}DR_{t-i} + \sum_{j=k+1}^{k+d_{max}}\lambda_{2j}DR_{t-j} + \varepsilon_{1t} \\
LE_t &= \beta_0 + \sum_{i=1}^{k}\beta_{1i}LE_{t-i} + \sum_{j=k+1}^{k+d_{max}}\beta_{2j}LE_{2t-j} + \sum_{i=1}^{k}\alpha_{1i}CO_{2t-i} + \sum_{j=k+1}^{k+d_{max}}\alpha_{2j}CO_{2t-j} + \sum_{i=1}^{k}\lambda_{1i}DR_{t-i} + \sum_{j=k+1}^{k+d_{max}}\lambda_{2j}DR_{t-j} + \varepsilon_{2t} \qquad (3.43) \\
DR_t &= \lambda_0 + \sum_{i=1}^{k}\lambda_{1i}LE_{t-i} + \sum_{j=k+1}^{k+d_{max}}\lambda_{2j}LE_{2t-j} + \sum_{i=1}^{k}\alpha_{1i}CO_{2t-i} + \sum_{j=k+1}^{k+d_{max}}\alpha_{2j}CO_{2t-j} + \sum_{i=1}^{k}\beta_{1i}DR_{t-i} + \sum_{j=k+1}^{k+d_{max}}\beta_{2j}DR_{t-j} + \varepsilon_{3t}
\end{aligned}
$$

The multivariate VAR model in equation (3.43) would be considered where the two series are different orders of integration says I(0) and I(1) which is the case in the context of this study. The VAR specification can be further re-represented in matrix form as follows:

$$
\begin{bmatrix} CO_{2t} \\ LE_t \\ DR_t \end{bmatrix} = \begin{bmatrix} \delta_{10} \\ \delta_{20} \\ \delta_{30} \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{11,i} & \delta_{12,i} & \delta_{13,i} \\ \delta_{21,i} & \delta_{22,i} & \delta_{23,i} \\ \delta_{31,i} & \delta_{32,i} & \delta_{33,i} \end{bmatrix} \begin{bmatrix} CO_{2t-i} \\ LE_{t-i} \\ DR_{t-i} \end{bmatrix} + \sum_{j=1}^{d_{max}} \begin{bmatrix} \delta_{11,k+j} & \delta_{12,k+j} & \delta_{13,k+j} \\ \delta_{21,k+j} & \delta_{22,k+j} & \delta_{23,k+j} \\ \delta_{31,k+j} & \delta_{32,k+j} & \delta_{33,k+j} \end{bmatrix} \begin{bmatrix} CO_{2t-k-j} \\ LE_{t-k-j} \\ DR_{t-k-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{CO_2} \\ \varepsilon_{LE} \\ \varepsilon_{DR} \end{bmatrix} \qquad (4.44)
$$

The above three variables TYDL VAR approach modified the original bivariate form of Toda and Yamamoto (1995) to accommodate our variables of interest, where *k* represents optimal lag length determined using SIC while d_{max} is the maximum order of integration. The direction of causality running from CO_2 to life expectancy (LE), from CO_2 to death rate (DR) and so on can be established through rejecting the null hypothesis which requires finding the significance of the Modified Wald (MWald) statistics for the group of the lagged independent variables identified above.

$H_{01}: \delta_{12,1} = \delta_{12,2} = ... = \delta_{12,k} = 0,$ implies that LE does not granger cause CO_2 emission.

$H_{02}: \delta_{21,1} = \delta_{21,2} = ... = \delta_{21,k} = 0,$ implies that CO_2 emission does not granger cause LE.

$H_{03}: \delta_{13,1} = \delta_{13,2} = ... = \delta_{13,k} = 0,$ implies that DR does not granger cause CO2 emission.

$H_{04}: \delta_{31,1} = \delta_{31,2} = ... = \delta_{31,k} = 0,$ implies that CO_2 emission does not granger cause DR.

3.5 Data

Based on the empirical specification, annual time series was collected for Nigeria between 1970 and 2016. Gross domestic product per capita at constant price of 2005 expressed in US dollar serves as a proxy for real income per capita (Y_t). Health outcomes (HE_t) is measured as Life expectancy (LE) at birth, total (years), and Death rate (DR). Financial development (FD) is measured as Broad money (% of GDP). Foreign direct investment (FDI) is measured as foreign direct investment, net inflows (% of GDP). Energy consumption (EC) is measured as fossil fuel energy consumption (ENC) % of total. Nevertheless, the robustness of the energy consumption indicator was tested with energy use (ENU) kg of oil equivalent per capita and electric power consumption (EPC) kWh per capita.

The CO_2 emission is measured as CO_2 emissions (metric tons per capita) (defined as Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. We also considered disaggregated CO_2 emission to include emission from coal, gas and petroleum respectively. These are explicitly measured as CO_2 emissions from solid fuel consumption (kt) (defined as Carbon dioxide emissions from solid fuel consumption refer mainly to emissions from use of coal as an energy source); CO_2 emissions from liquid fuel consumption (kt) (defined as Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source); and CO_2 emissions from gaseous fuel consumption (kt) (defined as Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of natural gas as an energy source). All the data were sourced from the World Bank's World Development Indicator.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

In this chapter we present our results. The results of the CO_2 – economic growth relationship models in the context of asymmetries, structural shifts and causality are presented and discussed. The policy implications of the empirical results are also brought into focus.

4.2 Preliminary Analysis

Following the standard practice in the literature, the pre-estimation stage of empirical analysis is usually divided into two, namely; informal preliminary analysis and formal pre-estimation analysis. The former in the context of the present study involves summary statistics and/or descriptive analysis as well as graphical illustration of the data employed in the analysis. Thereafter, the second stage of the preliminary analysis involves testing for the unit root of the series under consideration.

4.2.1 Descriptive Statistics

The descriptive statistics, reported in Table 4.1, includes the mean, the maximum, the minimum and the corresponding standard deviation statistic of the variables. The distributional properties of the variables are also examined via skewness and kurtosis statistics, while the Jarque-Bera test statistic is used to test for normality in the distribution. All the variables in the summary statistics table are expressed in their level form with the GDP per capita averaging 1,686 at constant US$ for the period under consideration. Consequently, the mean value for the squared and cubic value of the real GDP per capita are US$3,005 and US$5,640,000 respectively. Confirming the indication of high magnitude of spread between the maximum and minimum statistics is the corresponding high values of standard deviation statistics. However, the standard deviation statistics for the individual variables cannot be compared in absolute term and that is because they are expressed in varying unit of measurement.

For the purpose of comparison, the standard deviation statistics are normalized and a look at Table 4.1 shows that the cubic GDP per capita and the aggregated CO_2 per capita are the most volatile. This is given their relative higher value of standard deviation statistics when compared to other variables in the table except the FDI

Table 4.1: Descriptive/Summary Statistics

Statistics	Main Variable						
	Y	Y^2	Y^3	Greenhouse Gases Variable			
				CO_2	COAL	PET	GAS
Mean	1721	3005	5640000	0.64	233.06	26602.05	11185.74
Maximum	2563	6569	1680000 0	0.67	139.35	29471.68	9845.90
Minimum	1151	1325	1530000	1.01	858.08	39775.95	33131.35
Std-Dv.	406	1454	4070000	0.33	7.33	5496.83	212.69
Normalize Std-Dv.	0.24	0.48	0.72	0.52	0.03	0.21	0.02
Skewness	0.48	0.76	1.07	-0.11	1.27	-0.86	0.77
Kurtosis	2.03	2.57	3.32	1.99	3.31	2.36	2.78
J-Berra	3.47 (0.18)	4.69 (0.10)	8.81 (0.01)	1.99 (0.37)	12.22 (0.00)	6.32 (0.04)	4.56 (0.10)

Statistics	Control Variable							
	Energy Series			Other Series				
	ENC	ENU	EPC	LE	DR	FD	FDI	POP
Mean	17.64	691.80	87.39	46.39	18.16	22.59	2.65	30.70
Maximum	22.84	798.30	156.73	52.54	22.81	43.27	10.83	46.94
Minimum	5.00	572.74	24.41	40.97	13.07	10.04	-1.15	17.76
Std-Dv.	4.49	55.92	34.30	2.74	2.42	7.23	2.17	8.77
Normalize Std-Dv.	0.25	0.08	0.39	0.06	0.13	0.32	0.82	0.29
Skewness	-1.51	-0.35	0.15	0.40	-0.29	0.49	1.77	0.20
Kurtosis	4.37	2.60	2.38	3.04	2.74	3.27	7.04	1.87
J-Berra	20.55 (0.00)	1.24 (0.54)	0.87 (0.65)	1.18 (0.56)	0.74 (0.69)	1.95 (0.38)	54.06 (0.00)	2.67 (0.26)

Source: Author's Computation

Note: Std-Dv. denotes standard deviation statistic while the normalize standard deviation is computed as: standard deviation/mean variable. With respect to the statistical distribution of the variables, all the GDP per capita series appears to be positively skewed, but mixed for the greenhouse gas variables and the macroeconomic series under consideration. The kurtosis statistics is equally mixed such that its platykurtic for the linear and squared GDP per capita but leptokurtic for cubic and virtually all the measures for the greenhouse gas but the coal. Similarly, the kurtosis statistic is mixed for the energy consumption series as well as the various macroeconomic variables considered.

On the whole, the computed probability values associated with the Jarque-Bera normality test statistic appears to be less than 0.05 for the case of cubic GDP per capita, COAL, PET, ENC and FDI. This findings therefore suggests the rejection of the hypothesis that the series are normally distributed at 5% level of significance. On the other hand, the probability value appears to be larger in the case of other variables namely, GDP, GDP^2, CO_2, GAS, ENU, EPC, LE, DR and POP thus implying the non-rejection of the null hypothesis of normality in the respect of each of these series.

4.2.2 Graphical Illustrations

In this section, the study examined the possibility of co-movement between economic growth measured as GDP per capita and CO_2 emission. Quite an interesting observation in Figure 4.1 is the potential of both positive and negative co-movements between the economic growth and CO_2 emission. A cursory look at the Figure shows that both the aggregate CO_2 emission and economic growth appears to be moving in the same direction in the period between 1970 and 1987, but the movement was however found to be in the opposite direction between 1988 and 2016. For the disaggregated CO_2 emission, a further look at the Figure shows that the co-movement is mostly in the same direction between the economic growth and the emission from solid fuel until 2003 when both variables appear to be moving in the opposite direction.

In the case of emission from gaseous fuel and economic growth, the co-movement appears to be wholly in the opposite direction for the entire period under consideration. Except for the period between 1987 and 2003, the co-movement between the economic growth and emission from liquid fuel appears to be potentially negative. Although, these illustrations of mixed evidence of co-movements between economic growth and CO_2 gives little or no statistical credence to the wide spread hypothesis of squared or quadratic economic growth–CO_2 relationship, it however, strengthens our argument for the possible role of asymmetries in the relationship.

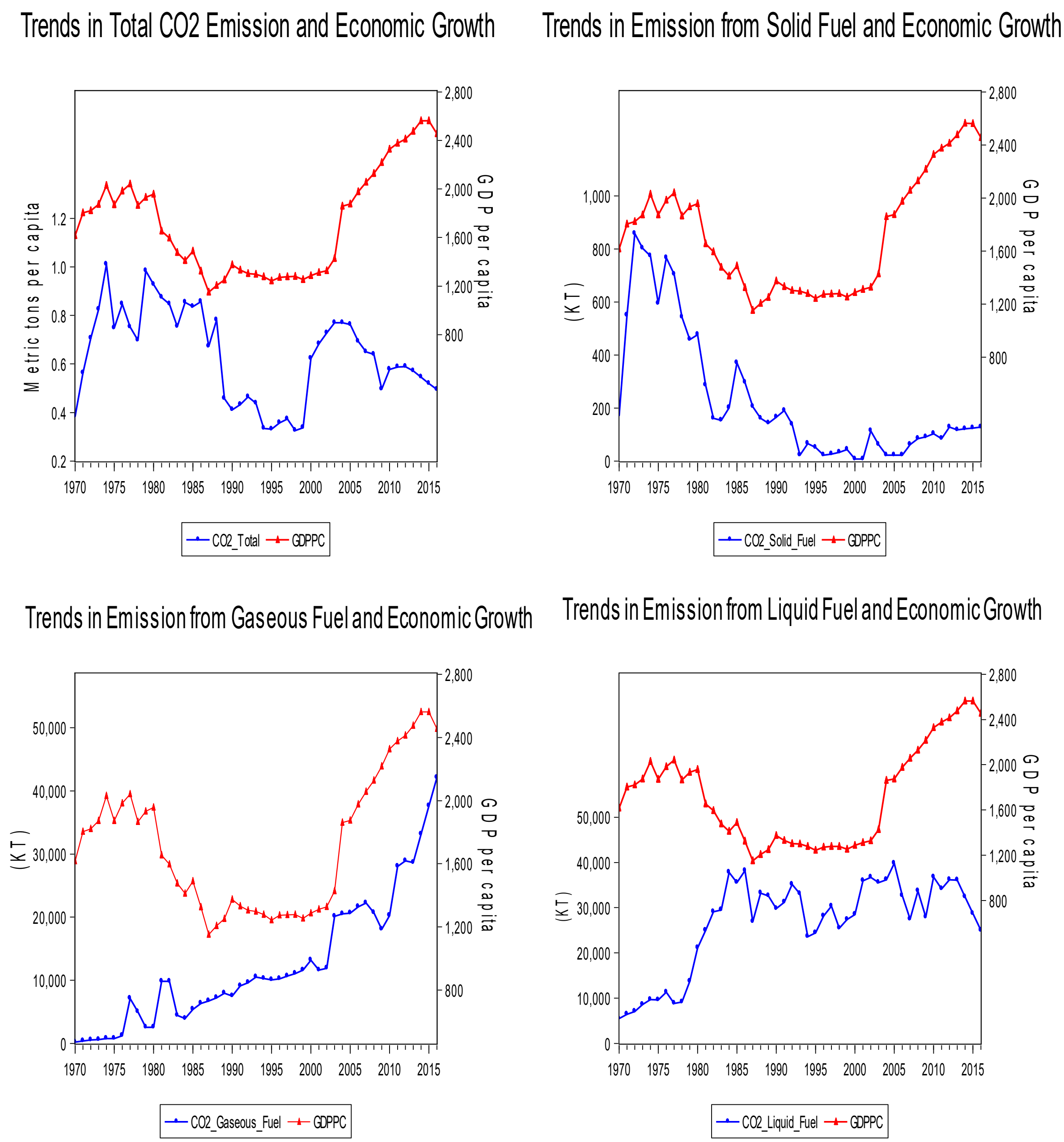

Figure 4.1: Trends in Economic Growth and CO_2 Emission

4.2.3 Unit Root Tests

This section presents the results of the unit root tests. This is to establish the standard inference procedure by identifying and categorizing the stationary and non-stationary variables. For robustness and consistence purpose, we consider a number of unit root tests. These are Augmented Dickey-Fuller (ADF) test, Dickey-Fuller GLS test, Ng-Perron test, and Kwiatkwoski-Phillips-Schmidt-Shin Unit Root (KPSS) test. Each of these tests were carried out with only the constant restriction and constant and trends restriction. It is instructive to note that, in each of these specification (i.e. the estimation with constant or the estimation with constant and trend), the unit root test are performed on the natural logarithm of the series, except with energy consumption (ENC) which was measured as fossil fuel energy consumption (% of total), financial development (FD) measured as broad money (% of GDP), foreign direct investment (FDI) measured as FDI net inflows (% of GDP), and population (POP) measured as urban population (% of total). This is because these variables are already in percentages.

Table 4.2 presents the result of the ADF unit root test. Noteworthy in the Table is the non-rejection of the null hypothesis of unit root for all the variants of economic growth series and the aggregated CO_2 series. The results is however, mixed in the case of the disaggregated CO_2 series, where the null hypothesis of unit root is failed to be rejected in the case of emission from solid fuel consumption (COAL), but rejected in the case of gaseous fuel consumption and liquid fuel consumption, respectively. To put it differently, while the variable on emission from solid fuel consumption appears to exhibit higher order of integration (i.e. I(1)), the gaseous fuel consumption and the liquid fuel consumption are both on the other hand integrated of order zero (i.e. I(0)). Equally evident in Table 4.2 is the stationarity test rest results which swing around I(0) and I(1) for the energy consumption variables namely, ENC, ENU and EPC as well as the macroeconomic series.

Despite the importance of the ADF as the workhorse of unit root test in the literature, the low power associated with the ADF null against the stationary alternative, particularly when trend is included in the specification has been the major shortcoming of the ADF test. Thus, Eliott, Rothenberg and Stock (1996) proposed an extension to the conventional ADF and the outcome of the augmented ADF test which has come to be known as DF-GLS show a significant greater power than the traditional ADF.

Table 4.2: ADF Unit Root Test Results

Variable	Model with Constant			Model with Constant & Trend		
	Level	First Difference	I(d)	Level	First Difference	I(d)
Y	-0.2877	-5.7375***	I(1)	-0.6504	-6.0590***	I(1)
Y^2	-0.2877	-5.7375***	I(1)	-0.6504	-6.0590***	I(1)
Y^3	-0.2877	-5.7375***	I(1)	-0.6504	-6.0590***	I(1)
CO_2	-2.2066	-6.8597***	I(1)	-2.7040	-6.7922***	I(1)
COAL	-1.4229	-8.1463***	I(1)	-0.9271	-8.2165***	I(1)
PET	-2.9234**	-	I(0)	-1.7671	-6.9278***	I(1)
GAS	-3.0780***	-	I(0)	-3.3125*	-	I(0)
ENC	-3.3172**	-	I(0)	-2.4770	-5.7695***	I(1)
ENU	-2.4633	-5.2402***	I(1)	-2.4581	-5.5341***	I(1)
EPC	-2.4661	-9.0633***	I(1)	-3.3328*	-	I(0)
LE	-2.2782**	-	I(0)	-0.5500	-2.5067**	I(1)
DR	-5.2627***	-	I(0)	1.1690	-7.8331***	I(1)
FD	-2.8322*	-	I(0)	-2.7030	-6.0471***	I(1)
FDI	-3.6580***	-	I(0)	-3.6363**	-	I(0)
POP	-3.3470**	-	I(0)	0.6981	-2.6982	I(1)

Note: The exogenous lags are selected based on Schwarz info criteria, while ****, **, * imply that the series is stationary at 1%, 5% and 10% respectively. ADF represent Augmented Dickey-Fuller. The null hypothesis for ADF is that an observable time series is not stationary (i.e. has unit root).

Consequently, in the addition to the ADF test, the DF-GLS and other alternative unit root tests were considered to complement or provide robustness to the ADF result. Table 4.3 present the DF-GLS unit root test results. Evidently, the economic growth variable remains non-stationary and only integrated at higher order of integration. Also, the DF-GLS result of mixed order of integration, particularly in the case of aggregated CO_2 is consistent with the ADF result. However, unlike the ADF test, where the unit root results hovered around I(0) and I(1) for energy consumption series, the results are mainly I(1) for the various energy consumption series when the stationarity test is DF-GLS, but still mixed for the macroeconomic variables irrespective of the unit root test.

Similar to DF-GLS, Ng and Perron (2001) modify ADF unit root tests by using a more accurate method for selecting lag length and therefore solve the size and power problems usually encountered with the ADF tests. Hence, in what appears to be consistent with our finding so far, the unit root test results using Ng-Perron test yet confirm the order of integration hovered around I(0) and I(1). A look at Table 4.4 shows that the null hypothesis of unit root cannot be rejected for the economic growth series, the greenhouse gas variable and the energy consumption series. The result is however, otherwise for FD, FDI and POP but with varying level of significance irrespective of whether the model is with constant or constant and trend.

However, unlike the three unit root tests consider so far, the Kwiatkowski, Phillips, Schmidt and Shin (1992), the KPSS unit root test is based on the null hypothesis of stationarity around a trend against the unit root alternative. This is opposite to the non-stationarity null hypothesis of the ADF, DF-GLS and Ng-Perron where the null hypothesis is that the series has unit root. To strengthening our stationarity test results, we further conducted the KPSS stationarity test and the result is presented in Table 5.5. An interesting finding in the Table is the fact that the stationarity or otherwise of the variables seems to be sensitive to whether the KPSS test is performed with constant or with constant and trend. For example, while the null hypothesis of stationarity consistently holds for all the variables when the KPSS is implemented with constant and trend, the result is mixed when the test only include constant.

Table 4.3: DF-GLS Unit Root Test Results

Variable	Model with Constant			Model with Constant & Trend		
	Level	First Difference	I(d)	Level	First Difference	I(d)
Y	-0.3563	-4.4828***	I(1)	-0.7600	-5.1178***	I(1)
Y^2	-0.3563	-4.4828***	I(1)	-0.7600	-5.1178***	I(1)
Y^3	-0.3563	-4.4828***	I(1)	-0.7600	-5.1178***	I(1)
CO_2	-2.0833	-2.3476**	I(1)	-1.7192*	-	I(0)
COAL	-1.3355	-3.7785**	I(1)	-1.3340	-3.4344**	I(1)
PET	-0.8464	-6.0577***	I(1)	-1.7877	-7.0546***	I(1)
GAS	0.5811	-1.7076*	I(1)	-1.2248	-8.5502***	I(1)
ENC	-0.7064	-5.2753***	I(1)	-1.3730	-5.8937***	I(1)
ENU	-0.4601	-5.2961***	I(1)	-1.6024	-5.6428***	I(1)
EPC	-0.3134	-7.9033***	I(1)	-2.3833	-9.2510***	I(1)
LE	-1.5950	-3.9879**	I(1)	-1.0253	-3.8167**	I(1)
DR	0.9499	-2.2108**	I(1)	-5.9140***	-	I(0)
FD	-2.0770**	-	I(0)	-2.5026	-6.1252***	I(1)
FDI	-3.5774***	-	I(0)	-3.6363**	-	I(0)
POP	1.7212	-5.3908***	I(1)	0.2988	-5.8923***	I(1)

Note: The exogenous lags are selected based on Schwarz info criteria while ****, **, * imply that the series is stationary at 1%, 5% and 10% respectively. DF-GLS represent Dickey-Fuller GLS. The null hypothesis for DF-GLS is that an observable time series is not stationary (i.e. has unit root).

Table 4.4: NP Unit Root Test Results

Variable	Model with Constant			Model with Constant & Trend		
	Level	First Difference	I(d)	Level	First Difference	I(d)
Y	-0.3492	-3.0449***	I(1)	-0.7342	-3.1918**	I(1)
Y^2	-0.3492	-3.0449***	I(1)	-0.7342	-3.1918**	I(1)
Y^3	-0.3492	-3.0449***	I(1)	-0.7342	-3.1918**	I(1)
CO_2	-1.5671	-2.0390**	I(1)	-1.7582	-3.2784**	I(1)
COAL	-1.0678	-4.5159***	I(1)	-1.2336	-4.8059***	I(1)
PET	-0.4680	-3.2814***	I(1)	-0.9215	-3.3419**	I(1)
GAS	1.0074	-3.1597**	I(1)	-1.0730	-6.4657***	I(1)
ENC	0.0863	-3.1784***	I(1)	-2.5787	-3.1756**	I(1)
ENU	-1.3153	-3.2039***	I(1)	-0.0388	-3.2859**	I(1)
EPC	0.1064***	-	I(0)	-1.9267	-3.1722**	I(1)
LE	-1.3597	-3.8332***	I(1)	-1.5902	-3.4910***	I(1)
DR	1.91354	-9.0227***	I(1)	1.4976	-7.1684***	I(1)
FD	-1.8452*	-	I(0)	-2.1508	-3.3406**	I(1)
FDI	-2.8093***	-	I(0)	-2.8639*	-	I(0)
POP	-8.6123***	-	I(0)	- 6.0417***	-	I(0)

Note: The exogenous lags are selected based on Schwarz info criteria while ****, **, * imply that the series is stationary at 1%, 5% and 10% respectively. NP represents Ng and Perron. The null hypothesis for NP is that an observable time series is not stationary (i.e. has unit root).

Table 4.5: KPSS Unit Root Test Results

Variable	Model with Constant			Model with Constant & Trend		
	Level	First Difference	I(d)	Level	First Difference	I(d)
Y	0.2650***	-	I(0)	0.2086***	-	I(0)
Y^2	0.2650***	-	I(0)	0.2086***	-	I(0)
Y^3	0.2650***	-	I(0)	0.2086***	-	I(0)
CO_2	0.2196 ***	-	I(0)	0.0981***	-	I(0)
COAL	0.5583***	-	I(0)	0.1693***	-	I(0)
PET	0.5780***	-	I(0)	0.1870***	-	I(0)
GAS	0.8106	0.3156***	I(1)	0.1766***	-	I(0)
ENC	0.4040***	-	I(0)	0.1774***	-	I(0)
ENU	0.8016	0.2626***	I(1)	0.1379***	-	I(0)
EPC	0.7884	0.2733***	I(1)	0.1344***	-	I(0)
LE	0.1101***	-	I(0)	0.1039***	-	I(0)
DR	0.7891	0.2818***	I(1)	0.1446***	-	I(0)
FD	0.1392***	-	I(0)	0.1080***	-	I(0)
FDI	0.2210***	-	I(0)	0.1510***	-	I(0)
POP	0.8925	0.6362***	I(1)	0.1924***	-	I(0)

Note: The exogenous lags are selected based on Schwarz info criteria while ****, **, * imply that the series is stationary at 1%, 5% and 10% respectively. KPSS represent Kwiatkwoski-Phillips-Schmidt-Shin Unit Root tests. The null hypothesis for KPSS test is that the series is stationary.

4.2.3.1 Unit Root with Structural Breaks

On the whole, the testing of the unit roots of a series is a precondition to the existence of cointegration relationship. Therefore, each of the aforementioned conventional unit root tests are widely used to test for stationarity. However, Perron (1989) showed that failure to allow for an existing break leads to a bias that reduces the ability to reject a false unit root null hypothesis. To overcome this, Perron proposed allowing for a known or exogenous structural break in the unit root test. Consequently, we extend the unit root test to include the Perron (2006) unit root test that accounts for structural breaks.

Table 4.6 show the result of the unit root test conducted using the Perron (2006) test which allows for the inclusion of structural breaks in the data series. In the table, after the first column which contains the name of the series, the second and third columns are sub-divided into three columns each. The first sub-column provides the break date while the second and third sub-columns contain the coefficient and the test statistics, respectively. Based on the reported test statistics, we cannot reject the significance of breaks in the unit root, particularly for both the aggregated and disaggregated CO_2 emission series. The significance of structural breaks in the unit root also holds for life expectancy (LE) and FDI series in level. For GDP per capita, ENC, ENU, EPC as well as FD, the presence of structural break in these series only become evident when the series are differenced. This mixed evidence of order of intergration of the unit root with structural break as represented in the fourth column tend to conform with our earlier reports with respect to the conventional unit root test where the order of integration fluctuated between I(0) and I(1).

4.3 Empirical Result and Discussion

The carbon dioxide –economic growth model specified in Equation (3.32) of Chapter Four can be estimated either in levels or in log form of the variables. However, the choice to estimate the model with the variables expressed in log form is in line with Cole et al. (1997), where it was argued that it is preferable to estimate the model in log form. Acheampong (2018) as well as Bouznit and Pablo-Romero (2016) are some of the recent studies that have also estimated the CO_2 –economic growth model with their variables expressed in natural logarithm. In the context of the present study, we introduce time trend in the estimated models in order to capture the effects on CO_2 emission that is caused by technological progress. Thus, the study presents the

Table 4.6: Results for Unit Root Test with Structural Break

Variable	Level			First Difference			Order of Integration
	Break Date	*Coefficient*	*T-stat*	*Break Date*	*Coefficient*	*T-stat*	*I(d)*
Y	2002	-0.2370	-3.8355	2002	-0.9864	-7.3236***	I(1)
CO_2	1998	-0.4342	-5.7762***	Not applicable			I(0)
COAL	1998	-0.8471	-5.7006***	Not applicable			I(0)
PET	1977	-0.4188	-5.1422**	Not applicable			I(0)
GAS	1975	-1.0145	-7.5418***	Not applicable			I(0)
ENC	1975	-0.3221	-3.723	1980	-1.0511	-6.6703***	I(1)
ENU	1982	-0.3546	-2.6750	1992	-0.9002	-6.2596***	I(1)
EPC	1993	-0.4809	-4.1849	2000	-1.4355	-10.2457***	I(1)
LE	2012	-1.7483	-16.4686***	Not applicable			I(0)
DR	2002	-0.0989	-4.0318	1978	0.1214	-3.5560	I(0)
FD	1985	-0.4826	-3.6395	2008	-0.8445	-6.8943***	I(1)
FDI	1987	-0.8312	-5.5223***	Not applicable			I(0)
POP	2012	-0.0215	-0.2642	1989	-1.3960	-2.2773	NIL

Note: The break points/dates as well as the stationarity property of the series using Perron (2006) test are determined via appropriate Critical values from Table 1(e) model 2 in Perron (1997), which are -5.28 and -4.6 for 1% and 5% level of significance, respectively.

empirical estimates from the log-linear, log-quadratic, and log-cubic version of the variants CO_2 –economic growth models.

4.3.1 Aggregated CO_2 and Economic Growth Relationship

The empirical estimates in Table 4.7 only relate the CO_2 emission to GDP per capita across three different functional relationships earlier specified, i.e. the linear, the squared and the cubic functions. In each of these specifications, the accuracy of the estimated models was evaluated, via a number of post estimation and/or diagnostic tests such as: serial correlation test (using correlogram Q-statistic and the squared version) and heteroscedasticity test (using ARCH LM test). Other tests are the adjusted R-square and the F-statistic to measures the explanatory powers and the joint significant of the independent variable included in the models. The bound cointegration F-statistic test in the Table is meant to determine the long run dynamic of the CO_2 and economic growth relationship. In addition, the Ramsey RESET test confirms the linearity of the model, while the Q-statistic, Q^2-statistic and the ARCH-LM test consistently reject the null hypothesis of autocorrelation and heteroscedasticity, respectively across the three functions.

Given that the empirical estimates obtained from the various estimated functions are efficient and robust for policy inference, the next step is to evaluate the economic and empirical implications of the regression results. On the bound cointegration testing results, the decision on whether to reject the null hypothesis of no long run relationship appears to be statistically unclear in both the squared and cubic estimation with the F-statistic hovering between the upper and lower bounds of the critical values at 10% level of significance. The hypothesis of no cointegration is however, significantly rejected when the GDP per capita is linearly expressed in the specification. The implication of this result is that the certainty of probable long run relationship between the CO_2 emission and economic growth is only statistically viable when the function is linear.

A cursory look at Table 4.7 shows that only the coefficient on GDP per capita exhibit the potential of causing increasing CO_2 emission both in the linear and squared models as well as across the short and long run situations. Starting with the short run estimates, in the level of GDP is 1.17% in the model with squared GDP per capita. However, the

Table 4.7: ARDL Estimates on Aggregate Carbon Dioxide –GDP per capita Relationship

	Linear Model			Squared Model			Cubic Model		
Short-Run	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*
Constant	-1.5709*	0.8625	-1.8212	-8.3035	4.7678	-1.7415	-22.4593	20.7078	-1.0845
Trend	-0.0052**	0.0021	-2.4267	-0.0030	0.0026	-1.1497	-0.0030	0.0026	-1.1475
ΔCO_{2t-1}	-0.2937***	0.0897	-3.2730	-0.3258***	0.0914	-3.5640	-0.3257***	0.0919	-3.5409
ΔY_t	0.2095*	0.1164	1.7997	1.1748*	0.6823	1.7217	3.3133	3.1197	1.0620
ΔY_t^2				-1.58E-07	1.10E-07	-1.4351	-1.16E-06	1.43E-06	-0.8112
ΔY_t^3							2.37E-10	3.38E-10	0.7027
ECM_t	-0.2937***	0.0818	-3.9728	-3.5882***	0.0820	-3.9728	-0.3257***	0.0801	-4.0661
Long-Run									
Y_t	0.7132**	0.3632	1.9632	3.6060*	2.0248	1.7808	10.1729	9.8149	1.0364
Y_t^2				-4.86E-07	3.33E-07	-1.4604	-3.57E-06	4.49E-06	-0.7937
Y_t^3							7.28E-10	1.06E-09	0.6890
Turning Point				**3,709,876.54**					
Bound Test Cointegration Results									
Level of Significance	**Linear Model**			**Model**			**Cubic Model**		
	F-stat	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	3.5043	2.63	3.35	2.8760	2.37	3.20	2.4494	2.20	3.09
5%		3.10	3.87		2.79	3.67		2.56	3.49
1%		4.13	5.00		3.65	4.66		3.29	4.37

Diagnostic and Post-Estimation Results

Model	***Adj-R2***	***F-stat.***	***Linearity test*** Ramsey RESET	***Autocorrelation test*** Q-Stat.	Q^2-Stat.	**ARCH-LM test**
Linear	0.72	39.6423***	0.7561 (0.3896)	1.4237 (0.491)	1.4237 (0.491)	0.0171 (0.9830)
Quadratic	0.72	30.9968***	NA	0.6340 (0.728)	0.6340 (0.728)	0.0665 (0.9357)
Cubic	0.72	24.5900***	NA	0.2992 (0.861)	0.2992 (0.861)	0.1338 (0.8751)

Note: The value in parenthesis represent the probability values for the various post estimation tests performance, ***, ** and * represent 1%, 5% and 10% level of significance, while the term NA means not applicable.

magnitude of the variance in production related to CO_2 emission appears to be more pronounced in the long run. For 1% percent long run increase in the level of GDP is likely to be responsible for 0.71% and 3.61% of the emission of CO_2 in the linear model and the model with squared GDP per capita, respectively. On the whole, the empirical evidence reported in Table 4.7 shows that the estimated coefficient on the income variable (i.e. GDP per capita) has a positive sign both in the linear and squared model, thus implying a linear relationship (monotonically increasing) among income and emissions. This by implication suggests that the EKC hypothesis does not hold in the case of Nigeria at least for the period under consideration. This is consistent with the reports of Aye and Edoja (2017), Ahmed, Rehman and Ozturk (2017), Aslanidis and Iranzo (2009), among others.

Given the fact that coefficient on GDP per capita in the cubic function appears to be consistently insignificant in both the short and long run situations, we therefore, follows the Shafik and Bandyopadhyay (1992) testing procedure to drop the cubic term in our subsequent analysis. The turning point calculated as: $x^* = -\frac{\beta_1}{2\beta_2}$ or in logarithmic term $x^* = -\frac{\beta_1}{e2\beta_2}$ though occurs outside the U-shaped relation at 3.71$ billion per capita income based on the long run coefficient in the squared model, yet it cannot be interpreted as monotonically decreasing relationship because the coefficient on Y_t^2 is not significant. Thus, the squared term is equally dropped thereby strengthening our earlier findings that the relationship between the CO_2 emission and economic growth is linear in the case of Nigeria. This in particularly, is an indication that of the various apriori expectations listed in Table 4.1, applicable to Nigeria case is the hypothesis of monotonically increasing or linear relationship which is number 2 on the Table. Our findings is similar to that of Mikayilov, Galeotti and Hasanov (2018), Lapinskienė and Peleckis (2017), Stern (2004) and Dinda (2004) all of which opines that previous EKC studies have failed to provide clear and inclusive findings on the inverted U-shaped relationship, the hypothesis of which is listed as number 4 in the table of a priori expectation.

To ascertain the robustness and reliability of our findings, we further disaggregated the emission variable into three different components including emission from solid fuel

(COAL), emission from liquid fuel (Petroleum: PET), and emission from gaseous fuel (GAS). In each of these disaggregated measures of CO_2 emission, we examine the CO_2 – economic growth relationship across the linear, quadratic and cubic functions, respectively.

This which is an extension of the study's first objective also constitutes one of the main innovations of this study, particularly in the context of the Nigerian economy. Song, Zheng and Tong (2008), using the case of China, is one of the previous studies that also disaggregated CO_2 emission into solid, water and gas sources in their analysis of CO_2 emission and economic growth relationship. The underlying intuition for the disaggregation of CO_2 emission into different sources of pollutants is to determine which of these sources of green-house emission is relatively more responsive to economic activity and whether they react differently to short and long run economic situations.

4.3.2 Disaggregated CO_2 and Economic Growth Relationship

A cursory look at Table 4.8 through to Table 4.10 shows that the null hypothesis of no cointegration is consistently rejected across the three variants of the disaggregated CO_2 emission and irrespective of whether the function is linear, quadratic or cubic. To this end, we estimated both the short and long run specifications of each of the disaggregated pollutants for linear, squared and cubic GDP per capita. Starting with the empirical estimates in Table 4.8, where the CO_2 is measure as emission from solid fuel, we find significant and probable positive impact of GDP per capita on CO_2 with 1% change in the level of GDP per capita capable of increasing emission from solid fuel by 1.60% and 2.96% in the short and long situations, respectively. Again and similar to our earlier findings, the portion of emission from solid fuel that is due to increasing per capita income is likely to be higher in the long run compared to short run situation.

Even though, the squared GDP per capita exhibit significant impact on emission from solid fuel both in the short and long run which is contrary to what is obtainable when the CO_2 emission is aggregated, but the fact that the relationship is positive yet confirmed the robustness of our earlier findings that the CO_2–economic growth relationship is linear in the case of Nigerian economy. The fact that the coefficient on Y^2 is positive in the squared model contradicts any of the known EKC hypotheses listed in Table 3.1.

Table 4.8: ARDL Estimates on Emission from Solid Fuel -GDP per capita Relationship

	Linear Model			Squared Model			Cubic Model		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	-8.3196**	3.0958	-2.6873	29.4333*	17.3855	1.6929	13.0478	72.3042	0.1804
Trend	-0.0418***	0.0118	-3.5327	-0.0690***	0.0167	-4.1219	-0.0691***	0.0169	-4.0791
ΔCO_{2t-1}	-0.5404***	0.1251	-4.3193	-0.6942***	0.1386	-5.0089	-0.6952***	0.1402	-4.9556
ΔY_t	1.6033***	0.4823	3.3239	-3.7010	2.4508	-1.5101	-1.2245	10.8858	-0.1124
ΔY_t^2				9.48E-07**	4.30E-07	2.2037	-2.15E-07	5.00E-06	-0.0430
ΔY_t^3							2.75E-10	1.18E-09	0.2336
ECM_t	-0.5404***	0.1186	-4.5552	-0.6942***	0.1299	-5.3421	-0.6952***	0.1299	-5.3515
Long-Run									
Y_t	2.9666***	0.7129	4.1609	-5.3307	3.2612	-1.6345	-1.7613	15.6398	-0.1126
Y_t^2				1.37E-06**	5.37E-07	2.5439	-3.09E-07	7.19E-06	-0.0430
Y_t^3							3.96E-10	1.70E-09	0.2337
Turning Point				**1,945,510.95**					
Bound Test Cointegration Results									
Level of Significance	**Linear Model**			**Squared Model**			**Cubic Model**		
	F-stat	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	4.8417	2.63	3.35	5.2003	2.38	3.20	4.2427	2.20	3.09
5%		3.10	3.87		2.79	3.67		2.56	3.49
1%		4.13	5.00		3.65	4.68		3.29	4.37

Diagnostic and Post-Estimation Results

			Linearity test	***Autocorrelation test***		
Model	***Adj-R2***	***F-stat.***	**Ramsey RESET**	**Q-Stat.**	**Q^2-Stat.**	**ARCH-LM test**
Linear	0.76	49.7484***	0.0136 (0.9075)	5.9333 (0.051)	5.9333 (0.051)	6.6930 (0.0031)
Quadratic	0.78	41.9514***	NA	7.4240 (0.024)	7.4240 (0.024)	3.8752 (0.0287)
Cubic	0.77	32.7982***	NA	7.2482 (0.027)	7.2482 (0.027)	3.8500 (0.0294)

Note: The value in parenthesis represent the probability values for the various post estimation tests performance, ***, ** and * represent 1%, 5% and 10% level of significance, while the term NA means not applicable

Table 4.9: ARDL Estimates on Emission from Liquid Fuel –GDP per capita Relationship

	Linear Model			SquaredModel			Cubic Model		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	1.9593	1.6724	1.1715	-3.0095	4.5571	-0.6604	-22.6961	20.0388	-1.1326
Trend	0.0007	0.0037	0.2015	0.0028	0.0041	0.6873	0.0036	0.0042	0.8639
ΔCO_{2t-1}	-0.1421	0.0874	-1.6242	-0.1456	0.0871	-1.6709	-0.1671*	0.0897	-1.8632
ΔY_t	-0.06915	0.1378	-0.5017	0.6499	0.6290	1.0331	3.6563	3.0457	1.2004
ΔY_t^2				-1.21E-07	1.03E-07	-1.1713	-1.54E-06	1.41E-06	-1.0918
ΔY_t^3							3.35E-10	3.32E-10	1.0088
ECM_t	-0.1421***	0.0424	-3.3436	-0.1456***	0.0402	-3.6138	-0.1671***	0.0438	-3.8128
Long-Run									
Y_t	-0.4866	0.7967	-0.6108	4.4626	5.3325	0.8368	21.8760	19.5006	1.1218
Y_t^2				-8.29E-07	8.51E-07	-0.9751	-9.21E-06	8.70E-06	-1.0590
Y_t^3							2.01E-09	2.02E-09	0.9912
Turning Point				NA					

Bound Test Cointegration Results

Level of Significance	Linear Model			SquaredModel			Cubic Model		
	F-stat	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	2.6086	2.63	3.35	2.3798	2.30	3.00	2.1537	2.20	3.09
5%		3.10	3.87		2.79	3.67		2.56	3.49
1%		4.13	5.00		3.65	4.66		3.29	4.37

Diagnostic and Post-Estimation Results

			Linearity test	*Autocorrelation test*		
Model	***Adj-R2***	***F-stat.***	**Ramsey RESET**	**Q-Stat.**	**Q^2-Stat.**	**ARCH-LM test**
Linear	0.90	141.269***	5.5807 (0.0230)	0.0180 (0.991)	0.0180 (0.991)	0.0624 (0.9395)
Quadratic	0.90	107.233***	NA	0.058 (0.971)	0.058 (0.971)	0.0251 (0.9752)
Cubic	0.90	86.0275***	NA	0.1391 (0.933)	0.1391 (0.933)	0.0788 (0.9243)

Note: The value in parenthesis represent the probability values for the various post estimation tests performance, ***, ** and * represent 1%, 5% and 10% level of significance, while the term NA means not applicable

Table 4.10: ARDL Estimates on Emission from Gaseous Fuel -GDP per capita Relationship

	Linear Model			Squared Model			Cubic Model		
Short-Run	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*
Constant	2.9548	2.1627	1.3662	3.9745	9.6969	0.4098	-12.8031	44.6435	-0.2867
Trend	0.0234**	0.0100	2.3450	0.0229**	0.0110	2.0735	0.0234**	0.0112	2.0810
ΔCO_{2t-1}	-0.3359***	0.1012	-3.3162	-0.3349***	0.1028	-3.2567	-0.3400***	0.1047	-3.2455
ΔY_t	-0.0557	0.2431	-0.2291	-0.2032	1.3885	-0.1463	2.3369	6.7417	0.3466
ΔY_t^2				2.48E-08	2.30E-07	0.1079	-1.17E-06	3.10E-06	-0.3761
ΔY_t^3							2.82E-10	7.31E-10	0.3852
ECM_t	-0.3359***	0.0737	-4.5520	-0.3349***	0.0735	-4.5541	-0.3400***	0.0742	-4.5808
Long-Run									
Y_t	-0.1658	0.7043	-0.2354	-0.6066	4.1507	-0.1461	6.8716	19.6717	0.3493
Y_t^2				7.40E-08	6.88E-07	0.1075	-3.43E-06	9.04E-06	-0.3794
Y_t^3							8.28E-10	2.13E-09	0.3883
Turning Point				NA					
Bound Test Cointegration Results									
Level of Significance	Linear Model			SquaredModel			Cubic Model		
	F-stat	*I(0)*	*I(1)*	*F-stat*	*I(0)*	*I(1)*	*F-stat*	*I(0)*	*I(1)*
10%	4.83	2.63	3.35	3.77	2.37	3.20	3.1087	2.20	3.09
5%		3.10	3.87		2.79	3.67		2.46	3.59
1%		4.13	5.00		3.65	4.66		3.29	4.37

Diagnostic and Post-Estimation Results

Model	*Adj-R2*	*F-stat.*	*Linearity test* Ramsey RESET	*Autocorrelation test* Q-Stat.	Q^2-Stat.	ARCH-LM test
Linear	0.91	155.156***	6.8408 (0.0124)	14.378 (0.001)	14.378 (0.001)	1.2027 (0.3107)
Quadratic	0.90	113.631***	NA	14.462 (0.001)	14.462 (0.001)	1.1993 (0.3117)
Cubic	0.90	89.0469***	NA	14.164 (0.001)	14.164 (0.001)	1.1344 (0.3315)

Note: The value in parenthesis represent the probability values for the various post estimation tests performance, ***, ** and * represent 1%, 5% and 10% level of significance, while the term NA means not applicable.

Unlike Table 4.8, the insignificance of coefficients on GDP per capita in Tables 4.9 and 4.10 appears to suggest that neither emission from liquid fuel nor emission from gaseous fuel is significantly due to variation in the level of per capital income and it doesn't matter whether the GDP per capita is expressed in level, squared or cubic. This, therefore, is an indication that emission from solid fuel is relatively more responsive to the level of economic activity or per capita income. Compared to emission from liquid fuel and/or emission from gaseous fuel, the potential of economic activity as the underlying source of CO_2 emission seems statistical viable but only when the emission is from solid fuel.

4.3.3 Controlling for Energy Consumption in CO_2 -Economic Growth Relationship

Given the confirmation of the linear function as the most appropriate specification for evaluating the CO_2 emission – economic growth relationship in comparison to the squared and cubic functions, we thereafter extend the specification to include the role of energy consumption. However, in addition to fossil fuel energy consumption (% of total) the choice of which is mainly motivated by the peculiarity of the Nigerian economy as a crude oil producing and exporting country, other indicators of energy consumption measures considered are energy use (kg of oil equivalent per capita) and electric power consumption (kWh per capita). Thus, Model 1, Model 2 and Model 3 in Table 4.4 capture the role of energy consumptions via each of these measures respectively. Starting with the post estimation and diagnostic tests, all the test statistics indicated by Ramsey RESET test for linearity, correlogram for autocorrelation and ARCH-LM test for heteroscedasticity tends to reject the null hypotheses of no linear relationship, presence of autocorrelation and heteroscedaticity respectively. This suggested that the estimated models are stable and adequate for policy formulation.

On the bound cointegration testing results, the empirical report in Table 4.11 shows that the null hypothesis of no long run relationship holds for Model 1 and Model 2. Hence, the term NA in the table means not available/applicable suggesting that the long run relationship is not evident in a model where energy consumption is measure as ENC or ENU which is the case in Model 1 and Model 2, respectively. However, when the measure for energy consumption is electricity power consumption (EPC) which is the case in Model 3, our bound cointegration result seems to be suggesting there is potential of long

Table 4.11: ARDL Estimates on the role of Energy Consumption in CO_2 -GDP per capita Relationship

	Model 1			**Model 2**			**Model 2**		
Short-Run	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*	*Coefficient*	*SE*	*T-stat.*
Constant	-1.4974	1.3128	-1.1406	-5.5226	6.5401	-0.8444	0.5832	1.2180	0.4788
Trend	-0.0050	0.0034	-1.4857	-0.0087	0.0061	-1.4336	0.0064	0.0053	1.2114
ΔCO_{2t-1}	-0.2895**	0.1073	-2.6978	-0.3254***	0.1043	-3.1203	-0.1755*	0.0984	-1.7822
ΔY_t	0.2011	0.1623	1.2390	0.2420*	0.1288	1.8783	0.1017	0.1192	0.8531
ΔENC_t	-0.0007	0.0102	-0.0750						
ΔENU_t				0.5771	0.9466	0.6096			
ΔEPC_t							-0.3547**	0.1486	-2.3869
ECM_t	NA			NA			-0.1755***	0.0383	-4.5736
Long-Run									
Y_t	NA			NA			0.5797	0.5786	1.0018
ENC_t									
ENU_t									
EPC_t							-2.0208	1.7228	-1.1729
Bound Test Cointegration Results									
Level of Significance	Model_1			Model_2			Model_3		
	F-stat	*I(0)*	*I(1)*	*F-stat*	*I(0)*	*I(1)*	*F-stat*	*I(0)*	*I(1)*
10%	2.34	2.37	3.20	2.44	2.37	3.20	3.81	2.37	3.20
5%		2.79	3.67		2.79	3.67		2.79	3.67
1%		3.65	4.66		3.65	4.66		3.65	4.66

Diagnostic and Post-Estimation Results

	Model_1	Model_2	Model_3
Adj-R^2	0.71	0.71	0.74
F-stat.	29.0292***	29.3798***	34.4815***
Ramsey RESET Test	0.7582 (0.3891)	0.5621 (0.4578)	3.0288 (0.0895)
Q-stat.	1.3079 (0.520)	2.4812 (0.289)	0.3543 (0.838)
Q^2-stat.	1.3079 (0.520)	2.4812 (0.289)	0.3543 (0.838)
ARCH-LM	0.0116 (0.9884)	0.0957 (0.9089)	0.0879 (0.9060)

Note: The energy consumption in model_1 is represented by fossil fuel energy consumption measure as percentage of total, log of kg of oil equivalent per capita in model_2, and log of electric power consumption in kWh per capita in model_3. Value in parenthesis represent the probability values for the various post estimation tests performance, while ***, ** and * denote 1%, 5% and 10% levels of significance. The term NA means not applicable run relationship between the CO_2 emission and economic growth at 5% level of significance. This notwithstanding, we find little or no significant evidence of energy consumption being the underlying source of CO_2 emission that is related to economic activity in Nigeria. That is, when the CO_2 emission-economic growth relationship is extended to include the role of energy consumption, the coefficient on GDP per capita surprisingly exhibit no potential of causing or reducing CO_2 emission not even in the short run situation except when the energy consumption is measured ENU.

The above though might be expected of a crude oil producing economy such as Nigeria, yet an interesting finding is the negative sign of the coefficient on electricity power consumption (EPC), which seems to be suggesting that electricity power consumption is capable of causing decline in the greenhouse emission. Balsalobre, Alvarez and Cantos (2015) as well as Balsalobre-Lorente, Shahbaz, Roubaud and Farhanic (2018) are some of the previous studies that have also acknowledged the potential of electricity power consumption to cause declining CO_2 emission, yet the viability of such in the context of Nigeria economy might depend on whether the electricity is sourced from renewable energy.

4.3.4 Controlling for Financial Development (FD), Foreign Direct Investment (FDI) and Population (POP) in CO_2 -Economic Growth Relationship

Similar to our earlier analysis in the immediate preceding section where the carbon emission function is extended to include variants of energy-mix, the carbon emission estimates in Table 4.12 is equally extended to include financial development (FD), foreign direct investment (FDI) and population (POP) in Model 1, Model 2 and Model 3 respectively. The fact that the fitness and adequacy of the estimates are equally not sensitive to the inclusion of these variables is evident in the post estimation statistics documented in Table 4.12. Essentially, we find the null hypothesis of no linear relationship; presence of autocorrelation and heteroscedasticity to be significantly rejected in Model 1, Model 2 and Model 3, respectively. The Bound cointegration testing results also indicate the rejection of the null hypothesis of no long run relationship when the estimated carbon emission –economic growth model is extended to include FDI and population (POP), but financial development (FD).

However, unlike our earlier findings where we find at least short run significant response of CO_2 emission to changes in the level GDP per capita when the relationship is augmented with energy consumption, the empirical estimates in Table 4.12 seems to be suggesting otherwise. For instance, the coefficient on GDP per capita reported in Table 4.12 seems to exhibit no significant impact on CO_2 emission when the relationship is extended to include the role of FD, FDI and POP, respectively. The fact that this evidence holds for both the short and long run situations is an indication that given the period under consideration, none of these macroeconomic fundamentals has the potential to significantly influence the impact of economic activity on CO_2 emission.

The above though, analyzing the direct response of CO_2 emission to these fundamentals individually, reveal the coefficients on FDI and POP as statistically significant for explaining CO_2 emission in Nigeria. However, the direction, dynamics and magnitude of their impact on CO_2 emission tend to vary. With respect to the direction of their impact, while the CO_2 emission tends to respond negatively to FDI, the relationship is however, positive with respective to population growth (POP). Hypothetically, the negative sign on the coefficient on foreign direct investment (FDI) is an indication that inflow of capital has the potential to reduce CO_2 emission and this is evident both in the short and long run situations. However, while a 1% increase in the inflow of FDI is capable of causing 0.04% decline in CO_2 emission, same magnitude of FDI inflow is likely to reduce the level of CO_2 emission by 0.12% in the long run.

The evidence of positive and significant impact of population (POP) on CO_2 emission mainly holds in the short run. However, when compared to other potential determinants of CO_2 emission including GDP per capita, the magnitude of the coefficient on POP at 8.88% is relatively the highest. Given the status of the investigated economy (i.e. Nigeria) as the most populous black nation in the world, this by indication suggests that high population growth is one of the major sources of carbon emission in Nigeria. This not only conforms to the a priori expectation of positive relationship between population growth and CO_2 emission, but is also in line with a number of the previous studies whose findings suggest that a positive relationship exists between population density and CO2 emissions (see for example, Lin et al, 2015 and Amuakwa-Mensah and Adom, 2017).

Table 4.12: ARDL Estimates on the role of FD, FDI & POP in CO_2 -GDP per capita Relationship

	Model_1			**Model_2**			**Model_3**		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	-1.4274	0.9592	-1.4881	-0.4161	0.8394	-0.4957	-153.3858**	70.2503	-2.1834
Trend	-0.0049**	0.0023	-2.0751	-0.0037*	0.0019	-1.8555	-0.2347**	0.1061	-2.2106
ΔCO_{2t-1}	-0.2753**	0.1042	-2.6425	-0.3455***	0.0814	-4.2427	-0.2170**	0.0931	-2.3305
ΔY_t	0.1950	0.1243	1.5679	0.0599	0.1125	0.5326	0.0535	0.1329	0.4023
ΔFD_t	-0.0015	0.0042	-0.3584						
ΔFDI_t				-0.0414***	0.0120	-3.4369			
ΔPOP_t							8.8881**	4.1125	2.1612
ECM_t	-0.2753***	0.0762	-3.6134	-0.3455***	0.0635	-5.4360	-0.2170***	0.0491	-4.4123
Long-Run									
Y_t	NA			0.1735	0.3155	0.5499	0.2465	0.5633	0.4375
FD_t									
FDI_t				-0.1200***	0.0406	-2.9509			
POP_t							40.9546	30.3635	1.3488
Bound Test Cointegration Results									
Level of Significance	**Model_1**			**Model_2**			**Model_3**		
	F-stat	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	2.38	2.37	3.20	5.38	2.37	3.20	3.54	2.37	3.20
5%		2.79	3.67		2.79	3.67		2.79	3.67
1%		3.65	4.66		3.65	4.66		3.65	4.66

Diagnostic and Post-Estimation Results

	Model_1	**Model_2**	**Model_3**
Adj-R^2	0.7144	0.7776	0.7428
F-stat.	29.1469***	40.3389***	33.4980***
Ramsey RESET Test	0.8312 (0.3674)	2.6452 (0.1117)	3.9804 (0.0529)
Q-stat.	1.2649 (0.531)	1.6626 (0.435)	0.2642 (0.876)
Q^2-stat.	1.2649 (0.531)	1.6626 (0.435)	0.2642 (0.876)
ARCH-LM	0.0175 (0.9826)	0.9612 (0.3909)	0.0133 (0.9868)

Note: Model_1 control for financial development, Model_2 control for foreign direct investment while model_3 control for population. Value in parenthesis represent the probability values for the various post estimation tests performance, while ***, ** and * denote 1%, 5% and 10% level of significance. The term NA means not applicable

4.4 Does Asymmetries Matter in CO_2 –Economic Growth Relationship

The analysis so far has considered the CO_2 emission and economic growth relationship mainly from linear perspective where both positive and negative shocks to economic activity is assume to have had identical (symmetric) impact on CO_2 emission. However, it is possible for the relationship to be asymmetric due to the complexity of economic systems and mechanisms leading to carbon emissions and its determinant. Hence, another important innovations of this study is that we relaxed the conventional assumption of linearity or symmetric to hypothesis that there is non-linear linkages between CO_2 and GDP per capita. Consequently, we explore as reported in the Table 4.13, a multivariate non-linear ARDL (NARDL) of Shin et al. (2014) to test for the potential of non-linearity and the presence of asymmetries in the variance of CO_2 emission that is related to economic activity in Nigeria. For the purpose of a robust comparison between the empirical findings from the linear (symmetric) and non-linear (asymmetric) estimates, our hypothesis of non-linear relationship between CO_2 and economic growth is also tested across the aggregated and disaggregated carbon emissions. Starting with the post estimation testing results, the result indicated that the probability value (*p-value*) associated with the Q-statistic, Q^2-statistic and the ARCH-LM test be reasonable larger than 0.01, 0.05 and 0.10 chosen levels of significance. The only exception was when the carbon dioxide is measured as emission from solid fuel. Contextually, the null hypothesis of autocorrelation and heteroscedasticity are rejected for both the aggregated and disaggregated CO_2 function except where emission from solid fuel is the measure for CO_2.

Given the appropriateness of the estimated NARDL models for both for the aggregated and disaggregated carbon dioxide, the analysis thereafter proceed to test for the evidence of long run relationship between the CO_2 emission and non-linear GDP per capita exploring the bound cointegration testing approach. We found the null hypothesis of no long run relationship to be rejected at 5% level of significance in virtually all the variants of carbon dioxide measures considered. The only exception however, is when the carbon dioxide is measured as emission from liquid fuel.

Table 4.13: NARDL Estimates on CO_2 –GDP per capita Relationship

				Disaggregate								
	Aggregate CO_2			CO_2 Emission from Solid Fuel			CO_2 Emission from Liquid Fuel			CO_2 Emission from Gaseous Fuel		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	0.0641	0.0647	0.9912	3.5418***	0.8670	4.0847	1.3368	0.9519	1.4043	2.6763***	0.7258	3.6869
Trend	0.02706**	0.0135	2.0020	-0.0469	0.0587	-0.7989	0.0143	0.2742	0.7852	0.0044	0.0294	0.1513
ΔCO_{2t-1}	-0.2657***	0.0857	-3.0987	-0.5447***	0.1357	-4.0145	-0.1290	0.1052	-1.2258	-0.3633***	0.1094	-3.3189
ΔY_t^+	0.5955***	0.1501	-1.7005	1.7309	1.5229	1.1365	-0.1451	0.3592	-0.4040	0.4463	0.7699	0.5796
ΔY_t^-	-0.6819**	0.2240	3.0439	1.5412*	0.8553	1.8018	0.0004	0.3338	0.0014	-0.4106	0.5711	-0.7189
ECM_t	-0.2657***	0.0577	-4.5996	-0.5447***	0.1195	-4.5566	-0.1290***	0.0384	-3.3544	-0.3633***	0.0784	-4.6345
Long-Run												
Y_t^+	2.2408**	0.6592	4.3505	3.1773	2.4728	1.2849	**N/A**			1.2281	2.0683	0.5937
Y_t^-	2.5662	2.1290	2.2728	2.8291	1.6983	1.6658				-1.1299	1.4330	-0.7884
Bound Test Cointegration Results												
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	3.85	2.37	3.20	3.78	2.37	3.20	2.05	2.37	3.20	3.91	2.37	3.20
5%		2.79	3.67		2.79	3.67		2.79	3.67		2.79	3.67
1%		3.65	4.66		3.65	4.66		3.65	4.66		3.65	4.66
Wald(W) Test for the Role of Asymmetry in CO_2 -GDP per capita Nexus												
$W_{SR} F-stat$	4.7402**(0.0141)			5.3978***(0.0083)			0.1493(0.8617)			0.2623(0.7705)		
$W_{LR} F-stat$	3.2197*(0.0801)			0.0079(0.9294)			**N/A**			0.5303(0.4706)		
Diagnostic and Post-Estimation Results												
Adj-R^2	0.74			0.75			0.90			0.91		
F-stat.	34.6429***			36.4318***			103.5754***			115.0251***		
Q-stat.	0.3687(0.832)			6.1277(0.047)			0.0348(0.983)			0.4085(0.523)		
Q^2-stat.	0.0034(0.998)			12.322(0.002)			0.1656(0.921)			0.21112 (0.303)		
ARCH-LM	0.0010(0.9989)			6.6808(0.0031)			0.0786(0.9245)			0.9140(0.4089)		

Note: The term W represents Wald restriction test distributed as $\chi(5)$ while subscripts SR denotes short run and *LR* long run. The value in parenthesis represent the probability values for the various post estimation tests performance, ***, ** and * represent 1%, 5% and 10% level of significance, while the term NA means not applicable

One of the main innovations of this study is to test whether asymmetries matter in the CO_2 –economic growth relationship. The Wald statistics in Table 4.13 and their corresponding *p-values* in parenthesis are therefore, meant to evaluate the hypothesis of no asymmetry in the CO_2 –economic growth relationship. The terms W_{SR} and W_{LR} denotes Wald restriction testing for the null hypothesis of no short and long run asymmetries, respectively. Starting with the model with aggregated CO_2 emission, the study showed that the null hypothesis of no asymmetries is rejected both in the short and long run situation at 5% and 10% levels of significance, respectively. For the disaggregated CO_2 emission function, the null hypothesis of no asymmetries is only rejected when the emission is from solid but mainly in the short run.

With respect to the asymmetric coefficients, both the positive and negative changes in GDP per capita tends to exhibit significant impact on CO_2 emission but vary in their direction of impacts. Essentially, the analysis revealed the short run positive impact of increasing GDP per capita on carbon emission. However, negative GDP per capita is likely to cause reduced carbon dioxide. The implication is that a booming economic activity in Nigeria is likely to cause an increase in the emission of carbon dioxide and the reverse is likely the case for the response of CO_2 emission to negative GDP per capita. The magnitude of the asymmetric effects of the economic activity on CO_2 however, appears to be higher in the long run when there is a positive change in GDP per capita. For the disaggregated carbon emission, the analysis revealed that a declining economic activity may result in an increasing carbon dioxide if solid fuel is the source of the emission. The study, however, found no evidence of significance response of CO_2 emission to GDP per capita, particularly when the CO_2 is disaggregated into emission from liquid fuel and gaseous fuel, respectively.

In view of the above, the significance of asymmetries in the CO_2 –economic growth relationship appears to be statistically more evident when the carbon dioxide is aggregated. Hence, to determine the extent to which the consumption of energy matters for the role of asymmetries in the CO_2 –economic growth relationship, this section focus mainly on the aggregated carbon dioxide. Therefore, we extend the aggregated carbon dioxide –based non-linear (asymmetric) function to account for ENC, ENU and EPC in the NARDL model. This is presented in Table 4.14. The empirical estimate from the augmented NARDL, where each of the energy-mix is reflected individually such that; empirical results from the NARDL model with ENC is represented under the column Specification (1), while Specification (2) and Specification (3) represent NARDL model with ENU and EPC, respectively.

Confirming the robustness of the fitness of the augmented NARDL model across each of the individual energy-mix is the post estimation tests, the results from the Q-stat, the Q^2-stat as well as the ARCH-LM test appears to significantly reject the null hypotheses of autocorrelation and heteroscedasticity, respectively. The bound cointegration testing results however further showed that our earlier finding of probable long run relationship between the CO_2 emission and economic growth is robust to ENC, ENU and EPC. In addition, the Wald statistics suggested that augmenting the NARDL with ENC and ENU has the potential for enhancing our hypothesis asymmetries in the CO_2 –economic growth relationship both in the short and long run situations. However, the hypothesis of no asymmetries failed to be rejected when the energy mix in the augmented NARDL is EPC.

Equally confirming the importance of ENC and ENU as the energy-mix that matter for the asymmetric effects of economic activity on CO_2 emission is the fact that coefficient on positive and negative GDP per capita mainly exhibit significant impacts on CO_2 emission when the NARDL model is augmented via ENC and ENU, respectively. More importantly, we find the direction of the impact of asymmetric GDP per capita on CO_2 emission to be robust to those established in the NARDL model that include no role of energy consumption. However, when compared with the magnitude of the asymmetric effects in the model without energy consumption, the asymmetric effects economic activities on CO_2 emission is relative higher in the model with energy consumption.

In addition to the consumption of energy, other fundamentals that have been established in the literature as important in the analysis CO_2 emission–economic growth relationship as discussed earlier: Financial Development (FD), Foreign Direct Investment (FDI) and Population Growth (POP). Hence, the study also extends the NARDL model to capture

Table 4.14: NARDL Estimates on the Role of Energy Consumption in CO_2 -GDP Relationship

	Specification (1)			Specification (2)			Specification (3)		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	-0.0698	0.1568	-0.4455	-11.9782**	6.1324	-1.9532	0.8269	0.7284	1.1351
Trend	0.0298**	0.0138	2.1549	0.0280**	0.0130	2.1452	0.0215	0.0144	1.4882
ΔCO_{2t-1}	-0.3156***	0.1010	-3.1248	-0.3581***	0.0953	-3.7566	-0.2071**	0.1021	-2.0276
ΔY_t^+	0.6213*	0.3517	-1.7663	0.7963**	0.3536	-2.2515	-0.3498	0.4206	-0.8318
ΔY_t^-	-0.8664***	0.2982	2.9050	-0.9679***	0.2610	3.7083	0.4375	0.3226	1.3560
ΔENC_t	0.0098	0.0104	0.9386						
ΔENU_t				1.8779**	0.9562	1.9638			
ΔEPC_t							-0.2079	0.1978	-1.0511
ECM_t	-0.3156***	0.0663	-4.7553	-0.3581***	0.0682	-5.2473	-0.2071***	0.0432	-4.7941
Long-Run									
Y_t^+	1.9682	1.3743	-1.4321	2.2236*	1.1879	-1.8718	-1.6888	2.0980	-0.8049
Y_t^-	2.7445***	0.9977	2.7505	2.7028***	0.8331	3.2441	2.1120	1.4392	1.4674
ENC_t	0.0310	0.0291	1.0670						
ENU_t				5.2436**	2.3237	2.2565			
EPC_t							-1.0037	1.2932	-0.7761
Bound Test Cointegration Results									
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	3.3501	2.20	3.09	4.0792	2.20	3.09	3.4050	2.20	3.09
5%		2.56	3.49		2.56	3.49		2.56	3.49
1%		3.29	4.37		3.29	4.37		3.29	4.37
Wald(W) Test for the Role of Asymmetry in CO_2 -GDP per capita Nexus									
$W_{SR}\ F-stat$	6.7238***(0.0132)			9.6811***(0.0034)			1.2532(0.2696)		
$W_{LR}\ F-stat$	4.4156***(0.0420)			6.4386***(0.0152)			1.2540(0.2695)		
Diagnostic and Post-Estimation Results									
Adj-R^2	0.77			0.76			0.75		
F-stat.	27.8102***			30.4166***			28.0063***		
Q-stat.	0.1406(0.932)			0.2349(0.889)			0.7079(0.702)		
Q^2-stat.	0.1013(0.951)			0.3096(0.857)			0.0251(0.988)		
ARCH-LM	0.0853(0.9582)			0.1233(0.8843)			0.0357(0.9823)		

Note: The term W represents Wald restriction test distributed as $\chi(5)$ while subscripts SR denotes short run and *LR* long run. The values in parenthesis are probability value while ***, ** and * denotes 1%, 5% and 10% levels of significance these fundamentals individually in the analysis of asymmetric effect of GDP per capita on carbon dioxide. Taking an insight from the bound cointegration testing results, Table 4.15 suggested that the null hypothesis of no long run relationship is consistently rejected across all the variants of the NARDL models considered in the analysis. This implies that the probability of the long run relationship between the CO_2 emission and economic growth appears to be robust to Specification (1), Specification (2) and Specification (3), where we controls for FD, FDI and POP in the augmented NARDL model.

Also reported in Table 4.15 is Wald restricted test results and the essence is to test whether our hypothesis of asymmetries in the CO_2 – economic growth relationship is sensitive to the inclusion of these fundamentals as capture in the augmented NARDL models. The study however, find *p-values* associated with both the short and long run Wald statistics to be relatively lower when compared to 5% and 10% levels of significance. This implies that the rejection of the null hypothesis of no asymmetries is evident both in the short and long run situations, particularly when the NARDL model is augmented with FD and POP. For the NARDL model augmented with FDI, the null hypothesis of no asymmetries is only rejected in the short run.

In line with the a-priori expectation on the linkage between CO_2 emission and financial development which has been widely predicted as ambiguous, the study revealed that when FD is included in the model, the coefficient on positive GDP per capita tends to exhibit negative impact on the CO_2 emission while the reverse is the case for the coefficient on negative GDP per capita. It is also interesting to note that in both the short and long run, the CO_2 only respond significantly to negative GDP per capita in the NARDL model that was augmented with FDI and POP, respectively. The sign of the relationship however, suggest that even in the period of declining economic activities and increasing inflow of FDI or rising population, CO_2 emission could increase. This possibility is also evident in the NARDL model augmented with FD but only in the long run.

Table 4.15: NARDL Estimates on the Role of FD, FD and POP in CO_2 -GDP per capita Relationship

	Model_1			Model_2			Model_3		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	0.0462	0.1116	0.4142	0.0849	0.0595	1.4274	0.5143	0.4110	1.2513
Trend	0.0275**	0.0138	1.9826	0.0199	0.0125	1.5877	0.0448**	0.0209	2.1398
ΔCO_{2t-1}	-0.2750***	0.0987	-2.7844	-0.3185***	0.0802	-3.9700	-0.2923***	0.0888	-3.2915
ΔY_t^+	-0.6040*	0.3569	-1.6921	-0.5150	0.3208	-1.6052	-0.4614	0.3695	-1.2488
ΔY_t^-	0.6993***	0.2431	2.8762	0.4267*	0.2212	1.9288	0.7532***	0.2324	3.2400
ΔFD_t	0.0008	0.0041	0.1978						
ΔFDI_t				-0.0363***	0.0120	-3.0278			
ΔPOP_t							-0.0291	0.0262	-1.1090
ECM_t	-0.2750***	0.0597	-4.6066	-0.3185***	0.0528	-6.0265	-0.2923***	0.0607	-4.8156
Long-Run									
Y_t^+	-2.1957	1.6279	-1.3487	-1.6172	1.1843	-1.3655	-1.5784	1.4901	-1.0592
Y_t^-	2.5422**	1.1049	2.3008	1.3399*	0.7735	1.7321	2.5763**	1.0254	2.5124
FD_t	0.0029	0.0146	0.2043						
FDI_t				-0.1141***	0.0421	-2.7077			
POP_t							-0.0995	0.0866	-1.1491
Bound Test Co-integration Results									
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	3.1438	2.20	3.09	5.3805	2.20	3.09	3.4356	2.20	3.09
5%		2.56	3.49		2.56	3.49		2.56	3.49
1%		3.29	4.37		3.29	4.37		3.29	4.37
Wald(W) Test for the Role of Asymmetry in CO_2 -GDP per capita Nexus									
$W_{SR}\ F-stat$	5.6247**(0.0226)			3.6316*(0.0639)			5.2722***(0.0270)		
$W_{LR}\ F-stat$	3.2555*(0.0787)			2.5931(0.1152)			3.0881*(0.0865)		
Diagnostic and Post-Estimation Results									
Adj-R²	0.74			0.79			0.75		
F-stat.	27.0726***			35.0689***			28.1158***		
Q-stat.	0.3679(0.832)			0.0427(0.979)			0.3062(0.858)		
Q²-stat.	0.0106(0.995)			1.6196(0.445)			0.1564(0.925)		
ARCH-LM	0.0089(0.995)			1.3179(0.5174)			0.1249(0.9395)		

Note: The term W represents Wald restriction test distributed as $\chi(5)$ while subscripts SR denotes short run and *LR* long run. The values in parenthesis are probability value while ***, ** and * denotes 1%, 5% and 10% levels of significance

4.5 Does Structural Break Matter in CO_2 –Economic Growth Relationship?

In addition to our understanding of the Nigerian economy being vulnerable to both the internal and external structural shocks, the unit root test results in Table 4.6 suggested there is significant presence of structural breaks as an inherent feature of the series. Ignoring this feature in the analysis of CO_2 emission and economic growth relationship, particularly where it matter may undermine the accuracy of the estimates. However, it is instructive that the structural break date unit root test results in Table 4.6 are series based. To determine a uniform break date(s) for the regression purpose, we further employ the Bai-Perron (2003) regression-based multiple break date test and the result is presented in Table 4.16.

After deriving the appropriate break dates for the CO_2 – economic growth relationship across the different regressions under consideration, the analysis thereafter proceeds to determine the extent to which the identified break dates matters for CO_2 and economic growth relationship in Nigeria represent structural shifts in the economy. Analysing from the empirical results in Table 4.17, the fact that the coefficient on GDP per capita is negative and significant both in the short and long run is an indication that the CO_2 emission and economic growth relationship in Nigeria might be sensitive to structural or policy shifts. For example, prior to the inclusion of structural break in the relationship, the findings mostly suggested that the CO_2 tend to respond increasingly to economic activity in Nigeria both in the booming and declining economic activity periods as further suggested when we account for asymmetries in the relationship.

To put it differently, our finding on the probability of declining carbon emission when structural break is introduced is an indication that a developing economy such as Nigeria should continue in her pursuit of economic growth but in the realm of policy shocks or initiatives that can help mitigate carbon dioxide emission. However, the effectiveness of such policy shift towards mitigating carbon dioxide emission may be sensitive to the underlying source of the emission. For example, when we disaggregated the CO_2 into different components, the study revealed that the coefficient on GDP per capita is positive and significant both in the short and long run especially when the emission is from solid fuel regardless of the inclusion of structural break in the model.

Table 4.16: Bai-Perron (2003) Multiple Structural Break Date Test Results

Model	T_1		T_2		NSB
	$\sup F_T(\ell+1\|\ell)$	**Break Date**	$\sup F_T(\ell+1\|\ell)$	**Break Date**	
CO_2	30.8285	1989	37.4810	2000	2
COAL	27.5408	1993	36.1052	2002	2
GAS	37.7038	1977	78.8089	1983	2
PET	22.8827	1979	9.4107	N/A	1
ENC	40.7649	1989	57.4908	2000	2
ENU	44.0004	1989	46.0664	2000	2
EPC	23.1453	1989	54.1079	2000	2
FD	44.1665	1989	31.2621	2000	2
FDI	40.7635	2000	18.8759	N/A	1
POP	39.6004	1989	24.2027	2000	2

Note: NSB denotes number of significant structural breaks, while $\sup F_T(\ell+1|\ell)$ is the test statistics for the breaks. The critical values for $\sup F_T(\ell+1|\ell)$ at 5% level of significance are 18.23 and 19.91 for T_2 & T_2 or for $\ell = 1, 2$, respectively. NA: Not available.

Presented in Tables 4.18 and 4.19 are the empirical results from the augmented structural break –based linear model in which the analysis controls for energy-mix such as ENC, ENU and EPC on one hand and FD, FDI and POP on another hand. Quite visible in both cases is the clear pronouncement of the long run relationship between the CO_2 and economic growth given the magnitude of the F-statistics when the energy-mix and other fundamentals are included in the structural break –based linear models. However, contrary to the model with asymmetric effects, the analysis found no evidence of statistically significance response of the CO_2 emission to changes in economic activity when energy-mix such ENC, ENU or EPC are included in the model with structural break. This is an indication that the extent to which the consumption of energy affects the impact of economic activity on carbon emission may be sensitive to structural shift.

On the contrary, the findings in Table 4.19 revealed the evidence of negative and significant response of CO_2 emission to GDP per capita when the structural break –based model is augmented with FD and FDI, respectively. This is robust to our earlier findings when these growth fundamentals are employed to augment the asymmetric effect of GDP per capita on carbon dioxide. This implies that accounting for structural breaks matter for the potential of these growth fundamentals to be maximized towards enhancing the reducing effect of economic activity on the emission of carbon dioxide in Nigeria.

4.6 The Health Implications of CO_2 Emission

Given the sensitivity of Toda and Yamamoto Vector Autoregressive (TY-VAR) causality testing approach to the choice of lag length, we started our empirical analysis on the causal relation between CO_2 emission and health with a series of nested likelihood ratio tests on level VARs to determine the optimal lag length (p) prior to performing causality test based on TY-VAR estimates. Employing the Schwarz information criterion (SIC), the optimal lag length, the preferred multivariate model for the analysis is presented in Table 4.13 as VAR (4).

Table 4.17: Empirical Estimates on the Role of Structural Breaks in CO_2 –GDP per capita Relationship

Short-Run	**Aggregate CO_2**			**Disaggregate CO_2**								
				CO_2 Emission from Solid Fuel			**CO_2 Emission from Liquid Fuel**			**CO_2 Emission from Gaseous Fuel**		
	Coefficient	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	1.0949*	0.6301	1.7375	-13.1712***	3.5926	-3.6661	3.3743**	1.3702	2.4626	6.9734***	2.2506	3.0984
Trend	-0.0100***	0.0033	-2.9885	-0.0059	0.0147	-0.4023	-0.0015	0.0030	-0.5008	0.0589***	0.0106	5.5179
ΔCO_{2t-1}	-0.6309***	0.0721	-8.7413	-0.8645***	0.1416	-6.1017	-0.4044***	0.0879	-4.5998	-0.8722***	0.1229	-7.0923
ΔY	-0.1517*	0.0852	-1.7797	2.4762***	0.5538	4.4710	0.0449	0.1128	0.3982	-0.1970	0.2848	-0.6917
$D1$	-0.3996***	0.0822	-4.8576	-1.3293***	0.3857	-3.4463	0.5254***	0.1063	4.9422	1.4702***	0.2627	5.5945
$D2$	0.5470***	0.0753	7.2628	-0.5898***	0.3785	-1.5581	N/A			-0.4405**	0.2243	-1.9635
ECM_t	-0.6309***	0.0601	-10.4970	-0.8645***	0.1360	-6.3535	-0.4044***	0.0624	0.0624	-0.8722***	0.1095	-7.9589
Long-Run												
Y	-0.2404*	0.1371	-1.7540	2.8642***	0.4719	6.0688	0.1111	0.2896	0.3835	-0.2259	0.3283	-0.6882
Bound Test Cointegration Results												
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%		2.63	3.35		2.63	3.35		2.63	3.35		2.63	3.35
5%	22.8512	3.10	3.87	9.3876	3.10	3.87	9.7707	3.10	3.87	14.7312	3.10	3.87
1%		4.13	5.00		4.13	5.00		4.13	5.00		4.13	5.00
Diagnostic and Post-Estimation Results												
Adj-R^2	0.89			0.81			0.93			0.95		
F-stat.	74.1924***			40.8984***			171.1545***			174.7407***		
Q-stat.	1.3063(0.520)			10.732(0.005)			1.8722(0.392)			12.389(0.002)		
Q^2-stat.	0.7497(0.687)			8.8287(0.012)			1.7732(0.412)			23.385(0.000)		
ARCH-LM	0.3724(0.691)			3.3750(0.0440)			0.8823(0.4215)			10.2614(0.0002)		

Note: The values in parenthesis are probability value while ***, ** and * denotes 1%, 5% and 10% levels of significance.

Table 4.18: Empirical Estimates on the Role Energy Consumption with Structural Break in CO_2 -GDP per capita Relationship

	Model_1			**Model_2**			**Model_3**		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	-0.6383	0.7285	-0.8762	-11.9233***	3.6116	-3.3013	0.7660	0.8329	0.9197
Trend	-0.0190***	0.0038	-4.9591	-0.0225***	0.0045	-4.9923	-0.0133**	0.0064	-2.0723
ΔCO_{2t-1}	-0.7927***	0.0772	-10.2651	-0.7700***	0.0737	-10.441	-0.6670***	0.0937	-7.1146
ΔY	0.0398	0.0913	0.4364	-0.0789	0.0771	-1.0224	-0.1449	0.0866	-1.6719
ΔENC_t	0.0224***	0.0061	3.6400						
ΔENU_t				1.9412***	0.5322	3.6471			
ΔEPC_t							0.0742	0.1216	0.6102
$D1$	-0.4060***	0.0719	-5.6393	-0.4331***	0.0725	-5.9722	-0.4032***	0.0831	-4.8510
$D2$	0.6628***	0.0731	9.0578	0.6075***	0.0679	8.9437	0.5802***	0.0933	6.2140
ECM_t	-0.7927***	0.0655	-12.0934	-0.7700***	0.0636	-12.1012	-0.6670***	0.0668	-9.9804
Long-Run									
Y	0.0502	0.1137	0.4419	-0.1024	0.1017	-1.0069	-0.2172	0.1352	-1.6066
ENC_t	0.0283***	0.0066	4.2969						
ENU_t				2.5209***	0.6028	4.1815			
EPC_t							0.1112	0.1728	0.6436
Bound Test Cointegration Results									
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	26.5293	2.37	3.20	26.5637	2.37	3.20	18.0687	2.37	3.20
5%		2.79	3.67		2.79	3.67		2.79	3.67
1%		3.65	4.66		3.65	4.66		3.65	4.66
Diagnostic and Post-Estimation Results									
Adj-R²	0.91			0.91			0.88		
F-stat.	69.6812***			83.0588***			60.9190***		
Q-stat.	1.5541(0.490)			1.4574(0.483)			1.2811(0.527)		
Q²-stat.	1.6897(0.430)			1.4974(0.473)			0.6278(0.731)		
ARCH-LM	1.0391(0.3629)			1.0034(0.375)			0.3418(0.7125)		

Note: The values in parenthesis are probability value while ***, ** and * denotes 1%, 5% and 10% levels of significance.

Table 4.19: Empirical Estimates on the Role of FD, FD, POP and Structural Break in CO_2 -GDP per capita Relationship

	Model_1			Model_2			Model_3		
Short-Run	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***	***Coefficient***	***SE***	***T-stat.***
Constant	1.1679*	0.6865	1.7012	1.2433*	0.6459	1.9247	0.8316	0.6405	1.2984
Trend	-0.0095**	0.0037	-2.5233	-0.0184***	0.0026	-6.8948	0.0095	0.01280	0.7488
ΔCO_{2t-1}	-0.6226***	0.0785	-7.9228	-0.4870***	0.0615	-7.9129	-0.6574***	0.0728	-9.0305
ΔY	-0.1593*	0.0902	-1.7655	-0.1510*	0.0859	-1.7579	-0.0589	0.1021	-0.5767
ΔFD_t	-0.0008	0.0028	-0.2867						
ΔFDI_t				-0.0406***	0.0085	-4.7648			
ΔPOP_t							-0.0276	0.0174	-1.5842
$D1$	-0.4055***	0.0857	-4.7272	0.4866***	0.0750	6.4882	-0.4182***	0.0816	-5.1255
$D2$	0.5428***	0.0776	6.9952	N/A			0.5274***	0.0749	7.0342
ECM_t	-0.6226***	0.0627	-9.9276	-0.4870***	0.0475	-10.2358	-0.6574***	0.0634	-10.3610
Long-Run									
Y	-0.2559*	0.1511	-1.6937	-0.3101	0.1857	-1.6695	-0.0896	0.1567	-0.5716
FD_t	-0.0012	0.0045	-0.2827						
FDI_t				-0.0834***	0.0188	-4.4227			
POP_t							-0.0420	0.0258	-1.6252
Bound Test Cointegration Results									
Level of Significance	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***	***F-stat***	***I(0)***	***I(1)***
10%	17.8780	2.37	3.20	19.0495	2.37	3.20	19.4729	2.37	3.20
5%		2.79	3.67		2.79	3.67		2.79	3.67
1%		3.65	4.66		3.65	4.66		3.65	4.66
Diagnostic and Post-Estimation Results									
Adj-R^2	0.88			0.88			0.89		
F-stat.	60.4221***			73.0379***			64.5787***		
Q-stat.	1.1852(0.533)			2.1293(0.345)			1.3552(0.508)		
Q^2-stat.	0.7555(0.685)			0.8822(0.643)			1.1562(0.561)		
ARCH-LM	0.3929(0.6776)			0.3491(0.7074)			0.6041(0.5513)		

Note: The values in parenthesis are probability value while ***, ** and * denotes 1%, 5% and 10% levels of significance

Nevertheless, to estimate the chosen multivariate VAR(4) model via TYDL causality testing approach, we select the lag length 5 as our maximum order of integration (d_{max}) and this is due to the outcomes of our unit root testing result, where the series order of integration are revealed as mixture of I(0) and I(1). Table 4.21 presents the causality testing results on CO_2 emission –health relationship. For the period under consideration, the causality testing result indicated no evidence significant causal relationship between the CO_2 emission and the health indicators considered. This in particular, contradicts Davidson (2003) assertion that carbon dioxide emissions are associated with more air pollution leading to health issues involving the lungs, heart and cardiopulmonary system. Such lack of causal relationship may yet be attributable to the developing characteristic of the investigated economy where industrialization process of growth and development is still very much at the premature stage.

Table 4.20: VAR Lag Order Selection Criteria

Endogenous Variables: Ln(CO_2) Ln(LE) Ln(DR)
Exogenous Variable: C
Included Observation: **31**

	LR	**FPE**	**AIC**	**SIC**	**HQ**
0	NA	0.000149	-0.29508	-0.16711	-0.24917
1	287.1038	6.51E-08	-8.03651	-7.52464	-7.85285
2	158.7706	7.30E-10	-12.5366	-11.6408	-12.2152
3	71.33839	1.01E-10	-14.535	-13.2553	-14.0758
4	42.63862	3.26E-11	-15.7134	-14.04980*	-15.1165
5	16.43553	2.72E-11	-15.9664	-13.919	-15.2318
6	17.67517*	2.01E-11	-16.3886	-13.9573	-15.5163
7	11.13259	1.98E-11	-16.582	-13.7667	-15.5719
8	10.8924	1.88e-11*	-16.89844*	-13.6993	-15.75061*

* 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

Table 4.21: TYDL VAR Granger Causality Result

Equation Variable	Equation 1	Equation 2	Equation 3
	***Ln*(*CO*₂)**	***Ln*(*LE*)**	***Ln*(*DR*)**
***Ln*(CO_2)**	*D.V*	2.4306 (0.6571)	1.6673 (0.7966)
***Ln*(*LE*)**	6.1948 (0.1851)	*D.V*	49.1574***(0.0000)
***Ln*(*DR*)**	7.0342 (0.1341)	22.2387 (0.0002)	*D.V*

Note: D.V. denotes dependent variable and the probability values are in in parentheses while ***, **, and * indicates significance at 1%, 5% and 10%.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter summarises the main findings of the study, draws conclusions from the findings and offer some policy recommendations.

5.2 Summary of Findings

The increasing emissions of carbon dioxide around the world and the enormous risk of environment degradation associated with it has led to proliferation of both theoretical and empirical literature in attempt to provide the policymakers with evidence –based policy recommendations regarding the dynamics and consequences of increasing CO_2 emission. The vastness of the literature nonetheless, reducing carbon dioxide emissions is still very much a challenge for countries and/or regions across the globe as empirical analysis regarding its determinants are yet characterised by mixed findings. Consequently, there has been no clear definite answer on which factor(s) constitute the main source of CO_2 emissions. To this end, this study contributes to the existing literature on determinants of CO_2 emissions and their influence on it by accounting for the role of energy consumption and other fundamentals in CO_2 emissions –economic growth relationship.

To determine the most appropriate functional form for modeling CO_2 economic – economic growth nexus in the context of Nigerian economy, we propose a baseline model that restricts the determinants of CO_2 emission mainly to linear, squared/quadratic and cubic GDP per capita. Following our finding of mixed order of integration regarding the stationarity property of the series, we then arrived at the choice of ARDL as the most appropriate method for the estimation of the baseline model. Deciphered from the estimation of the baseline model is evidence of linear relationship (monotonically increasing) among income and emissions. This by implication suggests that the EKC hypothesis does not hold for Nigeria over the period under consideration. We further subject the accuracy of this inference to robustness check but yet find the EKC hypothesis not to hold for Nigeria even when we disaggregate the CO_2 into emission from solid fuel, emission from liquid fuel and emission from gaseous fuel.

We further extend the preferred carbon dioxide functional form to include the role of energy consumption but find little or no significant evidence linking the increasing emission of CO_2 to energy consumption except when the energy use (ENU) is measure as kg of oil equivalent per capita. However, our finding of negative response of the CO_2 emission to electricity power consumption (EPC) is an indication that renewable energy if initiated vial electricity consumption has the potential for reducing CO2 emission in Nigeria. On the whole, we find the probable of long relationship between CO2 emission and economic growth as likely to be sensitive to the measure of energy-mix included in the relationship. We also find fundamentals such as financial development, foreign direct investment to have exhibit no significant influence on the extent to which increasing economic activity is likely to cause increasing carbon emission. From the perspective of their respective direct relationship with CO_2 emission, we however, find that inflow of capital (FDI) potentially reduces CO_2 emission in Nigeria but the reverse is case for population growth.

Accounting for nonlinearity in the CO_2 emission –economic growth relationship using NARDL model, we find significant evidence of asymmetries suggesting that the extent to which economic activity in Nigeria constitute CO_2 emission vary for the booming and declining economic periods. However, while we find the null hypothesis of no asymmetries rejected both in the long and short run situations in the case of aggregated CO_2 emission, the hypothesis of no asymmetries in the case of disaggregated CO_2 hold for emissions from liquid fuel and gaseous fuel but solid fuel.

Unlike the model without asymmetries, we find ENC and ENU as the energy-mix that matters for the asymmetric effects of economic activity on CO2 emission, the magnitude of the asymmetric effect seems to be relatively higher in the model without energy-mix. Similar to the energy-mix, we also find financial development and foreign direct investment as important in the asymmetric effect of GDP per capita on CO_2 emission. Finally, we account for the role of structural break in the relationship, and our finding of probable declining carbon emission when structural break is in introduced is an indication that a developing economies such as Nigeria may yet continue in her pursuit of economic growth but in the realm of policy shocks or initiatives that can help mitigate carbon dioxide emission. Nevertheless, the effectiveness or otherwise of such policy shift toward mitigating carbon dioxide emission may yet be sensitive to the underlying source of the emission.

5.3 Recommendations

The findings from this study offer a number of avenues to policymakers in Nigeria on how to strike a balance in their attempt to promote declining CO_2 emission without jeopardizing their mandate of ensuring sustainable economic growth.

- Notwithstanding our finding of monotonically increasing among income and emissions, we yet rooted on our finding of declining response of CO_2 emissions to electricity power consumption to recommend that the country has potential to materialise economic development without causing an increase in CO_2 emissions by encouraging consumption of efficient electricity power.
- On the finding of significant influence of energy-mix namely ENC and ENU, particularly on the asymmetric effect of economic growth on $CO_{2,}$ we recommend that caution must be exercised in the implementation of energy strategies that depends on these variants of energy-mix.
- On the significant evidence of declining response of CO_2 emission to the inflow of FDI, this present study do not explicitly provide any insight on whether such reducing effect of FDI on CO_2 emission hold for other variants of capital flow. Thus, we recommend that policymakers should consider trade action that can help restrict the inflow of capital to only those that can improve the country's quality of environment.
- On the whole, we recommend that the country continue in her pursuit of economic growth as expected of all developing economies but in the realm of policy shocks or initiatives that can help mitigate emissions of carbon dioxide.
- Premising on our finding of asymmetric response of CO_2 emission to economic activities, it is expected that the effectiveness of any economic strategy or policy initiated to address problem of carbon emission is likely to vary for the booming and recession periods. To this end, we encourage the concerned authority to be wary of the fact that the one-policy-fit-all approach may not likely work for Nigeria especially in the quest to reduce carbon emission across different episodes of economic cycle.

- The finding of significant role of structural breaks in the relationship is an indication that any policy initiative geared at tackling excess emission of CO_2 cannot be in isolation of institutional knowledge of important episodes of structural and/or policy shift.

5.4 Conclusion

Given the period under consideration coupled with the above empirical findings, it is only rationale therefore, to infer as follows: First, the EKC hypothesis did not hold for the Nigerian economy, hence the preference for the linear functional form as the most appropriate for evaluating CO_2 –economic growth relationship in Nigeria. Second, the potential of energy-mix as well as macro fundamentals such as FD, FDI and POP to induces or mitigate emissions of carbon dioxide tends to vary for the booming and declining economic periods thus justifying the importance of asymmetries when modelling CO_2 –economic growth relationship in Nigeria. Third, the significance of the energy-mix and other fundamentals considered also vary along the short and long run dynamics of the CO_2–economic growth relationship. Finally, the finding of significant role of structural breaks in the relationship suggests institutional knowledge of structural and/or policy shift cannot be ignored in the analysis of CO_2 and economic growth relationship in Nigeria.

5.5 Contribution to Knowledge

Objective 1: Empirically analyze the effects of economic growth, energy consumption on CO2 emissions at the aggregate and disaggregated level in Nigeria.

From the empirical results, we arrived at the linear function as the most appropriate for analyzing the carbon emission–economic relationship at least in the context of Nigerian economy. Deciphered from this is the fact the EKC hypothesis do not hold for the case of Nigeria at least for the period under consideration and not even when the carbon emission is disaggregated into sub-component such as emissions from solid fuel, liquid fuel and/or gaseous fuel. Thus, of all the EKC relationship listed in Table 4.1., it is only the hypothesis of monotonically increasing or linear relationship listed as number 2 that consistently hold for Nigeria. That said, we find the consumption of electricity power as well as the inflow of capital from abroad as capable of causing declining carbon emission, but the reverse is case for population growth.

Objective 2: Empirically establish the asymmetric effects of economic growth, energy consumption on CO2 emissions.

This objective is achieved by partitioning the GDP per capita variable into positive and negative and inn return explore the non-linear variant of ARDL (i.e. NARDL) to show that asymmetries matter in the responsiveness of carbon emission to economic activities, but mainly when the carbon emission is disaggregated into different sub-components. Estimates from the extended NARDL model further reveal energy mix such as ENC and ENU as well as macroeconomic fundamentals including FD and FDI as important in the extent to which asymmetries matter for the CO2 emission and economic growth relationship.

Objective 3: Determine the extent to which structural breaks and policy shift influence carbon emission and –economic growth relationship in Nigeria.

To achieve this objective, we considered a unit root with structural break in order to scientifically and endogenously determine the shift date using Perron (2003, 2006) tests. Notable in the respect of this objective is our finding of probable declining carbon emission when structural break is in introduced in the model. But the effectiveness or otherwise of such policy shift toward mitigating carbon emission seems to be sensitive to the underlying source of the emission.

Objective 4: Empirically evaluate the health effect of carbon emission in Nigeria.

The essence of this objective is to offer new insight on the health implications of carbon emissions in Nigeria. However, the empirical estimates as obtained from the implementation causality testing based on TYDL framework prove no evidence of significant causal relationship between the CO2 emission and the health indicators considered. This however, may not be unconnected the developing characteristic of the investigated economy where industrialization process of growth and development is still very much at the premature stage.

5.6 Limitations of Study

It must be pointed out that most of the activities capable of causing increasing carbon emission are often undergone at household level. One of the main limitations of this study therefore, hinges on its inability to validate the accuracy of some of its findings at household level.

5.7 Suggestion for Future Research

Future studies can focus on the extent to which some of the findings of this study hold at micro level using household level data.

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