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**AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN
ECONOMIC GROWTH, ENERGY CONSUMPTION, AND THE
ENVIRONMENT: EVIDENCE FROM NIGERIA**

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PHD

2023

**AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN ECONOMIC
GROWTH, ENERGY CONSUMPTION, AND THE ENVIRONMENT:
EVIDENCE FROM NIGERIA**

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ABSTRACT

Ahmad Ahmad

An Investigation into the Relationship Between Economic Growth, Energy Consumption, and the Environment: Evidence from Nigeria.

Keywords: Economic growth, energy consumption, environment, ARDL, OLS, Toda-Yamamoto, Nigeria.

This thesis employs the Autoregressive Distributed Lag model (ARDL), Toda-Yamamoto causality analysis, and ordinary least square (OLS for robust estimation) techniques to empirically investigate the impact of economic growth and energy consumption on the environment in Nigeria from 1980 to 2020. The results of cointegration demonstrate a long-term link between the model's input variables. The outcome of the first objective of the study shows that trade and economic development in Nigeria worsen the state of the environment. Environmental quality is accelerated by financial development; nevertheless, FDI is proven to be insignificant in predicting environmental quality. The result demonstrates that FDI and energy use both have the potential to significantly speed up the rate of environmental degradation. Nevertheless, trade has a negligible impact on the environment in the country, and financial development slows down environmental deterioration. The study also finds that the combination between energy and economic development improves Nigeria's environmental quality. The outcome of the fourth objective shows that economic expansion and energy consumption have a favorable impact on the environment. Additionally, environmental degradation, energy use, and economic growth are all causally related. Moreover, the outcome of the robust estimation reveals a positive and significant relationship between economic growth and energy consumption in the environment.

Therefore, the study suggests economic policies with environmental control measures. This could be through an emphasis on the use of other alternatives of low-emission energy, that will mitigate the level of CO₂ and enhance energy utilization for a better environment in the nation.

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DEDICATION

This work is dedicated to the blessed memory of my beloved late father Ahmad Yusuf AYM, and my beloved mother HRH Fatima Ado Bayero.

I also dedicate this work to my beloved paternal grandmother Amina Abdullahi Dantata, late maternal grandfather Sheik Usman Bashir, my wife Salma Ahmad Ahmad, and my children Ahmad Ahmad Ahmad, Adam Ahmad Ahmad, and Amina Ahmad Ahmad.

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ABBREVIATIONS

ADF	Augmented Dicky Fuller
AIC	Akaike information criterion
ARDL	Autoregressive Distributed Lag
CO ₂	Carbon dioxide
DW	Durbin-Watson
EKC	Environmental Kuznets Curve
FDI	Foreign Direct Investment
FPI	Foreign Portfolio Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PP	Philips Peron
SC	Schwartz Criterion
SSA	Sub-Saharan Africa
VAR	Vector Autoregressive
VECM	Vector Error Correction

CHAPTER 1: AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN ECONOMIC GROWTH, ENERGY CONSUMPTION, AND THE ENVIRONMENT: EVIDENCE FROM NIGERIA: INTRODUCTION

1.0 Introduction

This chapter provides an introduction to the thesis. It discusses the motivation and states the problem identified. It outlines the objectives and research questions to be addressed by this thesis, as well as the methods to be utilized in achieving the objectives. It also highlights the contribution of the study as well as the structure of the presentation for the rest of the thesis.

1.1 Background of the Study

Environmental concerns brought on by environmental toxins have drawn significant attention from academics and researchers around the globe. Every developed and emerging economy in the world strives for a certain level of economic growth and sustainable development, but achieving this goal is threatened by environmental challenges because of the drastic climate changes and global warming, as well as human efforts to keep the planet habitable for years to come (Alege, 2016). Although rapid economic growth is usually accompanied by increased energy consumption, the past few years have seen a consistent rise in the environmental quality degradation brought on by commercial, industrial, and human activities, including the extraction and utilization of natural resources. Azam (2016) asserts that environmental deterioration is a significant problem that hinders well-being and sustainable economic progress. Health, resources, and natural disasters linked to climate change are all affected by this effect (Azam and

Khan 2017; Azam et al. 2016). When the environment's nature is susceptible to its capacity to damage resources and economic stability, environmental deterioration results (Adeel-farooq, Abu Bakar, and Olajide 2018; Azam et al. 2016).

Energy, along with other factors of production (such as labor and capital) is a vital input and requirement for economic growth (Ghali and El-Sakka 2004). The energy sector contributes to sustained economic growth with its essential products, which are used as inputs in almost all goods and services (World Economic Forum 2012). Since the beginning of industrialization, most nations have experienced rapid economic expansion coupled with high levels of energy consumption. Since economic development is dependent on energy, and energy consumption inevitably leads to environmental pollution, the world is struggling to find a solution to strike a balance between sustainable economic development and environmental harm (Chol, 2020).

Energy demand is further increased by industrialization, which raises wages and hastens urbanization. For instance, the Africa Energy Review Report (2021) states that the continent's energy consumption has been rising at an annual pace of about 3 per cent, making it the continent with the highest energy demand among all those with substantial fossil fuel reserves. However, the use of energy, especially fossil fuels, as the major energy source has many adverse environmental effects. The consumption of energy in terms of non-renewables is a significant contributor to stationary energy greenhouse gas (GHG) emissions¹. Greenhouse gases are potentially essential to keep the earth's

¹. Climate change can be influenced by global warming, which is an average rise in the temperature of the atmosphere and the troposphere close to the Earth's surface. According to the Intergovernmental Panel on

temperature warm and Global warming causes climate change. Thus, as intensive use of energy and other natural resources worsens the environment, so do gas emissions from burning fossil fuels, which increase the quantity of CO₂ harming the environment and causing irreversible damage to the atmosphere, making it a key policy concern of this century.

Considering the foregoing, the pursuit of a theoretical relationship between environmental pollution and its causes has therefore increased, leading to debates and serving as the foundation for crucial theoretical background on this relationship since Kuznets' work (1955). This means Kuznets theory in this study illustrates the linkage between environmental pollution and its causes like economic growth and other variables that may influence environmental pollution through economic growth such as energy consumption, FDI, financial development, and trade. Hence, the existence of Kuznets theory has led to a further need for theoretical justifications on several factors that may affect environmental pollution via economic growth. This goal has proven to be an effective way to gauge numerous factors influencing environmental degradation, including economic growth, fossil fuel usage, finances, and governmental policies (Mrabet and AlSamara 2016; Danlami, Applanaidu, and Islam 2018). It is a common believe in the literature that using fossil fuels to explore more economic potential encourages ongoing disruption of the atmosphere's carbon levels. Consequently, this produces heat, contributes to global warming, and worsens the climate. In a similar vein, the IPCC report from 2018 shows that there is a strong correlation between global temperature and greenhouse gas

Climate Change (IPCC), 2007 there are many different reasons of global warming, both natural and human-induced.

emissions. Additionally, related to this is the fact that industrialization, which raises greenhouse gas (GHG) emissions, is a driving force behind rapid economic growth and progress. In this view, economic growth and development with the urbanization effects have increased energy consumption that has generated an increased amount of carbon dioxide (CO₂) emission, which is noted to be the dominant contributor to global warming and the GHG effect (Bakirtas & Akpolat, 2018; Heidari et al., 2015; Wang et al., 2018).

In this regard, the increase in CO₂ emissions from the energy sector caused total energy-related greenhouse gas emissions to reach their highest level ever in 2021. When considering a 100-year global warming potential time horizon, total greenhouse gas emissions reached 40.8 Gt of CO₂ equivalent (CO₂eq) in 2021, surpassing the previous record-breaking year of 2019. In 2021, the energy sector's greenhouse gas emissions from energy combustion accounted for around 82 per cent of the total. Another 6 per cent of CO₂ emissions came from industrial processes. In addition to CO₂, 12 per cent of the total emissions were from combustion-related methane and nitrous oxide.

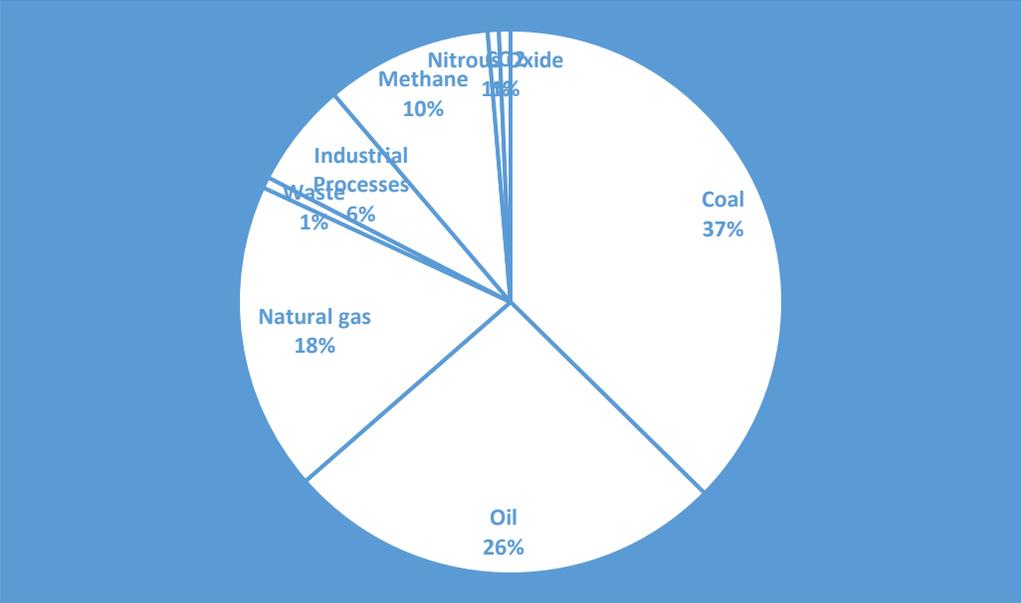


Figure 1. 1: Global Greenhouse Gas Emissions
Source: IEA (2022)

The growth of Carbon dioxide emissions is influenced by various factors like the level of economic growth, urbanization, use of energy resources, growth of population, and international trade. It is maintained that financial development could be an influencing factor in carbon dioxide emissions (Black et al., 2015; Qader, 2009; Sehwat et al., 2015). The magnitude to which each of these factors stimulates Carbon dioxide discharges in the atmosphere varies from one nation to another depending on how they exist in a nation. Assessment of how these factors stimulate the explosion of Carbon dioxide is essential for environmental policymaking.

With the sub-Sahara (SSA) countries' increasing urbanization, population increase, and pursuit of higher economic growth, CO₂ levels are deemed to be rising. It has been found that CO₂ emissions in SSA countries have significantly increased because of emissions from burning biomass, traffic, and the use of biofuels, as well as vehicle operation, motor oil, and fossil fuels for industrial use. Large sources of pollution have resulted from them in cities like Lagos (Nigeria), Bamako (Mali), Cotonou (Benin), and Dakar (Senegal) (Dumbia et al., 2012; Guinot & et al., 2014). SSA emissions are predicted to increase due to an increase in urban population, and rapid development of mining, oil, and industrial activities that persist across the region (CIESIN, 2012; UN, 2005). According to the International Energy Agency baseline scenario to 2040, energy generation in Sub-Saharan African nations would expand, and the portion of global Carbon dioxide emissions in the region would rise from 2 per cent to 3 per cent (Sy 2016). The use of fossil fuels in transportation, especially with the higher percentage of fairly used vehicles

imported from developed countries to Africa, has resulted in high urban air pollution in Sub-Saharan African countries (Agbola et al., 2017).

Adusah-poku (2016) also claimed that urbanization and population growth coupled with pressure on land to meet food demand in Sub-Saharan African economies are expected to increase the share of global Carbon dioxide discharges over the coming decade. The region has been identified with the dynamic nature of economic growth, higher population growth rate, and rapid urbanization, which could eventually raise the level of pollution (Zerbo 2015). Liousse et al., (2014) predicted that African countries' pollution could represent nearly 50 per cent of the global level by 2030 in comparison to the 2005 level, if not controlled. Hence, exploring other determinants of carbon dioxide emissions and the relationship among them is necessary to achieve sustainable development.

With the intensification of high economic growth, many studies have linked environmental pollution with economic progress. This has been justified in industrialized countries by testing the presence of the Environmental Kuznets hypothesis (EKC). The hypothesis stated that an increase in economic performance at the initial stage would rise environmental pollution until a certain stage then it declines (Dinda, 2004). With the current pressure to realize higher economic performance and development by most of the SSA nations. Testing the presence of the EKC hypothesis in the Sub-Saharan African region would be important because it will enable a better understanding of the relationship between economic progress and environmental pollution for effective policy regulations.

Low human development and extreme poverty have made it possible for the Sub-Saharan African region to re-engage its efforts towards improving financial resources in terms of

funds accessibility, volume, and efficiency that facilitate various investment opportunities and promote economic growth. Since the development of the financial sector in a nation plays a vital role in achieving higher income and growth, there is no doubt that an increase in economic growth will influence environmental degradation. Therefore, financial development is given priority because it enables people to have access to funds through loans and other credit facilities as well as the efficiency to use the capital for productive investment (Mlachila et al. 2016). In Sub-Saharan Africa, the banking system dominates the financial landscape in most of the countries, except Lesotho, Namibia, Swaziland, and South Africa. In recent times, development in the financial sector reveals that financial depth has increased in the region. Liquid liabilities percentage of GDP turns to about 53.4 percent, M2/GDP 49.8 percent, and 334.5 Bank accounts per 1000 adults, and the trends in the depth of banking sector assets increased by an average of 57 per cent of GDP in 2019 (WDI 2019). These generally imply that the trends in financial sector development would certainly accelerate economic growth and consequently affects the level of environmental quality in SSA nations.

Various studies have analyzed the extent to which financial development influenced Carbon dioxide emissions in both industrialized and emerging countries (Khan et. al. 2022; Abbasi & Riaz, 2016; Charfeddine & Khediri, 2016; Kais & Sami, 2016; Shahbaz et al., 2013.). Financial development, economic growth, and energy are linked to the environment either positively or negatively. Financial development can make it possible to borrow more money at lower rates, which will boost investments in the industrial sector and, as a result, increase industrial pollution and environmental deterioration (Tamazian, Chousa, and Vadlamannati 2009). While financial sector improvement inspires firms to

use low emissions and environmentally friendly technologies and eventually, promotes environmental quality (Tamazian, Chousa, and Vadlamannati 2009; Tamazian and Rao 2010), it could also encourage a rise in household demand, such as automobiles, and electrical appliances, and devices that emit pollution (Qader, 2009). Like how simple access to finance is made possible by financial sector development, environmental performance is improved. The expansion of the financial sector might draw international investment, which would spur economic growth and lead to an improvement in environmental quality (Charfeddine and Khediri 2016). Tadesse (2007) made the case that financial development spurs technological advancements that boost environmental quality and productivity by enabling capital mobilization. Taghizadeh-Hesary and Yoshino, (2020) however noticed that the major headwinds to green energy investment are the lack of long-term financing, the low rate of return, the existence of various risks, and the lack of capacity of market players.

Dasgupta and Benoit (2001) contend that environmental regulations in developing nations may attach to the financial market force through which environmental policy control can be reflected on firms to attain a clean environment. This shows that a strong financial system may induce firms to lessen the growth of their Carbon dioxide discharges. Given this evidence, financial sector development is likely a factor that can influence environmental quality. Despite many studies, inadequate empirical evidence was found concerning the channel of financial development and environmental quality, especially for Sub-Saharan African nations.

It is of chief concern in numerous newly industrializing nations, especially the SSA countries to prioritize and consider ecological sustainability and environmental issues in

their growth and development quest. The SSA countries are at an important stage of economic expansion. These economies are witnessing a swift rise in population with encouraging demographics of a young and growing workforce in urban areas. However, the region has relatively lower per capita levels of GHG releases, and the ever-increasing risks of adverse worldwide climatic changes indicate that economies need to avoid economic growth paths based on high-emission models. This atmospheric limitation conflicts with the growth trend which is witnessing rapid growth of GHG emissions in the region owing to increased fossil fuel extraction and use, population growth, deforestation, and a rise in cattle production (IEA, 2014 (Sehrawat, Giri, and Mohapatra 2015; Acaravci and Ozturk 2010)). Hence, SSA countries are trying to overcome several developmental challenges such as illiteracy, healthcare, conflicts, lack of energy access, and widespread poverty, they must design their economic development in such ways that it does not cause a large-scale rise in GHG emissions. In essence,

Nigeria is a country that is well-endowed with abundant human and material resources from which sustainable development and economic growth can be achieved. About 80 per cent of the land area of 923,773 km² is arable with varied soil types that suit a wide range of agricultural purposes. The country has large reserves of solid minerals such as coal, tin, bitumen, columbite, iron ore, and lignite. Mining activities are largely informal and are concentrated in areas of the country. Crude oil and natural gas are found in the southern area of Nigeria. The proven reserves of crude oil are well over 37 billion barrels, while reserves of natural gas stand at over 187 trillion standard cubic feet (WDI 2019).

The GDP growth in the country remains in a progressive trend as the oil and non-oil sectors are picking up in recent times. Nigeria is the most highly populated and strong

economic base in sub-Saharan Africa. Between 2006 and 2016 its GDP grew at an average of 5.7 per cent per annum. Figure 1.2 illustrates the trend of GDP in Nigeria from 1990 to 2019 showing an upward trend. According to the figure, GDP grew from 64,724,937,008 billion US Dollars in 1990 to 511,932,076,368 billion US dollars in 2019. Similarly, GDP grew from 64,724,937,008 billion US Dollars in 1990 to 502,942,019,448 billion US dollars in 2020, implying an improvement in the economic performance of the country. This explains the extent of the increase in CO₂ during the period not much relative to the GDP growth, it also shows that there is a link between the GDP growth and CO₂ increase in Nigeria. Therefore, the main concern is the presence and positive trend of CO₂, which lead to issues, and problems in the country concerning environmental pollution through economic growth.

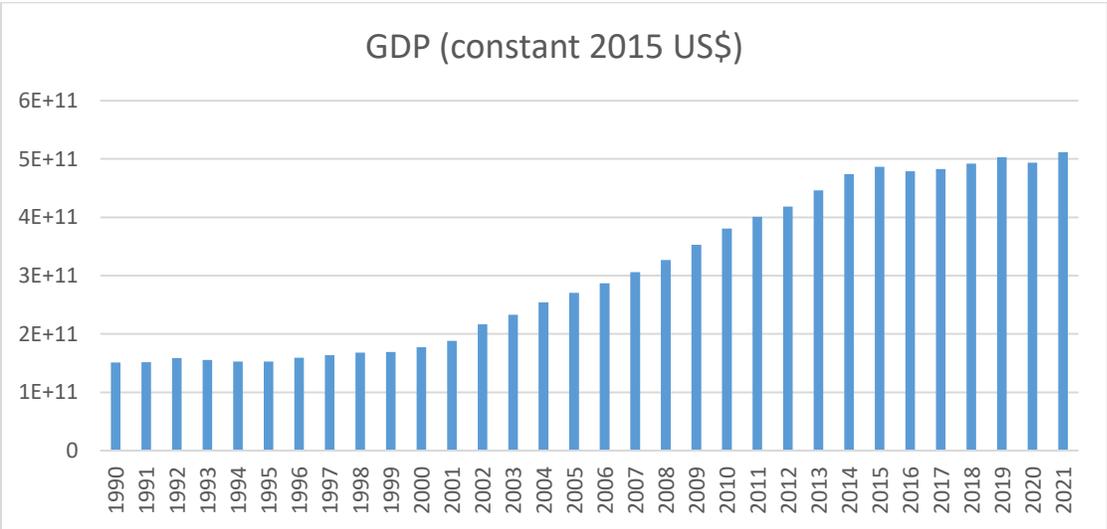


Figure 1. 2: Nigeria’s Gross Domestic Product (1990 - 2021)
 Source: World development indicators (WDI, 2022)

Similarly, it is observed that the level of CO₂ discharge is growing with the increase in economic growth performance arising mainly from increased energy consumption, rapid population growth, and urbanization. Figure 1.3 shows that Carbon dioxide discharge in

Nigeria possesses an increasing trend, which implies a decline in environmental quality. In this regard, the level of CO₂ explosion in Nigeria has increased from 72770 million kilotons (kt) in 1990 to 115280 million kt in 2020.

This growing trend of CO₂ discharge in the country is becoming worrisome as it may destruct environmental quality, viable economic growth, and development. Mirza and Kanwal (2017) claimed that the explosion of emissions from biomass burning, traffics and the use of biofuels, vehicles running, motor oil, and fossil fuels for industrial use have attributed much to the growth of CO₂ emissions in the country and harmfully pollute the environment.

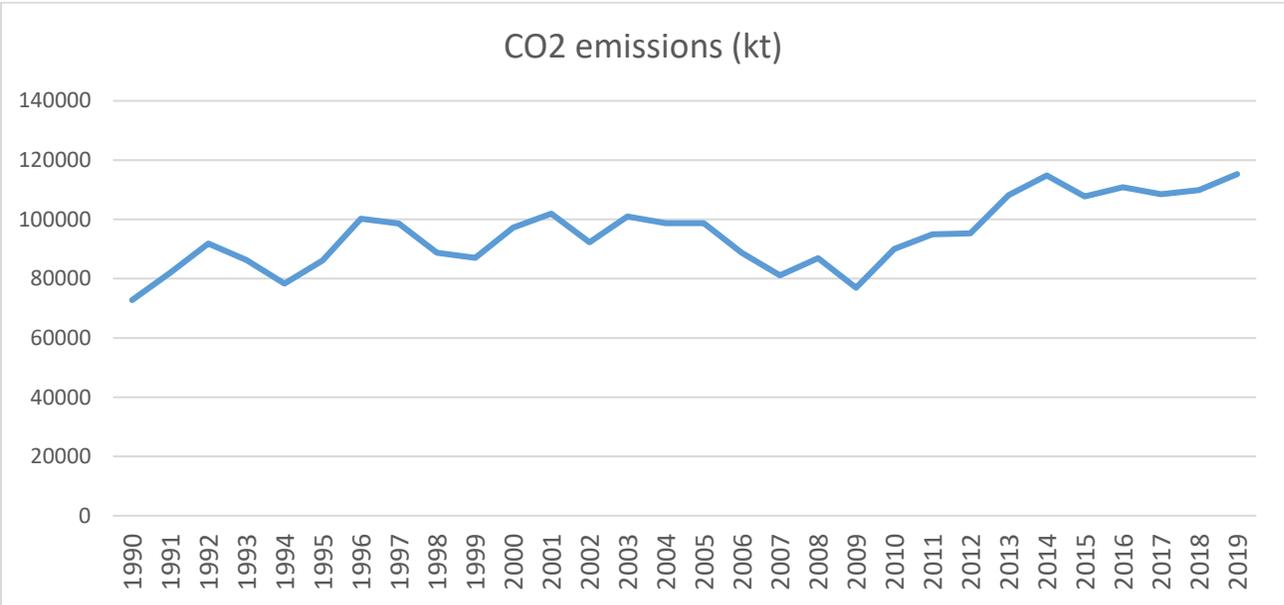


Figure 1. 3: Carbon emissions and GDP Growth between 1990-2020
Source: World Development Indicators (2022)

Furthermore, the increased energy utilization could be due to the urgent need for the nation to diversify the economic sectors toward accelerating the level of economic growth performance and development. It has been stressed that discharges from fuel energy

resources have augmented overtime with the aggregates of liquid and solid fuels with each accounting for 35 percent, and gas fuel 16.9 per cent in the nation’s fuel mix. For example, figure 1.4 shows that energy consumption increased from 66,433 million ktoe in 1990 to 172,902 million Ktoe in 2021. Hence, it indicates that for over a decade, energy consumption possessed an increasing trend and might have a direct link with an increased level of CO₂ discharge in Nigeria.

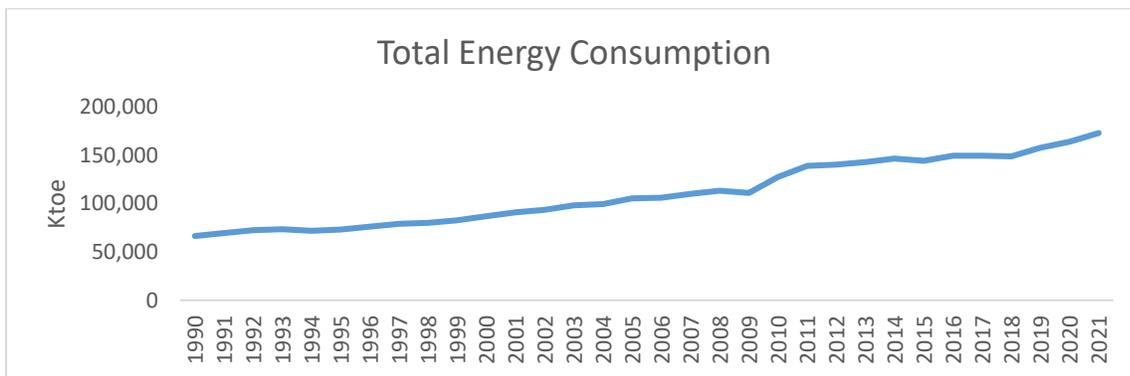


Figure 1. 4: Energy use in Nigeria (1990 – 2021)
Source: Energy Information Administration (EIA, 2022)

1.2 Problem statement

Greenhouse gas emissions have led to high levels of global warming. Mitigation of GHG emissions is a serious area that urgently requires a lot of exploration, as these gases are complex and emitted from daily human and animal activities. Due to the adverse effects, they are causing damage to our ecosystems; the identification of scientifically proven measures and options needs to be analyzed and scrutinized keenly through research. Interestingly, SSA has the lowest levels of emissions of greenhouse gases accounting for about 7 per cent of total global emissions. (Ntinyari, and Gweyi-Onyango, 2021). This implies that the region contributes to the increased level of CO₂ emission and highest on the vulnerability to the climate change effects.

This is because the region hosts some of the poorest societies and as such is unable to invest in mitigation and adaptation as well as resilience-building that will ameliorate the adverse impact of climate change on the most vulnerable people in the region. The dilemma, therefore, posed to policymakers in most developing economies today, is how should they pursue the much-needed economic growth and development to reduce poverty and improve citizens' welfare in their countries. The ability of a developing country to reduce poverty and improve welfare is heavily dependent on how fast it can grow its economy amidst the presence of strong institutions to achieve a significant level of wealth redistribution for the larger chunk of its citizenry as witnessed in China. According to Laniran (2021), the achievement of the core Millenium Development Goal (MDG) of halving global poverty by 2015 was significantly driven by the ability of China and by some extension India to grow at very high rates over the period. The achievement of the sustainable development goal (SDG) to end absolute poverty however largely relies on Africa which to a large extent failed in the MDGs as the number of poor people in the region continues to soar. The ability of Africa to grow at a very fast rate and improve the living conditions of its most vulnerable people is therefore critical for the achievement of the SDG. The policy dilemma before policy makers of the SSA region, a region that currently contributes the least to GHG emissions today, is the nature and manner in which the drive for economic growth should be pursued. Should economies in the region grow dirty and grow fast or grow clean and grow slow but in a more environmentally friendly and sustainable manner? However, the fact that these countries are largely poor and are heavily endowed in fossil fuels and hydrocarbon suggests their propensity to utilize their endowments and increase their emission levels in pursuit of economic growth.

As it stands, the adverse impact of climate change on developing countries increases inequality levels because its burdens are disproportionately borne by poorer households and countries and the costs for climate mitigation and adaptations measures might be prohibitively high (Löscher, and Kaltenbrunner, 2022). It is noteworthy that to underline the importance of addressing this issue, the UK government has recently hosted COP 26 in Glasgow between 31st October and 12th November 2021. While it initially aimed at building progress in four key areas (coal, cars, cash, and trees), problems rose among parties when attempting to get agreement on the first two: rapid phase-out of coal-based power and heating plants, and progressive shift from fossil-fuelled towards low-carbon driven automobiles (Schneider, 2022; Smith et al., 2021). Since 1995, besides the legally binding 1997 Kyoto Protocol, 25 COP meetings occurred along with other international agreements. Over the same period, atmospheric CO₂ emissions, the principal GHG component, increased from 360 to 420 ppm in 2020 (Rees, 2021). Therefore, non-negligible critics have been expressed towards the standard approach to global warming, which mainly consists in alleviating the constraints on economic growth while enabling a continuous technological development thought suitable to compensate for environmental damages. Acceptable approaches include the increased use of renewable technologies in energy generation and the use of non-renewable hydrocarbons and fossil fuels. This however poses a risk to biodiversity and may hinder the emergence of competitive industrial sectors in developing countries like Nigeria.

In this regard, the persistent growth of the global discharges of CO₂ emissions and the likely consequences to the global atmosphere have intensified the commitment of the international community to deliberate on the share of different nations in the total

emissions as well as their efforts to mitigate these discharges (Kojima & Bacon 2009). Nigeria has recorded an upsurge in CO₂ emissions. For example, in 1990 the country recorded 72,770 million kilo tonnes (kt) of CO₂ emissions. In 2019 carbon emissions increased to 115, 280 million kt. This indicates an almost 36.9 per cent rise during these periods. The increased CO₂ discharge in Nigeria might stimulate the concentration of greenhouse gas in the atmosphere and results in climate deterioration through global warming.

Climate deterioration degenerates agricultural productivity with a direct effect on human development. Global warming gives indications that yields may decline by about 15 to 20 per cent across all crops (Sy, 2016). Gas flaring in Nigeria releases a large amount of carbon dioxide discharge causing harsh climate change and resulting in health problems (Hassan & Kouhy 2013). Climate deterioration generates other problems such as droughts, floods, and an increase in food prices. Diseases outbreak due to extreme heat and flooding leads to poor health attainment that may directly affect child education performance and the general well-being of people in the country. This condition will degenerate economic performance and raise the poverty level. Thus, the effects of CO₂ discharge could be widespread.

Moreover, the level of economic growth and energy use in the country has increased over the past decades. For example, the GDP growth rose from \$6.9 billion in 2000 to US\$51.2 billion in 2021 (WDI, 2022). Similarly, energy consumption increased from 0.2488 million quad btu in 2000 to 0.6958 million quad btu in 2017. These improvements in economic growth performance and energy utilization may likely influence the level of CO₂ discharge (environmental degradation) that leads to higher global temperature and climate alteration

with negative consequences on the ecosystem, low agricultural productivity, diseases outbreak, increase poverty rate, deterioration of human development, low investment and ultimately reduce. Hence, to achieve economic growth and at the same time decrease environmental pollution, it is relevant to investigate the impact of economic growth and energy use on environmental degradation chiefly caused by CO₂ emission in Nigeria.

1.3 Research Objectives

This study seeks to understand the relationship between economic growth and energy use on environmental degradation mainly caused by CO₂ emission in Nigeria. This is important as it brings to bare how much impact the economic growth and energy consumption in Nigeria; a leading emerging economy in the SSA region has on the environment, particularly in terms of CO₂ emissions. In achieving the above general objective, the following specific objectives/questions have been identified:

1.4 Research Questions

Given the above problem statement, the main research question of this thesis is: To what extent do economic growth and energy consumption influence environmental degradation in Nigeria? The sub-questions of the study are stated thus:

1. What effect does economic growth have on environmental degradation in Nigeria?
2. How does energy consumption influence environmental degradation in Nigeria?
3. What is the interaction effect of energy consumption and economic growth on environmental degradation in Nigeria?

4. To investigate the shocks and forecast the effect of energy use and economic growth on the environment in Nigeria.

1.5 Scope of the Study

This study, in general, examines the effect of economic growth and energy use on environmental degradation in Nigeria, and It covers the period from 1980 to 2020. The choice of the scope is necessitated by the problem of getting data to the current date of carrying out this thesis. The focus of this study generates limitations as it is confined to Nigeria and limited economic and environmental indicators. Hence, the outcome of the study is more related to a country-specific study, in this case, Nigeria. The decision for selecting Nigeria is due to the availability of data, the enormous presence of gas flaring and other pollutants, the status of the country as a developing economy and the largest economic potential in Africa, being the highest oil-producing country, and it's relevant to the global nations in terms of emissions discharge.

1.6 Justification of the Study

Climate Change and Global Warming are the biggest threat facing humanity and the global economy in the 21st Century. Considerable uncertainties surround both the extent of future climate change and the extent of the economic impacts of such change. Notwithstanding the uncertainties, climate scientists have reached a consensus that in the absence of measures to reduce GHG emissions significantly, the climate changes will be substantial, with long-lasting effects on many of Earth's physical and biological systems with adverse economic implications.

Nigeria is not insulated from this risk as in recent years, the country has been affected by increases in temperature levels, unpredictable rainfall, rising sea levels flooding; drought land degradation, and desertification. Additionally, the increase in the frequency of extreme weather events, decline in freshwater resources, and a loss of biodiversity resulted in huge overflows and flooding in many parts of Nigeria. This study, therefore, contributes to the existing literature on the relationship between energy consumption, economic growth, and CO₂ emissions in Nigeria on several fronts. First, there seems to be a problem with the recent research that looked at the relationship between economic development, energy use, and environmental quality. Energy plays a crucial part in economic operations and serves as a vital tool for sustainable development, which is the reason. However, the Nigerian government has not been motivated to study and enact a wide range of policies to reduce CO₂ emissions due to worries about the continuing dependency on non-renewable energy sources, which are the primary cause of climate change. For a nation like Nigeria to accomplish its potential goal, more work and research must be done to reduce emissions. The goal of this study, therefore, is to examine the extent to which economic growth and energy consumption influence the environment in Nigeria. This would help to promote the strategies for enhancing economic growth performance and environmental quality, especially in increasing individual awareness and re-orientation on the risk of the deteriorating environment in search of economic development.

Second, in the design of an empirical model and framework in most of the previous studies (Salahuddin, Gow, and Ozturk 2015; Rafindadi 2016; Yahaya, Adamu, and Mustapha 2020), relationships between economic growth, energy, and environment were

assumed to be a linear one. This study incorporates the interaction of energy consumption with GDP in the model as a new approach to determining the new relationship between economic growth and the environment in Nigeria and by extension an empirical contribution of new knowledge to the literature on environmental pollution studies. It is believed that the incorporation of this variable would help in designing appropriate policies for sustainable development.

Third, this study includes a larger dataset in the analysis than earlier studies. third, since bivariate analysis is widely criticized for omitted variable bias, this study applies a multivariate framework in the analytical parts by incorporating several other independent variables that were found to be impactful on environmental degradation.

Fourth, among the identifiable reasons why various studies on economic growth, energy, and environmental pollution nexus have been characterized by mixed results and inconclusiveness as Javid and Sharif (2016) and Salahuddin and Gow (2015) noted are due to methodological problems like model specification and methods of estimation among others. This study has taken the challenge of minimizing these methodological problems by adopting appropriate modeling and estimation method. In this regard, the ARDL estimation method was adopted. It is interesting to state that the validity of the adoption of the ARDL technique as an appropriate estimation method for the framework of this study was noted in the work of Salahuddin, Gow, and Ozturk (2015).

Lastly, the outcome of this study contributes to the existing literature on economic growth, energy, and environmental quality. It would also help in improving policy analysis and recommendations to the government, stakeholders, and relevant organizations to

promote economic growth in a sustainable manner that takes into consideration environmental quality. There is no doubt that various findings and discussions emanating from this study shall have policy implications for Nigeria and other African economies.

1.7 Organization of Chapters

This research is made up of six chapters. Chapter one focuses on the introduction/ background of the study, statement of the problem, research questions, research objectives, justification of the study, the scope of the study as well as the structure of the thesis.

Chapter Two reviewed relevant economic theories (EKC theory, Pollution haven, and growth theories) as well as the empirical literature review concerning the empirical models of the study. The chapter also discussed the broad scope of existing literature on the relationship between economic growth, energy consumption, financial development, foreign direct investment, and the environment.

Chapter Three provides detailed information on Nigeria's history and its structure. The chapter further reviews the Nigerian economy and its sectors. Oil production, agriculture, mining services, and population. The chapter also discussed the trends in Nigeria's economic growth, key environmental indicators, and energy consumption including CO₂, Nitrous oxide, Methane, and agricultural and fossil fuels emissions.

Chapter four focuses on the theoretical framework of the study, data, and methodology used in conducting the study, furthermore, it discusses the methodological approach,

model Specification, and the choice of the method, it also covers, the data collection process, estimation technique, empirical model, and diagnostic tests.

Chapter Five discusses the results findings and analysis. The analysis investigates the relationship between economic growth, energy consumption, and the environment. In this regard, ARDL and causality testing as well as impulse response techniques were employed for the analysis, after which post-estimation checks reveal the validity and stability of the models for policy recommendations.

Finally, Chapter Six presents the summary of the study findings, conclusion, and recommendations for policy analysis. The chapter summarizes the major findings on economic growth, energy consumption, and environmental models. It also captured the implication of the findings and conclude necessary recommendations for policymakers and stakeholders to target a better environment, economy, and sustainability in the nation.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The environment is an essential part of human life that is linked to the ecosystem, improving the quality of life of people and economic development. International organizations such as the United Nations have urged all nations and stakeholders to explore means of elevating the environment. World Bank (2020) estimated that about 1.4 billion people live in poverty due to environmental deterioration. Recently, the initiative of sustainable development agenda was strictly on sustaining the environment and development for the future generation. Hence, several studies have discussed many elements that may deteriorate the environment including economic activities and energy utilization. In light of this, the previous chapter has illustrated the need to examine the relationship between economic growth and energy consumption in the environment. Therefore, this chapter deeply reviewed the theoretical and empirical studies on economic growth, energy consumption, and the environment. This aimed to identify other studies' contributions, and how the current debates in the literature on economic growth, energy consumption, and environment for a better environment. It also gives a detailed literature gap for analysis and policy recommendations on the study's findings in the next chapters of the thesis.

The review is organized into two Sections 2.1 and 2.2. The gap in the literature was illustrated in section 2.5. Section 2.1 discusses the theoretical review of the Environmental Kuznets hypothesis and pollution haven hypothesis. Section 2.2 presents a literature review of empirical studies on economic growth, energy consumption, financial

development, trade, and environmental degradation. Lastly, section 2.4 presents the chapter's conclusion

2.1 Theoretical Review

2.1.1 Environmental Kuznets curve (EKC) hypothesis

Environmental degradation grows with the improvements in economic progress, innovations, and development up to a certain level beyond which environmental quality improves with increased economic growth. In this regard, Kuznets's theory explains the effect of economic growth on environmental pollution. Kuznets's theory in this study illustrates the linkage between environmental pollution and its causes like economic growth and other variables that may influence environmental pollution through economic growth.

This relationship is shown by an inverted U-shaped curve in Figure 2.1 and it is illustrated as the EKC by Kuznets (1955). The EKC hypothesis represents a long-term linkage between environmental effects and economic growth performance. As economic progress improves with a high level of human activities, such as agriculture and extraction of natural resources at the initial stage the rate of environmental degradation is higher than the rate of resource generation and results in increasing environmental waste. In the presence of a higher level of economic development, environmental protection policies, environmental awareness, and better technology improve environmental quality and environmental degradation decline. Once, economic growth moves beyond the EKC threshold point; then environmental quality starts to improve (Dinda 2004).

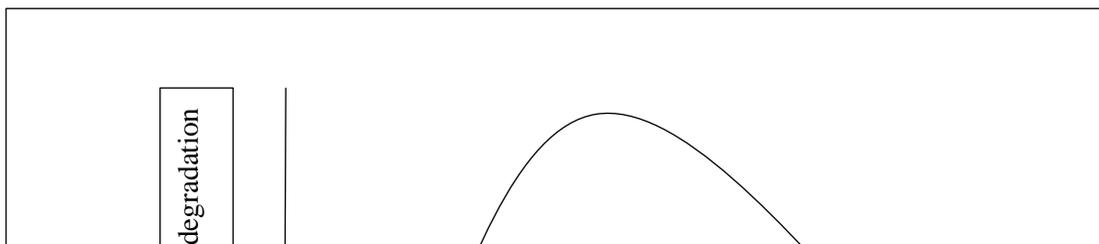


Figure 2. 1: Environmental Kuznets curve (EKC)

The hypothesis stated that an inverted U-shape relationship exists between income and environmental dilapidation (Kuznets 1955). Also, the theory explained that as society develops, environmental quality declines until a certain point where environmental quality begins to improve (Dinda, 2004). In another view, Panayotou (1993) emphasized that the capacity of environmental degradation at the initial level of economic progress is constrained for the sustenance of economic growth and the inability to utilize environmental waste. Moreover, as the economy develops with the rate of increase in agricultural activities, exploration of resources, and the development of industries, the environmental damage tends to be higher than the resource generation rate, thus a higher level of environmental degradation (Stern et al., 1996). The idea behind the EKC relation is naturally attractive. In the early stage of industrialization, pollution increases rapidly due to the need for higher production, and less priority is given to protecting the environment (Dasgupta and Benoit 2001).

EKC hypothesis entails a process in that structural change occurs together with economic performance (Dinda, 2004). Grossman and Krueger (1991). argued that

economic growth affects environmental quality in three ways, these include scale, structural and technological effects. The scale effect denoted that, with the state of technology more inputs and resources are committed to producing more commodities at the early stage of economic progress. This will promote the use of energy resources which could eventually result in to increase in pollution and waste that deteriorates the environment (Torras and Boyce 1998; Prieur 2009).

The structural effect stated that economic growth will affect the environment as the economy have a structural transformation. In other words, as the structure of the economy changes, national production grows and gradually influences environmental quality. Besides, the level of technology affects environmental conditions. However, the transition from old and dirty technology to new-technology-intensive knowledge reduced environmental pollution. Since nations with higher income can promote the level of research and development by allocating adequate resources, hence new technology enhances environmental quality. Therefore, at the beginning of economic progress environmental dilapidation increase and later decrease as a result of scale, structural and technological effects.

In a different view, the higher level of development is usually intensified with structural change, knowledge and environmental awareness, environmental control policies, and laws, and the use of low emissions technologies to increase the level of environmental quality (Panayotou 1993; Stern, Common, and Barbier 1996). Also, Stern (2004) maintained that the EKC relationship is influenced by the changes in economic structure, the scale of production, and technology that serves as transition channels of other elements (energy use, FDI, financial development, and trade) on environmental pollution.

Environmental degradation at any given time is determined by such factors. Heerink et al. (2001) demonstrate how to scale effect and the dynamic structure of the economy, as well as the changes in the technique of production, are the reason for the inverted U-shape relationship between economic growth and environmental degradation. Therefore, Katircioğlu (2014) asserted that energy consumption accelerates real income growth and increases environmental pollution. Similarly, EKC can be influenced by the composition effects such as financial reforms, trade liberalization, FDI, and therefore, entails that financial sector reform, eliminating trade barriers increase foreign direct investment, increases economic growth, and eventually influence environmental degradation (Bilgili, Koçak, and Bulut 2016).

Recently, issues regarding the development of a green economy have intensified to secure economic progress without deteriorating the environment. In this regard, EKC theory had linked the use of efficient resources toward achieving economic development without harm, since it has shown a technically efficient relationship between economic activities and environmental pollution. OECD considers green growth as future economic progress and development that maintains the value of natural resources unaffected and continuously improves societal well-being. World Bank (2020) defines green growth as efficient growth that mitigates pollution and promotes environmental management. Therefore, resources such as energy and economic potential should be efficiently used for environmental quality.

2.1.2 Pollution haven hypothesis (PHH)

The pollution Haven hypothesis emphasized that higher-income nations transfer pollution-intensive industries to less developed and developing nations, where there are

weak environmental regulations, through trade and foreign direct investment (Eskeland and Harrison 2003). However, the proponents of free trade have argued that environmental degradation occurs due to the appearance of externalities not by the trade itself (Gene, 1995). Therefore, the pollution haven hypothesis emerged to explain the ability of trade liberalization to demonstrate the extent to which pollution is shifted from rich to poor countries with poor environmental laws and regulations (Cole et al. 2006).

Eskeland and Harrison (2003) pointed out that the pollution haven hypothesis is the best to explain the possibility of industrialized nations engaging in pollution-intensive production and relocating to countries with weak environmental laws and regulations. Cole (2004) argued that the disparity in the environmental regulations between wealthy and poor nations has increased the volume of pollution in poor countries. Taylor (2004) emphasized that the variation in human capital development in different countries influences their income, regulations, production, and pollution levels. Therefore, the changes that occur in human capital development give an idea to take unwanted goods from a developed nation to less developed countries and it term as the transfer of pollution across nations. Zhang et.al (2021) using data from Belt and Road Initiative (BRI) member countries, however, found that public spending on human resources and R&D of green energy technologies prompts a sustainable green economy through labor and technology-oriented production activities and different effects in different countries.

Levinson and Taylor (2008) stressed that the cost and benefit circumstance for developed and industrialized economies in terms of the production of goods has led them to deposit their industries and pollution in less developed nations to achieve higher profit. Jiang (2015) argued that investments from foreign developed nations deteriorate environmental

quality in the host less economic power countries through the transfer of hazardous industries.

This hypothesis posits that environmental-related FDI will be more interested in countries where environmental regulations are relatively less strict. This implies that FDI is interested to invest in countries that have less or no environmental policy control as such it affects the environmental quality of that nation. The MNCs tend to move the high pollution level industries from industrialized economies with strict ecological guidelines to the newly industrialized economies with lower ecological protocols (Acharya, 2009). Multinational companies are flocking to economies that have lower environmental taxes and a lower degree of environmental regulation (Seker, Ertugrul & Cetin 2015). Thus, intending to save on greater environmental expenses levied in industrialized nations, the MNCs are moving industries with high pollution levels to developing economies. Due to this, developing economies are becoming pollution havens and there is a significant rise in their pollution level (Y. J. Zhang et al. 2017). This may harm the environment of the host countries if they do not take these issues seriously.

According to Acharya (2009), the pollution haven hypothesis specifies that the FDI inflow will increase the gas emissions/pollution level in developing countries by increasing the activities of industries with high pollution levels (Acharyya, 2009) apply cross-country studies and cross-sectional data for testing the pollution haven hypothesis. They assess the influence of ecological protocols over pollution-intensive industries in terms of export competition. While constructing the environmental regulations indicator, they considered factors including the estimated amount of money spent in the country for controlling water

and air pollution and the level of efforts for reducing pollution (Wilson, Tsunehiro & Sweadeh 2002).

Their findings indicate that stricter environmental standards led to the lesser export of dirty industries. Furthermore, implementing higher standards is largely impacted by reducing the net exports of developing countries as compared to the developed countries, thus implying that developing countries have a higher level of pollution-intensive output (Wilson, Tsunehiro, & Sewadeh, 2002).

2.1.3 The Brundtland Curve Hypothesis

The Environmental Kuznets Curve is not the exclusive conjectured curve utilized to define the ecological influences of fiscal progress. The World Commission on Environment and Development (WCED) statement since 1978 termed the Brundtland Report provides a different picture of the relationship between GDP and ecological harm (Brundtland, 1987). The report further illustrates that deprived nations contribute higher amounts of atmospheric toxic that eventually increase the level of environmental degradation. Conflicting with the EKC, the Brundtland curve is U-shaped.

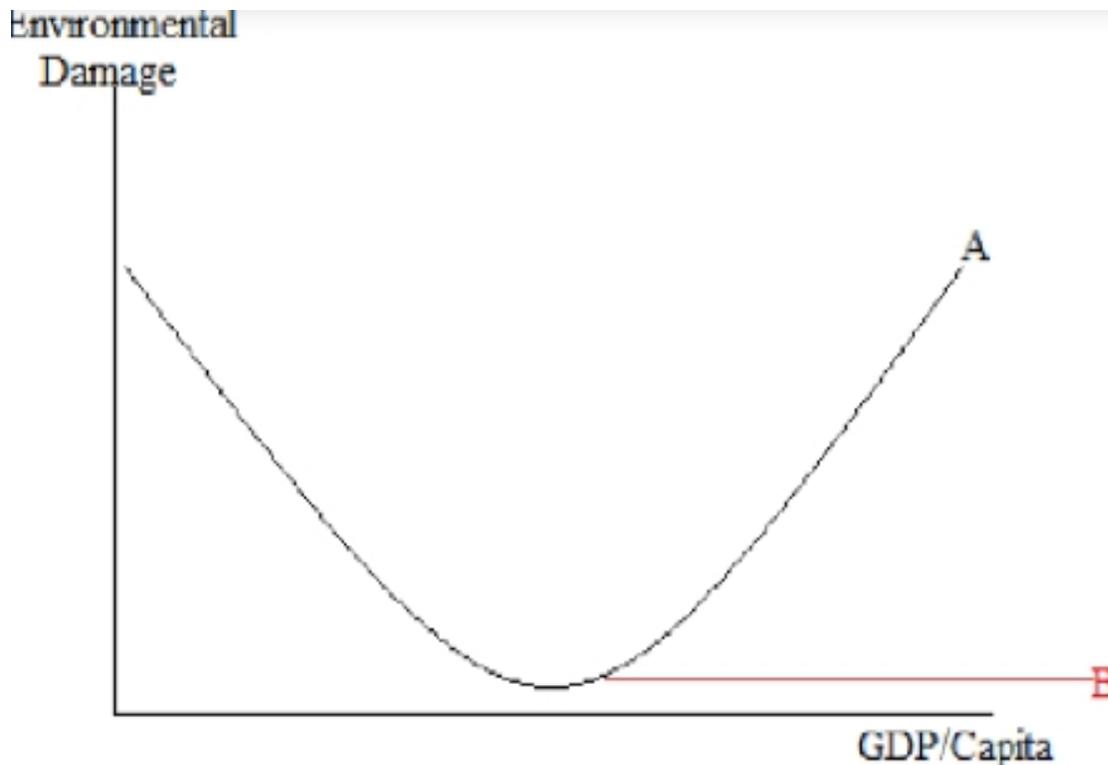


Figure 2. 2: The Brundtland Curve
 Source: Brundtland (1987)

As per the Brundtland Curve theory, deprived nations create greater harm to the ecosystem owing to the deficiency of capability to highlight ecological security. People in the depth of poverty resort to large-scale deforestation and makes over-exploitation of sensitive regions to survive with an evolution in the market, ecological damage harm suffers a decline (majorly owing to the decrease in devices holding the elevated parameters of ecological harm, that is, a decline in poorness). On attainment of the turning junction, pollution is believed to rise with fiscal progress and finally attain an all-time high. The constructive tendency in ecological dilapidation is rendered to the Brundtland Curve hypothesis instigated by amplified ingestion that created augmented manufacture. The

ecological harm rendered by risen manufacture is as harmful to the atmosphere as the difficulties instigated by the dearth conferring to the concept (Field & Barros 2014).

The Brundtland curve could appear to project a dark future, however, the curve comprises a substitute forecast. The theory proposes the likelihood of sluggishness of the amount of ecological harm at the turning junction. This pathway, at highly lower stages of ecological harm, is just conceivable if green technology and progress are of greater significance. Affluent nations could participate in green, advanced manufacturing to offset the swelling contamination stages. If affluent nations accurately use their brainpower then they can achieve great heights in controlling ecological damage and saving the environment. A prime mechanism that allows for greener development is an augmented inclination to recompense for a cleaner atmosphere (Field, 2014).

2.1.3 The Environmental Daly Curve Hypothesis

In 1973 the environmental economist Daly writes “Toward a steady state economy” where he defines the relationship between fiscal progress and ecological harm. Daly contends that in the present time the market which is propelled by augmented production-line is lost and a steady-state category of the market would be the best substitute (Daly, 1973). Daly talks about the topic later in 2004 in “Ecological Economics: Principles and Applications”, where he queries the influence of mortal creativeness and origination and contends that the inducements for greener technology are not sufficient to bring down pollution. Certain natural properties are non-renewable, and others are being utilized at a greater intensity than is necessary to maintain a maintainable quantity (Daly, 1973). Daly contends that green expansion is insufficient to counterpoise the utility of rare natural possessions and the total ecological harm. He adds that even if the inducements for

superior, high-quality air should exist when a nation attains a specific junction of affluence, the harm would previously be too great. The efforts to generate a greener production and maintainable ingestion would not be sufficient to minimize ecological harm. The ecological harm would augment as the fiscal wealth rises in a nation, without taking into account its citizen's will or the policymakers' mandate. The environmental Daly curve theory proposes that a rise in per-capita GDP would result in greater ecological harm. The ecological dilapidation would rise with per-capita GDP owing to augmented yield. The Daly curve fails to suggest a turning junction at any level of affluence, like the EKC and the Brundtland Curve.

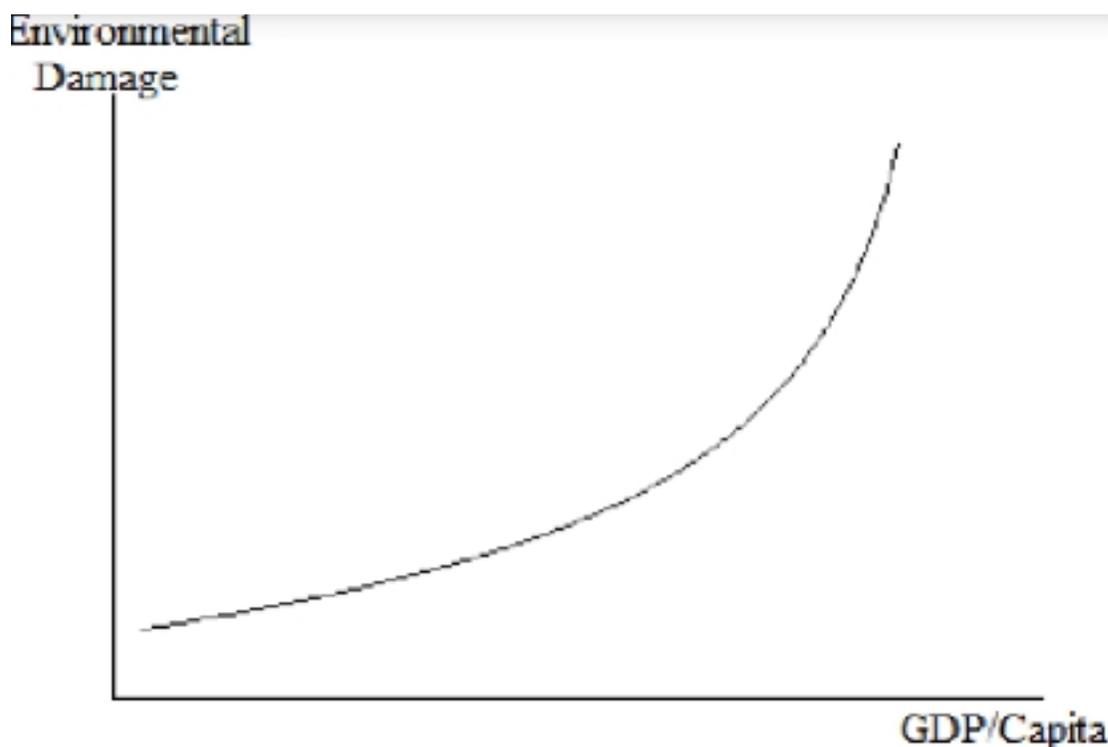


Figure 2. 3:Environmental Daly Curve
Source: Daly (1973)

The Brundland curve; shows the relationship between environmental damage and economic growth. The curve illustrates that at the initial stage environmental damage tends to be low as implements used in deforestation in the less developed nation are local and outdated, but with the coming of economic development the level of environmental damage tend to rise due to the use of new technologies and it shown from the turning point of the diagram at point E or lowest point of the graph.

2.2 Empirical Review

This part presents the empirical literature review. The section is divided into three subsections. Subsection 2.10.1 offers an empirical review of studies on economic growth and environmental degradation. Subsection 2.10.2 discussed a review of studies on energy consumption and environmental degradation. While Subsection 2.10.3 presents the review of studies on financial development, trade, and environmental degradation.

2.2.1 Impact of economic growth on environmental degradation

Various studies have discussed the link between economic growth and CO₂ explosion in recent literature. For example, Saboori et al. (2014) investigate the influence of GDP growth on CO₂ discharge for 27 OECD economies using the FMOLS method from 1960 to 2008. The outcome reveals that GDP growth accelerates the capacity of CO₂ discharge. Shahbaz et al. (2014) stressed that GDP increases the level of CO₂ in the UAE. Similarly, Mutascu, et al. (2014) examine the connection between economic progress, energy, and CO₂ explosion in Romania. The study reveals that economic progress and energy increase CO₂. They also confirm the validity of the EKC hypothesis. Asici (2015) emphasizes the positive link between economic progress and CO₂ in emerging nations. Heidari et al. (2015) documented that growth performance is positively

connected to CO₂ discharge in 5 ASEAN economies. Abdouli and Hammami (2017) investigate the impact of economic performance and the environment on MENA economies by employing the GMM approach from 1990 to 2010. The outcome reveals a positive link among the variables. This finding is similar to that obtained by Alvarado and Toledo (2017).

Al-mulali (2015) investigated the relationship between gross domestic product (GDP) growth and renewable and non-renewable energy consumption in 82 developing countries categorized by region. To achieve the goal of this study, the panel model was used taking the period from 1990 to 2009. The Kao co-integration test results showed that both renewable and non-renewable energy consumption had a long-running relationship with all the economic sectors in all regions. Moreover, the FMOLS revealed that renewable and non-renewable energy consumption had a long-run positive relationship with the economic sectors. However, the results also revealed that non-renewable energy consumption has a more significant effect on the economic sectors than renewable energy consumption. In addition, the Granger causality showed the same results, that the causal relationship between the economic sectors and the non-renewable energy consumption is more significant than the causal relationship between the economic sectors and renewable energy. The reason behind these results is that these regions still depend on fossil fuels to promote their economic growth. Fossil fuels contribute more than 80 per cent of their total energy consumption. Thus, the study recommends that developing countries increase their investment in renewable energy projects to increase the share of renewable energy in total energy consumption. Kahia, Ben Aïssa, and Charfeddine (2016) explore the economic growth and energy

consumption nexus for two samples of MENA Net Oil Exporting Countries (NOECs) during the period 1980 to 2012. Using the panel cointegration approach, the study found strong evidence for the existence of a long-run relationship between real GDP, renewable and non-renewable energy consumption, real gross fixed capital formation, and the labor force. Moreover, empirical results from the estimation of the panel error correction model indicate evidence of unidirectional causality running from economic growth to renewable energy consumption in the short run. In the long run, the results show evidence of bidirectional causality for the entire group of MENA NOECs. For the 5 selected MENA NOECs samples, the study found strong evidence for bidirectional causality between renewable energy and economic growth. Finally, the paper discusses the economic implications of the results and proposes certain policy recommendations.

Riti et al. (2017) apply the ARDL method to examine the effect of economic performance on CO₂. The result shows that GDP accelerates CO₂ in China from 1979 to 2015. Cetin and Ecevit (2017) illustrate that economic progress increases CO₂ positively in Turkey. Saimanul and Abdul-Rahim (2017) stressed that GDP increases the level of CO₂ explosion in Malaysia. Wang et al. (2018) examine the impact of economic progress on CO₂ discharge for 170 economies. The outcome reveals that GDP influences CO₂ positively. Also, a study by Salahuddin et al. (2018) confirms a positive link between economic progress and CO₂ in Kuwait. Chen et al. (2019) studied the influence of GDP on CO₂ in China. The result shows that GDP accelerates CO₂ emissions. Zheng-xin Wang and Li (2019) employ the nonlinear technique to assess the influence of economic progress on CO₂ in China. It indicates that economic progress increases CO₂ discharge.

Bekun et al. (2019) stress that economic performance increases CO₂ in EU nations. This result is similar to the result by (Hanif et al. 2019). Sarkodie and Strezov (2019) find that economic progress has a positive influence on CO₂ explosion in developing economies. Hechmy (2019) examined the link between renewable energy resources and GDP in MENA nations by applying the VECM approach from 2000 to 2014. These estimates aimed to sustain viable economic performance in the absence of environmental pollution and lessen the over-dependent on international economies. In this regard, the outcome of the study illustrates proof of cointegration among the variables and found two-dimension causality. Hence, these nations should promote the use of renewable energy resources against the use of other energy facilities.

Kalu et al. (2019) aim to examine whether any relationship exists between energy consumption and value-added of the agricultural and industrial sectors as well as the overall growth rate of the Nigerian economy. The study used annualized time series data from 1971 to 2014 drawn from the World Bank Development Indicators, adopting an autoregressive distributed lag technique in the data analyses as well as the bound test and error correction representation. There is very strong evidence of the existence of a long-run relationship between energy consumption and indicators of economic growth. There is very strong proof that economic growth and agricultural value-added adjust to the shocks and dynamics of the studied energy-consumption-related variables while manufacturing value-added proved otherwise.

Adedoyin et al. (2020) examine the influence of economic progress on environmental pollution in BRICS nations from 1990 to 2014. The outcome reveals a positive influence of GDP on environmental pollution. Taskin, Varda, and Okan (2020) argued that the

enhancement of the green economy is the most priority issue for academics and policymakers in the world. Therefore, it is essential to promote green economic performance. Hence. This study analyses the influence of renewable energy utilization and trade on economic progress in OECD nations from 1990 to 2015, using OLS and FMOLS techniques. The study outcome reveals that energy consumption and trade openness have a positive effect on GDP growth. Shastri, Mohapatra, and Giri (2020) examined the nexus between economic growth, non-renewable energy consumption, and renewable energy consumption in India over the period from 1971 to 2017. The study uses a nonlinear autoregressive distributed lags model and asymmetric causality test to explore nonlinearities in the dynamic interaction among the variables. The findings indicate that the impact of non-renewable energy consumption and renewable energy consumption on economic growth is asymmetric in both the long run and short run. In the long run, a positive shock in non-renewable energy consumption and renewable energy consumption exerts a positive impact on growth.

However, the negative shocks in non-renewable energy consumption produce larger negative effects on growth. The results of the nonlinear causality test indicate a unidirectional causality from non-renewable energy consumption and renewable energy consumption to economic growth and thus support the “growth hypothesis” in the context of India. The findings imply that policy measures to discourage non-renewable energy consumption may produce deflationary effects on economic growth in India. Further, the findings demonstrate the potential role of renewable energy consumption in promoting economic growth.

In another dimension, several studies have found a negative association between economic progress and CO₂ (Tamazian, Chousa, and Vadlamannati 2009; Tamazian and Rao 2010; Hossain 2011). Begum et al. (2015) discussed that in Malaysia economic progress reduces emissions discharges. Dogan and Seker (2016) discovered that GDP reduces the level of emissions for OECD nations. This outcome is consistent with the result reported by Acheampong, (2018) that GDP decreases CO₂ emissions in 116 emerging economies. Ito, (2017) using panel data from 42 developed countries over the period from 2002 to 2011 attempts to empirically examine the linkage between CO₂ emissions, renewable and non-renewable energy consumption, and economic growth. The results suggest that non-renewable energy consumption leads to a negative impact on economic growth for developing countries. Additionally, the study found that renewable energy consumption positively contributes to economic growth in the long run.

Hassan, Danmaraya, and Danlami, (2018) investigate the link connecting energy consumption with manufacturing performance by using panel data for sampled low-income Sub-Saharan Africa (SSA) and middle-income SSA from the period from 1995 to 2013. The panel cointegration test provides evidence of cointegration among the variables for both the low-income and middle-income groups in SSA. The result of the Fully Modified Ordinary Least Square indicates that in the long run, an increase in energy consumption leads to an increase in manufacturing performance for both the sampled low-income and middle-income SSA countries. This implied that both the low-income and middle-income SSA countries are energy-dependent countries. In this regard, this study shows that energy is a relevant factor in socio-economic development for both low-

income and middle-income SSA countries. Thus, policies on energy that will ensure a lower negative impact on manufacturing performance are recommended.

Banday and Aneja, (2018) find out the relationship between energy consumption, economic growth, and CO₂ emissions for the G7 countries over the period 1971–2014. The second intent of the authors is to make a comparison of whether it is renewable energy consumption, non-renewable energy consumption, or both that determine sustainable economic growth in G7 countries. The authors testify to the relationship between energy consumption, economic growth, and CO₂ emissions using numerous econometric techniques. The authors have applied pooled mean group autoregressive distribution model (ARDL) for long-run and short-run relationships for individual countries.

Kalu, Nwafor, Okoyeuzu, and Onodugo (2020) aim to investigate the energy–growth linkage in sub-Saharan Africa (SSA), with emphasis on real sectors' contribution to aggregate growth using dynamic panel estimation techniques that are practically and conceptually superior to the static models. Dynamic panel econometric techniques pooled mean group, mean group, and the dynamic fixed effect were used to investigate the linkage among energy consumption, real sector value added, and economic growth from 1967 to 2016 in 48 SSA countries. Strong empirical evidence in favor of the energy dependence and growth hypothesis in the investigated SSA countries was found. The finding that real sector value added, and overall growth rate adjust reasonably to the shocks and dynamics of the energy consumption variables makes energy consumption an enabler for growth. This indicates that well thought-out and implemented energy development policy will not only increase energy consumption but also elicit multi-sectoral growth while addressing the obvious energy deficiency in the SSA region.

It is also important to note the policy implications of the high adjustment profiles indicated by the error correction representations. All the speeds of adjustment of the three models denominated in time are slightly above a year and are all within predictable limits (they fall below unity or 100 per cent). We found that when agriculture value-added, manufacturing value-added, and overall economic growth rate in our SSA panel estimation exceed equilibrium levels as a result of deviations arising from energy-related variables, downward adjustments at 66 per cent, 62 per cent, and 78 per cent per year, respectively, take place. The study indicates that well thought-out and implemented energy development policy will not only increase energy consumption but also elicit multi-sectoral growth while addressing the obvious energy deficiency in the SSA region. Much as this study has made some addition to the literature on the energy-growth nexus in the SSA region, which undoubtedly is an unveiling of economic forces in a collection of developing an energy-deficient economy, it will be of great research significance if the form and style of this study are adopted for other economic blocs in the shapes and sizes of the SSA region.

Ondaye, Ondze, and Imongui (2021) studied the impact of economic growth on environmental degradation in the Republic of Congo. The overall aim of this study was to analyze the impact of economic growth on CO₂ emissions in the Republic of Congo. The data used represents the period 1980-2015. Using ARDL modeling, the results show that there is an inverted U-shaped curve between the Republic of Congo's economic growth and carbon dioxide emissions over the period. However, the variable value of the gross domestic product (GDP) does not affect CO₂ emissions in the short term. The Republic of Congo is a good example of governance in terms of environmental policy instruments.

The study, therefore, recommends that governments strengthen environmental protection and renewable energy policies to always achieve economic growth without carbon dioxide emissions exceeding ecologically acceptable limits.

Osuntuyi and Lean (2022) examined economic growth, energy consumption, and environmental degradation nexus in heterogeneous countries. Environmental concerns are growing globally. The world has suffered severe environmental deterioration over the years. Undeniably, the impact of environmental degradation on the earth's geographical space is alarming, making environmental stakeholders to be worried. Therefore, this study employed FMOLS, DOLS, ARDL-PMG, CCEMG, and heterogeneous panel causality test methodologies to investigate the direct and moderating effects of education in the growth-energy-environment linkages in heterogeneous income groups of 92 countries from 1985 to 2018 and the finding validates the EKC hypothesis. However, the finding could not confirm the EKC hypothesis for the LMIC and LIC, indicating that economic growth is not, on its own, a magic wand capable of solving environmental problems in the LMIC and LIC. In addition, energy consumption contributes to environmental deterioration in all income groups. Similarly, education directly affects the environment in all income groups except UMIC. However, the moderating effect of education is shown to mitigate the negative environmental impact of energy consumption in HIC and UMIC but exacerbates it in the LMIC and LIC.

Ilham (2018) examined that economic development in ASEAN still declines environmental quality, whereas the worst environmental quality became a negative externality reducing output in many sectors of ASEAN's economy. The paper aimed to analyze the two-way relationship between economic development and environmental degradation in ASEAN

with the factors which influenced it. The article used panel data from eight ASEAN countries between 2004 and 2013. The analysis method used a simultaneous equation model. The results showed the two-way relationship between economic development and environmental degradation in ASEAN existed. Moreover, Gross Domestic Product (GDP) per capita and energy consumption had a positive impact on environmental degradation. Meanwhile, carbon dioxide emission per capita and trade openness had a positive effect on economic development. Therefore, the economic development strategy for ASEAN countries should be directed to increase GDP per capita and reduce energy consumption.

Igbru, & Ifurueze (2021) investigated the association between environmental degradation and economic growth in Nigeria using a sample from 2011 to 2020. Three objectives were established to evaluate the effect of foreign direct investment, per capita GDP, and population density on carbon dioxide emissions. Ex post facto research design was adopted, and time series data was generated from the World Development Indicators. The augmented Dickey-Fuller (ADF) test was used to test the stationarity of the data, and when they were proved to be stationary, the Johansen Co-integration test was used to test the long-run relationships between the response and exogenous variables. The result showed that per capita GDP and population density have a significant effect on environmental degradation, but foreign direct investment shows no significant effect on environmental depletion as was measured by carbon dioxide.

Ali (2018) examined the relationship between economic development and environmental degradation for a global panel of 120 countries over the period 1990- 2016. The study applied the Fixed Effect Model (FEM) to evaluate the environmental impact of economic development. The research makes attempts to bring about the econometric weaknesses

of the Environmental Kuznets Curve (EKC) addressed by Stern (2004). Although, the results were not consistent with the Environmental Kuznets Curve (EKC) theory that shows that economic development brings about a decline in environmental degradation when the level of economic growth increases beyond some threshold point. The findings suggest that GDP growth rate, Research and Development (R&D), Energy Use (EU) and Oil rents have significant impacts on CO₂ emissions. The findings also indicated that FDI inflows are insignificant in explaining the levels of environmental quality.

Allah, Muhammad, Kashif, Saliha, and Ali (2021) analyzed that environmental degradation caused by modern technological changes is still an unsolved global problem. As the country grows, the cost of these gains must be paid in the form of increased carbon emissions. Pakistan's energy consumption has increased from 34 million tons in 1992 to 98 million tons in 2019 due to oil and gas-based production. Also, average temperatures in Pakistan have increased over the past 50 years. Based on the IPAT and climate change models, this study estimates a two-equation model to analyze the effects of economic growth, foreign direct investment, population density, and urban density on carbon emissions. The cointegration relationship was found to be consistent in both periods. This study proves the theory of EKC (Ecological Kuznets Curve) in Pakistan. The steep curve between carbon emissions and economic growth suggests that the negative environmental effects of current economic growth will last much longer into the future. Carbon emissions were also found to be responsible for increasing average temperatures in Pakistan, leading to climate change. These empirical results suggest that there is an urgent need to revise the growth strategy for sustainable economic growth.

Mohammad, Siti, Arna, Rozana, and Rifda (2019) have long assessed environmental degradation as a residue of economic development processes, especially in low-income countries. However, development measures must continue because people's well-being is the goal. The purpose of this study was to determine the impact of economic growth, population, and energy consumption on environmental pollution. Another objective was to prove the environmental Kuznets curve (EKC) hypothesis. The method used is panel data regression using a fixed effects model using the Driscoll-Kraay estimator. Studies show that higher GDP per capita and higher population growth cause more pollution in low-income countries, but energy consumption is not significantly affected. As a result, the EKC hypothesis for low-income countries was also confirmed.

2.2.2 The Role of energy consumption on environmental degradation

Many studies have discussed the association between energy consumption and CO₂ emissions in the literature. For instance, a study by BÖlük and Mert (2014) emphasizes that energy use accelerates CO₂ discharges in EU nations. Kuncic (2014) used analysis of data from 1990 to 2010 to examine the influence of institutional quality on GDP in 21 nations. The study recommends that policymakers should design policies aimed at upgrading institutions. Heidari et al. (2015) examine the effect of energy on CO₂ discharge in 5 Asian economies from 1980 to 2008. The outcome shows that energy increases CO₂. Al-mulali and Ozturk (2015) argued that energy utilization positively increases CO₂ in MENA nations. The outcome of Dogan et al. (2015) is consistent with the findings of Alshehry and Belloumi (2015) that energy utilization is positively linked with CO₂ in Saudi Arabia.

Solarin (2015) used data from 26 emerging nations to explore the link between energy consumption and CO₂ from 1965 to 2012. The result illustrates a positive link between energy consumption and CO₂ discharge. Sobhee (2017) studied the poor-quality institutions on economic performance in emerging nations. The outcome illustrates that low institutional quality adversely affects economic performance. Therefore, developing nations must take control measures, especially concerning the public sector in dealing with problems of institutions for better economic performance.

Alabi, Ackah, and Lartey (2017) investigate the connection between renewable energy utilization and GDP performance in African OPEC nations, using FMOLS and cointegration. The result indicates a two-way dimension causality among energy and GDP, non-renewable energy use and GDP as well as CO₂ discharge and economic performance finally, a one-way dimension causality was found from non-renewable energy use to CO₂. Therefore, is indicated that renewable energy use accelerates the capacity of growth performance in these nations, and it should be encouraged to upgrade energy efficiencies.

Ermolenko, Proskuryakova, and Ermolenko (2017) studied the effect of fuel, electrical, heat energy, and resource utilization on CO₂ discharge in Russia. The study provides the potential for energy efficiency and costs minimization toward viable economic performance and environmental efficiency. Raza, Ahmed, Alshebami, and Polyakova (2020) studied the influence of renewable energy utilization on CO₂ and GDP in Malaysia using the ARDL technique from 1989 to 2018.

The outcome of the study shows that energy utilization influences CO₂ discharge positively. However, the estimates indicate that CO₂ explosion does not determine GDP. Shastri, Mohapatra, and Giri (2020) analyze the linkage between renewable, and non-renewable energy consumption and economic performance in India from 1971 to 2017 by employing NARDL and causality. The outcome illustrates that renewable, and non-renewable energy resources enhanced economic performance. This is proved by the adverse shocks of energy use on GDP. However, the outcome indicates a one-way dimension of causality from non-renewable, renewable energy to GDP. Hence, government and stakeholders should provide measures to encourage renewable energy use in the country.

Kalu, Nwafor, Okoyeuzu, and Onodugo (2020) used the panel ARDL method to investigate the link between energy consumption, industrial value, and economic performance in 48 SSA nations from 1976 to 2016. The estimated outcome proves the existence of a positive influence of energy resources on economic performance. The shocks in energy resources on economic performance were also found positive in promoting growth rate. This indicates that energy performance in these nations has a general impact on different sectors of the economy. Hence, policymakers need to initiate all avenues toward promoting energy efficiency for viable economic performance. This became necessary because agricultural values have raised to 66 per cent, 62 per cent, and 78 per cent annually because of energy efficiency.

Kwakwa (2020) investigates the influence of energy resources, urbanization, financial performance, and the effect of the interaction of urbanization and financial progress on CO₂ discharge in Tunisia using ARDL and FMOLS methods. The outcome reveals that

energy resources, GDP, urbanization, trade, and financial progress increase CO₂ discharge. Nonetheless, the interaction effect of financial performance and urbanization decreases CO₂ explosion. Hence, it is suggested that policies should be toward financial reforms to reduce the capacity of CO₂ explosion.

Kacho (2017) Uses GMM dynamic panel data from 2002 to 2014 to assess the influence of institutions and financial progress indices on economic performance in MENA nations. The empirical analysis suggests that financial progress and institutional quality have a negative and statistically significant effect on GDP in MENA countries. Arabia. Jebli et al. (2017) indicate a positive influence of energy on CO₂ in 25 OECD economies. The finding is in line with the result obtained by Wang et al. (2018) that illustrates energy use influences CO₂ positively in 170 nations. Chen, Wu, Xu, Song, and Liu (2018) analyze the role of energy utilization and GDP on CO₂ discharge in developed nations from 1985 to 2015. The findings illustrate energy use and income increase the level of CO₂ explosion.

Gbatu et al., (2018) used a fixed effect method to analyze the link between economic progress, energy consumption, and the environment in selected ECOWAS nations from 1980 to 2014. The result illustrates that energy resources and GDP performance influence CO₂ discharge positively. Bhat and Mishra (2018) examine the link between GDP, energy resources, trade, and CO₂ in India using the ARDL approach from 1971 to 2013. The study reveals that GDP performance reduces CO₂ discharge, while energy resources and trade accelerate CO₂ explosion. The study suggests that policymakers should emphasize research and development to enhance energy use and efficiency.

Danlami et al., (2018) apply the ARDL method to examine the association between economic progress, energy production, and population growth in Malaysia from 1971 to 2011. The outcome reveals that GDP performance, energy production, and population growth accelerate the capacity of CO₂ discharge. Therefore, the study suggests policies aimed at promoting energy use and growth performance toward reducing CO₂ explosion. Sathyamoorthy and Tang (2018) investigate the impact of the quality of institutions on trade in 119 nations using fixed and random effect techniques. The outcome reveals that institutional performance promotes trade in all the sampled nations.

Sehrawat and Giri (2018) analyze the influence of the quality of institutions, financial performance, and globalization on GDP in India from 1982 to 2016 by applying the ARDL technique. The outcome indicates that the quality of institutions and globalization enhance the level of GDP growth. thus, policymakers should embark on financial reform and corruption measures for viable economic performance in the nation.

Islam and Abdul Ghani, (2018) investigate the relationship between energy utilization, CO₂, GDP, population, and poverty in ASEAN nations from 1995 to 2014. The outcome reveals that growth performance and population influence energy utilization positively, while CO₂ and poverty decelerate energy consumption in Malaysia. However, GDP and poverty increase energy efficiency and CO₂ discharge as well as population reduce the level of energy use in Singapore. CO₂ explosion and population influence energy consumption negatively, while growth performance, population, and poverty decrease energy performance in the Philippines. Hence, the study recommends that policymakers should emphasize energy efficiency policies for viable economic growth.

Similarly, Sarkodie and Strezov (2019) reveal the positive influence of energy on CO₂ explosion in developing economies. Bekun, Alola, and Sarkodie (2019) examine the effect of energy resources on the environment in 16 EU economies from 1996 to 2014. The result shows that energy resources increase CO₂ in EU nations. This outcome is similar to that reported by (Y. Chen, Wang, and Zhong 2019). Nguyen and Kakinaka (2019) investigate the effect of energy on CO₂ in 107 economies from 1990 to 2013. The finding shows that energy use decreases the level of CO₂. Also, Hanif, Raza, Gago-de-santos, and Abbas (2019) reveal that the consumption of fossil fuels increases CO₂ in 15 Asian economies from 1990 to 2013. Liu, Kumail, Ali, and Sadiq (2019) apply ARDL, DOLS, and causality techniques to investigate the connection between GDP growth, tourism, energy, and CO₂ in Pakistan from 1980 to 2016. The outcome shows that tourism, GDP growth, and energy utilization increase CO₂ discharge. Salman, Long, Dauda, and Mensah (2019) studied the influence of institutional quality, energy resources, and trade in East Asian nations using FMOLS, DOLS, and VECM techniques from 1990 to 2016. The findings indicate that institutional quality reduces the capacity of CO₂ explosion and also enhances economic performance. The outcome also reveals one-way dimension causality from institutional quality to economic performance, CO₂ and energy resources, and trade to CO₂ discharge. The study suggests a regulatory measure to enhance institutions targeting low CO₂ discharge and economic progress.

Liu, Kumail, Ali, and Sadiq (2019) apply ARDL, DOLS, and causality techniques to investigate the connection between GDP growth, tourism, energy, and CO₂ in Pakistan from 1980 to 2016. The outcome shows that tourism, GDP growth, and energy utilization increase CO₂ discharge. Salman, Long, Dauda, and Mensah (2019) studied the influence

of institutional quality, energy resources, and trade in East Asian nations using FMOLS, DOLS, and VECM techniques from 1990 to 2016. The findings indicate that institutional quality reduces the capacity for CO₂ explosion and enhances economic performance. The outcome also reveals one-way dimension causality from institutional quality to economic performance, CO₂ and energy resources, and trade to CO₂ discharge. The study suggests a regulatory measure to enhance institutions targeting low CO₂ discharge and economic progress.

Hechmy (2019) examined the link between renewable energy resources and GDP in MENA nations by applying the VECM approach from 2000 to 2014. These estimates aimed to sustain viable economic performance in the absence of environmental pollution and lessen the over-dependence on international economies. In this regard, the outcome of the study illustrates proof of cointegration among the variables and found two-dimensional causality. Hence, these nations should promote the use of renewable energy resources against the use of other energy facilities.

Can and Kormaz (2019) analyzed the influence of renewable energy and GDP in Bulgaria from 1990 to 2016, using the ARDL technique and Toda Yamamoto during the Balkans and various crises in the nation. The outcome reveals that renewable energy enhances the level of GDP. The second dimension of the estimate shows that economic performance influences energy use, while the last dimension of the finding reveals that renewable energy does not cause electricity energy.

Yahyaoui, Ibrahim, and Saggaf (2019) examined the influence of financial resources, quality of institutions, and GDP in Arab nations from 1995 to 2012. The outcome reveals

that financial performance and institutional quality increase growth performance. The study suggests the provision of adequate measures to improve the quality of institutions which are essential for viable economic progress.

Ansari, Haider, and Khan (2020) studied the influence of GDP performance, trade, and energy resources on CO₂ discharge in industrialized economies from 1971 to 2013 by employing ARDL and VECM causality approaches. The outcome illustrates that energy utilization, trade, and growth performance influence CO₂ positively. In addition, the EKC curve was validated. Raza, Ahmed, Alshebami, and Polyakova (2020) studied the influence of renewable energy utilization on CO₂ and GDP in Malaysia using the ARDL technique from 1989 to 2018. The outcome of the study shows that energy utilization influences CO₂ discharge positively. Kirikkaleli and Ozbaser (2022) examine the effect of GDP on the environment in China from 1950 to 2016. The study found a positive link between GDP and environmental pollution. However, the estimates indicate that CO₂ explosion does not determine GDP.

Rasool, Malik, and Tarique (2020) used ARDL and VECM methods to assess the influence of GDP performance, energy, and financial progress on CO₂ discharge in India from 1971 to 2014. It is revealed that GDP performance enhances environmental quality, while energy and financial progress increases the level of CO₂ explosion. Lin and Xu (2020) studied the influence of fossil fuel use and economic performance in China. The outcome of the study reveals that energy use and GDP increase environmental degradation. Moreover, the study proved the occurrence of the EKC hypothesis.

Karasoy and Akcay (2019) examined the performance of energy use and trade on CO₂ explosion in Turkey from 1965 to 2016 by applying the ARDL technique. The outcome shows that energy use increases CO₂ and the EKC hypothesis was valid. Koshta, Bashir, and Samad (2020) explore the link between growth performance, energy, and CO₂ in developing economies from 1990 to 2014, using FMOLS and DOLS methods. The outcome illustrates that GDP growth and energy accelerate the explosion of CO₂ and that EKC was validated in the nations.

Shahbaz and Sinha (2019) examined the association between GDP, population, energy, and CO₂ in developing nations from 1991 to 2017. It illustrates that GDP and energy influence environmental pollution positively and the EKC curve occurs. Lau, Choong, and Ng (2018) used the GMM technique to prove the occurrence of the EKC hypothesis in 100 developed and emerging economies. The study found the EKC hypothesis only in developed nations. Furthermore, institutional value, FDI, and trade reduce the capacity of CO₂ explosion in industrialized nations and increase in developing economies. The study suggests more relevant policies that can enhance economic performance and environmental quality.

Egbetokun et al. (2020) examined the association between GDP performance, population, FDI, and institutional value in Nigeria using the ARDL approach. The outcome indicates the occurrence of the EKC hypothesis. The study recommends that the efficiency of institutional value should be improved to promote environmental quality. Kwakwa (2020) investigates the influence of energy resources, urbanization, financial performance, and the effect of the interaction of urbanization and financial progress on CO₂ discharge in

Tunisia using ARDL and FMOLS methods. The outcome reveals that energy resources, GDP, urbanization, trade, and financial progress increase CO₂ discharge.

Raza, Ahmed, Alshebami, and Polyakova (2020) aim to analyze the impact of renewable energy use in Malaysia on the environment and economic growth and direct study findings to stimulate developing economies in the Arab region to evaluate its economic returns from renewable energy uses. In this study, a set of time series data has been used which is ranging from the year 1989 to 2018. Moreover, the stationarity of the data was tested through Augmented-Dickey Fuller (ADF) test. The normality test of the data distribution was also conducted with the help of the Jarque Bera test. In addition to the methods, due to the existence of unit roots, an ARDL technique was also incorporated which tested the influence of renewable energy use on the growth and environment of Malaysia. The findings of the study imply that the usage of renewable sources in Malaysia was found to have a positive and significant relation to CO₂ emissions in the case of Malaysia. Furthermore, the findings of the study also suggested that there is no significant relationship between renewable energy use and GDP. Also, it was identified that there was no long-run influence in the variables and hence short-run influences were recognized.

Hechmy (2019) examined the relationship between renewable energy consumption and economic growth in non-oil countries in the Middle East and North Africa (non-oil-MENA) during the period from 2000 to 2014.

The Pedroni (2000) test shows that there is a long-term cointegration relationship between those variables; however, the Granger causality test in the vector error

correction model (VECM) shows that this relationship is bidirectional in the short and long term. Thus, to ensure sustainable economic growth without pollution and to reduce dependence abroad, renewable energies can be chosen as substitutes for conventional energies in non-oil-MENA countries. First, LLC and IPS unit root tests are used to test the stationarity of the variables; and second, Pedroni panel cointegration and Engle-Granger causality by VECM analysis are used to check the relationship between the studied variables. Empirical results show that renewable energy consumption and economic growth are cointegrated and that there are two-way causal relationships between them in the long and the short term. These countries must therefore encourage the consumption of renewable energy instead of traditional energy to reduce their dependence on energy from abroad and CO₂ pollution.

Can and Kormaz (2019) investigate the relationship between renewable energy and the economic growth of Bulgaria. This study analyses the relationship between renewable energy and the economic growth of Bulgaria for the period 1990-2016, based on annual data, by using the Toda Yamamoto analysis and Autoregressive Distributed Lag (ARDL) bound test. This period is characterized by the democratization of the Balkans and several crisis cycles in Bulgaria. Renewable energy consumption (REC, percentage of total final energy consumption), renewable electricity output (REO, percentage of total electricity output), and economic growth (GDP constant 2010 US\$) were used. The levels or differences of the variables that are stationary were investigated using the Augmented Dickey-Fuller (ADF), Philips Perron (PP), and Kwiatkowski-Philips-Schmidt-Shin (KPSS) unit root tests. Three different results were obtained from this study. One showed that renewable energy consumption and renewable electricity output are the causes of

economic growth. Another result of this study is that economic growth and renewable electricity output are the causes of renewable energy consumption. The last result is that economic growth and renewable energy consumption are not causes of renewable electricity output. There was no long-term relationship between the variables. The ARDL and Toda–Yamamoto tests were used because of a lack of data sets. Thus, it is estimated that there is no long-term relationship.

Nonetheless, the interaction effect of financial performance and urbanization decreases CO₂ explosion. Hence, it is suggested that policies should be toward financial reforms to reduce the capacity of CO₂ explosion.

In another development, country-based studies found a positive link between energy and CO₂ (Begum et al. 2015; Shahbaz et al. 2014). Ohlan (2015) assesses the impact of energy on CO₂ in India. The outcome confirms that the use of energy influences CO₂ positively. Mirzaei and Bekri (2017) show that energy use increases CO₂ in Iran. Saimanul and Abdul-Rahim (2017) examine the influence of energy use on CO₂ in Malaysia. It finds that energy use accelerates CO₂. Yahaya, Adamu, and Mustapha (2020) studied the influence of energy production and use in Nigeria. Their outcome reveals a positive impact of energy on CO₂ discharge.

several studies found a negative relationship between energy utilization and CO₂ (Jebli & Youssef, 2015; Shafiei & Salim, 2014; Shahbaz et al., 2014) Moreover, Zoundi (2017) investigate the effect of energy use on CO₂ in 25 African economies. The result indicates that energy has a negative impact on CO₂. Jebli et al. (2017) argue that energy use decreases the capacity of CO₂ in OECD nations. Dong et al. (2017) stressed that energy

decelerates CO₂ in BRICS countries. Sarkodie and Adams (2018) examine the influence of energy on environmental pollution in South Africa using the ARDL approach from 1971 to 2017. The outcome reveals that energy consumption reduces environmental pollution.

Ibrahim & Maji (2021) investigated the impact of renewable energy consumption on environmental quality by sector in the context of Nigerian government efficiency. Regression analysis was used to evaluate the data set from 1989 to 2019. Industry indicators of environmental quality and industrial production and per capita indicators of agriculture, manufacturing and construction, transport, oil, housing, trade and utility services, and other industries were considered. As a result, it was found that the consumption of renewable energy did not have a positive effect on the quality of the environment in agriculture, manufacturing and construction, and oil. However, the consumption of renewable energy has a positive impact on the quality of the environment in the transport, housing, trade, and public services sectors. However, the use of renewable energy has a neutral impact on the quality of the environment in other sectors. The research considered the expected value of the environmental quality index for each sector with great flexibility as policy implications

Mehmood (2021) examines the impact of renewable energy on CO₂ emissions in G11 countries over the period 1990-2019, considering other factors such as education, GDP, natural resources, and foreign direct investment. It is important for both developed and developing countries. Appropriate sustainable development policies to protect the environment are a serious issue for developing countries. Purpose of this paper Empirical results shows that renewable energy and education reduce CO₂ emissions by 0.49 per cent and 0.11 per cent, respectively. Foreign direct investment and natural resources

burden the environment by 0.15 per cent and 0.09 per cent respectively. Heterogeneous causality results indicate a feedback relationship between renewable energy sources, education, GDP, and CO2 emissions. This report provides policy implications for G11 investments in renewable energy and education. This enables these countries to systematically achieve their Sustainable Development Goals.

Muhammad, Samia, & Aviral (2021) empirically assesses the relationship between renewable energy consumption, forest cover, and CO2 emissions in 33 BRI partner countries between 1986 and 2018. The study investigates the causal and long-run relationships between the variables using cointegration and the heterogeneous Granger causality framework. Empirical evidence shows that increased consumption of renewable energy and increased forest cover can help reduce CO2 emissions in the BRI economy. However, the estimated Granger causality results show an inverse causal relationship between renewable energy consumption and forest area and a unidirectional causal relationship between per capita income and environmental quality. The study highlights the importance of investment in renewable energy projects and forest management among BRI partner countries.

Kahia, Omri, and Jarraya (2021) studied a combination of three laterals between economic renewable energy and the quality of the environment using simultaneous comparison methods in Saudi Arabia. The most important results listed below are influenced by the economic growth of the consumption of renewable energy to confirm the recovery hypothesis. Bidirectional relations have been identified between economic growth and CO2 emissions, discharge, discharge, and discharge and renewable energy. Closed the gap between the economic growth of Saudi Arabia and the protection of the

environment of renewable energy; The curved hypothesis of the environment Kuznets (EKC) is accepted.

2.2.3 Financial Development, trade, and environmental degradation

Several studies have analyzed the link between financial development, trade, and environmental degradation in the literature. For example, Salahuddin et al. (2015) apply the FMOLS method to examine the influence of financial progress on CO₂ discharge for GCC economies from 1980 to 2012. The finding indicates that financial progress decreases the level of CO₂ explosion. Al-mulali et al. (2015) emphasize that financial sector development has a negative impact on CO₂ for 129 nations. Dogan and Seker (2016) discover a negative connection between financial progress and CO₂ in developing economies. Abid (2016) analyzed the effect of financial development on CO₂ using the GMM approach from 1996 to 2010 in 25 SSA nations. The outcome reveals that financial progress negatively affects CO₂.

Paramati et al. (2017) examined the effects of the stock market, and energy use on CO₂ for G-20 nations, by employing the FMOLS technique from 1991 to 2012. The result illustrates that stock market growth and energy reduce CO₂. Similarly, Saidi and Mbarek (2017) reveal that financial progress decreases the level of CO₂ in 19 emerging nations. This finding is consistent with the result obtained by Shahzad et al. (2017). Zafar, Saud, and Hou (2019) studied OECD economies and conclude that financial development decelerates environmental pollution.

On a different dimension, Boutabba (2014) examined the connection between CO₂ discharge, GDP, financial progress, trade, and energy in India, by employing the ARDL

approach from 1971 to 2008. The outcome shows that financial sector development increases CO₂. Similarly, Sehrawat et al. (2015) emphasize that financial development accelerates the level of CO₂ in India. Javid and Sharif (2016) analyzed the influence of financial progress, income, energy, and trade on CO₂ in Pakistan. The result indicates that financial development, income, and energy promote CO₂. Cetin and Ecevit (2017) stressed that financial progress enhances CO₂ in Turkey. Similarly, Ozatac et al. (2017), and Meng et al. (2018) find similar results that financial progress is positively linked with CO₂ in Turkey and Saudi Arabia. Ganda (2019) examines the role of financial progress on CO₂ in OECD economies from 2001 to 2012, using the GMM technique. The outcomes illustrate a positive connection between financial progress and CO₂.

Charfeddine and Kahia (2019) argue that financial development increases the level of CO₂ in MENA nations. Gokmenoglu and Sadeghieh (2019) investigate the performance of financial development, energy, and GDP on CO₂ in Turkey from 1960 to 2011. The outcome indicates a positive link between financial progress and environmental pollution. This result is in line with the result obtained by Zakaria and Bibi (2019) that financial progress accelerates environmental pollution in South Africa. Yahaya, Mohd-jali, and Raji (2020) stressed that financial progress influences environmental degradation positively in SSA economies. However, Ozturk and Acaravci (2013) stressed that financial development does not affect CO₂ in Turkey. This outcome is consistent with the conclusion of Dogan and Turkekul (2015) and Salahuddin et al. (2018) that financial progress does not affect CO₂ in the USA and Kuwait. Seetanah et al. (2019) argue that financial sector development does not determine environmental pollution in 12 nations.

Furthermore, the association between trade and CO₂ has been discussed in the economic literature. For example, Al-Mulali et al. (2015) illustrate negative connotations of trade and CO₂ in Europe. Dogan and Turkekul (2016) investigate the influence of trade on CO₂ in the USA and emphasize that trade increases the level of environmental quality. Jebli et al. (2017) studied the association between trade and CO₂ in 25 OECD nations using FMOLS and DOLS approaches from 1980 to 2010. The result indicates a negative link between trade and CO₂. Zhang (2018) confirm that trade influences CO₂ negatively in developed nations. The finding of this study is in line with the result documented by Asongu (2018) that trade decreased CO₂ in 44 SSA nations. Liobikienė and Butkus (2019) examine the effect of trade on CO₂ by employing the GMM approach in 147 nations from 1990 to 2012. The study indicates a negative influence of trade on CO₂. The result is in line with that obtained by Zafar, Mirza, Zaidi, and Hou (2019) that trade decreases CO₂ in emerging nations.

Farhani and Ozturk (2015) stressed that trade increases CO₂ in Tunisia. Shahbaz et al. (2015) ascertain the effect of trade on CO₂ in Portugal from 1996 to 2012. The outcome shows that trade stimulates CO₂. Similarly, Al-mulali and Ozturk (2015) examine the role of trade on CO₂ for 14 MENA economies, by applying the FMOLS method from 1996 to 2012. The outcome indicates that trade is positively linked to CO₂. Jamel and Maktouf (2017) studied the association between trade, GDP, financial progress, and CO₂ for 40 EU economies from 1985 to 2014. The study reveals a positive link between trade and environmental pollution. Hasanov, Liddle, and Mikayilov (2018) examine the impact of trade on CO₂ in oil-exporting emerging nations. The outcome indicates that trade influences CO₂ positively.

Similarly, Mutascu (2018) stressed that trade increases the capacity of CO₂ in emerging economies. Yasmeen, Li, and Hafeez (2019) investigate the influence of trade on CO₂ in 39 nations. The study stressed that trade has a positive influence on CO₂. Likewise, Lv and Xu (2019) emphasize that trade increases the level of CO₂ in 55 nations. Muhammad et al. (2020) argue that both imports and exports accelerate the capacity of CO₂ explosion in emerging nations.

Using a nonlinear autoregressive distributed lag (NARDL) model, Iorember, Usman, & Djelilov (2019) showed that renewable energy consumption (REC), trade openness (TOP), and GDP per capita (GDP) are asymmetric for the quality environment in Nigeria. Its effects have been studied in South Africa, from the first quarter of 1990 to the fourth quarter of 2014. To ensure this, the Zivot-Andrews unit root test and the non-linear ARDL cointegration test are used. The empirical results show that REC, TOP, and GDP have asymmetric effects on long-term environmental quality and short-term dynamics in Nigeria and South Africa. In particular, the long-term effects of negative changes in REC and GDP are stronger than positive changes of the same magnitude. Similarly, the effect of positive TOP changes was stronger than negative changes. The short-run results for Nigeria show that the impact of negative changes in REC and GDP is stronger than positive changes and positive changes in TOP are stronger than negative changes. For South Africa, positive changes in REC and GDP are stronger than negative changes, and for TOP, negative changes are stronger than positive changes.

Dimnwob, Madichi, Ekesiobi & Asongu (2022) examined the relationship and implications of financial development for renewable energy consumption in Nigeria (Africa's largest and most populous economy). This study used massive data on the Financial

Development Index to effectively handle the multidimensional characteristics of financial development and the share of renewable energy in total energy consumption as major variables. Other important information (GDP per capita), foreign direct investment, and consumer price index). ARDL was used to identify long-term relationships using data from 1981 to 2019. The survey assessment highlights, among other things, the importance of financial development for renewable energy consumption in Nigeria and recommends policies to improve financial and energy performance. section.

Xin, Shupe, Haizhong, Samuel, and Brian (2021) investigated how financial development affects environmental quality, where China's decision-makers need to financially improve environmental quality. A smooth transition regression model is used to analyze the gender-level data for China from 2001 to 2017. Paths at different levels of financial development may determine different indirect effects of financial development on environmental quality and the rate of change in the power of these effects. The results show that financial development has a significant indirect impact on environmental pollution through different pathways, and the impact of these pathways varies between regions with low and high levels of financial development. Insufficient financial development in regions with poor financial development can indirectly cause environmental pollution by promoting economic growth and promoting the development of secondary and tertiary industries. In regions with a relatively high level of financial development, financial development has a mixed effect on environmental pollution, that is, stimulating technological innovation and attracting foreign direct investment to improve environmental quality and decreasing environmental quality through secondary support.

It is. and tertiary industry. Local authorities should consider the different characteristics of local financial development when formulating environmental protection policies.

Adebayo (2020) re-examined the long-run and causal effects of trade openness, energy usage, gross capital formation, and real growth on CO₂ emissions in Mexico utilizing recent econometric techniques. The study utilized yearly data spanning between 1971 and 2016. No prior study has used the wavelet coherence approach to collect information on the correlation and/or causal relation between these economic variables at different frequencies and time frames. Thus, this study proposes to fill the gap in the literature. To capture long-run effects, the study utilized ARDL, FMOLS, and DOLS estimators, while the wavelet coherence technique is utilized to explore causal effects among the variables. The empirical findings confirm that the EKC hypothesis is valid for Mexico, and gross capital formation, energy usage, and economic growth impact CO₂ emissions positively. The wavelet coherence technique revealed bidirectional causality between economic growth and CO₂ emissions; unidirectional causality from CO₂ emissions to energy usage; and one-way causality running from CO₂ emissions to gross capital formation.

Acheampong (2019) used a generalized moment method to investigate the direct and indirect impact of financial development on carbon emissions in 46 sub-Saharan countries between 2000 and 2015. Empirical results, using various indicators of financial development, show that foreign direct investment, current debt, and domestic credit, while financial development, measured as money supply, domestic credit to the private sector, and domestic bank credit to the private sector, increase carbon emissions. The private sector has no impact on the CO₂ emissions of the financial sector. The results show that none of the financial development indicators has a significant non-linear effect on CO₂

emissions. The results show that FDI regulates economic growth to reduce carbon emissions but does not regulate energy use for carbon emissions. Instead, financial development is measured by money supply, domestic credit to the private sector by banks, domestic credit to the private sector in the financial sector, and domestic credit to the private sector by energy consumption normalized to increase carbon emissions. The three measures of financial development are economic growth normalized against the growth of CO₂ emissions. The results do not support the EKC hypothesis but confirm that population, energy consumption, trade openness, urbanization, and economic growth increase CO₂ emissions. There are some differences in these results between regional and income groups. These findings not only provide information but also provide various implications for sustainable development policies.

2.2.4 Empirical Studies on Environmental Kuznets Curve (EKC) Hypothesis

The EKC hypothesis assumes that the relationship between fiscal progress and ecological contamination could be depicted in an inverted-U curve. Therefore, in the primary phase of monetary progress, the development of the air pollutant would see an upward curve, however, this would just progress to a specific progress parameter and later a decrease would be witnessed. The earlier research on EKC was engaged by Grossman and Krueger, (1991), and Panayotou (1993). This denotes that progress is connected with an upsurge in CO₂ releases at the initial stage and later declines as soon as the market develops. Current researches such as the ones engaged by Grossman and Krueger (1994) Dong, Sun, Li, and Liao (2018), and Danlami, Aliyu, and Danmaraya, (2019) investigated the association between revenue and discharges in trying to authenticate, the presence of the EKC supposition.

A finding from previous studies on the EKC hypothesis was also found to be contradicting. While some studies validated the Environmental Kuznets Curve (EKC) supposition, others argued that the EKC theory cannot hold. Taking the instance Tang and Tan (2014) studied the influence of output surge and FDI on CO₂ emanations in Vietnam in the interval from 1976 to 2009. The result reveals output growth, FDI promotes CO₂ discharges and the applicability of the EKC hypothesis is revealed.

Similarly, Al-mulali et al. (2014) tested the cogency of the EKC premise in 93 countries. The outcome of the study supports the existence of the EKC premise. Gao and Zhang (2014) investigate the effect of EKC in 14 Sub-Saharan African nations using FMOLS and DOLS techniques from 1980 to 2009. The outcome discloses that EKC is effective in SSA. Li et al. (2016) test the reality of the EKC hypothesis in 28 Provinces of China from 1996 to 2012. The result reveals the presence of the EKC hypothesis. Nasreen and Anwar (2015) utilize the FMOLS approach to validate the presence of the EKC postulate in 57 developing countries in the interval from 1980 to 2010. Their finding backs the existence of the EKC theory.

Omri et al. (2015) assess the reliability of the EKC premise in 12 MENA republics. The outcome reveals the occurrence of the EKC hypothesis. Likewise, Sehrawat et al. (2015) study the consequence output surge in CO₂ in India. The outcome shows that EKC is valid. Javid and Sharif (2016) investigate the validity of the EKC hypothesis in Pakistan from 1972 to 2013. The study reveals the EKC hypothesis exists in Pakistan. Charfeddine and Khediri (2016) studied the effect of the EKC hypothesis in the UAE. The finding supports the applicability EKC hypothesis. Rafindadi (2016) inspects the impression of GDP on CO₂ and even validates the applicability of the EKC hypothesis in Japan from

1961 to 2012, the study finds that energy use increases CO₂ and the EKC hypothesis is valid. Jebli et al. (2017) use FMOLS and DOLS to assess the effect of the EKC premise in 25 OECD nations, the study reveals the presence of EKC supposition.

Dong et al. (2017) studied the effect of fiscal rise on CO₂ in 5 BRICS nations for the period 1985 to 2016, the finding supports the presence of the EKC postulate. This conclusion is consistence with the outcome by Ozatac et al (2017), which emphasizes that the EKC premise is legal in Turkey. Sarkodie and Adams (2018) reported that the EKC hypothesis is applicable in South Africa, a similar exercise was conducted by Masron and Subramaniam (2018) to investigate the presence of EKC in 64 emerging countries, and the study reveals the applicability of the EKC postulate. In addition, other studies reveal the applicability of EKC theory in both industrialized and developing countries (Ganda 2019; Hanif et al. 2019; Zakaria and Bibi 2019; Zafar, Saud, and Hou 2019; Arminen and Menegaki 2019).

However, a study by Lau et al. (2014) investigated the cogency of the EKC theory in Malaysia. The study shows EKC hypothesis does not exist. Mrabet and AlSamara (2016) check the rationality of EKC in Qatar from 1980 to 2011, the study reveals that EKC is not valid. Al-Mulali et al. (2016) examine the existence of the EKC proposition in Kenya by employing the ARDL method from 1980 to 2012. The outcome reveals the EKC hypothesis does exist. Similarly, Dogan and Turkekul's (2016) study of the EKC proposition in the USA from 1960 to 2010, the study indicates that EKC is not valid. Saidi and Mbarek (2017) studied the presence of the EKC hypothesis for 19 developing nations, and the study finds that the EKC postulate does not occur. Likewise, Chen et al. (2019) reveal that the EKC hypothesis is not applicable in China.

According to Jebli et.al. (2022), over the past three decades, researchers have extensively examined the environmental Kuznets curve (EKC) hypothesis, they, however, conducted a state-of-the-art review of this topic and shed light on the methodological challenges that the literature attempted to overcome so far. Using quarterly data from 1990Q1-2018Q4 they observed that empirical results failed to support the existence of an inverted-U-shaped relationship between export product diversification and carbon release from fuel combustion in China. Also, as income grows, low-carbon resources seem to improve export diversification and vice versa.

Ojonugwa, Paul, and Ifedolapo (2019) in their study revisited the environmental Kuznets curve (EKC) hypothesis in India, including the role of energy consumption and democratic regimes in the functioning of environmental degradation between 1971 and 2014. By doing this the study employed Zivot–Andrews nonstationarity test, Bayer–Hanck cointegration test, autoregressive distributed lag (ARDL) model, and vector autoregressive model (VECM) Granger causality test, and the results found a stable cointegration among the series. The results confirm the EKC hypothesis for India and show that energy consumption increases environmental degradation in the short and long term. The impact of democracy on reducing environmental degradation is weak in the long run (not statistically significant) but strong in the short run (statistically significant). As a result of the VECM Granger test, it was found that there is a long-term causal relationship between the primary variable and environmental destruction. Also, the short-term results showed a unidirectional Granger causal relationship from energy consumption to environmental degradation, from energy consumption to real income, and from energy consumption to real income squared. The findings suggest that energy

conservation policies should prioritize the use of energy from clean sources to reduce environmental degradation and increase economic growth.

Aguir (2021) proposed solutions to climate change challenges such as efficient use of renewable energy sources and fossil fuels in the face of increasing urbanization in the MENA region. We attempt to quantify the effects of population, economic well-being, urbanization, fossil fuels, energy efficiency, and renewables, especially solar, wind, and hydro, on population, economic well-being, urbanization, and renewables for the period 2000-2018 using GMM estimators for 18 MENA countries. carbon dioxide emissions. The results enable the validation of the Kuznets curve for the environment and show the contribution of energy efficiency to environmental improvement. However, the percentage of renewable energy used in the energy mix does not significantly affect the quality of the environment. Solar energy also helps reduce emissions. Expected levels of wind and hydropower do not allow for environmental improvements in these countries.

Nuhansyah (2017) examined environmental degradation as one of the issues resulting from economic development. ASEAN countries are no exception. As a 'new economic market', economic growth has affected environmental degradation. The basic theory of the relationship between economic growth and environmental degradation was introduced by Grossman and Krueger in 1991 by adapting the Kuznets Curve inequality theory published by Simon Kuznets in 1955. This theory, Environmental Curve Kuznets theory (EKC), posited that there is the possibility of economic growth which could pose a positive impact on the ecosystem and environmental improvement. The study attempted to prove that the EKC theory can occur in ASEAN countries. In addition, the study also aims to illustrate the position of the turning point of the inverted U-curve in the ASEAN

region and compare the real and estimated value of the EKC theory of each country. Several variables used in the study are Gross Domestic Product per capita, the added value of the industrial sector, and the percentage of urban population growth. These variables were used as a reference to prove the influence between economic growth and environmental degradation, as reflected by Carbon Dioxide (CO₂) pollution variables. Findings from this study indicated that all economic variables have a significant impact on CO₂ pollution levels. Furthermore, this study proves that there is a turning point where ASEAN countries will enjoy positive results from economic growth on the environment. Nevertheless, not all ASEAN countries were able to pass the point due to the close distance between the real and estimated value of the EKC theory that rises annually.

Prasetyanto and Sari (2021) reviewed the environmental Kuznets curve (EKC) as a hypothesis for the impact of the relationship between environmental degradation and economic growth (GDP per capita) in terms of economic development. The purpose of this study is to demonstrate the effect of economic growth on environmental degradation under the U-shaped EKC hypothesis and to understand the impact of Indonesia's primary energy consumption, income inequality, education level, and environmental degradation on sustainable development. This study used the Engel and Granger estimation method of the error correction model (ECM) to determine the short-term and long-term impacts of the period 1994-2018 in Indonesia. The results showed that SCC proved to be effective in the short and long term. Economic growth and primary energy consumption variables have a positive and significant impact on environmental degradation. Income inequality has a negative but not significant impact in the short and long run, and education is negligible in the short run but positive and significant in the long run. The effect was

positive and significant for export variables in the short run, but not in the long run for environmental degradation.

2.2.5 Empirical studies on the impact of other greenhouse gases (Methane, and nitrous oxide) on environmental degradation

Hanif S, Lateef M, Hussain K, Hyder S, Usman B, Zaman K, et al. (2022) examined the impact of various methane emissions (from the agricultural, energy, and industrial sectors), urbanization, resource depletion, and livestock farming. Carbon emissions from a group of selected Asian countries from 1971 to 2020. The results show that energy-related methane emissions, livestock farming, resource depletion, and urbanization are the major damaging factors of environmental degradation in several countries. Causal estimates show unidirectional relationships from livestock and agriculture methane emissions to carbon emissions, from total methane emissions and carbon emissions to urbanization, and from urbanization to energy-methane and livestock emissions. Projections suggest that overall methane emissions, resource depletion, and urbanization could increase carbon emissions over the next decade. The study recommended among others that the energy sector should use renewable energy sources in production processes to minimize carbon emissions. Achieving carbon neutrality requires limiting urbanization and excessive resource use.

Tariwari, Elijah, and Donbebe (2018) investigated the emission of methane from dumpsites have become a global mantra due to its remarkable effect on global climate change. This study assessed the levels of methane emissions from 6 dumpsites using a portable air quality meter (AEROQUAL-Series 300). Results showed that the spatial level of methane ranged from 1.00 – 6.44 ppm. Based on temporal variation level of methane

ranged from 1.59 – 4.09 ppm ($p < 0.05$), with higher values in the wet season. Meanwhile, methane emission was not detected in the control station. Based on the model for Air Quality Index (AQI), methane emissions were predominantly rated as safe and moderate, except for stations LE and LF. Notwithstanding, these results confirmed the emission of methane from the dumpsite due to anthropogenic activities. The study, therefore, recommended policies aimed at the sequestration of methane emissions, including the reuse, recycling, and reduction of the waste stream.

Nicolae, Corneliu, Ion, and Cristian (2020) studied the environmental impact of methane released from coal mines. The methane gas that accompanies coal deposits has formed because of successive steps in the anaerobic process of converting plant matter into coal at high temperatures and pressures without an external supply of oxygen. During the process of metamorphosis, the content of C, H, and O changes, i.e., the content of carbon increases, hydrogen, and oxygen decrease, while the content of nitrogen and sulfur remains constant. This produces water and carbon dioxide, with water forming in the early stages of conversion. In the slow oxidation process, gaseous products, particularly methane and carbon dioxide, are produced by bacteria-stimulated fermentation using the oxygen contained in the plants. Findings indicate that methane emitted into the atmosphere after coal mining has a double effect on the environment, contributing to the strengthening of the greenhouse effect and the destruction of the ozone layer. At the same time, methane gas released into the atmosphere during coal mining can be used commercially or used by mine operators as a primary energy source to meet the mine's electricity needs.

Majeed and Mazhar (2019) examined the link between environmental indicators and output volatility, unlike the previous literature that mainly emphasized the importance of carbon emissions and the economic growth nexus. Output uncertainty is considered a serious global issue as it undermines economic gains and quality of life. This study scrutinizes the impact of greenhouse gas emissions on output volatility in 155 countries over the period 1971-2017. The empirical analysis is based on Pooled Ordinary Least Squares, Random, and Fixed Effects Models. The empirical results confirm that carbon dioxide (CO₂), nitrogen oxide (NO_x), methane (CH₄), and total greenhouse gas (GHG) emissions are positively contributing to amplifying global output volatility. Moreover, the Principal Component Analysis (PCA) of pollutant indicators also confirms the main results. Comparatively carbon emissions are contributing more to augment output volatility. Comparative analysis also reveals that all pollutants augment output volatility more in agricultural economies. The results of Granger causality confirmed the bidirectional causality between environmental degradation and output volatility providing evidence of the endogeneity problem. To address it, the system GMM estimator was used by incorporating the instruments in the output volatility model and the results of system GMM are also consistent with the main findings. The findings of the study imply that a promising path of sustainable growth can be achieved by adopting alternative ways of energy resources that produce fewer pollutants relative to greenhouse gasses.

Mebrate, Tewodros, and Dawit (2019) reviewed Methane Production in Ruminant Animals: Implication for Their Impact on Climate Change. Agriculture accounts for about 47 per cent to 56 per cent of the total anthropogenic methane (CH₄) emission. It is known that from the agricultural sector, ruminant livestock (dairy, beef, goats, and sheep)

substantially contributes to the increase in CH₄ production through the continuous natural rumen fermentation process. Methane emission is now the second contributor to global warming, and it has 23 times more influence than that carbon dioxide (CO₂). Many factors affect the amount of ruminant CH₄ production, including the level of feed intake, type and quality of feeds, energy consumption, animal size, growth rate, level of production, and environmental temperature. Methane is also produced from the manure of animals depending on the physical form of the feces, the amount of digestible material, the climate, and the time they remained intact. A major part of methanogenesis in ruminants occurs in the large fermentative chamber, which is the rumen. Ruminal digestion of feed by microorganisms, under anaerobic conditions, results in the production of acetate, propionate, and butyrate (volatile fatty acids) which are used by the animal as an energy source, and the production of ruminal gases such as carbon dioxide (CO₂) and CH₄, which eliminated through eructation. Therefore, this review aimed to summarize the status of methane production from ruminants and its implication for their impact on climate change.

He, Naik, Horowitz, Dlugokencky, and Thoning (2020) investigated the global methane budget from 1980 to 2017 using GFDL-AM4.1. Changes in atmospheric methane abundance have implications for both chemistry and climate as methane is both a strong greenhouse gas and an important precursor for tropospheric ozone. A better understanding of the drivers of trends and variability in methane abundance over the recent past is therefore critical for building confidence in projections of future methane levels. The representation of methane in the atmospheric chemistry model AM4.1 is improved by optimizing total methane emissions (to an annual mean of 580 ± 34 Tg yr⁻¹)

to match surface observations from 1980 to 2017. The simulations with optimized global emissions are in general able to capture the observed trend, variability, seasonal cycle, and latitudinal gradient of methane. Simulations with different emission adjustments suggest that increases in methane emissions (mainly from agriculture, energy, and waste sectors) balanced by increases in methane sinks (mainly due to increases in OH levels) lead to methane stabilization (with an imbalance of 5 Tg yr^{-1}) during 1999 to 2006 and that increases in methane emissions (mainly from agriculture, energy, and waste sectors) combined with little change in sinks (despite small decreases in OH levels) during 2007 to 2012 lead to renewed growth in methane (with an imbalance of 14 Tg yr^{-1} for 2007 to 2017). Compared to 1999 to 2006, both methane emissions and sinks are greater (by 31 and 22 Tg yr^{-1} , respectively) from 2007 to 2017. The tagged tracer analysis indicates that anthropogenic sources (such as agriculture, energy, and waste sectors) are more likely major contributors to the renewed growth in methane after 2006. A sharp increase in wetland emissions (a likely scenario) with a concomitant sharp decrease in anthropogenic emissions (a less likely scenario), would be required starting in 2006 to drive the methane growth by wetland tracer. Simulations with varying OH levels indicate that a 1 per cent change in OH levels could lead to an annual mean difference of $\sim 4 \text{ Tg yr}^{-1}$ in the optimized emissions and a 0.08-year difference in the estimated tropospheric methane lifetime. Continued increases in methane emissions along with decreases in tropospheric OH concentrations from 2008 to 2015 prolong methane's lifetime and therefore amplify the response of methane concentrations to emission changes. Uncertainties still exist in the partitioning of emissions among individual sources and regions.

Staniaszek, Griffiths, Folberth, et al. (2022) examined the role of future anthropogenic methane emissions in air quality and climate. Mitigation of greenhouse gas emissions is crucial for achieving the goals of the Paris climate agreement. One key gas is methane, whose representation in most climate models is limited by using prescribed surface concentrations. Here we use a new, methane emissions-driven version of the UK Earth System Model (UKESM1) and simulate a zero anthropogenic methane emissions scenario (ZAME), to attribute the role of anthropogenic methane emissions on the Earth system and bracket the potential for theoretical maximum mitigation. We find profound, rapid, and sustained impacts on atmospheric composition and climate, compared to a counterfactual projection (SSP3-7.0, the 'worst case scenario' for methane). In ZAME, methane declines to below pre-industrial levels within 12 years and global surface ozone decreases to levels seen in the 1970s. By 2050, 690,000 premature deaths per year and 1° of warming can be attributed to anthropogenic methane in SSP3-7.0. This study demonstrated the significant maximum potential of methane emissions reductions and their air-quality co-benefits but also reiterates the need for action on carbon dioxide (CO₂) emissions. It was established that a methane emissions-driven treatment is essential for simulating the full Earth system impacts and feedback of methane emissions changes.

Arvid (2022) investigated the relationship between methane emissions and economic growth with panel data from the G20 countries for the period of 1992 to 2018. The aim was to find evidence for an N-shaped Environmental Kuznets Curve (EKC) for the data sample and explore how various explanatory variables like energy consumption and natural gas consumption affect methane emissions. The main results from the Fixed Effects Regression Model (FEM) revealed evidence for an N-shaped EKC. Further, total

energy consumption was found to have a positive impact on methane emissions, but no statistically significant estimator was found for natural gas consumption. The key takeaway from this study is that solely economic growth will not solve the problem of global warming, according to the N-shaped form of the EKC. Policymakers need to act and, for example, implement new environmental regulations and create incentives for actors in society to mitigate methane emissions.

Harmsen, et al. (2020) examines model-specific assumptions and projections of methane (CH₄) emissions in deep mitigation scenarios generated by integrated assessment models (IAMs). For this, scenarios of nine models are compared in terms of sectoral and regional CH₄ emission reduction strategies, as well as resulting climate impacts. The models' projected reduction potentials are compared to sector and technology-specific reduction potentials found in the literature. Significant cost-effective and non-climate policy-related reductions are projected in the reference case (10 to 36 per cent compared to a "frozen emission factor" scenario in 2100). Still, compared to 2010, CH₄ emissions are expected to rise steadily by 9 to 72 per cent (up to 412 to 654 Mt CH₄/year). Ambitious CO₂ reduction measures could by themselves lead to a reduction of CH₄ emissions due to a reduction of fossil fuels (22 to 48 per cent compared to the reference case in 2100). However, direct CH₄ mitigation is crucial and more effective in bringing down CH₄ (50–74 per cent compared to the reference case). Given the limited reduction potential, agriculture CH₄ emissions are projected to constitute an increasingly larger share of total anthropogenic CH₄ emissions in mitigation scenarios. Enteric fermentation in ruminants is in that respect by far the largest mitigation bottleneck later in the century with a

projected 40 to 78 per cent of total remaining CH₄ emissions in 2100 in a strong (2 °C) climate policy case.

Allen, et al. (2021) examined significant climate benefits from near-term climate forcer mitigation despite the aerosol reduction. Near-term climate forcers (NTCFs), including aerosols and chemically reactive gases such as tropospheric ozone and methane, offer a potential way to mitigate climate change and improve air quality called 'win-win' mitigation policies. Prior studies support improved air quality under NTCF mitigation, but with conflicting climate impacts that range from a significant reduction in the rate of global warming to only a modest impact. Here, we use state-of-the-art chemistry-climate model simulations conducted as part of the Aerosol and Chemistry Model Intercomparison Project (AerChemMIP) to quantify the 21st-century impact of NTCF reductions, using a realistic future emission scenario with a consistent air quality policy. Non-methane NTCF (NMNTCF; aerosols and ozone precursors) mitigation improves air quality but leads to significant increases in global mean precipitation of 1.3 per cent by mid-century and 1.4 per cent by end-of-the-century, and corresponding surface warming of 0.23 and 0.21 K. NTCF (all-NTCF; including methane) mitigation further improves air quality, with larger reductions of up to 45 per cent for ozone pollution, while offsetting half of the wetting by mid-century (0.7 per cent increase) and all the wetting by end-of-the-century (non-significant 0.1 per cent increase) and leading to surface cooling of -0.15 K by mid-century and -0.50 K by end-of-the-century. The study suggests that methane mitigation offsets warming induced by reductions in NMNTCFs, while also leading to net improvements in air quality.

Benavides et al. (2017) explored the nexus between methane emissions and GDP in Austria, using time series data for the period from 1970 to 2012. The authors employ a long-run as well as a short-run model and the results differ between the two. In the short run, the results indicate a U-shaped nexus between methane emissions and GDP suggesting that further economic growth will increase methane emissions. However, in the long run, findings show an inverted U-shaped nexus, indicating that methane emissions will decrease with GDP growth after reaching a turning point. According to their data, this turning point has not yet been reached by 16 Austria in the sample period, meaning that methane emissions are increasing with GDP growth.

Reyes and Ochoa (2021) evaluated agricultural production and environmental pollution: the relationship between agricultural methane emissions, agricultural production, and export of ICT services in Latin America. The study aimed to estimate the Kuznets curve for the environment for a group of 17 countries that emigrated to Latin America, in the period 1970 to 2008, specifying a panel data model, to show whether there is a Kuznets curve for the environment in these countries. The main results showed that the relationship between agricultural methane gas emissions, agricultural production, and ICT service exports can describe an inverted U-shaped curve, indicating that agricultural production and ICT service exports play an important role in increasing the effects of growth on environmental degradation.

Ilissa. et al (2021) analyzed the climate benefits of fast action to reduce methane emissions as compared to slower and delayed mitigation timelines. The study found that the scale-up and deployment of greatly underutilized, but available mitigation measures will have significant near-term temperature benefits beyond that of slow or delayed action.

Overall, strategies exist to cut global methane emissions from human activities in half within the next ten years, and half of these strategies currently incur no net cost. Pursuing all mitigation measures now could slow the global-mean rate of near-term decadal warming by around 30 per cent, avoid a quarter of a degree centigrade of additional global-mean warming by midcentury, and set ourselves on a path to avoid more than half a degree centigrade by end of the century. On the other hand, slow implementation of these measures may result in an additional tenth of a degree of global-mean warming by midcentury and a 5 per cent faster warming rate (relative to fast action), and waiting to pursue these measures until midcentury may result in an additional two-tenths of a degree centigrade by midcentury and 15 per cent faster warming rate (relative to fast action). Slow or delayed methane action is viewed by many as reasonable given that current and on-the-horizon climate policies heavily emphasize actions that benefit the climate in the long-term, such as decarbonization and reaching net-zero emissions, whereas methane emitted over the next couple of decades will play a limited role in long-term warming. However, the study recommended that given that fast methane action can considerably limit climate damages in the near term, it is urgent to scale up efforts and take advantage of this achievable and affordable opportunity as we simultaneously reduce carbon dioxide emissions.

Etminan, Myhre, Highwood, & Shine (2016) studied the radiative forcing of carbon dioxide, methane, and nitrous oxide: a significant revision of the methane radiative forcing. New calculations of the radiative forcing (RF) are presented for the three main well-mixed greenhouse gases, methane, nitrous oxide, and carbon dioxide. Methane's RF is particularly impacted because of the inclusion of the shortwave forcing; the 1750–

2011 RF is about 25 per cent higher (increasing from 0.48 W m^{-2} to 0.61 W m^{-2}) compared to the value in the Intergovernmental Panel on Climate Change (IPCC) 2013 assessment; the 100-year global warming potential is 14 per cent higher than the IPCC value. We present new simplified expressions to calculate RF. Unlike previous expressions used by IPCC, the new ones include the overlap between CO_2 and N_2O ; for N_2O forcing, the CO_2 overlap can be as important as the CH_4 overlap. The 1750–2011 CO_2 RF is within 1 per cent of IPCC's value but is about 10 per cent higher when CO_2 amounts reach 2000 ppm, a value projected to be possible under the extended RCP8.5 scenario.

When exploring a possible EKC between methane emissions and GDP for OPEC countries, Tarazkar et al. (2020) find an N-shaped relationship. The authors used panel data and they included energy consumption and agricultural crop and livestock production as explanatory variables in the model. The authors find a large positive correlation between methane emissions, energy consumption, and GDP indicating that increases in fossil energy consumption and GDP will increase methane emissions. Also, their results support evidence of the fact that larger livestock- and agricultural crop production will lead to higher methane emissions, with livestock as the most contributing factor.

Alexander, Christian, Paul, and Daniel (2017) analyzed the ambiguity in the causes for decadal trends in atmospheric methane and hydroxyl Methane is the second strongest anthropogenic greenhouse gas and its atmospheric burden has more than doubled since 1850. Methane concentrations stabilized in the early 2000s and began increasing again in 2007. Neither the stabilization nor the recent growth is well understood, as evidenced by multiple competing hypotheses in recent literature. Here we use a multispecies two-

box model inversion to jointly constrain 36 y of methane sources and sinks, using ground-based measurements of methane, methyl chloroform, and the C13/C12 ratio in atmospheric methane ($\delta^{13}\text{CH}_4$) from 1983 through 2015. We find that the problem, as currently formulated, is underdetermined and solutions obtained in previous work are strongly dependent on prior assumptions. Based on our analysis, the mathematically most likely explanation for the renewed growth in atmospheric methane, counterintuitively, involves a 25-Tg/y decrease in methane emissions from 2003 to 2016 that is offset by a 7 per cent decrease in global mean hydroxyl (OH) concentrations, the primary sink for atmospheric methane, over the same period. However, we are still able to fit the observations if we assume that OH concentrations are time-invariant (as much of the previous work has assumed) and we then find solutions that are largely consistent with other proposed hypotheses for the renewed growth of atmospheric methane since 2007. The study concluded that the current surface observing system does not allow unambiguous attribution of the decadal trends in methane without robust constraints on OH variability, which currently relies purely on methyl chloroform data and its uncertain emissions estimates.

With panel data from 19 Sub-Saharan African countries, an inverted U-shaped EKC is presented for methane emissions and GDP growth (Doku et al., 2021). More importantly, the results show that all countries in the sample currently have a lower level of GDP than the estimated turning point on the EKC, implying that further economic growth will increase methane emissions in these countries. One thing to point out is that the calculated turning point on the EKC is much higher for methane and nitrous oxide than it is for carbon dioxide emissions.

Ari and Şentürk (2020) explored the relationship between per capita Gross Domestic Product (GDP) and CH₄ (methane) emissions from solid waste disposal as environmental pollution in the Group of Seven (G7) countries. All the G7 members are high-income, developed, and industrialized countries. According to the United Nations Framework Convention on Climate Change (UNFCCC), stabilization of greenhouse gases, including CH₄, concentrations in the atmosphere is required to combat the global climate change problem. CH₄ emission has local, regional, and global negative effects on the environment, humans, and living things. The critical function of the improved management of municipal solid waste is to reduce problems associated with local waste pollution and to switch CH₄ emissions to CO₂ emissions through energy generation facilities. In the waste management hierarchy, refuse, reduction, reuse, recycle, and recovery is recommended for sustainable consumption and production (SCP) patterns in developed and developing countries. No clear evidence exists for the transition to SCP patterns in developed countries, particularly for the G7. This study uses the Environmental Kuznets Curve (EKC) hypothesis the inverted U-shape between income and environmental pollution to obtain empirical evidence for the G7 countries. It examines CH₄ emissions per capita from solid waste and GDP per capita for these countries between 1960 and 2016 using a panel data analysis technique. The study concludes that there is no evidence for the traditional EKC hypothesis for the G7 countries. It observed an inverted N-shaped curve between CH₄ emissions per capita and GDP per capita. The study recommends that increasing GDP per capita should be aligned with strong policies for the transformation of countries into sustainable practices and patterns of consumption and production.

Mohajan (2012) discusses the effects of methane gas which causes severe global warming in the atmosphere. Global warming becomes the main issue in economics in the 21st century. Because global climate change becomes more dangerous, and every nation realized that this is due to greenhouse gas emissions. Methane is a dangerous greenhouse gas since it is 21 times more global warming potential than carbon dioxide. The study performed a comparison of the global warming potential of CO₂ and CH₄ up to 500 years. Since CH₄ is a dangerous gas in the atmosphere we must take immediate steps to reduce this gas emission. All the nations talk about the reduction of only carbon dioxide and no nation stresses methane reduction. Due to global warming, the ocean levels are increasing, as a result, most of the coastal areas will submerge by 2050, and some insects and animals will extinct. In this paper, an attempt has been taken to discuss the aspects of methane gas emissions and the importance of methane gas emissions reduction. The study recommended that methane mitigation provides an opportunity to improve air quality globally, which can be a cost-effective component of international ozone management, bringing multiple benefits for air quality, climate, agriculture, and human health.

Farhan, Imtiaz, Shazia & Saira (2022) evaluated the environmental impact of industrialization and foreign direct investment: empirical evidence from the Asia-Pacific Region. To determine the gone thorough impact of industrialization and foreign direct investment on environmental degradation, this study utilized panel data from 55 countries of the Asia-Pacific region from 1995 to 2020 and it applies an autoregressive distributed lag (ARDL) model. The results showed that FDI, in general, has a significant negative impact on the environment and causes to increase in methane and CO₂ emissions.

Moreover, industrialization has a positive and significant impact on the environment. However, the size of the impact is moderate. This study also concludes that in the Asia-Pacific region, the environment Kuznets curve (EKC) and pollution heaven (PH) hypothesis are accepted. Finally, this study suggests the strict implication of environmental guidelines, or the adoption of a new policy would be the key to ensuring the quality of the environment. Furthermore, the results confirmed that most of the panel countries are developing countries and do not have strict environmental management guidelines.

Mikaela (2022) examined the relationship between methane emissions and economic growth between High income and Low-income countries. The Intergovernmental Panel on Climate Change 2018 highlights the importance of short-lived greenhouse gases to combat global warming. This study explores the relationship between Gross Domestic Product per capita and methane per capita. The relationship is explored concerning the Environmental Kuznets Curve theory where the subjects to examination used are high-income countries and low-income countries based on United Nations classifications in 2019. In total 47 countries are examined where 30 countries are high-income Countries and 17 are low-income countries. The relationships are examined for the periods 1970 to 2017 through Fixed Effect Models. To improve accuracy additional control variables are added: Population in agriculture (per cent of total employment), the balance of payments, and forest areas. With the added control variables, the time frame used in Fixed Effect Models changes from 1991 to 2017. The different Fixed Effect Models provide inverted U-shaped relationships for low-income countries and uncertain results for high-income countries according to the Environmental Kuznets Curve.

Kathleen, Charlotte, Ludmila, and Tim (2022) examined the impacts of methane on climate, ecosystems, and health beyond CO₂ equivalence. Methane emissions have been increasing rapidly in recent years, contributing significantly to global warming. Despite this, methane is not adequately treated within existing national and international governance frameworks. The study adopted a review method. Researchers at the Institute for Advanced Sustainability Studies (IASS) in Potsdam have recommended the urgent need for action in new studies that will gear towards drastically reducing Methane emissions in the environment to decrease emissions.

Nisbet, et al (2019) examined Methane Mitigation, Methods to Reduce Emissions, on the Path to the Paris Agreement, the atmospheric methane burden is increasing rapidly, contrary to pathways compatible with the goals of the 2015 United Nations Framework Convention on Climate Change Paris Agreement. It was reviewed that urgent action is required to bring methane back to a pathway more in line with the Paris goals. Emission reduction from “tractable” (easier to mitigate) anthropogenic sources such as the fossil fuel industries and landfills is being facilitated by technical advances in the past decade, which have radically improved our ability to locate, identify, quantify, and reduce emissions. Measures to reduce emissions from “intractable” (harder to mitigate) anthropogenic sources such as agriculture and biomass burning have received less attention and are also becoming more feasible, including removal from elevated-methane ambient air near sources. The wider effort to use microbiological and dietary intervention to reduce emissions from cattle (and humans) is not addressed in detail in this essentially geophysical review. Though they cannot replace the need to reach “net-zero” emissions of CO₂, significant reductions in the methane burden will ease the timescales needed to

reach required CO₂ reduction targets for any particular future temperature limit. The study recommended that there is no single magic bullet, but the implementation of a wide array of mitigation and emission reduction strategies could substantially cut the global methane burden, at a cost that is relatively low compared to the parallel and necessary measures to reduce CO₂, and thereby reduce the atmospheric methane burden back toward pathways consistent with the goals of the Paris Agreement.

Gedney, Huntingford, Comyn-Platt, & Wiltshire (2019) analyzed emissions from wetlands are the single largest source of the atmospheric greenhouse gas (GHG) methane (CH₄). This may increase in a warming climate, leading to positive feedback on climate change. For the first time, the study extends interactive wetland CH₄ emissions schemes to include the recently quantified, significant process of CH₄ transfer through tropical trees. The research constrained the parameterizations using a multi-site flux study, and biogeochemical and inversion models. This provides an estimate and uncertainty range in contemporary, large-scale wetland emissions and their response to temperature. To assess the potential for future wetland CH₄ emissions to feedback on climate, the schemes are forced with simulated climate change using a 'pattern-scaling' system, which links altered atmospheric radiative forcing to meteorology changes. We perform multiple simulations emulating 34 Earth System Models over different anthropogenic GHG emissions scenarios (RCPs). Hence the study provided a detailed assessment of the causes of uncertainty in predicting wetland CH₄–climate feedback. Despite the constraints applied, uncertainty from wetland CH₄ emission modeling is greater than from projected climate spread (under a given RCP). Limited knowledge of contemporary global wetland emissions restricts model calibration, producing the largest individual cause of

wetland parameterization uncertainty. Wetland feedback causes an additional temperature to increase between 0.6 per cent and 5.5 per cent over the 21st century, with feedback on climate ranging from 0.01 to 0.11 Wm⁻² K⁻¹. Wetland CH₄ emissions amplify atmospheric CH₄ increases by up to a further possible 25.4 per cent in one simulation and reduce remaining allowed anthropogenic emissions to maintain the RCP2.6 temperature threshold by 8.0 per cent on average.

Abernethy, Connor, Jones, and Jackson, (2021) examined Methane removal and the proportional reductions in surface temperature and ozone. It was established that mitigating climate change requires a diverse portfolio of technologies and approaches, including negative emissions or the removal of greenhouse gases. Previous literature focuses primarily on carbon dioxide removal, but methane removal may be an important complement to future efforts. Methane removal has at least two key benefits: reducing temperature more rapidly than carbon dioxide removal and improving air quality by reducing surface ozone concentration. While some removal technologies are being developed, modeling of their impacts is limited. Here, we conduct the first simulations using a methane emissions-driven Earth System Model to quantify the climate and air quality co-benefits of methane removal, including different rates and timings of removal. We define a novel metric, the effective cumulative removal, and use it to show that each effective petagram of methane removed causes a mean global surface temperature reduction of $0.21 \pm 0.04^{\circ}\text{C}$ and a mean global surface ozone reduction of 1.0 ± 0.2 parts per billion. The study findings demonstrated the effectiveness of methane removal in delaying warming thresholds and reducing peak temperatures and allow for direct

comparisons between the impacts of methane and carbon dioxide removal that could guide future research and climate policy.

Saunio et al (2016) examined the growing role of methane in anthropogenic climate change. Unlike CO₂, atmospheric methane concentrations are rising faster than at any time in the past two decades and, since 2014, are now approaching the most greenhouse-gas-intensive scenarios. The reasons for this renewed growth are still unclear, primarily because of uncertainties in the global methane budget. New analysis suggests that the recent rapid rise in global methane concentrations is predominantly biogenic-most likely from agriculture-with smaller contributions from fossil fuel use and possibly wetlands. The research recommended that attention is urgently needed to quantify and reduce methane emissions. Methane mitigation offers rapid climate benefits and economic, health, and agricultural co-benefits that are highly complementary to CO₂ mitigation.

Marais, et al (2014) investigated Anthropogenic emissions in Nigeria and the implications for atmospheric ozone pollution. Nigeria with a high population density and large fossil fuel resources but a very poorly managed energy infrastructure. Satellite observations of formaldehyde (HCHO) and glyoxal (CHOCHO) reveal very large sources of anthropogenic nonmethane volatile organic compounds (NMVOCs) from the Lagos megacity and oil/gas operations in the Niger Delta. This is supported by aircraft observations over Lagos and satellite observations of methane in the Niger Delta. Satellite observations of carbon monoxide (CO) and nitrogen dioxide (NO₂) show large seasonal emissions from open fires in December–February (DJF). Ventilation in central Nigeria is severely restricted at that time of year, leading to very poor ozone air quality as observed from aircraft (MOZAIC) and satellite (TES). Simulations with the GEOS-Chem

chemical transport model (CTM) suggest that maximum daily 8-h average (MDA8) ozone exceeds 70 ppbv over the region on a seasonal mean basis, with significant contributions from both open fires (15–20 ppbv) and fuel/industrial emissions (7–9 ppbv). The already severe ozone pollution in Nigeria could worsen in the future because of demographic and economic growth, although this would be offset by a decrease in open fires.

Connor, et al (2010) reviewed the possible role of wetlands, permafrost, and methane hydrates in the methane cycle under future climate change. The study reviewed the available scientific literature on how natural sources and the atmospheric fate of methane may be affected by future climate change. We discuss how processes governing methane wetland emissions, permafrost thawing, and destabilization of marine hydrates may affect the climate system. Methane wetland emissions will likely increase over the next century. Uncertainties arise from the temperature dependence of emissions and changes in the geographical distribution of wetland areas. Another major concern is the possible degradation or thaw of terrestrial permafrost due to climate change. The amount of carbon stored in permafrost, the rate at which it will thaw, and the ratio of methane to carbon dioxide emissions upon decomposition form the main uncertainties. Large amounts of methane are also stored in marine hydrates, and they could be responsible for large emissions in the future. The time scales for the destabilization of marine hydrates are not well understood and are likely to be very long for hydrates found in deep sediments but much shorter for hydrates below shallow waters, such as in the Arctic Ocean. Uncertainties are dominated by the sizes and locations of the methane hydrate inventories, the time scales associated with heat penetration in the ocean and sediments, and the fate of methane released in the seawater. Overall, uncertainties are large, and it

is difficult to be conclusive about the time scales and magnitudes of methane feedbacks, but significant increases in methane emissions are likely, and catastrophic emissions cannot be ruled out. It also identified gaps in our scientific knowledge and make recommendations for future research and development in the context of Earth system modeling.

Gedney et al., (2004) examined Climate feedback from wetland methane emissions. The potential for wetland emissions to feedback on climate change has been previously hypothesized. The study assessed the hypothesis using an interactive wetland scheme radiatively coupled to an integrated climate change effects model. The scheme predicts wetland area and methane (CH₄) emissions from soil temperature and water table depth and is constrained by optimizing its ability to reproduce the observed inter-annual variability in atmospheric CH₄. In transient climate change simulations, the wetland response amplifies the total anthropogenic radiative forcing at 2100 by about 3.5 to 5 per cent. The modeled increase in global CH₄ flux from wetlands is comparable to the projected increase in anthropogenic CH₄ emissions over the 21st century under the IS92a scenario.

Voulgarakis et al., (2013) in analyzing present-day and future OH and methane lifetime in the ACCMIP simulations identified that most atmospheric CH₄ is lost in the troposphere via oxidation by the OH radical. Even without considering the effects of climate change, CH₄ has feedback on its lifetime via atmospheric chemical cycles: increased CH₄ concentrations lead to less OH (as it is consumed in reaction with CH₄), resulting in less CH₄ destruction. Climate change adds another layer of complexity when considering the effects on the relevant chemical cycles: climate change is expected to increase the

concentration of atmospheric water vapor, the emissions of biogenic volatile organic compounds (VOCs), and the rate of the $\text{CH}_4 + \text{OH}$ reaction. All of these effects have competing influences on the CH_4 atmospheric lifetime, and it is uncertain what the net effect will be. The oxidation of CH_4 by soils only represents about 5 per cent of its loss, but it is also sensitive to environmental conditions. Soil oxidation is projected to increase under climate change due to rising CH_4 concentrations, higher soil temperatures, and lower soil moisture. Taking this into consideration, the study concluded that the potential for increased emissions under climate change is larger than the potential for increased sinks. That is, considering changes in both emissions and loss processes, climate change is expected to amplify atmospheric concentrations of CH_4 .

West et al., (2006) examined the global health benefits of mitigating ozone pollution with methane emission controls. Methane (CH_4) contributes to the growing global background concentration of tropospheric ozone (O_3), an air pollutant associated with premature mortality. Methane and ozone are also important greenhouse gases. Reducing methane emissions, therefore, decreases surface ozone everywhere while slowing climate warming, but although methane mitigation has been considered to address climate change, it has not for air quality. The study showed that global decreases in surface ozone concentrations, due to methane mitigation, result in substantial and widespread decreases in premature human mortality. Reducing global anthropogenic methane emissions by 20 per cent beginning in 2010 would decrease the average daily maximum 8-h surface ozone by ≈ 1 part per billion by volume globally. By using epidemiologic ozone-mortality relationships, this ozone reduction is estimated to prevent $\approx 30,000$ premature all-cause mortalities globally in 2030, and $\approx 370,000$ between 2010 and 2030. If only

cardiovascular and respiratory mortalities are considered, $\approx 17,000$ global mortalities can be avoided in 2030. The marginal cost-effectiveness of this 20 per cent methane reduction is estimated to be $\approx \$420,000$ per avoided mortality. If avoided mortalities are valued at \$1 million each, the benefit is $\approx \$240$ per tonne of CH₄ ($\approx \$12$ per tonne of CO₂ equivalent), which exceeds the marginal cost of the methane reduction. The research discovered that estimated air pollution ancillary benefits of climate-motivated methane emission reductions are comparable with those estimated previously for CO₂. Hence, Methane mitigation offers a unique opportunity to improve air quality globally and can be a cost-effective component of international ozone management, bringing multiple benefits for air quality, public health, agriculture, climate, and energy.

Table 2. 1: Summary of selected studies on the association between energy consumption and economic performance

Authors	Objectives	Methodology	Empirical evidence /findings
Moriarty, Honnery, Moriarty, and Honnery, (2014)	Investigate the effects of energy resources and economic performance in developing nations to limit global CO ₂ and increase energy use efficiency and viable growth performance	Using GMM method	The estimated outcome illustrates that energy resources positively influence growth performance.
Nawaz, Iqbal, and Khan (2014)	Examines the performance of institutional quality on GDP in Asian nations from 1996 to 2012	Using GMM technique	The outcome reveals that institutional quality enhances economic performance
Al-mulali (2015)	Investigate the influence of renewable and non-renewable energy use on GDP in 82 emerging nations from 1990-2009	Using FMOLS approach	The estimated result reveals that renewable and non-renewable energy resources promote the capacity for economic progress
Solarin (2015)	Explore the link between energy use and CO ₂ from 1965 to 2012	Using FMOLS technique	The result illustrates a positive link between energy use and CO ₂ discharge

Abid (2016)	Examines the influence of GDP, financial progress, and institutional value on CO ₂ explosion in 25 SSA economies from 1996 to 2010	Using the GMM approach.	The study found that GDP and financial performance increase the level of CO ₂ explosion. However, institutional value reduces environmental pollution.
Abuzayed and Al-Fayoumi (2016)	Analyzed the effect of the quality of institutions on GDP in 15 MENA countries from 1996 to 2010.	Using static and dynamic panel data analysis	The outcome illustrates that institutional quality accelerates the capacity of GDP and the banking sector.
Bhattacharya et al. (2016)	analyzed the influence of renewable energy resources on GDP in 38 renewable energy users' nations from 1991 to 2012,	Using FMOLS method	The outcome reveals that renewable energy use accelerates the level of economic performance by almost 57 per cent in these nations.
Ibrahim and Law, (2016)	Investigate the effect of trade, institutional value, and their interaction on CO ₂ discharge in 40 SSA nations	Using GMM approach	The study found trade adversely affects environmental settings, while institutional value accelerates the capacity of CO ₂ discharge
Kahia et al. (2016)	examine the effect of energy use, capital, and labor on growth performance in MENA nations from 1980 to 2012	Using the panel cointegration approach	The estimate confirms the two-way dimension of causality among renewable, and non-renewable energy on GDP growth, it also shows that renewable, non-renewable, capital and labor positively influence growth
Alabi, Ackah, and Lartey (2017)	Investigate the connection between renewable energy utilization and GDP performance in African OPEC nations	Using FMOLS and cointegration.	The result indicates that renewable energy use accelerates the capacity of growth performance in these nations.
Bhattacharya (2017)	Studied the effect of renewable energy utilization and institution on GDP performance in 84 industrialized and emerging economies from 1991 to 2012	Using system GMM and FMOLS approaches	The result shows that renewable energy resources increase growth performance and reduce the level of CO ₂ explosion. The quality of institutions positively influences GDP performance and decelerates the capacity of CO ₂
Jebli, Youssef and Ozturk (2017)	Examine the influence of GDP growth, renewable, and non-renewable energy utilization, and trade on CO ₂ discharge in 25 OECD economies from 1980 to 2010.	The study applies FMOLS, DOLS, and VECM techniques for the analysis.	The outcome reveals a two-way dimension causality from renewable energy to trade and non-renewable energy resources are capable of reducing CO ₂ discharge and there is the occurrence of the EKC hypothesis in the nations
Kacho (2017)	Assess the influence of institutions and financial progress indices on economic performance in MENA nations from 2002-2014.	Using GMM dynamic panel data	The empirical analysis suggests that financial progress and institutional quality have a negative and statistically significant effect on GDP in MENA countries.

Banday and Aneja, (2018)	analyzed the linkage among energy resources, GDP, and CO2 discharge in G7 economies from 1971 to 2014	Using panel ARDL technique.	The outcome indicates energy resource utilization and GDP increase the capacity of CO2 discharge while energy use causes economic performance and CO2 explosion.
Bhat and Mishra (2018)	Examine the link between GDP, energy resources, trade, and CO2 in India from 1971-2013	using ARDL approach	The study reveals that GDP performance reduces CO2 discharge, while energy resources and trade accelerate CO2 explosion.
Danlami et al., (2018)	Examine the association between economic progress, energy production, and population growth in Malaysia from 1971 to 2011.	applies ARDL method	The outcome reveals that GDP performance, energy production, and population growth accelerate the capacity of CO2 discharge
Gbatu et al., (2018)	Analyzed the link between economic progress, energy use, and the environment in selected ECOWAS nations from 1980 to 2014	used fixed effect method	The result illustrates that energy resources and GDP performance influence CO2 discharge positively.
Hassan, Danmaraya, and Danlami, (2018)	Examine the link between energy resource use and industrial performance in SSA from 1995 to 2013.	Using FMOLS technique	The outcome shows that energy use enhances industrial value.
Islam and Abdul Ghani, (2018)	Investigates the relationship between energy utilization, CO ₂ , GDP, population, and poverty in ASEAN nations from 1995 to 2014.	Using the Granger Causality test	The outcome reveals that growth performance and population influence energy utilization positively, while CO ₂ and poverty decelerate energy use in Malaysia. However, GDP and poverty increase energy efficiency and CO2 discharge as well as population reduce the level of energy use in Singapore. CO2 explosion and population influence energy use negatively, while growth performance, population, and poverty decrease energy performance in the Philippines.
Lau, Choong, and Ng (2018)	Aims to prove the occurrence of the EKC hypothesis in 100 developed and emerging economies.	Using GMM technique	The study found the EKC hypothesis only in developed nations. Furthermore, institutional value, FDI, and trade reduce the capacity of CO2 explosion in industrialized nations and increase in developing economies.
Sathyamoorthy and Tang (2018)	Investigates the impact of quality of institutions on trade in 119 nations	Using fixed and random effect techniques.	The outcome reveals that institutional performance promotes trade in all the sampled nations.

Sehrawat and Giri (2018)	analyzed the influence of the quality of institutions, financial performance, and globalization on GDP in India from 1982 to 2016	By applying the ARDL technique.	The outcome indicates that the quality of institutions and globalization enhance the level of GDP growth.
Can and Kormaz (2019)	analyzed the influence of renewable energy and GDP in Bulgaria from 1990 to 2016,	Using the ARDL technique and Toda Yamamoto	The outcome reveals that renewable energy enhances the level of GDP. While economic performance influences energy use, in addition, renewable energy does not cause electricity energy.
Hassan, Meyer, and Kot (2019)	Investigated the influence of institutional quality on GDP in 35 oil-exporting emerging nations from 1984 to 2016	Using the ARDL approach.	The outcome shows that all the variables are cointegrated. In addition, institutional quality reduces the performance of economic growth
Hechmy (2019)	Examined the link between renewable energy resources and GDP in MENA nations from 2000-2014	By applying the VECM approach	The outcome of the study illustrates proof of cointegration among the variables and found two-dimension causality.
Kalu et al. (2019)	analyzed the influence of energy resources and industrial value on GDP performance in Nigeria from 1971 to 2014	Using the ARDL method.	The outcome proves the long-run condition among the variables. In addition, energy resources and industrial value accelerates the level of economic progress.
Karasoy and Akcay (2019)	Examined the performance of energy use and trade on CO2 explosion in Turkey from 1965 to 2016	Applying the ARDL technique.	The outcome shows that energy use increases CO2 and the EKC hypothesis was valid.
Liu, Kumail, Ali and Sadiq (2019)	Investigate the connection between GDP growth, tourism, energy, and CO2 in Pakistan from 1980 to 2016.	Applies ARDL, DOLS, and causality techniques	The outcome shows that tourism, GDP growth, and energy utilization increase CO2 discharge.
Salman, Long, Dauda, and Mensah (2019)	Studied the influence of institutional quality, energy resources, and trade in East Asian nations from 1990-2016.	using FMOLS, DOLS, and VECM techniques	The findings indicate that institutional quality reduces the capacity of CO2 explosion and also enhances economic performance as well as one-way dimension causality from institutional quality to economic performance, CO2 and energy resources, and trade to CO2 discharge.
Shahbaz and Sinha (2019)	Examine the association between GDP, population, energy, and CO2 in developing nations from 1991 to 2017.	Using cross-sectional and panel data estimation techniques	It illustrates that GDP and energy influence environmental pollution positively and the EKC curve occurs.
Yahyaoui, Ibrahim, and Saggaf (2019)	Examine the influence of financial resources, quality of	Using FMOLS and DOLS	The outcome reveals that financial performance and institutional quality increase growth performance.

	institutions, and GDP in Arab nations from 1995 to 2012.		
Ansari, Haider, and Khan (2020)	Studied the influence of GDP performance, trade, and energy resources on CO2 discharge in industrialized economies from 1971 to 2013	By employing ARDL and VECM causality approaches.	The outcome illustrates that energy utilization, trade, and growth performance influence CO2 positively. In addition, the EKC curve was validated.
Egbetokun et al.(2020)	Examine the association between GDP performance, population, FDI, and institutional value in Nigeria	Using ARDL approach	The outcome indicates the occurrence of the EKC hypothesis. The study recommends that the efficiency of institutional value should be improved to promote environmental quality.
Kalu, Nwafor, Okoyeuzu, and Onodugo (2020)	Investigate the link between energy use, industrial value, and economic performance in 48 SSA nations from 1976 to 2016.	Applying the panel ARDL method	The estimated outcome proves the existence of a positive influence of energy resources on economic performance.
Koshta, Bashir, and Samad (2020)	Explore the link between growth performance, energy, and CO2 in developing economies from 1990 to 2014	Using FMOLS and DOLS methods.	The outcome illustrates that GDP growth and energy accelerate the explosion of CO2 and that EKC was validated in the nations.
Kwakwa (2020)	Investigates the influence of energy resources, urbanization, financial performance, and the effect of the interaction of urbanization and financial progress on CO2 discharge in Tunisia	Using ARDL and FMOLS methods.	The outcome reveals that energy resources, GDP, urbanization, trade, and financial progress increase CO2 discharge. Nonetheless, the interaction effect of financial performance and urbanization decreases the CO2 explosion
Rasool, Malik, and Tarique (2020)	Assess the influence of GDP performance, energy, and financial progress on CO2 discharge in India from 1971 to 2014	Used ARDL and VECM methods	It reveals that GDP performance enhances environmental quality, while energy and financial progress increases the level of CO2 explosion. Moreover, the study proved the occurrence of the EKC hypothesis.
Raza, Ahmed, Alshebami, and Polyakova (2020)	Studied the influence of renewable energy utilization on CO2 and GDP in Malaysia from 1989 to 2018.	Using ARDL technique	The outcome shows that energy utilization influences CO2 discharge positively. However, the estimates indicate that CO2 explosion does not determine GDP.
Shastri, Mohapatra, and Giri (2020)	analyzed the linkage between renewable, and non-renewable energy use and economic performance in India from 1971 to 2017	By employing ARDL and causality techniques	The outcome illustrates that renewable, and non-renewable energy resources enhance economic performance. This is proved by the adverse shocks of energy use on GDP. However, the outcome indicates a one-way dimension of causality from non-renewable, renewable energy to GDP.

Taskin, Varda and Okan (2020)	This study analyses the influence of renewable energy utilization and trade on economic progress in OECD nations from 1990 to 2015	Using OLS and FMOLS techniques.	The study outcome reveals that energy performance and trade accelerate the level of economic progress.
Zahirah and Sidek (2020)	Studied the performance of government spending and institutional quality on GDP in 30 emerging nations from 1984 to 2017.	Using the system GMM technique	The findings reveal that government spending and the quality of institutions promote economic performance.

Source: Authors Compilation

2.3 Research Gaps

The study explored a wide scope of literature on energy, economic performance, and the environment. The reviewed literature established a justification for a relationship between economic growth, energy consumption, and the environment. It noted the intensity and root cause of climate and temperature deterioration as environmental degradation through unguided human activities. The reviewed literature give focuses on identifying significant areas concerning energy consumption and economic growth on environmental sustainability that have not been adequately examined. The review establishes that most studies on energy consumption, economic growth, and the environment have largely not investigated the influence of the interaction effect of GDP and energy consumption on the environment more particularly in Nigeria, as attempts to examine the effect of the combined influence (interaction effect) of GDP and energy consumption on the environment has little attention in the literature. Investigating the effect of energy consumption on economic performance toward enhancing environmental quality is however highly essential, particularly for Nigeria; a fast-developing emerging market economy and the largest economy in the SSA region. This investigation is also in line with

the target of sustainable economic performance and Nigeria is also a signatory to several sustainable environment protocols and agreements.

Several attempts have been made to examine the role of energy consumption on environmental degradation in developing economies with an emphasis on disaggregated forms of energy use non-renewable energy. However, very few studies are done to investigate the effect of non-renewable energy use per capita on environmental degradation in Nigeria (Abid, 2016; Ibrahim & Alagidede, 2018). Therefore, it is important to consider the non-renewable energy use per capita on environmental quality in Nigeria.

Following the critical review of the literature, the study examines the influence of economic growth, and energy consumption on the environment in Nigeria and consequently has the following contribution to the existing literature. The research certainly implies a theoretical framework for the economic growth, energy, and environmental degradation nexus. Among the interesting contributions of this study is that the economic growth and energy use further empirically explain the environmental Kuznets curve hypothesis (EKC) framework recommended by Dinda (2004) which argued that energy utilization influenced economic growth and consequently causes environmental pollution. Therefore, incorporating energy consumption variables would enhance robustness and finding. This adoption has further supported that energy consumption is another strong determinant of environmental degradation in Nigeria earlier found by Sehwat, Giri, and Mohapatra (2015).

In the design of an empirical model and framework in most of the previous studies (Salahuddin, Gow, and Ozturk 2015; Rafindadi 2016; Yahaya, Adamu, and Mustapha

2020) relationships between economic growth, energy consumption, and the environment were analyzed. This study incorporates the interaction of energy consumption with GDP in the model as a new approach for determining the new relationship between economic growth and the environment in Nigeria and by extension an empirical contribution of new knowledge to the literature on environmental pollution studies. The findings believed that the incorporation of this variable would help in designing appropriate policies for sustainable development. There is no doubt that various findings and discussions emanating from this study shall have policy implications for Nigeria and other African economies. Therefore, the study also contributes to the existing literature on how to promote strategies for enhancing economic growth performance and environmental quality, especially on increasing individual awareness and re-orientation on the risk of the deteriorating environment in search of economic development.

Similarly, among the identifiable reasons why various studies on economic growth, energy, and environmental pollution nexus have been characterized by mixed results and inconclusiveness as Javid and Sharif (2016) and Salahuddin and Gow (2015) noted are due to methodological problems like model specification and methods of estimation among others. Therefore, this study has taken the challenge of minimizing these methodological problems. Hence, the appropriate model, model specification, and estimation method were selected. In this regard, the ARDL estimation method minimized the methodological loopholes, that previous studies suffered from. Therefore, it is interesting to state that the method of estimation is adopted better than other traditional methods. The validity of the adoption of the ARDL technique as an appropriate estimation method for the framework of this study was noted in the work of Salahuddin, Gow, and

Ozturk (2015). In general, Among the contributions of this study is the application of the environmental Kuznets hypothesis in Nigeria concerning the study variables (economic growth and energy use) that are empirically used to the impact of economic growth and energy consumption on environmental pollution in Nigeria as the EKC hypothesis stated. Therefore, this empirical evidence found in Nigeria serves as a contribution to this study to the existing literature. Similarly, the existence of a new variable (interaction of economic growth with energy use) is another contribution of the study.

Lastly, the outcome of this study contributes to the existing literature on economic growth, energy consumption, and environmental quality. It would also help in improving policy analysis and recommendations to the government, stakeholders, and relevant organizations to promote economic growth and environmental quality.

2.4 Conclusion

This chapter discusses the review of the related theoretical and empirical literature, concerning economic growth, energy consumption, financial development, trade, and environmental degradation. Under the theoretical review, the Kuznets curve hypothesis and pollution heaven theory were discussed. The second part of the chapter presents the

empirical review of studies on environmental degradation, economic growth, energy consumption, financial development, and trade. In this regard, the reviewed literature has given a guide to the empirical investigation of the study's model, and as such the chapter is linked to the establishment of the study's model of analysis, findings as well as recommendations, and policy analysis.

CHAPTER 3: OVERVIEW OF NIGERIA, THE ECONOMY, AND THE ENVIRONMENTAL INDICATORS

3.0 Introduction

This chapter provides an overview of the Nigerian economy, its structure, environmental indicators, and energy consumption, being a country used as a case study for this research. It aims to provide contextual linkages with the subject being investigated in the study. The chapter lays out the broad framework that brings fundamental discussions about different issues regarding the economic and environmental context of Nigeria. In doing so, a brief history and geography of Nigeria are discussed. Hopkins (2014) stressed that in explaining the economic performance or otherwise of West African countries, it is impossible to ignore the historical perspectives that have shaped what the countries of the region have evolved into. In general, the chapter provides background information on crucial factors that make up the contextual situation of Nigeria concerning the economy and environment.

3.1 Brief History and Geography of Nigeria

Nigeria's history could be traced back to the colonial days. The British colonial masters governed two protectorates namely Northern and Southern protectorates which were before 1914, after consideration and recommendations of Sir Frederick Lugard on the 1st of January 1914, the two protectorates were amalgamated to form the Colony and Protectorate of Nigeria under a single governor-general resident in the city of Lagos of the Southern Protectorate. Nigeria became an independent Nation on the 1st of October 1960 from the colonial masters, and the new constitution was established based on the

federal system with an elected prime minister and a ceremonial head of state. Also, United Nations supervised a referendum, in which the northern part of the Trust Territory of the Cameroons joined the Northern region in June 1961, while in October the Southern Cameroons united with Cameroon to form the Federal Republic of Cameroon.

On October 1, 1963, Nigeria became a republic nation. Nnamdi Azikiwe became the first president of the country, while Alhaji Tafawa Balewa became the first prime minister which has more power compared to the president. Even though Nigeria had adopted a republican constitution in 1963, it was also elected to stay a member of the Commonwealth. Nigeria is located on the western coast of Africa. It has a landmass of about 923,768.0 square kilometers with an estimated population of over 193,392,517 million people in 2019 (NBS, 2020). The country's landmass springs from the Gulf of Guinea on the Atlantic coast in the south to as far as the Sahara Desert in the north. Nigeria's borders are Niger and Chad Republics to the north, the Cameroon Republic to the east, and the Benin Republic to the west. Nigeria has a diverse geography, with climates ranging from arid to humid equatorial.

The topography of Nigeria consists of plains in the north and south interrupted by plateaus and hills in the centre of the country. The Sokoto Plains lie in the north-western corner of the country, and Borno Plains in the north-eastern corner extend as far as the Lake Chad Basin. The Lake Chad basin and the coastal areas, including the Niger River delta and the western parts of the Sokoto region in the far northwest, are underlain by soft, geologically young sedimentary rocks. Gently undulating plains, which become waterlogged during the rainy season, are found in these areas. The characteristic landforms of the plateaus are high plains with broad, shallow valleys dotted with

numerous hills or isolated mountains, called inselbergs; the underlying rocks are crystalline, although sandstones appear in river areas. The Jos Plateau rises almost in the center of the country; it consists of extensive lava surfaces dotted with numerous extinct volcanoes. The most mountainous area is along the southeastern border with Cameroon, where the Cameroon Highlands rise to the highest points in the country.

The major drainage areas in Nigeria are the Niger-Benue Basin, the Lake Chad Basin, and the Gulf of Guinea Basin. The Niger River, for which the country is named, and the Benue, its largest tributary, are the principal rivers. The Niger has many rapids and waterfalls, but the Benue is not interrupted by either and is navigable throughout its length, except during the dry season. Rivers draining the area north of the Niger-Benue trough include Sokoto, Kaduna, Gongola, and Rivers draining into Lake Chad. The coastal areas are drained by short rivers that flow into the Gulf of Guinea. In the pre-colonial period, the country normally produced enough agricultural commodities to feed its population and maintained a surplus for export (Watts, 2008).

3.2 Population of Nigeria

Currently, Nigeria has been ranked seventh in the world in terms of population and is the most populous nation in Africa. In 2016, the population was estimated above 190 million people. Although when a census was last conducted in 2012 by the Nigeria Population Commission (NPC) and Nigeria National Bureau of Statistics (NBS), the total population of citizens in Nigeria was 166.2 million people (NBS, 2014). Ever since the population of the country has been growing high. Figure 3.1 below presents the trend of the population in Nigeria in millions from 1980 to 2021.

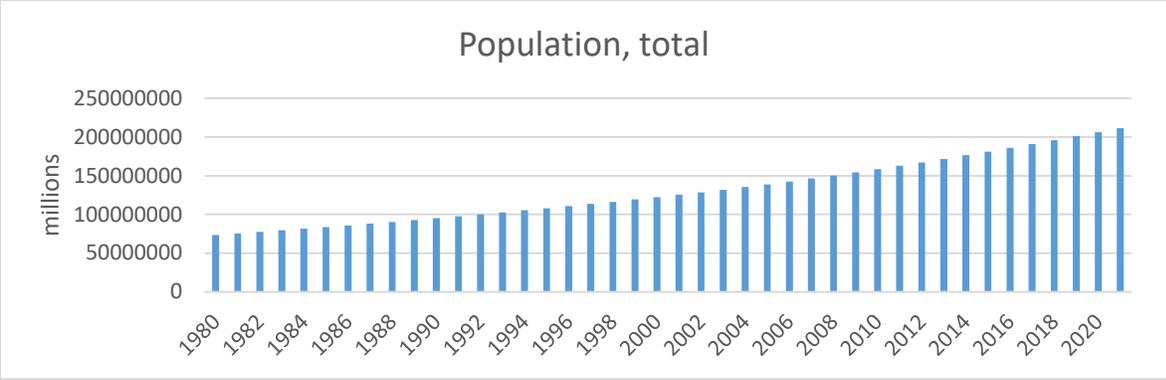


Figure 3. 1:Population of Nigeria from 1980 to 2021 (millions)
 Source: World development indicators (WDI, 2022)

Currently, Nigeria’s population is estimated to have exceeded 200 million with a 2.5 per cent annual increase. The entire population of Nigeria accounts for about 2.64 per cent of the world’s population. This means that about 1 out of every 43 are Nigerians. The country’s population continued to grow over the years and is estimated to have doubled its current population by 2050 (United Nations, 2022). Figure 3.2 below presents the growth trend of the population in Nigeria from 1980 to 2021.

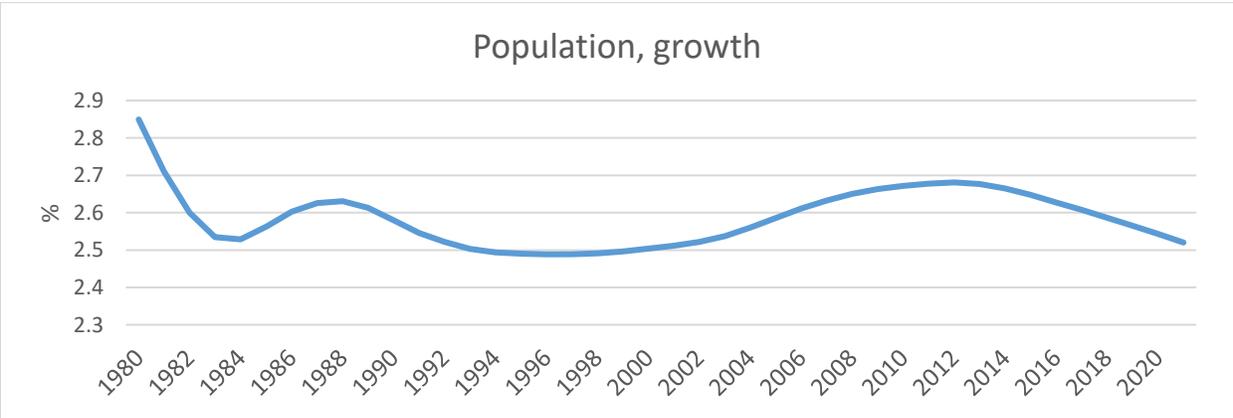


Figure 3. 2: Population Growth Rate of Nigeria from 1980 to 2021 (per cent)
 Source: World development indicators (WDI, 2022)

3.3 Overview of the Nigerian Economy

As earlier mentioned, Nigeria has been ranked seventh in the world in terms of population and is the most populous nation in Africa. The Country is located on the western coast of Africa on a landmass of about 923,768.0 square kilometers with an estimated population of over 193,392,517 million people in 2019. The Nigerian economy's size is the largest in Africa. The country's economy was rebased in the year 2014, which makes the economy to be accounted for about 17 per cent of the economic size of Africa. Even though the country remains among the top 20 countries in the African region based on economic growth per capita (World Bank 2020). However, this development does not impact the welfare of the population size in the country.

Nigeria's economy has been based mostly on the petroleum industry since the late 1960s. Since 1973, a series of rises in the price of oil has led to a rapid expansion of the transportation, building, manufacturing, and government services industries. Due to the considerable migration of rural residents into the bigger urban areas, agricultural productivity became so stagnant that cash crops like cotton, peanuts (groundnuts), and palm oil lost their significance as export commodities. Additionally, starting around 1975, Nigeria was compelled to import basic foodstuffs like rice and cassava for domestic use. The agriculture sector has been in a persistent state of crisis since the late 1970s due to the erratic global oil market and the nation's rapid population expansion. Even though a large portion of the population was still working in agriculture, there was still insufficient food production, necessitating expensive imports. The various governments (the majority of which are military-run) have addressed this issue by prohibiting the import of certain

types of food items and concentrating, albeit short, on a variety of agriculture and indigenization initiatives.

3.4 Structure of Nigeria's Economy and Environmental Implications

The economic structure of a country comprises resource ownership, production, and distribution of goods and services. The structure of an economy may be viewed as the basic organs and process of generating economic value and growth (CBN, 2018). To fully understand the relevance and the linkage of Nigeria's economy and environmental issues, it is important to look at the structure and the elements of the economy over the review period. It will help the study to be able to capture all forms of economic activities taking place within the economy and their linkage to environmental sustainability.

Nigeria's economy is made up of the major interrelated sectors that function together and also reflect the environmental condition in the nation. These sectors are significant and strategic as they all play an important role in the development of Nigeria's economy (CBN, 2018). It involves Agriculture, Industry, and oil sectors.

3.4.1 Agriculture

Agriculture was the main source of the country's revenue in the 1960s and 1970s before oil was discovered in the country, the agricultural activities of the country's economy accounted for about 64.1 per cent and 47.6 per cent of the GDP in 1960 and 1970, respectively (CBN, 2018). Nigeria ranked sixth in terms of agricultural output in the world. The sector contributes to about 18 per cent of the GDP and secures almost one-third of employment generation in recent times (World Bank, 2019). The nation is the major producer of agricultural products, including Cocoa, groundnut, rubber, palm oil, rice,

millet, sorghum, and yam. In 2019, livestock production increased especially in the production of eggs, milk, beef, and poultry. Similarly, fish production also reached 505.8 metric tons in the same year. Table 3.1 describes some of Nigeria's agricultural production output and world ranking.

Table 3. 1: Nigerian's Agricultural Output and World Ranking

S/N	Product	Output	World ranking
1	Cassava	59.4 million tons	Largest producer
2	Yam	47.5 million tons	14 th largest producer
3	Maize	10.1 million tons	4 th largest producer
4	Palm oil	7.8 million tons	2 nd largest producer
5	Sorghum	6.8 million tons	14 th largest producer
6	Rice	6.8 million tons	4 th largest producer
7	Cocoa	332 thousand tons	4 th largest producer
8	Peanuts	2.8 million tons	3 rd largest producer
9	Millet	2.2 million tons	4 th largest producer
10	Cowpeas	2.6 million tons	Largest producer

Source: National Bureau of Statistics (2020)

With a projected value of N18.74 trillion in 2021, Nigeria's agricultural sector is still the largest economic sector in the country, providing 25.9 per cent of the real GDP. The

industry increased from the N18.35 trillion reported the year before by 2.1 per cent. Despite multiple CBN interventions to strengthen the sector, the agricultural sector is still far below targeted levels as agricultural imports continue to consume a sizable portion of our foreign exchange reserves with little to no significant inflow in the form of export revenues. Additionally, the sector's year-over-year growth in 2021 was 2.13 per cent, which was lower than the 2.17 per cent growth seen the year before. Crop production, livestock, forestry, and fisheries are the four main subsectors of the agricultural sector, with respective values of N16.92 trillion, N1.24 trillion, N193.22 billion, and N384.45 billion.

3.4.2 Industry

In Nigeria, the industrial sector—which includes manufacturing, mining, and utilities—represents a very small part of overall economic activity. This is despite attempts made by policymakers throughout the past 60 years, and particularly more recently, to speed up the industrialization process. An economic sector in Nigeria known as manufacturing contributes roughly 10 per cent of the nation's annual GDP (Gross Domestic Product). Large southern cities like Lagos, Port Harcourt, and Ibadan are the main centers of manufacturing activity in the nation. Millions of people work in the manufacturing of consumer goods, agriculture, mining, cement, autos, household goods, consumer products, building materials, etc.

Production of food and drink, tobacco, chemicals and fertilizers, timber, textiles, and building materials dominate Nigeria's industrial industry. Out of all manufacturing output, only 3 subsectors—food & beverage, cement, and textile—generate the highest value, accounting for 77 per cent of the total. Breweries and wheat mills are also important

contributors to the manufacturing industry. The N3.18 trillion value of the food, beverage, and tobacco subsector and the N1.32 trillion cement industry were major contributors to the sector's contribution. Other industrial sectors that contribute more than 5 per cent of the real GDP include mining and quarrying (7.4 per cent) and real estate (5.6 per cent).

Nigeria's massive oil reserves have a significant impact on its economy, accounting for barely 0.3 per cent of its total GDP. Due to its underdeveloped mining industry, Nigeria imports minerals like salt and iron ore that it could produce domestically. All natural resource rights in Nigeria are legally owned by the federal government, which grants companies permits to conduct mineral resource exploration, development, and marketing activities.

Mining regulation is the responsibility of the Ministry of Solid Minerals Development, which is in charge of managing all mineral resources. Mining regulations are codified in the Federal Minerals and Mining Act of 1999. Historically, Nigeria's entire mining industry was under the hands of state-owned public companies. This resulted in a decrease in productivity across almost all mining industries. The mining sector in Nigeria has grown since the "Economic Diversification Agenda," from Oil & Gas to Agriculture, Mining, etc., began in the country.

3.4.3 Oil and Natural Gas

Nigeria discovered crude oil in the 1970s with exploration in commercial quantity, then more emphasis and more attention have been focused on crude oil production, which has over time become the country's largest source of foreign exchange earnings and major export product (CBN, 2018). The boom of crude oil has recently been joined by the

production of natural gas in commercial quantities. Nigeria is estimated to hold approximately 193 Tscf of proven natural gas reserves, making it the tenth-largest gas reserve holder in the world and the largest in Africa. Nigeria has proven oil reserves of approximately 37.0 billion, ranking as the second largest in Africa and the tenth largest in the world. In 2021 Nigeria produced an average of 1.79 MMbopd, making it the largest oil producer in Africa, with substantially all production coming from the Niger Delta region (BP, Statistical Review, 2021).

Nigeria became and remained a member of the Organization of the Petroleum Exporting Countries (OPEC) since 1971. The major oil wells of the country are in the Niger Delta region of the southern part of the country, particularly in the Gulf of Guinea, the Bight of Benin, and the Bight of Bonny (offshore). The main export destination of Nigeria's crude oil export mostly Western Europe and North America. Unfortunately, despite the fact of the country's oil export capacity, the country imported a large substance of refined crude oil products for internal usage. The exploration activities of the country are mainly concentrated in the deep and ultra-deep offshore, partly north-eastern part of the country at the Chad basin and most recently in southwestern Lagos state (NBS, 2020).

In this regard, these sectors have contributed much to the growth of economic activities as the value of estimate shows in the nation that promotes economic potentialities. However, this might reflect on the environmental condition in the country ranging from the release of Carbon emissions from agriculture and deforestation, Industrial pollution, and oil exploration as well as the leakages of oil on land, damaging soil fertility, and the

environment that need to be considered to attaining environmental sustainability and growth.

3.5 Overview of Nigeria's key environmental indicators and Energy Consumption

In a decade, Nigeria's GDP grew by an average of 4.9per cent per year in total, and 2.1per cent per capita. Over the same period, energy-related CO₂ emissions increased by 3.1 per cent, per year in total, and 0.3per cent per capita. Biofuels accounted for 86.2 per cent of CO₂ emissions from energy use in 2019, down from 89.6per cent in 2007, while gasoline, the main fossil fuel used in Nigeria, accounted for 6.3 per cent in 2017, up from 4.1per cent in 2007. Noncombustible energy sources, mainly hydropower, accounted for 0.3 per cent of primary energy use in 2019, down from 0.5per cent in 2007. Nigeria is a net energy and oil exporter. In 2019, 57per cent of the population had access to electricity with only 10per cent able to use clean cooking fuels and technologies. The government of Nigeria has committed to pursuing sustainable economic development policies focused on addressing Nigeria's vulnerability to climate change and expanding domestic renewable energy production in its First Nationally Determined Contribution. In this NDC, Nigeria set an unconditional GHG emissions reduction target of 20per cent by 2030, relative to the BAU scenario. Nigeria's tax-to-GDP ratio of 5.7per cent is lower than the OECD, LAC, and African average 1 of 33.9per cent, 22.8per cent, and 17.2per cent, respectively EIA, (2019).

The country remains noticeable in terms of CO₂ discharge, energy production, and usage in the African continent. Indeed, the nation accounted for about 0.12 percent of CO₂ discharge annually (EIA, 2019). Hence, CO₂ emissions occupied almost 90 percent of greenhouse gas. For instance, figure 3.6 illustrates the trend of CO₂ discharge from 1980

to 2017. It indicates that the country possesses had positive growth in CO2 explosion for these decades. The country's CO2 emission level was in a steady decline from the early 1980s through to the late 1990s. There was a spike in CO2 emission around the year 2000, which coincides with the return of civilian government in the country, however, lasted only for a short period. From around the mid-2000s whilst the economy was still growing the CO2 emission began a decline since then despite sustained growth in the economy.

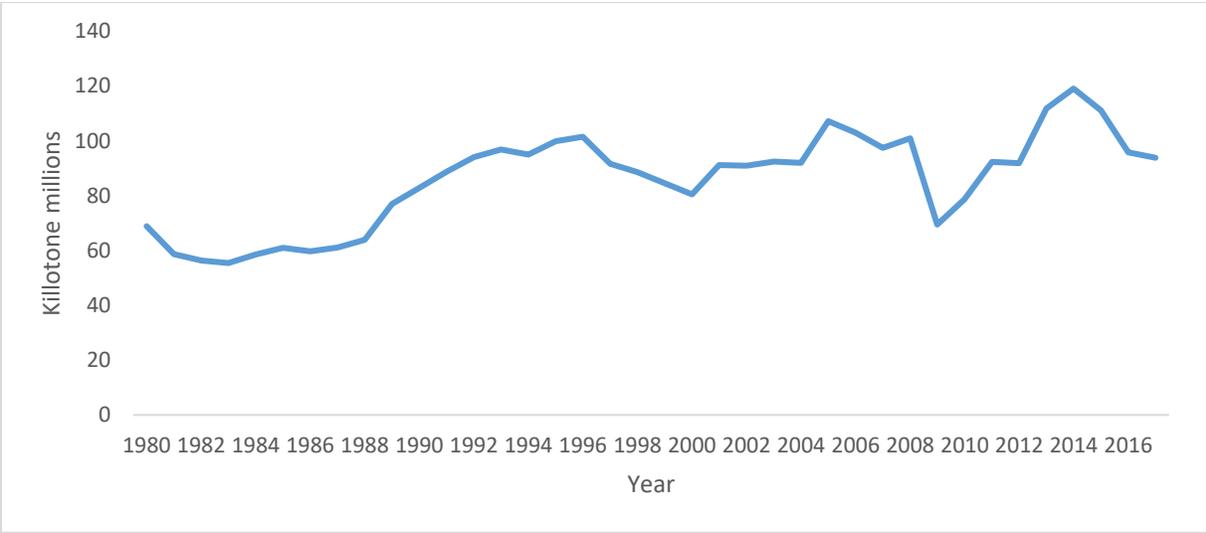


Figure 3. 3: Carbon emissions in Nigeria (1980 – 2017)
 Source: Energy Information Administration (EIA, 2019)

Similarly, based on the data extracted from the Nigerian Oil Spill Monitor, an arm of the Nigerian Oil Spill Detection and Response Agency, NOSDRA, oil and gas companies in the country flared 126bn standard cubic feet (SCF) of gas in the first half of the year (H1 2022). This resulted in 6.7million tonnes of carbon dioxide (CO2) emissions and an equivalent amount of US\$441.2m lost compared with 136.6bn standard cubic feet of gas, resulting in 7.3million tonnes of carbon dioxide (CO2) emissions and an equivalent amount of US\$478.1m lost in H1 2021. For the full year 2021, the country flared 255.2bn

standard cubic feet of gas, resulting in 13.6million tonnes of carbon dioxide (CO₂) equivalent emissions with an equivalent amount of US\$893.1m lost Elsewhere, the World Bank's Global Gas Flaring Reduction Partnership (GGFR) in its 2022 global gas flaring tracker report ranked Nigeria as the 7th largest gas flaring country globally in 2021. Based on the satellite data, about 143.4 billion cubic meters (bcm) equivalent of c.5.1tn standard cubic feet of gas was flared at upstream oil and gas facilities across the globe in 2021, resulting in 382.4 million tonnes of carbon dioxide (CO₂) equivalent emissions with an equivalent amount of US\$16.5bn lost. Specifically for Nigeria, data from the World Bank was broadly in line with data from the Nigerian Oil Spill Monitor above (EIA, 2021).

Gas flaring in Nigeria has been an insurmountable problem for the country, especially in the Niger Delta region (Rivers, Akwa Ibom, Bayelsa, and Imo state) since the commercial exploration of crude oil started. The country has on several occasions set a target to end gas flaring, which all have been missed with the most recent unmet deadline in the year 2020. In February 2021, the Minister of State for Petroleum Resources, Timipre Sylva, noted that the government had committed to achieving a complete elimination of gas flaring by the year 2025, before the World Bank's Zero Routine Flaring by 2030. Meanwhile, the Federal Government continues to lose potential revenue to gas flaring. As seen by both the NOSDRA data and the World Bank report, Nigeria lost potential income of between US\$761.2m and US\$893.1m to gas flaring in 2021. Beyond that, the agricultural ecosystem of the Niger Delta has been severely damaged. Due to increased soil temperature, crop yield has been affected with many lands now barren. Furthermore, water bodies are now black while rainfall in the area is also black destroying many homes. The black water bodies have destroyed fishing potential while burning bushes and lands

have forced animals to desert the forests in the area. The health of citizens residing in communities prone to gas flaring has also been severely impacted. Gas flaring has been linked to cancer and lung damage alongside neurological and reproductive problems which have become prominent among pregnant women and newborns in the region. Furthermore, the spate of gas flaring which has worsened the economic situation of affected villages has led to the development of insurgency (EIA, 2021).

Moreover, figure 3.6 shows the trend of Nitrous oxide, Methane, Agricultural, and CO₂ emissions from fossil fuel consumption per cent of the total in Nigeria. It reveals that emissions in the nation possess an increasing trend most especially with regards to methane emissions from 1980 to 2008. This figure shows (vertical axis) the percentage of these emissions from the entire total emission (greenhouse gas) or it shows each of these emissions portion of percentage from the total emission at various times (Years) on the horizontal axis.

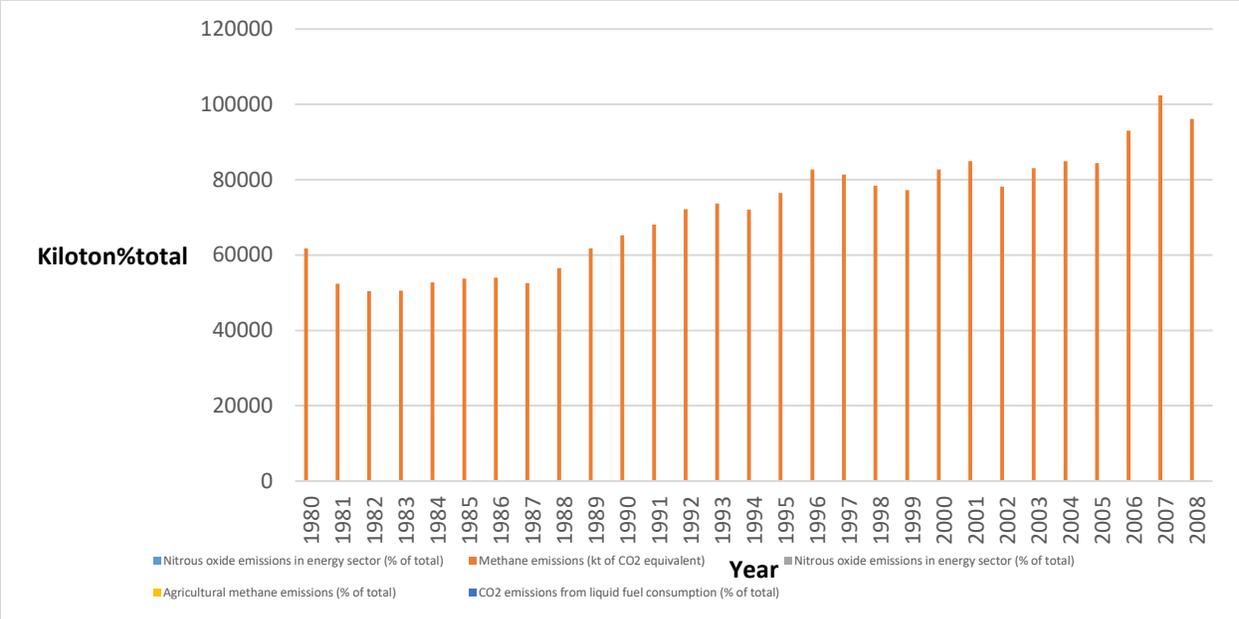


Figure 3. 4: Nitrous oxide, Methane, Agricultural, and CO2 emissions from fossil fuel consumption in Nigeria (per cent of the total) 1980 – 2008
 Source: World development indicators (WDI, 2019)

3.5.1 Methane Emissions in Nigeria

Nigeria, the most populous nation in Africa and one of the largest producers of oil and gas in the world is setting the stage for deep reductions in methane pollution from the oil and gas sector. Nigeria’s recent submission to the UNFCCC on its commitments to the Paris climate accords sets a specific goal of slashing methane emissions by 60per cent by 2031, showing that Nigeria is committed to leading the way in cutting methane pollution. In 2019, methane emissions for Nigeria were 135,840 kt of CO2 equivalent. Methane emissions of Nigeria increased from 110,050 kt of CO2 equivalent in 2000 to 135,840 kt of CO2 equivalent in 2019 growing at an average annual rate of 1.17per cent (IPCC 2019).

In recent decades, Nigeria has taken a global leadership role in implementing policies to tackle polluting emissions from the oil and gas sector. A member of the Global Gas Flaring Reduction Partnership (GGFR) and endorser of the Zero Routine Flaring by 2030 Initiative led by the World Bank, Nigeria has dramatically cut natural gas flaring – by roughly 70per cent since 2000. This was a huge success – but there remains room for improvement: Nigeria still flared 7.2 billion cubic meters of gas in 2020, making it the 7th largest flare in the world (World Bank, 2020).

Nigeria has now turned its full attention to methane pollution. In 2019, Nigeria published its National Action Plan to reduce short-lived climate pollutants and joined the Global Methane Alliance, pledging absolute methane reduction targets of at least 45per cent by 2025 and 60-75per cent by 2030. The inclusion of specific methane targets in Nigeria’s 2021 update of its Nationally Determined Contribution sets up a process to develop legally binding policies in Nigeria over the coming year (FME, 2022). This 60per cent reduction is a conditional objective which means it is dependent on international support (this includes finance, technology transfer, and capacity building).

Clean Air Task Force and Carbon Limits Nigeria, with the support of the Climate and Clean Air Coalition, worked hand in hand with the Federal Ministry of Environment, the Federal Ministry of Petroleum Resources, the Department of Petroleum Resources, and other Nigerian stakeholders to analyze of the sources of Nigeria’s methane emissions and their abatement potential. Employing CATF’s Country Methane Abatement Tool, Nigeria’s emissions were mapped out and we explored mitigation pathways (FME 2022).

The Global Methane Assessment, published in May this year, shows that human-caused methane emissions must be reduced by 45 per cent this decade, and oil and gas methane need to be cut by roughly 60 per cent. This level of reduction would avoid nearly 0.3°C of global warming by 2045 and make it possible to meet the Paris Climate Agreement's goal to limit global temperature rise to 1.5°C. Nigeria is stepping up to do its part. While implementation will be a critical next step, Nigeria is showing the world the direction that we must go to avoid the most catastrophic impacts of global climate change (IPCC 2022).

Nigeria has joined the list of countries that have signed up for a global methane pledge, vowing to reduce emissions of the potent greenhouse gas by 30 per cent by 2030. The call to cut methane emissions by 2030 was pushed by the United State President, Mr. Joe Biden, at the White House in October 2022. Methane is not as long-lived in the atmosphere as carbon dioxide, which is the main greenhouse gas, but methane is more than 80 times more powerful over the years. The heat-trapping gas is produced by coal mining, the oil and gas industry, and agriculture and livestock. According to an International Energy Agency report (2022), the technology exists to cut 75 per cent of global methane emissions from oil and gas operations by 2030. This follows as scientists projected that future global warming could be reduced by 0.36 degrees Fahrenheit by the 2040s if countries take up the challenge to cut methane now.

At a virtual ministerial meeting hosted in Belgium, the European Union's top climate negotiator, Mr. Frans Timmermans, and the White House special envoy for climate, Mr. John Kerry, announced the new signatories and stressed the importance of less methane. Accordingly, the pledge is now backed by nine of the world's top 20 methane-emitting

countries, which account for 60 per cent of the global economy. Today, Nigeria was named to be one of the new 24 supporters who will join the earlier signatories, including the United States, European Union, Argentina, Ghana, Indonesia, Iraq, Italy, Mexico, and Britain. Other new countries include Canada, Central Africa Republic, the Republic of Congo, Costa Rica, Ivory Coast, the Democratic Republic of the Congo, Federal States of Micronesia, France, Germany, Guatemala, Guinea, Israel, Japan, Jordan, Kyrgyz Republic, Liberia, Malta, Morocco, Pakistan, Philippines, Rwanda, Sweden, and Togo.

The US and EU negotiators further reveal that some of the world's biggest methane emitters, including Russia, China, India, and Brazil have still not signed the pledge. In all now, 34 countries have signed the pledge. The bid to reduce methane emissions is referred to as the single most effective strategy to reduce near-term global warming. More than 100 countries are hoping to pledge to cut methane by the United Nations COP26 climate summit in Scotland. In addition to the new methane pledges by nations, more than 20 philanthropies announced a plan to spend \$200 million to support the implementation of the global methane goals (IEA, 2022).

3.5.2 Biomass Energy in Nigeria

The burning of solid biomass is the prominent source of energy in Nigeria, generating almost 80 per cent of the energy consumed in this region, with the main consumption being household cooking. Almost 80 per cent of households in Nigeria region do not have modern cooking facilities and are dependent upon charcoal or wood fuel for cooking (EIA, 2016). While in rural areas, the use of fuel wood is more prevalent as it is available for free, the urban areas use charcoal for cooking as its energy content per kilogram is higher

and it is more suitable for transportation from the rural areas. Furthermore, biomass is the biggest energy source for industries that use it to produce process heat (EIA, 2016). Relatedly, charcoal and fuel wood industries are generating significant employment opportunities for charcoal and wood producers, vendors, and transporters. For example, the charcoal markets and fuel wood transaction values were \$122 million in 2007, which was 5 per cent of the output, and approximately 50 per cent of these revenues remained in the rural region (EIA, 2016).

However, even after being such a significant source of employment and income generation, a major part of charcoal production and consumption is carried out in the informal economy. According to data from the World Bank (2013), over 80 per cent of the manufacture and sale of charcoal is in the informal economy.

As per the report from “United Nations Environment Programme (UNEP) and International Criminal Police Organization” (INTERPOL) (2017), the lack of regulation in the charcoal industry has made it into a profitable foundation for generating revenue for the local paramilitaries and is an unexploited prospect for the regime to earn profits. It is projected that African governments lose approximately US\$1.9 billion of potential revenue yearly due to a lack of regulation in the charcoal industry. In addition, the use of charcoal and fuel wood in traditional cooking practices poses a major health hazard, more so in deprived houses.

According to the World Health Organization (2019), there are around 600 thousand premature deaths in Africa every year due to indoor air pollution. Interior air contamination was ranked the second largest hazard caused in East, West, and Central Africa causing

the disease burden (calculated in disability-adjusted life years) among children just after the risk of low body weight due to malnutrition. Generally, African women are more prone to this indoor air pollution than men are as they spend more time near stoves.

3.5.3 Biomass Energy and Carbon Dioxide Emissions

As per data from the International Energy Agency (2022), the total fuel wood consumption in Nigeria, including fuel wood used for charcoal consumption and direct consumption by households was 658 million tons in 2017, which was 0.5 per cent of the overall accessible biomass store of 130 gigatons. However, the estimation of the overall carbon dioxide emission level produced due to biomass burning is very difficult. Since biomass is a renewable energy form, if it is consumed and harvested sustainably, it will create nil or even a negative impact on GHG emissions. Nevertheless, the unsustainable rate of harvesting and consumption of biomass can lead to climate change because of deforestation. The present rate of consumption is already causing the depletion of biomass stores in several regions. Further, even deforestation causes limited conservational effects such as reduced watershed maintenance and soil erosion.

As per the Food and Agriculture Organization (2018), the collection of fuel woods is responsible for over 75 per cent of woodcutting from the African forest region. Nonetheless, the degree of deforestation caused due to fuel wood collection is a highly debated subject matter. In general, the fuel wood collected and consumed by rural people for their household consumption is mostly from dead trees while the wood, which is converted into charcoal to be used for industrial and urban household consumption, is from felled plants. Hence, although the unsustainable assortment of fuel wood

contributes to forestry dilapidation, the charcoal business causes both deforestation and jungle depletion. When there is charcoal production from the felled trees, subsequent deforestation often happens there for timber production or agriculture.

3.5.4 Justification for using CO₂ emission for Nigeria in the Study

The volume of fossil fuel consumption is extremely high in Nigeria (EIA, 2016). The nation as the largest oil producer in Africa consumes a large amount of fuel for both industrial power generation and motor vehicle use (Rafindadi 2016; Yahaya, Iro, and Kabiru 2019). It is argued that higher levels of motor use, especially in the urban areas in the country as well as gas flaring from the oil-producing areas, produce a large amount of CO₂ emissions. Several studies and indicators have revealed on the huge amount of CO₂ explosion for more than a decade in the nation has resulted in to increase in environmental deterioration (Egbetokun et al. 2020; Sulaiman and Abdul-Rahim 2018; Odugbesan and Adebayo 2020). It also reveals an almost 1 per cent annual increase in CO₂ emissions in Nigeria. Therefore, much amount of CO₂ emissions has exploded into the atmosphere. Moreover, there is always available and updated data on CO₂ emissions compared to other forms of emissions in the country. However, other forms of emissions such as Methane and Nitrous oxide emissions have very little contribution to the emissions released into the atmosphere (IPCC 2019). Therefore, it is a more important, relevant, and practical reality to use CO₂ emissions as the measurement of environmental pollution in Nigeria than any other form of emission in the nation.

3.6 Energy situation in Nigeria

Nigeria is Africa's energy giant, it is the continent's most prolific oil-producing country, which, along with Libya, accounts for two-thirds of Africa's crude oil reserves. Nigeria

ranks second to Algeria in natural gas, most of Africa's bitumen and lignite reserves are found in Nigeria, and with its mix of conventional energy reserves, Nigeria is simply unmatched by any other country on the African continent, it's not surprising therefore that energy export is the mainstay of the Nigerian economy. Also, primary energy resources dominate the nation's industrial raw material endowment. Several energy resources are available in Nigeria in abundant proportions. The country possesses the world's sixth-largest reserve of crude oil. Nigeria has an estimated oil reserve of 36.2 billion barrels. It is increasingly an important gas province with proven reserves of nearly 5,000 billion m³.

The oil and gas reserves are mainly found and located along the Niger Delta, the Gulf of Guinea, and the Bight of Bonny. Most of the exploration activities are focused on deep and ultra-deep offshore areas with planned activities in the Chad basin, in the northeast. Coal and lignite reserves are estimated to be 2.7 billion tons, while tar sand reserves represent 31 billion barrels of oil equivalent. The identified hydroelectricity sites have an estimated capacity of about 14,250 MW. Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation (EIA 2021).

There has been a supply and demand gap as a result of inadequate development and inefficient management of the energy sector. The supply of electricity, the country's most used energy resource, has been erratic.

The situation in the rural areas of the country is that most end users depend on fuel wood. Fuel wood is used by over 70 per cent of Nigerians living in rural areas. Nigeria consumes over 50 million tonnes of fuel wood annually, a rate that exceeds the replenishment rate through various afforestation programs. Sourcing fuel wood for domestic and commercial

uses is a major cause of desertification in the arid-zone states and erosion in the southern part of the country. The rate of deforestation is about 350,000 ha/year, which is equivalent to 3.6 per cent of the present area of forests and woodlands, whereas reforestation is only at about 10 per cent of the deforestation rate.

The rural areas, which are generally inaccessible due to the absence of good road networks, have little access to conventional energy such as electricity and petroleum products. Petroleum products such as kerosene and gasoline are purchased in rural areas at prices 150 per cent above their official pump prices. The daily needs of the rural populace for heat energy are therefore met almost entirely from fuel wood. The sale of fuel wood and charcoal is mostly uncontrolled in the unorganized private sector.

The sale of kerosene, electricity, and cooking gas is essentially influenced and controlled by the Federal Government or its agencies - the Nigerian National Petroleum Corporation (NNPC) in the case of kerosene and cooking gas, and the PHCN in the case of electricity. The policy of the Federal Government had been to subsidize the pricing of locally consumed petroleum products, including electricity. In a bid to make the petroleum downstream sector more efficient and in an attempt to stem petroleum product consumption as a policy focus, the government has reduced and removed subsidies on various energy resources in Nigeria.

The various policy options have always engendered price increases for the products. With the restructuring of the power sector and the imminent privatization of the electricity industry, it is obvious that for logistic and economic reasons, especially in the privatized power sector, rural areas that are remote from the grid and/or have low consumption or

low power purchase potential will not be attractive to private power investors, such areas may remain unserved into the distant future (EIA, 2021).

Moreover, Table 3.3 illustrates the capacity and the trend of fossil fuel energy consumption in Nigeria from 1980 to 2017, it is revealed that energy use in Nigeria has been increasing trend for several decades. This means that energy consumption in the country has a direct link to the accelerated capacity of CO₂ discharge in the country.

Table 3. 2: Fossil Carbon Dioxide (CO₂) emissions of Nigeria

Year	Fossil CO ₂ Emissions (tons)	CO ₂ emissions change	CO ₂ emissions per capita	Population	Pop. change	Share of World's CO ₂ emissions
2016	82,634,214	0.70 per cent	0.44	185,960,241	2.66 per cent	0.23 per cent
2015	82,056,175	4.73 per cent	0.45	181,137,448	2.68 per cent	0.23 per cent
2014	78,350,318	-4.54 per cent	0.44	176,404,934	2.70 per cent	0.22 per cent
2013	82,073,244	-0.46 per cent	0.48	171,765,816	2.71 per cent	0.23 per cent
2012	82,456,230	-5.21 per cent	0.49	167,228,794	2.72 per cent	0.23 per cent
2011	86,986,580	9.24 per cent	0.53	162,805,077	2.71 per cent	0.24 per cent
2010	79,625,990	11.36 per cent	0.50	158,503,197	2.71 per cent	0.22 per cent
2009	71,505,270	-7.59 per cent	0.46	154,324,933	2.70 per cent	0.20 per cent
2008	77,377,690	3.25 per cent	0.51	150,269,623	2.69 per cent	0.22 per cent
2007	74,944,790	-7.40 per cent	0.51	146,339,977	2.67 per cent	0.21 per cent
2006	80,932,470	-11.54 per cent	0.57	142,538,308	2.65 per cent	0.23 per cent
2005	91,490,070	3.10 per cent	0.66	138,865,016	2.62 per cent	0.26 per cent
2004	88,737,050	-4.27 per cent	0.66	135,320,422	2.59 per cent	0.25 per cent
2003	92,691,710	5.77 per cent	0.70	131,900,631	2.57 per cent	0.26 per cent
2002	87,634,980	-8.76 per cent	0.68	128,596,076	2.55 per cent	0.25 per cent
2001	96,051,730	6.28 per cent	0.77	125,394,046	2.54 per cent	0.27 per cent
2000	90,376,230	11.37 per cent	0.74	122,283,850	2.54 per cent	0.25 per cent
1999	81,151,170	0.23 per cent	0.68	119,260,063	2.53 per cent	0.23 per cent
1998	80,965,200	-11.11 per cent	0.70	116,319,759	2.52 per cent	0.23 per cent
1997	91,082,810	-0.06 per cent	0.80	113,457,663	2.52 per cent	0.25 per cent
1996	91,136,410	16.23 per cent	0.82	110,668,794	2.52 per cent	0.25 per cent

Year	Fossil CO2 Emissions (tons)	CO2 emissions change	CO2 emissions per capita	Population	Pop. change	Share of World's CO2 emissions
1995	78,412,970	6.05 per cent	0.73	107,948,335	2.52 per cent	0.22 per cent
1994	73,940,640	-7.59 per cent	0.70	105,293,700	2.52 per cent	0.21 per cent
1993	80,015,580	-3.25 per cent	0.78	102,700,753	2.53 per cent	0.22 per cent
1992	82,701,460	10.12 per cent	0.83	100,161,710	2.55 per cent	0.23 per cent
1991	75,098,160	8.74 per cent	0.77	97,667,632	2.58 per cent	0.21 per cent
1990	69,062,280	-5.79 per cent	0.73	95,212,450	2.61 per cent	0.19 per cent
1989	73,305,200	2.11 per cent	0.79	92,788,027	2.65 per cent	0.21 per cent
1988	71,788,380	13.26 per cent	0.79	90,395,271	2.67 per cent	0.20 per cent
1987	63,383,410	-4.86 per cent	0.72	88,048,032	2.66 per cent	0.18 per cent
1986	66,619,990	-2.41 per cent	0.78	85,766,399	2.64 per cent	0.19 per cent
1985	68,266,440	4.24 per cent	0.82	83,562,785	2.60 per cent	0.19 per cent
1984	65,489,590	-0.09 per cent	0.80	81,448,755	2.56 per cent	0.18 per cent
1983	65,551,730	0.27 per cent	0.83	79,414,840	2.57 per cent	0.18 per cent
1982	65,377,570	-3.71 per cent	0.84	77,427,546	2.63 per cent	0.18 per cent
1981	67,896,340	-17.04 per cent	0.90	75,440,502	2.75 per cent	0.19 per cent
1980	81,842,290	-9.03 per cent	1.11	73,423,633	2.89 per cent	0.23 per cent
1979	89,962,980	41.46 per cent	1.26	71,361,131	3.02 per cent	0.25 per cent
1978	63,594,570	5.18 per cent	0.92	69,271,917	3.08 per cent	0.18 per cent
1977	60,464,462	-10.78 per cent	0.90	67,203,128	3.04 per cent	0.17 per cent
1976	67,771,043	17.70 per cent	1.04	65,221,378	2.91 per cent	0.19 per cent
1975	57,580,263	-23.19 per cent	0.91	63,374,298	2.75 per cent	0.16 per cent
1974	74,968,397	26.12 per cent	1.22	61,677,177	2.60 per cent	0.21 per cent
1973	59,440,354	20.26 per cent	0.99	60,114,625	2.47 per cent	0.17 per cent
1972	49,426,356	29.44 per cent	0.84	58,665,808	2.39 per cent	0.14 per cent
1971	38,183,651	46.66 per cent	0.67	57,296,983	2.35 per cent	0.11 per cent

Sources: CO2 Emissions from Fuel Combustion – (IEA, 2020)

Based on the source of data, this is the current and updated data on fossil carbon dioxide emission in Nigeria

3.7 Conclusion

This chapter provides a detailed overview of Nigeria, its economy, and the link to environmental sustainability. The chapter has reviewed Nigeria's economic structure and discussed a brief overview of some key environmental indicators and energy consumption in Nigeria. The chapter gives a brief history and geography of the nation, the size of the population, and GDP growth as well as the composition of the economic structure that consists, of agriculture, industries, and oil sectors which all indicate a positive trend. These indicators are significant in determining the nation's capacity in making assessments and policies on environmental sustainability and growth. Moreover, the chapter illustrates the trends in environmental indicators that may be linked to the nature of the nation's economic settings. Thus, this chapter reveals the basic variables of the study such as economic growth and energy use, to examine the influence of these factors on environmental pollution in Nigeria to attain viable economic development. In this regard, the chapter has provided the study's framework on the variables including CO₂ emission, energy consumption, and economic growth on which the empirical review for the related studies will be based on. Hence, the next chapter will be on the research methodology for these factors.

CHAPTER 4: RESEARCH METHODOLOGY

4.0 Introduction

This chapter gives detail of the theoretical framework, and the methodology applied in the model estimation and analysis. It elaborates on the relationship between the study's objectives, empirical models of the analysis that are linked to the findings, and recommendations of the study. The chapter illustrates the EKC theory linked to the empirical models of the study, the method of exploring stationarity of the variable through the Augmented Dickey-fuller and Philips Peron testing approach. Similarly, the techniques of estimation including ARDL, VAR, and Toda-Yamamoto Granger causality analysis were presented. Lastly, the models were subjected to various post-estimation checks for the reliability of the policy recommendations of the study. In a nutshell, the chapter gives information about the theory, techniques of estimation, model specifications, data used, measurement of the study's variables, and post-estimations analysis within the context of this study.

4.1 Research Framework

The research framework shown in Figure 4.1 is based on the literature review and research problem. The framework focuses on the relationship between environmental degradation and economic growth with energy use and the interaction effects of these relationships. Environmental degradation which is a proxy by CO₂ is the dependent variable, while economic growth, energy use, financial development, FDI, and trade openness are the independent variables. Energy use serves as the interacting variable in the model. An interacting variable refers to a variable that affects the direction or strength

of association between explanatory and explained variables (Baron & Kenny 1986). An interacting effect implies that the relationship between the independent and dependent variables varies as a function of the value of the third variable. The research framework of this study is as follows

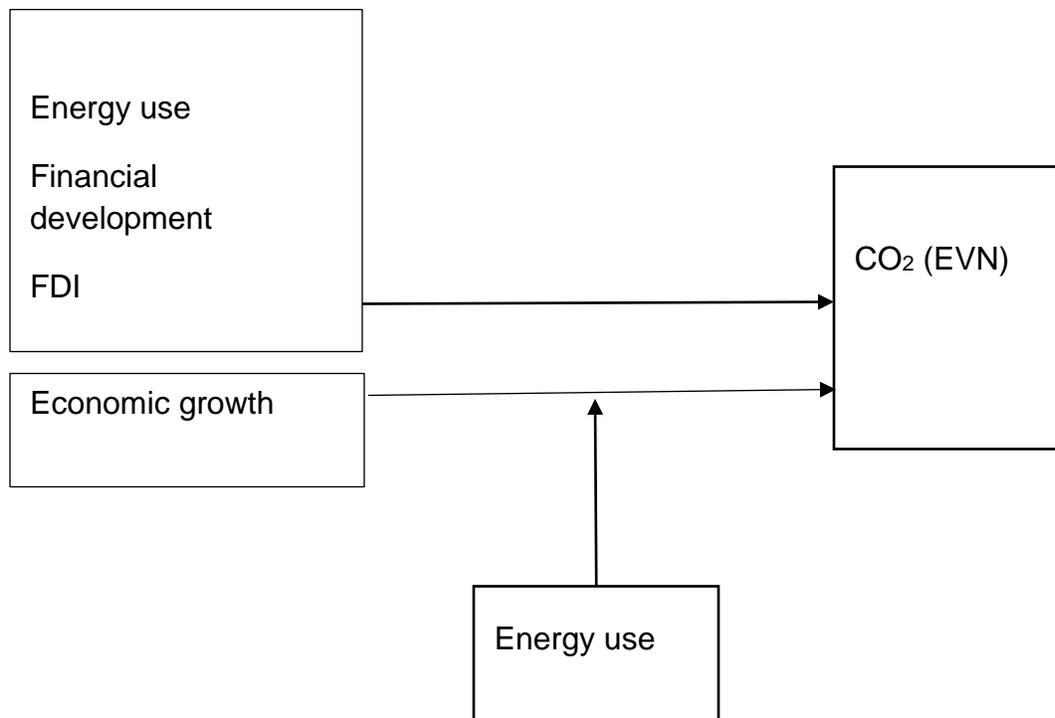


Figure 4. 1: Research Framework
Source: Authors Compilation

4.2 Theoretical Framework

The theoretical framework visualizes theory that linked the relationship between identified factors (Sekaran & Bougie 2003). For this reason, the theoretical framework in this study highlighted the influence of energy utilization and economic variables on CO₂ discharge. The framework for this study was developed based on the Environmental Kutznet Curve (EKC) hypothesis. Therefore, this study is formed along with the boundary of the

Environmental Kuznet Curve (EKC) hypothesis that is developed to explain how economic performance influences environmental degradation.

The Environmental Kuznet Curve (EKC) hypothesis endeavors at pointing out the influence of economic activities on environmental quality. This is because of the Environmental Kuznets Curve (EKC) hypothesis on the role of economic variables on environmental pollution. Taking the two models and relating them to the global context, output performance significantly pollutes the environment because of human economic activities.

The Kuznets curve was initially proposed by Simon Kuznets (1955) in his article Economic Growth and income inequality, where he demonstrated an inverted U-shape relationship between income inequality and economic development. The Environmental Kuznets curve hypothesis is an important dynamic process of change in income and pollution over a period. The hypothesis revealed that an inverted U-shape relationship exists between environmental degradation and income (Dinda, 2004). That is at the initial stage, change in income, increased environmental degradation up to a certain level, and then decline. Moreover, as the structure of the economy changes, national production grows and gradually influences environmental quality. Besides, the level of technology affects environmental conditions. However, the transition from old and dirty technology to new-technology-intensive knowledge reduced environmental pollution. Since nations with higher income can promote the level of research and development by allocating adequate resources, hence new technology enhances environmental quality. Therefore, at the beginning of economic progress environmental dilapidation increase and later decrease because of scale, structural and technological effects.

In a different view, a higher level of development is usually intensified with structural change, knowledge and environmental awareness, environmental control policies, and laws, and the use of low emissions technologies to increase the level of environmental quality (Panayotou 1993; Stern, Common, and Barbier 1996).

In addition, Stern (2004) maintained that the EKC relationship is influenced by the changes in economic structure, the scale of production, and technology. Environmental degradation at any given time is determined by such factors. Heerink et al. (2001) demonstrate how to scale effect and the dynamic structure of the economy, as well as the changes in the technique of production, are the reason for the inverted U-shape relationship between economic growth and environmental degradation. Therefore, EKC can be influenced by the composition effects such as financial reforms, trade liberalization, FDI, and therefore, entails that financial sector reform, eliminating trade barriers increase foreign direct investment, increases economic growth, and eventually influence environmental degradation (Bilgili, Koçak, and Bulut 2016). Katircioğlu (2014) asserted that energy use accelerates real income growth and increases environmental pollution.

4.3 Analytical Model

This section illustrates the models of estimation based on the objectives of this study.

4.3.1 Empirical Model of economic growth and environmental degradation

To examine the effect of economic growth on environmental degradation, a transformed model by Azam et al. (2016) is used. In this empirical model, a copied or changed version of the model by Azam et al. (2016) was used to theoretically justify the validity of the study's empirical model. The study uses the following model:

$$ENV = f(GDP, FD, FDI, TO) \quad (4.1)$$

Where *ENV* is environmental degradation, *GDP* represents economic growth, *FD* is financial development, *FDI* is foreign direct investment, and *TO* represents trade openness.

Thus, the econometric specification of equation (4.1) is shown as follows:

$$LENV_t = \alpha + \beta_1 LGDP_t + \beta_2 LFD_t + \beta_3 LFDI_{it} + \beta_4 LTO_t + \varepsilon_t \quad (4.2)$$

Subscript *t* stands for the period (*t* = 1980.....2020), α and β signify the parameters and ε denotes the stochastic error, the rest as defined in the previous equation. The apriori expectation for the beta coefficients is greater than zero (*i.e.* $\beta_1, \beta_2, \beta_3, \beta_4 > 0$). Therefore *LGDP*, *LFD*, *LFDI*, and *LTO* are positively related to environmental degradation. All The variables will be in their natural log values for ease of interpretation.

4.3.2 Empirical Model of energy use and environmental degradation

To study the influence of energy use on environmental degradation. The study considers the following modified model by Azam et al. (2016) as follows:

$$ENV = f(EU, FD, FDI, TO) \quad (4.3)$$

Where *ENV* is environmental degradation, *EU* illustrates energy use, *FD* is financial development, *FDI* is foreign direct investment, and *TO* represents trade openness.

Hence, the econometric specification of equation (4.3) is as follows:

$$LENV_t = \alpha + \beta_1 LEU_t + \beta_2 LFD_t + \beta_3 LFDI_{it} + \beta_4 LTO_t + \varepsilon_t \quad (4.4)$$

The apriori expectation for the beta coefficients is greater than zero ($\beta_1 \beta_2 \beta_3 \beta_4 > 0$). Hence, LEU, LFD, LFDI, and LTO are positively related to environmental degradation. All The variables will be in their natural log values for ease of interpretation.

4.3.3 Empirical Model of environmental degradation and interactive variables

To examine the interaction effect of energy use and economic growth on environmental degradation, a reformed model by Baltagi, Demetriades, and Hook (2009) will be used.

The following model is stated:

$$ENV = f(GDP, EU, FD, FDI, TO, EU * GDP) \quad (4.5)$$

Where ENV is environmental degradation, GDP represents economic growth EU illustrates energy use, FD is financial development, FDI is foreign direct investment, TO represents trade openness, and EU*GDP represents the interaction term between energy use and economic growth.

Therefore, the econometric specification of equation (4.5) is as follows:

$$LENV_t = \alpha + \beta_1 LEU_t + \beta_2 LGDP_t + \beta_3 LFD_t + \beta_4 LFDI_{it} + \beta_5 LTO_t + \beta_6 LEU * GDP_t + \varepsilon_t \quad (4.6)$$

The apriori expectation for the beta coefficients is greater than zero ($\beta_1 \beta_2 \beta_3 \beta_4 \beta_5 \beta_6 > 0$), therefore LEU, LFD, LFDI, LTO, and EU*GDP are positively related to environmental degradation. All The variables are in their natural log values for easy interpretation.

4.3.4 Model of dynamics in carbon dioxide emissions using the forecast error variance decomposition, impulse response, and Toda-Yamamoto Granger causality.

This study employed a modified model developed by Ohlan (2015) to investigate the extent to which energy consumption, foreign direct investment, financial development, trade openness, and gross domestic product growth explain dynamics in carbon dioxide emissions using the forecast error variance decomposition and impulse response analysis using quarterly data Q11980 to Q12020.

The functional form of the model is presented in Equation 4.7

$$CO_2 = f(ENU, GDP, FD, FDI, TO) \quad (4.7)$$

Where carbon dioxide is the emission discharge, ENU represents energy consumption, FDI indicates the foreign direct investment, FD is the financial development, TO is the trade openness performance and GDP is the economic growth.

The econometric specification of the functional form equation 4.7 is represented as follows in equation 4.8:

$$CO2_t = \alpha + \beta_1 ENU_t + \beta_2 FDI_t + \beta_3 FD_t + \beta_4 TO_t + \beta_5 GDP_t + \varepsilon_t \quad (4.8)$$

The apriori expectation is $\beta_1 > 0$; $\beta_2 > 0$; $\beta_3 > 0$; $\beta_4 > 0$; $\beta_5 </> 0$. Therefore ENU, FDI, FD, and TO are positively related to carbon dioxide discharge while theory provides that gross domestic product growth could either increase or decrease carbon dioxide emission depending on the stage of economic development. The variables ENU, FDI, FD, and TO are in their natural log values for easy interpretation in elasticity form.

4.4 Source of Data and Variables Measurement

The study will employ annual time series data from 1980 to 2020 on CO₂ emissions, energy use, financial development, FDI, and trade from the World Bank World Development Indicators. Environmental degradation will be measured by CO₂ Emissions in kilo tonnes (kt), energy use measured by fossil fuel consumption in kg of oil equivalent, economic growth will be measured by GDP current USD, financial development measured by domestic credit per cent of GDP, foreign direct investment FDI inflows, and trade will be measured by total exports and imports (WDI 2022).

4.4.1 Variables measurement

Table 4. 1: **Description of the study variables**

Variables	Description	Definition	Source
ENV	DV	CO ₂ emissions in kilo terms (kt)	WDI
GDP	IV	Current USD	WDI
EU	IV	Energy use kg of oil equivalent	WDI
FD	IV	Domestic credit per cent GDP	WDI
FDI	IV	Foreign Direct Investment	WDI
TO	IV	Total exports and imports	WDI

Note: *DV refers to the dependent variable and *IV refers to the independent variable

4.4.2 Justification of the Variables

In this study, the link between environmental degradation, economic growth, and energy use will be examined. The variables used in this study are based on the extensive literature review conducted in the study and as presented in Chapter Two of the study. Therefore, the study will use environmental degradation as an explained variable, while the explanatory variables are energy use, economic growth, financial development, FDI,

and trade openness. The description and measurement of these variables are explained in the following subsections.

4.4.2.1 CO₂ emissions in kilo tonnes (kt)

CO₂ (carbon dioxide) emissions mainly comprise emission that arises due to the burning or combustion of fossil fuels. These are also known as greenhouse gases (GHG) which are highly polluting and harmful to the environment. These gasses are harmful mainly because they tend to captivate as well as release infrared radiation which is harmful to the entire universe. They keep the heat trapped and do not allow the same to get released into space. The outcome is the rising temperatures of the Earth making it a difficult place to live. The calculations for the CO₂ emission are done by calculating the total number of people living and the overall quantum of CO₂ emitted per person (Saboori & Sulaiman 2013). Thus, an average is derived to identify per capita emissions. For simplicity, and to ensure a holistic analysis is executed in the present study, CO₂ emissions are measured based on Kilo tone. Hence, CO₂ in this study will measure environmental degradation.

4.4.2.2 Real GDP per capita

Real GDP per capita (current USD). It is the gross domestic product all over the midyear population. It is also the summation of gross value added by entire resident producers in the economy added with any product taxes and minus any subsidies that are not included in the value of the exports. In the present study, real GDP per capita measured economic growth. Similarly, this measure has been widely used in the literature as a measure of economic growth (Alkathlan and Javid 2013; Ayadi et al. 2015; Yıldırım, Sukruoglu, and Aslan 2014; Menyah, Nazlioglu, and Wolde-rufael 2014).

4.4.2.3 Energy Consumption kg of oil equivalent

Energy consumption (kg of oil equivalent) involves the utilization of primary energy before it is changed to other end-use fuels. Therefore, in this study, energy use measures the level of energy consumption. It is frequently used in the literature as a measure of energy consumption (Heidari, Katirciog, and Saeidpour 2015; Yıldırım, Sukruoglu, and Aslan 2014; Osigwe and Arawomo 2015; Shahbaz, Mutascu, and Azim 2014).

4.4.2.4 Financial development

Domestic credit to the private sector (percentage of GDP). It is the value of credit issued by deposit money banks and other financial institutions to the private sector. Therefore, in this study, domestic credit to the private sector measures the extent to which financial development influences environmental degradation and economic growth as the private sector has access to funding. It is the main measurement of financial development that has been widely used in the literature that is related to the ability to channel funds to the public. It also captured both banks and other financial institutions including government institutions that are suitable for developing countries (Mahdi 2015; Ductor and Grechyna 2015; Shahbaz, Hye, et al. 2013; J. Muhammad and Ghulam Fatima 2013).

4.4.2.5 Foreign Direct Investment

Foreign Direct Investment (FDI) is investments made by individuals and companies in a foreign nation to generate mutual companies. FDIs are executed with the primary intention to pursue business in a foreign land. A nation welcomes FDI as it supports industrial development which in turn supports overall national development. Through FDIs, a nation can get additional sources of funds and thus add to the resources required for capital building. FDI also helps nations to develop powerful and positive international

relationships. FDI is not only about the channelization of funds into foreign lands but also consists of the transfer of knowledge, competencies, skills, and technologies (Shao, 2018). With the help of FDI, individuals or firms can use their idle capital and thus support economic progress by supporting the movement of funds and other resources from the haves to the have-nots.

4.4.2.6 Trade openness

Trade openness (sum of exports and imports, percentage of GDP). It is the totality of exports and imports of goods and services measured as the percentage of GDP. However, in this study trade measures the extent to which trade openness influences environmental degradation and economic growth. This measure is popular and frequently used in the literature to measure the openness of an economy (Shahbaz, Hye, et al. 2013; Menyah, Nazlioglu, and Wolde-rufael 2014; Fauzel 2016; Ling et al. 2015).

4.5 Estimation Techniques

4.5.1 Unit Root Test

Time series analysis requires series to be stationary and in deciding the order of integration of series, there is a need to analyze the stationarity of the data (Maddala & Kim, 1998). Maddala and Kim (1998) give an overview of the various statistical tests for stationarity analysis that have been proposed in the literature. The various tests have their strengths and weaknesses under different conditions.

A standard practice in macroeconomics and Time series analysis in the literature is the presence of non – stationarity in the data. The data to be analyzed has to be transformed to stationarity, to remove the trend before the analysis. In this regard, there are

procedures for trend removal which are differencing, and time trend regression, which is commonly used to render the data stationary. To avoid spurious regressions, it becomes necessary to carry out a pre-testing for unit roots for cointegration analysis.

Hence, the investigation of the existence of a long-term relationship between economic growth, energy use, FD, FDI, trade, and CO₂ emissions in Nigeria, must start with the test for the Unit root for the time series of the variables. There are various standardized tests in the literature, including Augmented Dickey-Fuller (ADF), and the Philip – Peron (PP) are applied for the data validation. Before modeling the time series data, it is important to determine the order of integration of the variables. There are various unit root tests available for testing the time-series properties of the variables.

4.5.2 Augmented Dickey-Fuller (ADF)

Equation 3.3 to 3.5 is the coefficient of interest where Y is based on a t-statistic estimated from an OLS equation. Lütkepohl, Krätzig, and Phillips (2004) state that the test does not have an asymptotic standard normal distribution, the critical values are derived by simulation and are different where a constant or linear term is included. If the equation is in the first difference has a unit root. The tests assume that the errors are independent and have constant variance. In this case, the non-rejection of the null hypothesis suggests that the time series under investigation is non – stationary.

This study uses the ADF test Dickey and Fuller (1979) and Phillips and Perron (1988) unit root tests to check the stationary property of the variables. For this purpose, all the data series of CO₂ emissions, FDI, trade, financial development, and energy consumption will be examined using the ADF unit root test.

The ADF test is augmented from an earlier version known simply as the DF test. Assume, for example, a first-order Autoregressive process of y :

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \varepsilon_t \quad (4.7)$$

where α stands for parameters and ε_t represents white noise error term. Series y is said to be stationary if it does not possess a unit root. Meaning that the characteristic root of the processes α_1 : $-1 < \alpha_1 < 1$, and non-stationary if $\alpha_1 = 1$. By subtracting y_{t-1} from Equation [3.6], the basic test is carried on:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \varepsilon_t \quad (4.8)$$

where Δ stands for difference operator and $\rho = \alpha_1 - 1$ and the test consists of testing the null hypothesis $H_0 : \rho = 0$. ADF parametrically corrects for higher order Autoregressive process by assuming:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \beta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \quad (4.9)$$

4.5.3 Philip – Perron (PP) Unit Root Test

Philip – Perron test, developed by Philip and Perron (1988), is a modified version of the ADF test with lighter stringent assumptions concerning the distribution of errors. The use of complementary unit root testing approach is employed from the perspective of models with inadequately dependent errors (Philip & Perron, 1988). Asteriou and Hall (2007) note “While the ADF test corrects for higher-order serial correlation by adding lagged difference terms on the right-hand side, the PP test corrected the t-statistic of the coefficient α from AR (1) regression to account for the serial correlation in ε_t ”. Meaning

that the PP test administers a non-parametric correction on the t- statistic of the attribute of the first-order autoregressive process to take care of serial correlation in the error term.

Furthermore, the null hypothesis for the PP test, in the same way, as the ADF is the existence of a unit root $1(1)$, signifying a rejection of the null hypothesis if the series is $1(0)$. There are similarities in the two tests in the use of the same asymptotic distribution of the t – statistic and both can be conducted with the option of including a constant and a linear time trend or none in the test regressions.

As in the ADF test, the Philip – Perron (PP) Unit Root Test PP test is developed on the first-order autoregression of ADF, this test is based on the requirement to create residuals that are exempted from serial correlation. Nonetheless, the use of a complementary unit root testing approach employed with the perspective of models with inadequately dependent errors (Phillips & Perron, 1988) is also known as the Phillips-Perron [PP] unit root tests. Contrary to the ADF approach, a PP test considers serial correlation in errors by use of a nonparametric serial correlation correction factor, depending on the uniform estimation of the long-run variance of the error process. Furthermore, a comprehensive analysis of the conduct of the PP test wherein the variable forms of first-order AR and MA dependences are approved for, the errors is provided (Perron & Ng 1996).

The function of PP unit root tests depends on ordinary least squares (OLS) parameter estimation, α^{\wedge} from AR (1) (pseudo-) equation

$$x_t = \alpha x_{t-1} + \mu_t \tag{4.10}$$

By use of α^{\wedge} PP unit root, statistics are subsequently calculated as:

$$Z_{\alpha} := T (\alpha^{\wedge} - 1) - \frac{1}{2} (\lambda^{\wedge 2} - s^2) (1/T^2 \sum_{t=1}^T x^2_{t-1})^{-1} \tag{4.11}$$

$$Z_t := s / \lambda^{\wedge t} \alpha^{\wedge t-1} - \frac{1}{2} (\lambda^{\wedge 2} - s^2) (\lambda^{\wedge}/T^2 \sum_{t=1}^T x^2_{t-1})^{-1/2} \tag{4.12}$$

Where $t_{\alpha=1} := s^{-1} (\alpha - 1) (\sum_{t=1}^T x_{t-1}^2)^{1/2}$ and $s^2 := T^{-1} (\sum_{t=1}^T \mu^2 t)$ and λ^2 can be stated as estimators of short and long term variance represented by μ and t

The major difference is that the PP test administers a non-parametric correction on the t-statistics of the attribute of the first-order autoregressive process to take care of serial correlation in the error term. Confirming the series to be stationary qualifies the study to test for the presence of long-run cointegration among the variables. The null hypothesis is that the series is not stationary and contains unit roots while the alternative hypothesis is that the series is stationary and does not contain unit roots.

4.5.4 Cointegration Test

Cointegration is a process of determination of the long-run relationship between variables in economic theory when there is the existence of non – stationary time series. After testing for unit root, this study tests the cointegration hypothesis for the long-run relationship between CO₂ emissions, GDP, energy consumption, financial development, FDI, and trade. In the last few decades, there have been various econometric procedures applied to investigating environmental pollution. In testing cointegration, various techniques have been proposed, such as the maximum likelihood estimation procedure which allows for the testing of the number of cointegrating relations advanced by Johansen (1988) the residual-based method proposed by (Engle & Granger 1987) as well as the Autoregressive Distributed Lag (ARDL) approach advanced by (Pesaran, Shin, & Smith 2001).

4.5.5 Autoregressive distributed lag model (ARDL) technique

To empirically explore the relationships identified in the objectives of this study, the study conducted multiple regression estimations. Econometric theory suggests that there is a long-run relationship between variables under consideration (Azam et al., 2016). This means that the mean and variance are constant and time-independent. However, empirical studies have shown that the constancy of the means and variances is not satisfied in analyzing time series variables (Nkoro and Uko, 2016). To overcome this problem of non-stationarity, time series econometric analysis has increasingly gravitated towards the issue of co-integration. The rationale for this is that co-integration is a very useful tool for analyzing the presence of steady-state equilibrium between variables. Co-integration has become an overriding requirement for economic models using non-stationary time series data. If the variables do not co-integrate, this suggests problems of spurious regression. In resolving this, various co-integration techniques have emerged. In applied econometrics, the Granger (1981) and Engle and Granger (1987), co-integration technique and, Johansen and Juselius (1990) co-integration techniques have been used to determine the long-run relationship between series that are non-stationary, as well as re-parametrizing them to the Error Correction Model (ECM). The re-parametrized result gives the long and short-run dynamics of the underlying variables. Recently, however, a series of studies by Pesaran and Shin (1996); Pesaran and Pesaran (1997); Pesaran and Smith (1998), and Pesaran et al. (2001) have introduced an alternative co-integration technique known as the 'Autoregressive Distributed Lag (ARDL) bound test. This technique has some benefits over the Johansen co-integration techniques. According to Ghatak and Siddiki, (2001), the ARDL technique provides a

more statistically significant approach to determining the co-integration relationship in small samples as in this study (with 40 annual observations per variable) while the Johansen co-integration techniques often require large data samples for validity.

Also, the ARDL technique does not require the same order of integration for all regressors as against other techniques (Ouattara, 2004a). It can be applied irrespective of the regressors being of the order of integration one $I(1)$ and/or level $I(0)$. The estimations can proceed with or without the knowledge of variables being of $I(0)$ or $I(1)$ (Pesaran and Pesaran, 1997: 304). This suggests that the ARDL technique does not necessarily require the pre-testing issues associated with other co-integration techniques, which require variables classified into $I(1)$ or $I(0)$ (Pesaran et al., 2001). In the case where there is a mix or, doubt concerning the unit root properties of the data, applying the ARDL technique remains the most appropriate technique for empirical analysis (Bahmani-Oskooee and Nasir, 2004:485). They argued that the order of integration of a variable can be a function of the choice of unit root test used. Hence the contradictory results are often recorded on a variable and concluded on the ability of the ARDL technique in avoiding this problem. It is, however, crucial to note that this technique crashes in the presence of a variable integrated of order two $I(2)$ (Phillips & Perron, 1988). To avoid a wrong application of the ARDL technique, it, therefore, becomes important to test for unit roots.

In a similar vein, unlike most other co-integration estimation techniques, which are sample size sensitive, the ARDL is less sensitive to sample size and can produce reliable results with even a small sample size. Harris and Sollis, (2003), posited that the ARDL generates unbiased long-run estimates and valid t-statistics, even if there are some endogenous regressors in the model. The procedures of the ARDL bound test are hinged on the joint

F-statistics (Wald statistics) for testing co-integration (Odhiambo, 2009). The F-statistics asymptotic distribution is non-standard under the null hypothesis (Ho) of no cointegration. The computed test statistics have to exceed the value of the upper critical bounds for the null hypothesis to be rejected. The test becomes inconclusive if it falls within the bounds, and the null hypothesis gets accepted if the computed test statistics fall below the lower bounds (Pesaran and Pesaran, 1997, Pesaran et al., 2001).

Another advantage of this technique over other techniques is its ability to avoid a lot of decisions that must be made before estimation as these techniques are very sensitive to these decisions. These decisions include the number of endogenous and exogenous variables (if any) to be included, the treatment of deterministic elements, as well as the order of VAR, and the optimal number of lags to be used (Pesaran and Smith, 1998). They noted the ability of the ARDL technique to accommodate a varying number of lags for different variables in one model as against other estimation techniques which do not. According to Pesaran and Pesaran (1997), the ARDL technique involves the following steps. The first step tests for the existence of any long-term relationship among the variables of interest using an F-test. In this stage, each behavioral equation is transferred to the error correction form of the underlying ARDL model. According to Pearsan et al. (2001), the error-corrected version of the ARDL (p,q) for variables X_t and Z_t is represented as :

$$\Delta X_t = \alpha + \sum_{i=1}^p A_i \Delta X_{t-i} + \sum_{j=1}^q B_j \Delta Z_{t-j} + C_0 X_{t-1} + C_1 Z_{t-1} + \mu_t \quad (4.13a)$$

Where X_t = endogenous variable, α = intercept, Z_t = explanatory variable and μ_t =error term

The F-statistics for the joint test of the coefficients C_0 and C_1 is computed to test for the long-run relationship between endogenous variable X_t and explanatory variable Z_t . The null hypothesis is that the coefficients C_0 and C_1 in the equation above are both equal to zero (i.e., the null hypothesis is that there is no long-run relationship between endogenous variable X_t and explanatory variable Z_t). The computed F-statistics are then compared with the critical value bounds of the tabulated F-statistics. If the F-statistics is higher than the upper bound of the critical value, the null hypothesis is rejected, and vice versa (Narayan, 2004).

The second step involves the estimation of the coefficients of the long-run relationship, followed by an estimation of the short-run elasticity of the variables with the error correction representation of the ARDL model. This only proceeds if the null hypothesis in the first step is rejected. By applying the ECM version of ARDL, the speed of adjustment to equilibrium will be determined. According to Pearsan et al. (2001), the dynamic structure of the ARDL (p, q) model is represented as:

$$X_t = \alpha + \sum_{i=1}^p A_i X_{t-i} + \sum_{j=0}^q B_j Z_{t-j} + \mu_t \quad (4.13b)$$

Where is the lag length for X_t and Z_t are p and q respectively and μ_t is the random error term.

The study proceeds by conducting a formal investigation for co-integration by using the ARDL co-integration technique, due to the nature of mixed integration among the variables. A direct regression of output per capita on the variables of interest is likely to produce biased estimates due to the well-known problems of time-series regression. To deal with these issues, the study utilizes the autoregressive distributed lag (ARDL) or Bounds Testing framework of Pesaran and Shin (1999) and Pesaran, Shin, and Smith

(2001). This framework is known to possess several advantages over the traditional co-integration models (such as Engle and Granger, 1987, and Johansen and Juselius, 1990). Some of these advantages include; (1) appropriate for modeling limited data (2) applicability in data with a mixture of I(0) and I(1) (3) Different variables in the model can be assigned different lag-lengths (4) involves a single-equation set-up making it simple to interpret and (5) the error correction method helps in the integration of long-run equilibrium with the short-run dynamics without losing the long term information (Pesaran, Shin, and Smith 2001).

The study uses the ARDL-Bound testing approach to examine long-run cointegration among the variables. As stated earlier, the ARDL technique is preferred as it has certain various properties with econometric advantages.

The ARDL model to be used in this study is given by equation (4.13c):

$$\begin{aligned} \Delta LCO2_t = & \beta_0 + \sum_{j=1}^n \beta_1 \Delta CO2_{2t-j} + \sum_{j=0}^n \beta_2 \Delta LGDP_{t-j} + \sum_{j=0}^n \beta_3 \Delta LEU_{t-j} + \sum_{j=0}^n \beta_4 \Delta LFD_{t-j} + \\ & \sum_{j=0}^n \beta_5 \Delta LFDI_{t-j} + \sum_{j=0}^n \beta_6 \Delta LTO_{t-j} + \phi ECT_{t-1} + \alpha_1 LCO2_{2t-1} + \alpha_2 LGDP_{t-1} + \alpha_3 LEU_{t-1} + \alpha_4 LFD_{t-j} + \\ & \alpha_5 LFDI_{t-1} + \alpha_6 LTO_{t-1} + \varepsilon_t \end{aligned} \quad (4.13c)$$

Where, ε_{1t} is the residual, which is assumed to be normally distributed, Δ represents the first difference operator, and ϕ is the dynamics of error correction as δ represents long-run relationships.

Using the F-test, the cointegration relationship is examined among the variables where

the null hypothesis $H_0 : \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = \delta_{15} = 0$ is tested against

$H_1 : \delta_{11} \neq \delta_{12} \neq \delta_{13} \neq \delta_{14} \neq \delta_{15} \neq 0$. In deciding the cointegration among the variables, H_0 is

rejected if the F-statistic is greater than the upper bound. On the contrary, if F-statistic is

less than the lower bound, H_0 cannot be rejected, while the result becomes inconclusive if the F-statistic is between the upper and the lower bounds. In this circumstance, therefore, we then consider adding or dropping some variables in the study.

Also, e_t represents the white noise error term and ECM_{t-1} . The ECM measured the speed of adjustment back to long-run equilibrium. It is the adjustment mechanism that stabilizes the disequilibrium in the model.

4.5.6 Determination of Lags

When using regressions in time series data, lagged values of the dependent variable and independent variables are included. The number of stars in lagged indicates how many numbers of lag should be used in the study. Other than that, an essential element in the specification of VAR models is the determination of the lag length of VAR (Ozcicek & McMilin 1999). Besides, according to Ozcicek and McMilin (1999), lag length determination is important because if the estimation of VAR used lags length differs from a true lag length, it showed an inconsistent result with impulse functions and variance decompositions from the VAR. While there are various criteria, the most criteria that are used are Akaike Information Criterion (AIC) and Schwarz's Bayesian Information Criterion (SBIC). Below are explanations of AIC and SIC (Gujirati 2003):

$$AIC = e^{2k/n} \sum \frac{\hat{u}_i^2}{n} = e^{\frac{2k}{n} RSS/n} \quad (4.14)$$

$$SIC = n^{2k/n} \sum \frac{\hat{u}_i^2}{n} = n^{\frac{k}{n} RSS/n} \quad (4.15)$$

Where k is the number of regressors, while n is the number of observations included in this model. Another $2k/n$ is a penalty factor in AIC and $[k/n \ln n]$ in SIC. However, these two criteria cannot use at one time.

The guideline of the Akaike Information Criterion (AIC) is the lower the AIC value, the better the model, it is also stated by Gujarati (2003). So, once the number of lags had been determined, a cointegration test can be conducted to determine the cointegration between variables.

4.5.7 Variance Decomposition and Impulse response

Variance decomposition can identify which variables have a short and long-run relationship with dependent variables. Variance decomposition also can describe the percentage of the fluctuations in the time series of variables. In addition, it also can explain the changes in the dependent variable can be explained by the chosen independent variables. Variance is explained by the relationship between Y and X. The variance of Y (dependent variable) will expect two conditions:

$$E (Var [Y|X]) = \text{explained variation directly because of changes in } X$$

$$Var (E [Y|X]) = \text{unexplained variation that comes from other than } X$$

Variance decomposition is based on complete variance decomposition of the uncertainty of y. It is expressed as follows:

$$V (CO_2) = \sum_{j=1}^{nx} V_j + \sum_{j=1}^{nx} \sum_{k=j+1}^{nx} V_{jk} + \dots V_{12, \dots nx} \quad (4.16)$$

Where V_j = Contribution of x_j to $V (CO_2)$, V_{jk} = Contribution of the interaction of x_j and x_k to $V (CO_2)$ and $V_{12, \dots nx}$ = Contribution of the interaction X_1, X_2, X_n to $V (CO_2)$

4.5.6 Justification for using Toda-Yamamoto Causality Approach

The traditional Granger causality test was developed based on the asymptotic distribution theory which is seen to result in a spurious conclusion especially when variables are cointegrated (Granger & Newbold 1974). Most times, the method of modeling causality in the traditional sense was found to have overlooked some elements of the forecasting which led to invalid results of non-causality in the presence of causation. This implies that

in some cases causality exists but is spuriously not found due to the inefficiency of the employed techniques (Granger 1988). Most of the causality tests in the past were conducted on the vector error correction models, cointegration as well as simple vector autoregressive frameworks which all suffer from size distortion and nuisance parameters in the estimates (Guru-Gharana, 2012).

Another limitation of the Granger causality is that the null hypothesis at level estimation suffers from non-standard asymptotic distribution whereas, the integrated Granger causality suffers from the independence of nuisance parameter estimates (Toda and Phillips 1993). Furthermore, most previous studies were carried out based on a bivariate model without controlling for possible explanatory variables which may also lead to a different result. The advantage of estimating a multivariate model is highlighted in Stock and Watson (2001).

Moreover, the vector error correction model's hypothesis of Granger non-causality employs nonlinear parameter restriction matrices. The Wald and likelihood ratio test statistics for the Granger test are associated with a rank deficiency which leads to size distortion under the null hypothesis (Toda & Philips, 1993). The Granger method also mandates testing for stationarity and cointegration processes which are less relevant if the objective of the study is to find a causal relationship between variables (Hacker & Hatemi-J 2006). Finally, the traditional Granger causality test loses its power when structural changes exist between the post-sample and actual sample (Granger, 1988).

4.5.8 Toda-Yamamoto Causality Model

The prevailing shortcomings of the traditional causality model motivate Toda and Yamamoto (1995) to develop modified Wald test statistics based on an augmented vector autoregressive (VAR) framework that applies the asymptotic chi-square distribution to solve the difficulties encountered in the asymptotic Granger causality test. Their approach is applicable irrespective of whether the series is stationary at a level $I(0)$, integrated of arbitrary order, or arbitrarily co-integrated. The procedure can also test for coefficient linearity and non-linearity restriction through Wald criterion application on estimated level VAR (Hacker & Hatemi-J, 2006).

Toda and Yamamoto (1995) proposed an augmented VAR($p \square d$) framework that can be employed to test causality among variables of the model depicted in Equation 4.17. The use of this model is based on the argument that causality should be tested within the jurisdiction of an acceptable theory. It simply assists in determining the appropriate variables to be tested in the model. This helps in capturing the required information on causality (Granger, 1988). Furthermore, including control variables in the test of causality may lead to the presence of causality between variables under investigation. In other words, causality might not be found in the absence of control variables (Granger, 1988).

The augmented VAR ($p \square d$) model is specified in Equation 4.17 below:

$$y_t = \hat{\nu} + \hat{A}_1 y_{t-1} + \dots + \hat{A}_p y_{t-p} + \dots + \hat{A}_{p+d} y_{t-p-d} + \hat{\varepsilon}_t \quad (4.17)$$

The p order of the VAR model is considered to be known, whereas d is the highest integration order of the variables in the model, and the circumflex represents estimated variables using ordinary least squares (OLS). The Wald test statistics of Toda-Yamamoto's (1995) causality are asymptotically distributed regardless of the series co-

integration level, co-integrated or not (Toda & Yamamoto, 1995). The model in its general form is presented in equation 4.18 below:

$$y_t = \beta_0 + \beta_1 t + \dots + \beta_q t^q + \eta_t \quad (4.18)$$

η_t is the k^{th} order of the VAR process which is further defined as $I d ()$ and possibly $Cl d b (,)$.

$$\eta_t = J_1 \eta_{t-1} + \dots + J_k \eta_{t-k} + \varepsilon_t \quad (4.19)$$

where k in Equation 4.19 represents a known lag length to be employed in the estimation process.

$$\text{Therefore, } y_t = \gamma_0 + \hat{\gamma}_1 t + \dots + \hat{\gamma}_q t^q + j_1 y_{t-1} + \dots + j_k y_{t-k} + j_p y_{t-p} + \hat{\varepsilon}_t \quad (4.20)$$

The restricted hypothesis is formulated as $H_0: f(j) \leq 0$.

4.5.8 Ordinary Least Squares for Robust estimation analysis

Ordinary least squares (OLS) is a type of linear least squares method for estimating the unknown parameters in a linear regression model. OLS chooses the parameters of a linear function of a set of explanatory variables by the principle of least squares. The study utilizes the OLS technique for the model estimation because the dependent variable is a continuous variable and OLS is more appropriate for this analysis. Therefore, the theoretical Specification of OLS is expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + U.$$

The model is linear in its parameters, the dependent variable Y and the independent variables $X_1, X_2, X_3, \dots, X_K$ are observable random scalars, i.e. they can be observed in a random sample of the population. U is the unobservable random disturbance or error and $\beta_0, \beta_1, \beta_2, \dots, \beta_k$ are the parameters. Nonetheless, the OLS estimation technique has some underline assumptions that consist of zero mean of the error (i.e. $E(U)=0$) Zero co-variability (i.e. $cov(X_j, U)=0$), homoscedasticity of the variance of the error term and non-appearance of perfect multicollinearity on the independent variables.

4.6 Conclusion

The chapter exhibits the methodological procedures to be employed for this study. The annual time series data from the period 1980 to 2020 on CO₂ emissions in (kt), economic growth, energy use, foreign direct investment, and trade using Autoregressive Distributive Lag (ARDL) are presented in this section. All the chosen variables selected in this study are primarily situational as they are present within the environment. Use of ARDL-Bound testing approach is utilized to examine long-run cointegration among the variables. Also, various post estimations check such as heteroscedasticity, serial correlation, and normality tests will be used for model validation. Similarly, impulse response, variance decomposition for the models forecasting, and Toda-Yammamota causality will be tested in the next chapter. Hence, the chapter guides in discussing the study's findings and contributions leading to recommendations to policymakers targeting sustainable environment, economic growth, and development.

CHAPTER 5: RESULT AND DISCUSSION

5.0 Introduction

This chapter deeply discussed the study's estimated models. It takes into account the estimates of the empirical models on economic growth and environmental degradation, energy use, and environmental degradation, the interaction of energy consumption and economic growth, Bi-variate analysis, and the Toda-Yamamoto causality approach. The chapter looks at the essential components of pre-estimation analysis for the models, including a descriptive analysis of the variables and unit root tests for the variables' stationarity and order of integration, which are done to choose the appropriate technique for the model estimation. In this regard, the techniques involve Augmented Dickey-fuller (ADF), Phillips Perron (PP) unit root tests, Autoregressive distributed lag model (ARDL), impulse response function, variance decomposition, and Toda-Yamamoto causality test. Similarly, the post-model estimation analysis consists of a test for heteroscedasticity, normality of the models, and serial correlation for the validity and stability of the model used in the event of policy recommendations. This was done in line with the reviewed literature, the study's empirical models as well as the relationship of study variables.

Therefore, Section 5.2 offers the descriptive statistics, Section 5.3 – 5.11 consists of the results of the unit root test, the ARDL Bounds test result, the long-run relationship, the short-run analysis, and lastly, diagnostics checking which includes: Normality of the residuals, Heteroskedasticity, and Autocorrelation for the model estimated. Section 5.12 Bi-variate analysis and causality test. Section 5.13 concludes the chapter.

5.1 Descriptive Statistics

This section explains the reliability as well as the degree of confidence of the data employed. Before estimating the models, this study first described the summary of statistics for all the variables utilized in the study.

Table 5. 1 Descriptive characteristic of the variables

Variables	Minimum	Maximum	Mean	Standard Deviation
LCO ₂	55.44	119.1	86.89	17.00
LENC	0.417	1.757	0.940	0.363
LFD	8.709	38.38	15.29	5.935
LFDI	1.150	5.790	1.707	1.324
LGDP	27.02	35.22	13.1	9.835
LTO	6.235	53.27	31.86	13.34

Source: Author's Computation

Table 5.1 illustrates the descriptive characteristics of the variables utilized in the study. The table shows that in Nigeria economic growth possesses the highest value among the variables in terms of mean variation (13.1) and standard deviation (9.835). However, the table reports that ENC and FDI have the lowest value of mean variation for this nation (0.94, 1.71) and standard deviation.

5.2 Unit Root Test Result

The first process for the estimation of the models within the ARDL framework is to start by testing the stationarity properties of the series. This is because statistical inferences cannot be done when the variables in the model are non-stationary. In addition, the ARDL technique is suitable when the series are $I(0)$, $I(1)$, or mixed.

Unit root tests were developed to examine the stationary properties and the order integration of the time-series observations. This study utilized the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to investigate the unit root properties of the variables. Table 5.2 displays the unit root test results for the variables under consideration. The ADF and PP unit root test results of the variables for Nigeria show that the LC0₂, LENC, and LFD are stationary at first difference while LGDP and FDI were found stationary at level. Thus, in general, the variables turn the series into mixed stationary. That is some variables are found stationary at level I (0) while other variables are at the first difference I (1). Therefore, based on the result of the stationarity obtained the ARDL approach is suitable for the model's estimation.

Table 5. 2: Unit Root Test

Series	ADF		PP	
	Levels	First Difference	Levels	First Difference
LCO ₂	-1.729 (0.408)	-5.809* (0.000)	-1.849 (0.659)	-5.566* (0.003)
LENC	-0.7267 (0.827)	-4.335* (0.001)	-3.856* (0.024)	- -
LFD	-2.845* (0.061)	- -	-3.262* (0.088)	- -
LFDI	-3.665* (0.008)	- -	-4.339* (0.007)	- -
LGDP	-1.296 (0.620)	-6.548* (0.000)	-2.516 (0.318)	-4.339* (0.007)
LTO	-2.596 (0.102)	-7.807* (0.000)	-2.428 (0.623)	-6.731* (0.001)

Notes: * represents statistically significant at a 5 per cent level of significance. Figures in parentheses represent probability.

Source: Author's Computation

Table 5. 3:ARDL Bounds Test Results

	F-stat	Lag	Sig. Level	Critical values	
				I(0)	I(1)
$F_{[CO_2][CO_2, HYD, GDP, FDI]}$	9.411**	4	10 per cent	2.45	3.52
			5 per cent	2.86	4.01
			1 per cent	3.74	5.06

Note: *, ** represents 1 and 5 per cent levels of significance, respectively.

5.3 Justification of the model's estimation and the application of the ARDL model

It has been acknowledged that environmental problems have become a threat to human and sustainable development (Danlami, 2018). These issues adversely affect human health, ecological system, and social development in developing nations particularly, Nigeria. World agencies and stakeholders like United Nations, World Bank, and environmentalists have been urged to explore all avenues to reduce global environmental issues. Hence, this justifies the reasons for investigating the effect of economic growth and energy use on the environment. This influence may prove the intensity of the effects and provide solutions for human and sustainable development. Therefore, for this

investigation, an empirical model of economic growth and energy consumption on the environment is designed for the estimation. However, the nature of the data stationarity, the need to see the influence of economic growth and energy use on the environment, and the great advantages of the ARDL method of estimation are among the reason to apply the technique for reliable, and dependable estimations. On this note, these are the reasons to design the model and the application of the ARDL technique of estimation.

5.4 An estimated model of economic growth and environmental degradation

Establishing the existence of cointegration among the variables allowed this study to estimate the coefficients of the short-run and long-run among the variables. Table 5.4 examined the short-run relationship between CO₂, GDP, foreign direct investment, financial development, and trade in Nigeria. The size of the ECT coefficients of the model is -0.75. It indicates about 75 per cent existence of variables relationship towards the long-run equilibrium within a year for this country's model. In Nigeria, the short-run estimates reveal that economic growth and foreign direct investment increase the level of environmental pollution while financial progress and trade are negatively related to the environment.

The outcome implies that a per cent increase in economic performance leads to CO₂ discharge rising by 0.01 per cent. Also, a per cent increase in foreign direct investment caused CO₂ to increase by 3.3 per cent. A 1 per cent increase in financial development and trade results in a 0.9 and 0.1 per cent decrease in CO₂ emissions. The result shows evidence of the relationship between economic growth, FDI, financial development, trade, and CO₂ emission.

The implication of this finding illustrates that economic growth and FDI contribute more to environmental damage in Nigeria by 0.01 and 3.3 per cent annually and financial development and trade promote environmental quality in the nation for the short run. Thus, it requires serious attention from policymakers and stakeholders to promote environmental quality in the nation.

Table 5. 4: Short Run Coefficients. Dependent Variable: Δ ICO₂ Emissions. ARDL (1, 2, 2, 0, 0)

Variable	Coefficient	Standard Error	t-Statistic	Prob.
Δ LGDP	0.011***	0.005	-1.078	0.000
Δ LFD	-0.940*	0.271	-4.208	0.002
Δ LFDI	3.304*	0.915	3.680	0.000
Δ LTO	-0.186**	0.104	1.638	0.069
ECT(-1)	-0.758**	0.152	-5.519	0.002

Note: *, **, *** represent 1, 5, and 10 per cent levels of significance, respectively.

Source: Author's Computation

Furthermore, table 5.5 presents the long-run estimate. The result indicates a positive and significant relationship between economic performance, foreign direct investment, trade, and environment while financial development found a negative link with the level of CO₂. For instance, economic performance influences the level of CO₂ discharge positively in Nigeria. This means that a per cent increase in the economic growth performance results in a 0.01 per cent increase in the level of CO₂. It further shows there is a 0.01 per cent increase in environmental damage in Nigeria due to rising in economic activities. The outcome shows evidence of the relationship between economic growth, FDI, trade, and the environment in Nigeria. The positive relationship between economic performance and CO₂ in Nigeria is not surprising as policies are towards promoting production and

investment. Hence, the government is encouraging individual citizens and firms to utilize low-emission technologies for a better environment. This finding is consistent with the result obtained by Mrabet and AlSamara (2016), Begum et al. (2015), Dogan and Seker (2016).

Similarly, a per cent rise in financial development caused environmental quality to increase by 2.80 per cent. In the same regard, trade accelerates CO₂ discharge by 0.64 per cent in the nation. However, FDI is not significant in determining the CO₂ explosion in Nigeria. The result is similar to that of Yahaya et al. (2020). Therefore, the implication of these findings indicates that economic growth and trade increase environmental pollution by 0.01 and 0.64 per cent annually in the long run in Nigeria. Hence, result in policymakers and stakeholders engaging in designing policies to enhance environmental quality in the nation. However, financial development increases environmental quality by 2.8 per cent annually in Nigeria. Financial progress, in general, enhances the level of environmental quality in Nigeria. Thus, policymakers should design policies that promote the performance of these indicators.

**Table 5. 5: Long Run Coefficients. Dependent Variable: ΔCO_2 Emissions
ARDL (1, 2, 2, 0, 0)**

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LGDP	0.013*	0.002	5.635	0.000
LFD	-2.898*	0.585	-4.435	0.000
LFDI	2.502	2.741	1.288	0.194
LTO	0.647**	0.203	3.766	0.007
C	85.24*	11.47	6.966	0.000

Note: *, **, *** represents 1, 5, and 10 per cent level of significance, respectively.

Source: Author's Computation

5.5 Diagnostic Check

To ensure the efficiency of the models it is important to apply the post estimation checking. Table 5.6 shows the diagnostic test of the ARDL model. Table 5.6 presents the result of diagnostic tests. It indicates that the null hypothesis of no serial correlation, homoscedasticity as well as the normality of the distribution of the residuals cannot be rejected. In addition, figure 5.1 shows the outcome of the stability test. The result reveals that the model is stable since in both the CUSUM and CUSUM Square the lines are within the critical bound at the 5 per cent level. Hence, it is concluded that the models are free from econometrics problems and proved that the model produced an efficient estimation.

Table 5. 6 Diagnostic Checks

	F-stat	Prob.
Autocorrelation	0.051	0.195
Heteroskedasticity	0.181	0.240
Normality	0.175	0.915

Source: Author's Computation

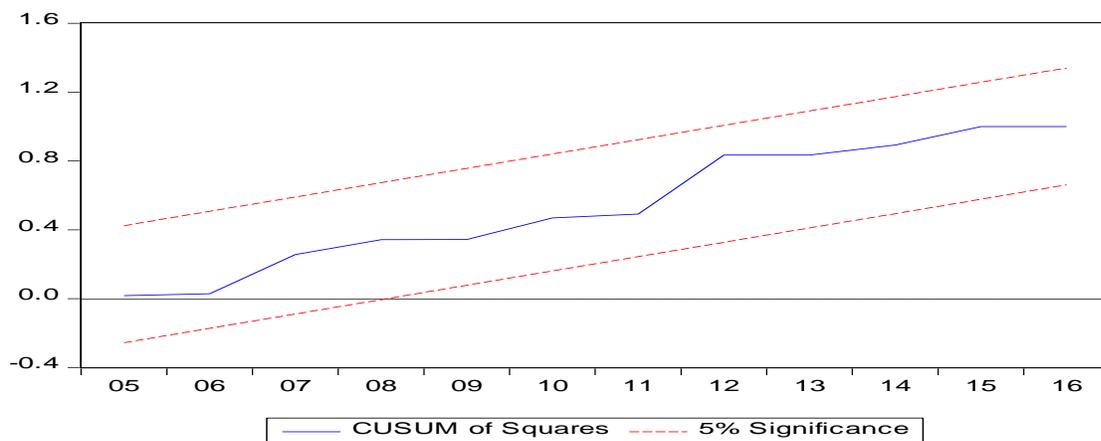
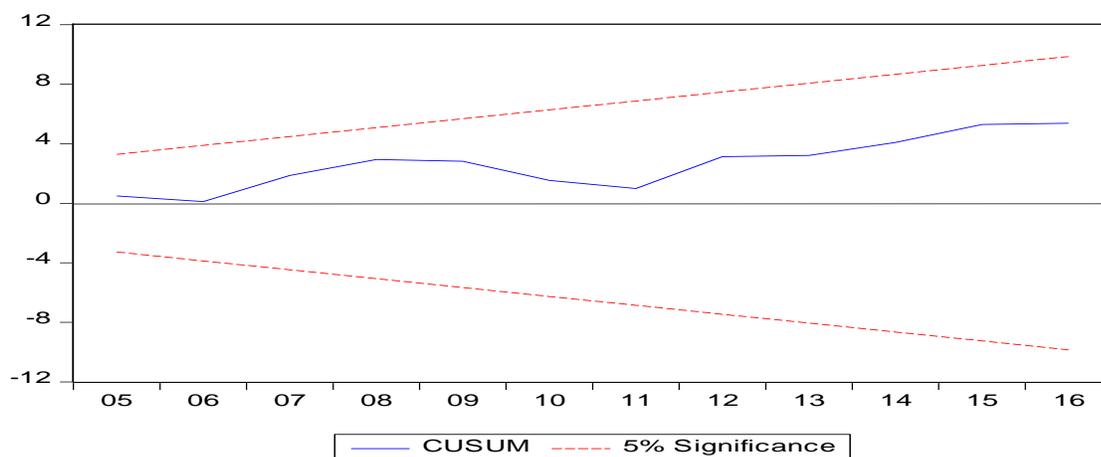


Figure 5. 1: CUSUM and CUSUM of squares stability test

Source: Author's Computation

5.6 An estimated model of energy consumption and environmental degradation

Table 5.7 illustrates the outcome of the bound test. The result shows that the value of F-statistics is higher than the upper bound critical value at the 1 per cent significance level.

This result suggests that the null hypothesis of no co-integration is rejected. Thus, it can be concluded that there is a long-run relationship between the environment, energy consumption, and financial development in Nigeria.

Table 5. 7: ARDL Bounds Test Results

	F-stat	Lag	Sig. Level	Critical values	
				I(0)	I(1)
$F_{\Delta CO_2[CO_2/HYD,GDP,FDI]}$	4.560**	4	10 per cent	2.45	3.52
			5 per cent	2.86	4.01
			1 per cent	3.74	5.06

Note: *, and ** represents 1 and 5 per cent levels of significance, respectively.

Source: Author's Computation

5.7 The Short run and Long Run estimations for the model

The existence of cointegration among the variable led the study to estimate the coefficients of the short run and long run among the variables. The estimates of the short-run coefficients are shown in Table 5.8.

Table 5. 8: Short Run Coefficients. Dependent Variable: ΔCO_2 Emissions. ARDL (1, 2, 2, 0, 0)

	Variable	Coefficient	Standard Error	t-Statistic	Prob.
Nigeria					
	$\Delta LENC$	5.748*	9.041	6.358	0.000
	ΔLFD	0.456***	0.206	2.226	0.039
	$\Delta LFDI$	1.694**	0.751	2.253	0.037
	ΔLTO	-0.304**	0.108	-2.808	0.012
	ECT(-1)	-0.835*	0.228	-3.650	0.002

Note: *, **, *** represent 1, 5, and 10 per cent levels of significance, respectively.

Source: Author's Computation

Table 5.8 examined the short-run relationship between environment, energy use, foreign direct investment, financial development, and trade in Nigeria.

The size of the ECT coefficients of the model is -0.83. It indicates the existence of about 83 per cent relationship among the variable towards the long run and it represents the Speed of adjustment. In Nigeria, the short-run estimates reveal that energy consumption, financial development, and foreign direct investment have increased the level of environmental damage in Nigeria while trade is negatively related to the environment.

This implies that a per cent increase in energy use leads to environmental pollution increase of 5.74 per cent. Similarly, a per cent rise in financial development leads environmental pollution to increase by 0.45 per cent. Also, a per cent increase in foreign direct investment caused CO₂ to increase by 1.69 per cent. However, a 1 per cent increase in trade results in a 0.30 per cent decrease in CO₂ emissions. This result shows evidence of the relationship and implies that energy use, financial development, and FDI increase the capacity of environmental pollution on an annual basis by 5.74, 0.45, and 1.69 per cent respectively in the short run. The result also shows that energy use, financial development, and FDI deteriorates the environment. Hence, policies to enhance environmental quality have to be put in place in Nigeria. Nevertheless, trade improves environmental quality in the country.

Furthermore, the estimated long-run coefficients are presented in Table 5.9.

**Table 5. 9: Long Run Coefficients. Dependent Variable: ΔCO_2 Emissions
ARDL(1, 2, 2, 0, 0)**

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LENC	2.8301*	3.435	8.253	0.000
LFD	-0.498*	0.243	-2.050	0.015
LFDI	4.289	1.203	3.564	0.002
LTO	0.503	0.103	4.883	0.001
C	4.342*	6.430	6.751	0.000

Note: *, **, *** represents 1, 5, and 10 per cent level of significance, respectively.

Source: Author's Computation

The long-run estimated result illustrates evidence of the relationship between energy use, FDI, trade, and environment, while financial progress has a negative link with the level of CO₂. For example, energy consumption increases the level of environmental pollution in Nigeria. This implies that a per cent increase in energy use leads to a 2.83 per cent rise in the level of CO₂. The positive link between energy use and CO₂ in Nigeria may be associated with economic diversification policies aimed to encourage production. Therefore, policymakers should design policies to encourage the use of low-emission technologies for a better environment. This finding is consistent with the result obtained by Zakarya et al. (2015), Dogan and Seker (2016).

In addition, A per cent increase in FDI leads to environmental damage rise by 4.28 per cent. Similarly, trade increased CO₂ explosion by 0.50 per cent in the nation. Nonetheless, financial progress decreases the level of CO₂ in Nigeria which is a per cent upsurge in financial progress leading to a 0.49 per cent decrease in CO₂.

This outcome is consistent with that of Seker et al. (2015). The implication of these findings indicates that energy consumption, trade, and FDI raise the level of

environmental degradation by 2.83, 4.28, and 0.50 per cent annually in the long run. It reveals that energy use, trade, and FDI rise environmental pollution. Meaning that energy use, trade, and FDI are not promoting environmental quality in the nation. Therefore, policies to enhance environmental quality need to be designed in respect of these indicators. Nevertheless, financial development promotes the level of environmental quality in Nigeria. Thus, policymakers should design policies that promote environmental quality.

5.8 Diagnostic Checking

To ensure the efficiency of the models it is important to apply the post estimation checking. Table 5.10 shows the diagnostic test of the ARDL model.

Table 5. 10: Diagnostic test

	F-stat	Prob.
Autocorrelation	0.797	0.468
Heteroskedasticity	0.512	0.915
Normality	0.175	0.915

Source: Author's Computation

Table 5.10 shows the result of diagnostic tests. It indicates that the null hypothesis of no serial correlation, homoscedasticity, and normality cannot be rejected. Moreover, figure 5.2 shows the outcome of the stability test. The result indicates that the model is stable since in both the CUSUM and CUSUM Square the lines are within the critical bound at the 5 percent level. Therefore, it is concluded that the model has no econometric problems and proves that the model produced an efficient estimation.

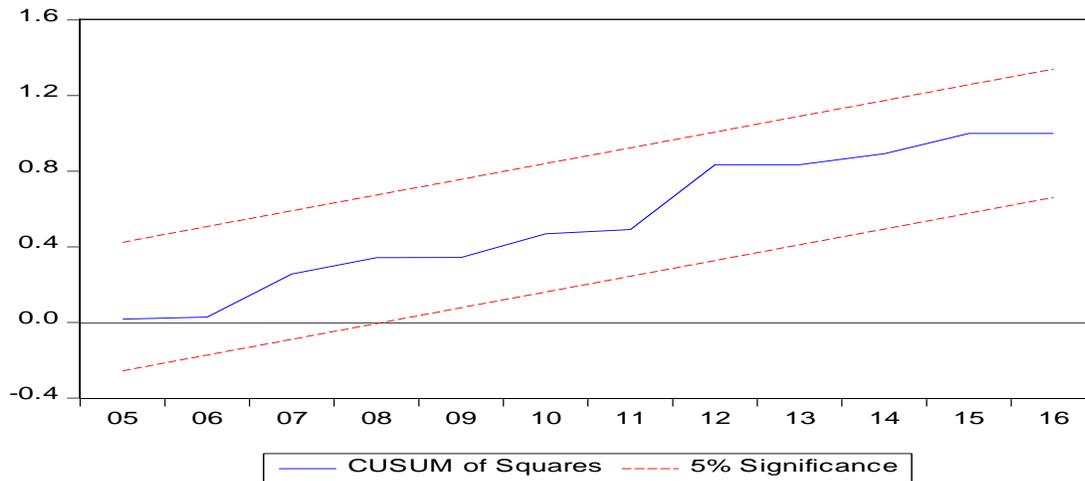
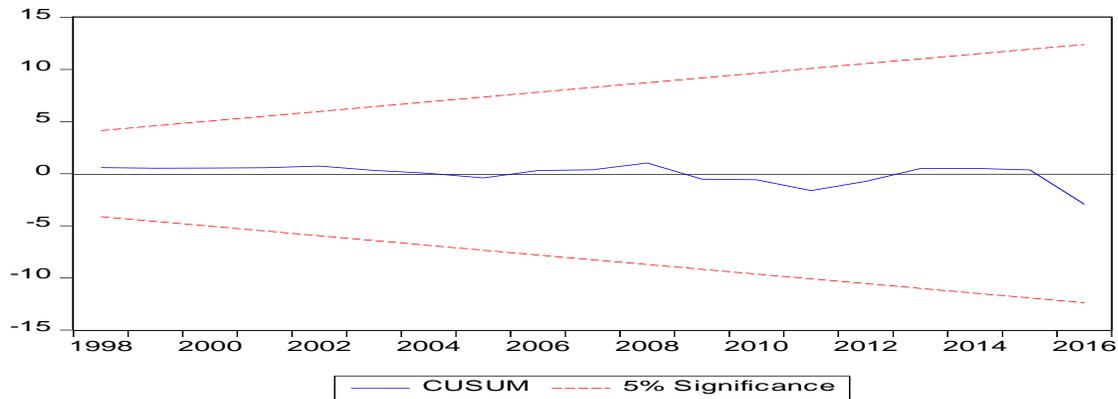


Figure 5. 2: CUSUM and CUSUM of squares stability test
 Source: Author's Computation

5.9 Justification of the Estimation of the interaction model

The adverse effect of environmental problems on human health, ecological system, and social development in developing nations particularly, Nigeria with regard to economic progress and energy use justify the need for estimating the interaction model. This means investigating the influence of energy consumption via economic growth. It is asserted that for a higher level of economic progress, there is a need for other factors like energy use, which is used for power generation in industries for the production of goods and services.

Hence, since economic growth cannot go with energy, then it is essential to investigate the influence of energy use via economic growth on the environment. The interaction model was first initiated by Baron & Kenny in 1986. An interacting variable refers to a variable that affects the direction or strength of association between explanatory and explained variables (Baron & Kenny 1986). An interacting effect implies that the relationship between the independent and dependent variables varies as a function of the value of the third variable. World agencies and stakeholders like United Nations, World Bank, and environmentalists have been urged to explore all avenues to reduce global environmental issues. Hence, this justifies the reasons for investigating the interaction effect of economic growth and energy use on the environment. This influence may prove the intensity of the effects and provide solutions for human and sustainable development. Therefore, investigating the interaction model is essential for sustainable development.

5.10 An estimated model of interaction energy consumption and economic growth on environmental degradation

The interaction model in this study is done to examine the effect of energy use on environmental degradation through economic growth. That is in the presence of economic growth how does energy use affect environmental degradation in Nigeria? Hence, this model is estimated due presence and availability of energy, especially fossil fuel in Nigeria and also to see the extent of the combination of the energy consumption and economic growth influence environmental pollution in the country. Secondly, interacting with these variables means developing or establishing a new variable that is incorporated into the empirical model that has not been investigated in Nigeria based on the literature and also

serves as a major contribution to this study. Therefore, these are among the reason for interacting energy use and economic growth.

Table 5. 11 illustrates the outcome of the bound test. The result shows that the value of F-statistics is higher than the upper bound critical value at the 1 per cent significance level. This result suggests that the null hypothesis of no co-integration is rejected. Thus, it can be concluded that there is a long-run relationship between the environment, energy consumption, GDP, financial development, foreign direct investment, and trade in Nigeria.

Table 5.11: ARDL Bounds Test Results

	F-stat	Lag	Sig. Level	Critical values	
				I(0)	I(1)
$F_{[2]CO_2[CO_2/HYD,GDP,FDI]}$	3.967**	4	10 per cent	2.12	3.23
			5 per cent	2.45	3.23
			1 per cent	3.15	4.43

Note: *, ** represent 1 and 5 per cent levels of significance, respectively.

Source: Author's Computation

5.11 The Short-run Long Run estimations for the model

The existence of long-run linkage among the variable led the study to estimate the coefficients of the short-run and long-run among the variables. The estimates of the short-run coefficients are illustrated in Table 5.12.

Table 5.12 examined the short-run link among environment, energy use, foreign direct investment, financial development, GDP, trade, and the interaction of energy use with GDP growth in Nigeria. The size of the ECT coefficients of the model is -0.71. It indicates the evidence of the relationship of about 71 per cent towards the long-run equilibrium

among the variables model. In Nigeria, the short-run estimates reveal that energy consumption, GDP, FDI, and trade positively increase the level of environmental damage while the interaction of energy use with GDP and financial development is negatively related to the environment.

This means that a per cent increase in energy use leads to environmental damage rise by 1.0 per cent. Also, a per cent increase in GDP causes CO₂ to increase by 0.03 per cent. A per cent upsurge in FDI results in a 2.7 per cent rise in CO₂ emissions. In addition, a per cent increase in trade results in a rise in environmental pollution by 0.1 per cent. However, a per cent increase in the interaction of energy use with GDP leads 0.02 decrease in environmental pollution. The outcome is similar to the finding of Sulaiman and Abdul-Rahim (2017). The outcome shows evidence of the relationship between the interaction of GDP with energy use and the environment, meaning that in the presence of economic activities energy use decreases the capacity of environmental damage in Nigeria. the implication of these findings shows that the interaction of GDP and energy use in the short-run upsurge the level of environmental quality as environmental pollution decreases by 1.0 and 0.3 per cent due to the effect of the interaction of GDP and energy use on an annual basis. The result further explains that in the presence of economic progress, energy consumption increases the environment quality by 0.02 per cent in Nigeria. Therefore, policies to promote energy alternatives have to be re-designed to mitigate CO₂ in the nation. Furthermore, trade increased environmental deterioration by 0.1 per cent. However, financial progress reduces the level of CO₂ discharge by 0.8 per cent in Nigeria.

Table 5. 12: Short Run Coefficients. Dependent Variable: Δ CO₂ Emissions. ARDL (1, 2, 2, 0, 0)

Variable	Coefficient	Standard Error	t-Statistic	Prob.
Δ LENC	1.032*	1.746	6.175	0.002
Δ LFD	-0.863**	0.293	-2.944	0.016
Δ GDP	0.031***	0.010	3.025	0.014
Δ LFDI	2.710*	0.682	3.972	0.003
Δ LTO	0.197**	0.106	1.852	0.097
Δ LENC*GDP	0.021*	0.006	-3.277	0.009
ECT (-1)	-0.714*	0.234	-4.752	0.001

Note: *, **, *** represent 1, 5, and 10 per cent levels of significance, respectively.

Source: Author's Computation

In addition, the estimated long-run coefficients are shown in Table 5.13. The long-run estimated result indicates evidence of the positive and significant relationship between energy use, economic growth, and foreign direct investment, while the interaction of energy use with GDP and environment and financial development found a negative link with the level of CO₂. For example, energy use increases the level of environmental damage in Nigeria. This implies that a per cent increase in energy use results in a 5.1 per cent increase in the level of environmental damage. The positive relationship between energy use and CO₂ in Nigeria is not surprising as environmental policies are not put in place to promote environmental sustainability. Hence, the government is to encourage individual citizens and firms to utilize low-emission technologies for a better environment. This finding is consistent with the result obtained by Dogan and Seker (2016).

Similarly, a per cent rise in foreign direct investment caused CO₂ to rise by 6.5 per cent. In the same regard, economic growth accelerates CO₂ discharge by 0.04 per cent in the nation. However, the interaction of energy use with GDP and financial development

reduces the level of CO₂ explosion in Nigeria which is a per cent increase in the interaction of energy use with GDP leads to a 0.02 decrease in environmental pollution. Similarly, financial development leads 3.8 per cent decrease in the level of environmental pollution. The implication of these findings shows that the interaction of GDP and energy use, in the long run, promotes the level of environmental quality as environmental quality increases by 5.1 per cent due to the effect of the interaction of GDP and energy use on an annual basis. The result further explains that in the presence of economic progress, energy consumption deteriorates environmental pollution by 5.1 per cent in Nigeria. Nonetheless, trade does not influence environmental pollution in Nigeria. Thus, policies to promote energy use have to be designed to further mitigate CO₂ emissions in the nation.

**Table 5. 13: Long Run Coefficients. Dependent Variable: Δ ICO₂ Emissions
ARDL (1, 2, 2, 0, 0)**

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LENC	5.160*	1.758	2.934	0.016
LFD	-3.861**	0.641	-6.020	0.002
LGDP	0.043*	0.009	4.672	0.001
LFDI	6.527*	0.694	9.405	0.000

LTO	-0.175	0.156	-1.117	0.292
LENC*GDP	-0.027**	0.008	-3.316	0.009
C	7.367*	1.439	5.116	0.006

Note: *, **, *** represents 1, 5, and 10 per cent level of significance, respectively.

Source: Author's Computation

5.12 Diagnostic Checking

For the efficiency of the models, it is necessary to apply post-estimation checking. Table 5.14 indicates the diagnostic test of the ARDL model.

Table 5. 14:Diagnostic checks

	F-stat	Prob.
Autocorrelation	0.403	0.146
Heteroskedasticity	0.575	0.146
Normality	0.636	0.727

Source: Author's Computation

Table 5.14 presents the outcome of diagnostic tests. It indicates that the null hypothesis of no serial correlation, homoscedasticity as well as the normality of the distribution of the residuals cannot be rejected. Furthermore, figure 5.3 shows the outcome of the stability test for the model. The result reveals that the model is stable since in both the CUSUM and CUSUM Square the lines are within the critical bound at the 5 per cent level. Hence, it is concluded that the models are free from econometrics problems and proved that the model produced an efficient estimation.

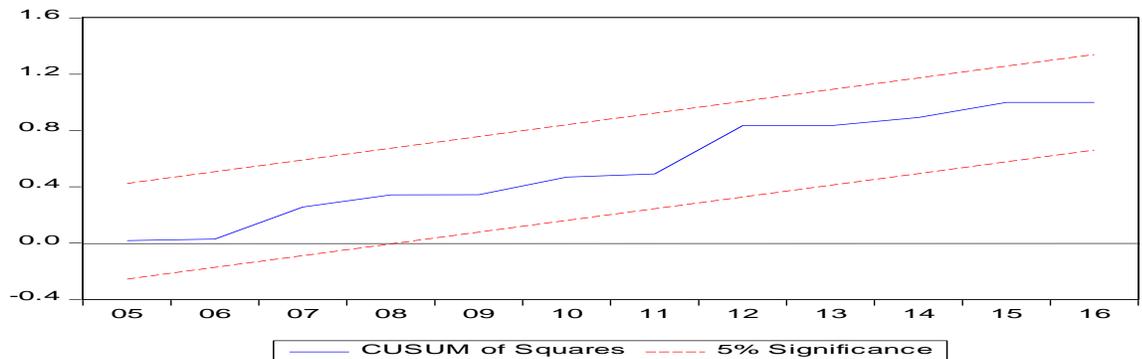
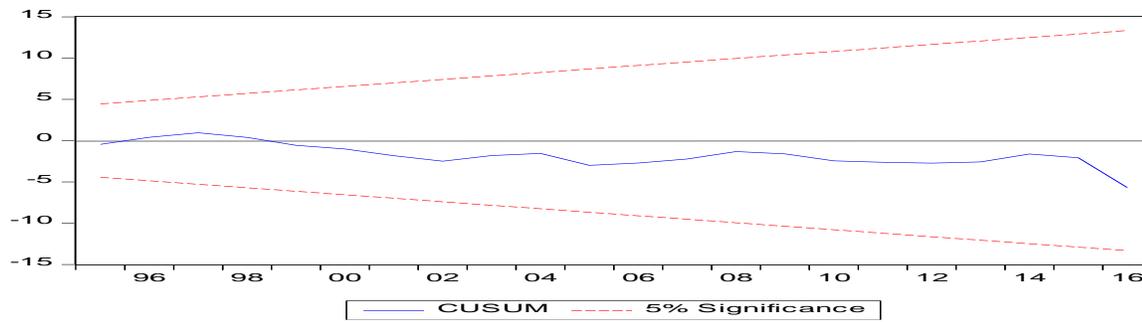


Figure 5. 3: CUSUM and CUSUM of squares stability test
 Source: Author's Computation

5.13 Justification for bi-bivariate model estimation

It is essential to investigate the response, forecast analysis, and causal effect of economic growth and energy use on the environment in Nigeria. The response of the long-run effect and the forecasting as well as the causal effect of the factors would help in providing viable solutions for a better environment in Nigeria and the avenue for sustainable development. The model has the advantageous feature to provide a reliable and dependable result for sustainable policy designing and implementation (Asari et al, 2011).

5.14 Estimation of Impulse Response

5.14.1 Lag Order Selection Criteria

Table 5.13 present the Lag Order Selection Criteria. As indicated in the table, the lag order selection criteria show the optimal lag preference (6) as identified by all available

information criteria at the 5 per cent significance level, namely Sequential Modified LR test statistic (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan-Quinn (HQ) information criterion. Thus, the optimal lag employed in the Toda-Yamamoto multivariate models is justified.

Table 5. 15: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1133.978	NA	0.424280	16.16990	16.29538	16.22089
1	135.7614	2413.405	1.07e-08	-1.329949	-0.451595	-0.973016
					-	-
2	457.2701	583.7321	1.86e-10	-5.379718	3.748489*	4.716843*
3	466.4034	15.80513	2.75e-10	-4.998629	-2.614526	-4.029812
4	481.3896	24.65822	3.75e-10	-4.700562	-1.563583	-3.425802
5	568.8007	136.3861	1.85e-10	-5.429797	-1.539944	-3.849095
				-		
6	669.2496	148.1799*	7.63e-11*	6.343966*	-1.701238	-4.457322
7	680.9144	16.21485	1.13e-10	-5.998785	-0.603182	-3.806199
8	698.6001	23.07928	1.55e-10	-5.739009	0.409469	-3.240480

** indicates lag order selected by the criterion*

Source: Author's Computation

5.14.2 Impulse Responses of Carbon Dioxide Emissions to Other Variables

Figure 5.8 shows the impulse response function of the models for Nigeria that determine the response of variables as a result of one standard deviation shock of other variables.

The IRF was considered through the generalized impulse response analysis of multiple graphs, and analytical asymptotic for the standard error.

Similarly, the default of the ten-period split is maintained to predict the impact of the shock on the concerned variable at each of the quarter periods. A shock of one standard deviation of almost all variables to themselves except for CO₂ and energy use leads to a negative adjustment in the short run, up to the long run quarter period in Nigeria. The response reveals that one shock in CO₂ discharge results in a negative change in energy use, FDI, domestic credit, and trade over a certain period. The result further illustrates that energy use responds negatively to CO₂ discharge from the short-run to long-run horizons. Similarly, FDI and financial development, and trade have decreased the capacity of CO₂ from the period of short to the long run. However, economic growth has increased in response to the CO₂ explosion in Nigeria.

These results are similar to the outcome of earlier studies (Sulaiman and Abdul-Rahim 2017; Qureshi, Rasli, & Zaman 2016). Their findings confirm the negative effect of these variables on CO₂ discharge. Thus, governments and policymakers need to continue with enhanced measures for mitigating CO₂ discharge for environmental and economic sustainability.

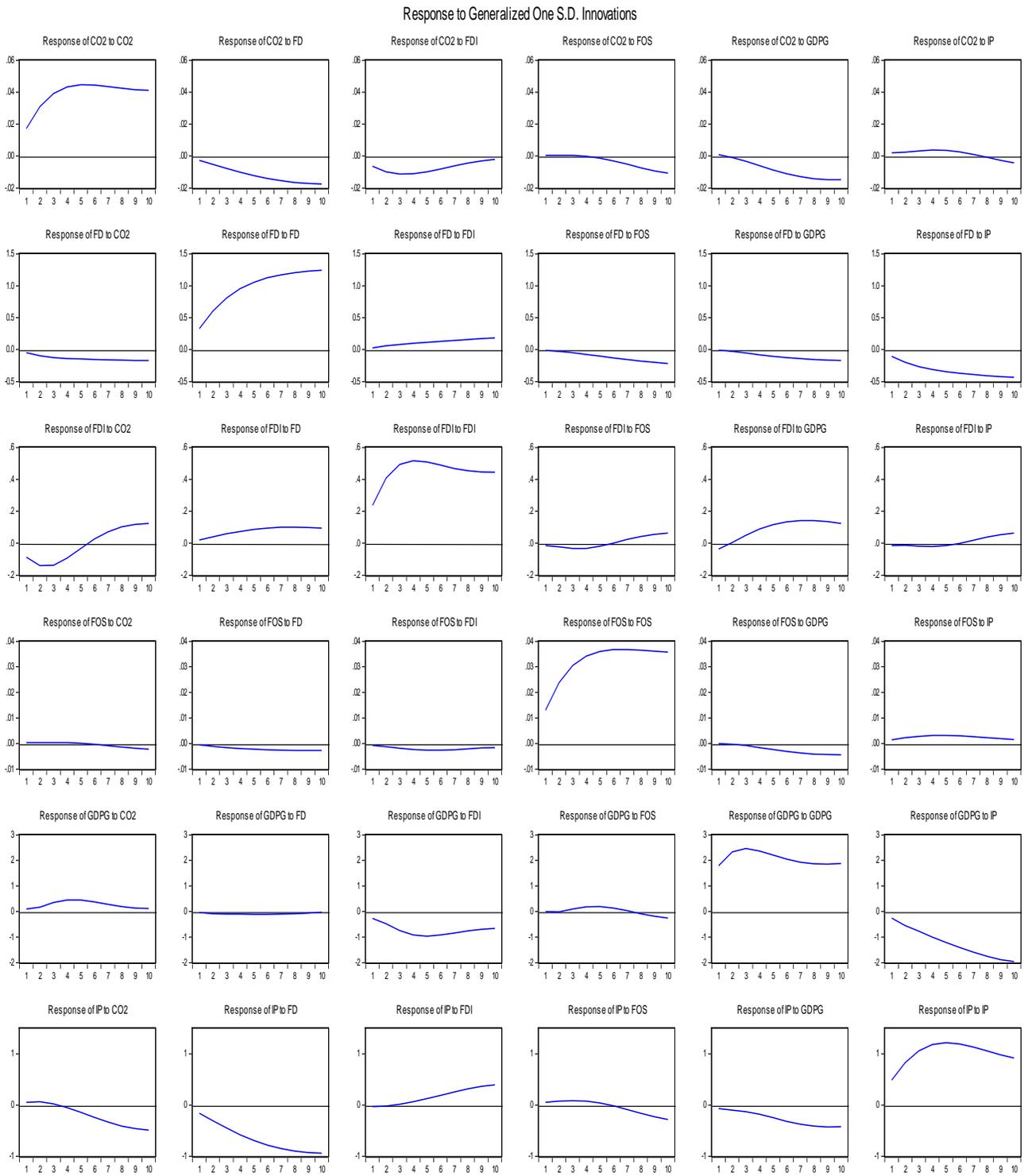


Figure 5. 4: Impulse Responses of Carbon Dioxide Emissions to Other Variables
 Source: Author's Computation

5.14.3 Variance Decomposition of Carbon Dioxide Emissions

Table 5.16 presents the decomposition outcome of the five CO₂ determinants in which each vector focused on one variable for Nigeria. The table shows that less than 100 per cent variance against CO₂ for both short and long-run quarter periods among the determinants in the vector in Nigeria. Meanwhile, energy use contributed 0.17 and 1.89 per cent in the short and long-run quarter periods, respectively. The finding indicates that energy has a 1.89 per cent influence on CO₂ in the long run quarter period. Consequently, economic growth is more influential to CO₂ compared to other variables that recorded 1.09 and 6.45 per cent in the short and long-run quarter periods, respectively.

Similarly, the variance as a result of FDI has accounted for 0.05 per cent in the short run and continued decreasing up to 4.32 per cent in the long run period. Furthermore, the result of trade 0.40 and 3.55 forecast variances was recorded in the short and long-run horizon. In addition, the overall result of FDI and economic growth have the highest influence compared to other variables within the vector.

Therefore, the hierarchical order for policymakers in mitigating CO₂ emission has to begin with economic growth and FDI with greater emphasis followed by domestic credit. It is argued that an increase in economic growth and FDI and energy utilization accelerates the capacity of environmental pollution (Ohlan 2015).

Table 5. 16: Variance Decomposition of Carbon dioxide (CO2) Emissions

Period	S.E.	Financial Development	Foreign Direct investment	Trade Openness	GDP Growth	Energy Consumption	CO2 Emission
1	0.017293	0.000000	0.000000	0.000000	0.000000	0.000000	2.305781
2	0.035600	0.026661	0.209376	0.274901	0.462561	0.014419	2.558611
3	0.053449	0.130021	0.502493	0.400334	1.094373	0.017800	2.478252
4	0.069670	0.337874	0.884249	0.518895	1.880686	0.036687	2.326168
5	0.084102	0.656631	1.355049	0.707105	2.778199	0.100539	2.187723
6	0.096992	1.067563	1.906275	1.019524	3.723213	0.250181	2.084458
7	0.108701	1.530064	2.514403	1.486074	4.631010	0.516958	2.014832
8	0.119555	1.993569	3.144559	2.099516	5.419859	0.903539	1.970642
9	0.129783	2.412494	3.758030	2.813104	6.034067	1.379404	1.942964
10	0.139515	2.757018	4.320677	3.555495	6.454869	1.891985	1.924195

Source: Author's Computations

Following the determination of the stationary properties of the variables and the investigation of the long-run relationship among the variables under study, the next step is to estimate the multivariate models for the Nation. In this view, the Toda-Yamamoto model (T-Y model) in the framework, proposed by Toda and Yamamoto (1995) is the appropriate estimation method for Nigeria, since mixed variables are found in the model, and can be accommodated in the T-Y estimation model.

5.14 Granger Causality Test Result

The rationale for employing the Granger causality test in this study is based on the influence and significance levels of economic growth, energy use, and other variables on environmental degradation from the ARDL model. There is a need to estimate a robust model to see the extent of the study's variable on environmental degradation. Therefore, Granger causality is estimated to see the extent of causation of economic growth and energy use on the environment in Nigeria to further justify their influence.

The Toda-Yamamoto estimation model is presented in Table 5.17. The Granger causality test result shows that among all variables, foreign direct investment granger causes carbon dioxide emissions, and credit provided by financial sector granger causes carbon dioxide emissions. In this regard, energy consumption granger causes carbon dioxide emissions in Nigeria, directly pointing to the country's reliance on the hydrocarbon industry for fiscal sustenance. Similarly, carbon dioxide emissions granger cause Trade on one hand, as well as carbon dioxide emissions and output growth, measured by the growth rate of gross domestic product, on the other. However, there was no causality between credit to the public and CO₂ emission in Nigeria.

Table 5.17: Granger Causality Test

	Null Hypothesis	Chi-square	P-Value	Remark
	CO2 Emission does not granger cause FD	2.37	0.88	No causality
	FD does not granger cause CO2 Emission	17.6	0.00	Causality
	CO2 Emission does not granger cause IP	18.7	0.00	Causality
	IP does not granger cause CO2 Emission	29.4	0.00	Causality
	CO2 Emission does not granger cause GDPg	11.6	0.00	Causality
	GDPg does not granger cause CO2	20.6	0.00	Causality
	CO2 Emission does not granger cause FOS	1.88	0.92	No causality
	FOS does not granger cause CO2 Emission	12.5	0.05	Causality
	CO2 Emission does not granger cause FDI	40.3	0.00	Causality
	FDI does not granger cause CO2 Emission	2.85	0.82	No causality

Source: Author's Computation

5.15 Ordinary least squares analysis as the robust estimated model

For reliable, and dependable policy analysis and recommendation, it is essential to estimate another model for the robust analysis. This is to ensure that the initial models estimated have strong backing and reliability to make strong policy design for environmental and development issues in Nigeria. Similarly, to confirm the resemblance or otherwise of the variable relationships, significance, and their influence to be sure on the later estimation, hence are the reasons for the robust analysis. Therefore, the estimated models are illustrated in the following tables.

Table 5.18 illustrate the estimation of the OLS model for economic growth and environmental degradation in Nigeria. The estimate reveals that in the long run economic growth is significant and positively influences environmental degradation in Nigeria. This implies that economic progress increased the level of environmental pollution in Nigeria by 0.01 per cent. Similarly, FDI and trade have also a positive and significant influence

on environmental degradation in the country. This means that a per cent increase in FDI and trade in Nigeria accelerate the capacity of environmental pollution by 6.7 and 0.3 per cent respectively. This outcome is similar to the result reported by NS Yahaya (2020). However, financial progress in the country significantly reduces the level of environmental pollution by 0.8 per cent. Moreover, the level of R Square is 86 per cent indicating that economic growth; FD, FDI, and trade explain environmental pollution in the nation by 86 per cent. In addition, the model is proved efficient and valid as the post-estimation tests show that the model is stable and normal in table 5.19. Nonetheless, this outcome implies that economic development promotes environmental pollution in Nigeria annually by 0.01 per cent, hence policymakers should consider designing policies to reduce environmental problems through economic progress. Similarly, the robust model also replicates the ARDL estimates indicating economic growth destroyed the environment in Nigeria.

Table 5. 18: OLS estimate for economic growth and environmental degradation

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LGDP	0.011578	0.002258	5.128020	0.0000
LFD	-0.856885	0.352518	-2.430755	0.0202
LFDI	6.374338	1.571433	4.056385	0.0003
LTO	0.392410	0.149625	2.622616	0.0127
C	60.82709	7.830303	7.768165	0.0000
R square	86.80558			

Table 5. 19:Diagnostic checks

	F-stat	Prob.
Autocorrelation	0.001	0.313
Heteroskedasticity	0.037	0.215
Normality	3.659	0.160

Source: Author's Computation

Table 5.20 presents the estimated outcome of the energy consumption and environmental degradation model. The finding illustrates a significant and positive association between energy use and environmental pollution in Nigeria. This means that energy consumption increases the level of environmental pollution annually by 3.5 per cent. This outcome is justified by the work of Danlami (2018). Similarly, the outcome shows that FDI and trade also accelerate the capacity of environmental degradation by 4.0 and 0.3 per cent respectively in the nation. Nonetheless, financial development is not significant in determining environmental pollution in Nigeria. Accordingly, the R square reveals the variables that explain the environmental pollution in the long run in Nigeria by 82 per cent. The outcome implication reveals that energy use adversely influences the environment in Nigeria, therefore, policymakers should address such issues by making strong policies via energy use reform policies, laws, and regulations. Moreover, table 5.21 shows that the estimated model is valid for policy analysis as the model is free from econometrics problems.

Table 5. 20: OLS estimate for energy consumption and environmental degradation

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LENC	3.503183	3.355726	10.43942	0.0000
LFD	-0.240977	0.212308	-1.135035	0.2639
LFDI	4.041666	0.992733	4.071250	0.0002
LTO	0.377659	0.098057	3.851410	0.0005
C	38.48242	5.832840	6.597544	0.0000
R square	82.61788			

Table 5. 21: Diagnostic checks

	F-stat	Prob.
Autocorrelation	0.022	0.116
Heteroskedasticity	0.031	0.303
Normality	1.445	0.485

Source: Author's Computation

Table 5.22 reveals the outcome of an estimated model of the interaction. The outcome shows a negative and significant link between the interaction of energy use with economic growth and environmental degradation in Nigeria. This shows that a per cent increase in the interaction of energy use with economic growth reduced the level of environmental pollution by 0.006 per cent annually. The implication of the outcome shows that the interaction of energy use and economic growth decreases the amount of environment pollution in the country. Hence, policymakers should consider making or designing policies on environmental problems via economic growth with energy use in Nigeria. Nonetheless, economic growth, energy use, and trade accelerate the capacity of

environmental degradation by 2.3, 0.007, and 0.4 respectively. However, financial development does not influence environmental pollution in Nigeria. The R square shows that the model variable explains the environmental degradation by 79 per cent in the long run. Additionally, the model is valid for policy recommendation as indicated in table 5.23 and the model has no econometric problems.

Table 5. 22: OLS estimate for the interaction and environmental degradation

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LGDP	2.366988	10.77627	2.196481	0.0350
LENC	0.007587	0.004996	-1.518540	0.1381
LFD	-0.136542	0.230461	-0.592471	0.5575
LFDI	3.737713	0.999208	3.740674	0.0007
LTO	0.438077	0.099682	4.394761	0.0001
LENC*LGDP	-0.006474	0.004590	1.410438	0.0675
C	4.666972	8.585104	5.436127	0.0000
R square	79.28712			

Table 5. 23: Diagnostic checks

	F-stat	Prob.
Autocorrelation	0.022	0.116
Heteroskedasticity	0.031	0.303
Normality	1.445	0.485

Source: Author's Computation

5.16 Conclusion

This chapter revealed the analysis of data and the discussions of findings for the model estimation. It started by describing the data. Following the descriptive statistics, the study

used the ADF and PP unit root test to test for the stationarity properties and order of integration of the data. The result of the ADF and PP unit root test established mixed stationery of the variables for the nation. Following the stationarity test, the study further moves ahead to find out whether a long-run equilibrium relationship exists between the variables using the ARDL-Bounds testing approach to co-integration. The finding proved a long-run relationship among the variables in all three models. The study further revealed both short-run and long-run coefficients of the variables post-estimation diagnostic tests for the country in the analysis as well as Bi-variate and causality analysis. Finally, the study confirms the former estimation by robust estimation using the OLS technic. The outcome reveals a significant negative influence of the interaction of energy use with economic growth on environmental pollution in Nigeria. Similarly, the result also confirms that economic growth and energy use accelerate the level of environmental pollution in the country as was found in the ARDL estimate.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.0 Introduction

The research is concerned with environmental quality issues and related factors. The study empirically examines how factors like economic growth, energy use, financial development, and trade influence environmental degradation in Nigeria. It is argued that environmental quality is the engine of sustainable growth. This chapter is linked to the problem statement, objectives, and questions of the study. It summarises and presents the main and significant findings of the study. The chapter also summarised policy implications, some limitations of the study, and the contributions of the study, and finally suggests an area for further future research. In particular, Section 6.2 offers a summary of the findings. Section 6.3 presents the policy implications, while Section 6.4 provides the limitations of the study. Section 6.5 suggests future research and finally, Section 6.6 concludes the chapter.

6.1 Summary of the study's Findings

The study investigates the effects of economic performance and energy consumption on the environment in Nigeria. To achieve this broad objective, the review of previous studies on CO₂ emission, economic progress, energy use, economic progress, financial development, FDI, and trade literature was critically reviewed. The study investigates an econometric ARDL and OLS model that explains the relationship between economic growth, energy consumption, financial performance, trade, and CO₂ discharges in Nigeria. This established an avenue to ascertain the consequences of the effect of economic growth and energy consumption on CO₂ in the nation. The study further, examines the long-duration influence of economic performance, energy use, FD, FDI, and trade on the

CO₂ explosion in Nigeria to actualize the performance of economic growth and energy use on the level of CO₂ discharge as well as the influence of the interaction effect on the environment. Finally, the study presents relevant information and evidence-based policy implication that reconciles environmental policies with the economic performance and energy use of the nation in such ways that it does not cause a large-scale rise in greenhouse gas (GHG) emissions and environmental degradation. Furthermore, established a relationship among these factors through Bi-variate and causality analysis.

To achieve the above-stated objectives, the study first conducted a descriptive statistical analysis of all variables. Hence, the bound test result confirms the existence of a long-run association in all three models, and the Autoregressive distributed lag model (ARDL), impulse response function, variance forecast analysis, Toda-Yamamoto causality, and OLS for the robust estimation were employed to estimate the models.

In general, the results obtained from the present study are quite interesting. Evidence from the long-run estimations shows that economic performance and trade have a positive and significant effect on CO₂. This shows that economic performance increases the level of CO₂. It also indicates that FDI and trade increase the level of environmental degradation. Nonetheless, financial progress improves environmental quality in Nigeria. Several studies such as Wang et al. (2018) have been conducted on the issue of economic growth and energy consumption on CO₂. These studies are mostly conducted in developed nations. Hence, this study investigates the influence of economic performance and energy consumption on the level of CO₂ discharge in Nigeria. The review of the relevant and related literature of past studies indicates contradicting and

inconclusive findings as such further examination of the related issues contributes to the existing gap in the literature.

Moreover, the estimated outcome for the second objective indicates that energy use and FDI increases the level of environmental damage. However, financial progress obtained a significant negative effect on CO₂ discharge. Studies such as Charfeddine and Khediri (2016) for UAE, Rafindadi (2016) for Japan, Dong et al. (2017) for BRICS countries, and Jebli et al. (2017) for OECD nations have proved the existence of a relationship between energy use and environment mostly in developed and industrialized countries. Nevertheless, this study examines the influence of energy use on the environment in Nigeria.

In addition, the result from the third objective reveals a negative interaction effect of energy use with economic growth on environmental degradation. Previous studies on environmental dilapidation and energy consumption exist in the literature among them are (Salahuddin & Gow 2015; Meng et al. 2018; Paramati, Mo, and Gupta 2017; Zafar, Saud, and Hou 2019). However, none of these studies examine the influence of the interaction of economic growth and energy use on environmental degradation. This study examined the influence of the interaction effect of GDP and energy use on environmental degradation in Nigeria.

Moreover, the outcome from the fourth objective shows that the bi-variate analysis shows positive shocks of economic growth and energy use on environmental pollution. Similarly, FDI, and energy use granger cause environmental degradation in Nigeria. Studies like (Salahuddin & Gow 2015; Meng et al. 2018) have analyzed the link between energy use

and the environment. However, the studies have not captured the quarterly data analysis based on the bi-variate analysis and causality.

6.2 Contributions of the study

The contributions of this study are identified in this section as follows:

(a) The study developed and tested a conceptual framework, which offers additional justification for the economic growth and environmental degradation discussion, grounded, and supported by the EKC. It is among the very few studies that integrate the theory in a single framework. Moreover, it is believed that the environmental Kuznets hypothesis has been used in analyzing situations regarding environmental pollution mostly in developed nations. In this regard, identifying factors like energy use, financial development, and trade influencing environmental degradation in Nigeria and linking these factors with EKC theory in the study's conceptual model becomes an empirical contribution to the on-going validation of the EKC hypothesis. Several studies have been done concerning environmental problems in Africa, however, engaging factors like economic performance, energy use, and financial development and incorporating these factors through EKC theory, particularly in Nigeria proved a significant contribution to knowledge.

(b) As Nigeria is a major emerging economy from the SSA region, with a fast-developing financial sector and a leading exporter of crude hydrocarbon, an in-depth analysis of the Nigerian case is thought to bring a valuable country and sector-specific insights useful for both economic development and environmental purposes. Hence, to

the best we know, this study is the first to assess the interaction of energy use and economic growth on CO₂ emissions as well as the causal linkage between financial development and CO₂ emissions for the single case of Nigeria and also the use of OLS analysis as the robust estimation. In this regard, this study provides an empirical model of interaction that extended the literature on environmental, energy use, and economic growth studies in the context of Nigeria, which has not been investigated in the literature. The interaction of energy use with economic growth is considered the creation of a new variable that has never been investigated particularly in Nigeria. Hence, the incorporation of the new variable into an empirical model has become a major contribution to this study. In this development, the combination of different factors influencing the CO₂ discharge based on the study model in Nigeria context has added to the new wave of emerging literature concerning empirical studies focusing on the relationship between the environment and economic growth in SSA countries' environmental studies in SSA economies. Moreover, considering the measurements of the study's variables proxies on environmental degradation and energy utilized in this study have little consideration concerning studies on the environment in Nigeria. Therefore, considering these measurements in this study's empirical analysis is an additional contribution of this study to the existing knowledge.

(c) The framework and EKC hypothesis were validated in Nigeria, which received little attention from past studies. Traditional diagnosis and robustness checks related to the stability of the coefficients are conducted. In sum, beyond conducting an in-depth review of the EKC topic, this study aims at enriching the EKC discipline with a multivariate approach and incorporates trade, FDI energy use, and the interaction of energy use and

economic growth in the emission of CO₂. Herein, we ask whether the environmental Kuznets curve (EKC) hypothesis holds for an emerging economy like Nigeria. In this respect, the findings of this study can aid in designing more appropriate suggestions and policies aimed at mitigating CO₂ discharge as well as achieving sustainable development in Nigeria and by extension SSA region.

6.3 Policy implications

The findings of the study indicate that economic performance has a positive effect on CO₂ discharge. This entails that it is important to consider policies on the mitigation of CO₂ emissions, especially concerning policies that will promote environmental quality. Since economic growth contributes to the level of CO₂ discharge in Nigeria. There is a need to implement economic policies in Nigeria that will concern with environmental issues. This would be in line with environmentally friendly policies in the practise of economic activities in Nigeria. This could be through making economic policies with environmental control measures to ensure environmental quality in the light of economic progress. Similarly, Nigeria's government should establish environmental quality institutions that will control and overlook the extent to which households and industries discharge CO₂ emissions and at the same time put restrictions on the importation of high CO₂ emission technologies to this country. This means it is significant to explore enabling conditions to enhance environmental quality for targeting sustainable economic growth and development.

Moreover, this will accelerate the level of investment, employment creation, and income, thereby increasing the standard of living and reducing the level of poverty among various

communities in the countries. Considering the fact that credit facilities stimulate environmental pollution in Nigeria, it will be paramount that the policymakers give directives to the financial institutions that credit allocation should be towards low-emission technologies and domestic appliances to reduce environmental pollution without jeopardizing the achievement of viable economic growth.

Based on the findings of the study, energy consumption has a positive and significant relationship with CO₂ discharge. It has been indicated from the estimated result that energy consumption accelerates the capacity of environmental degradation to a grater percentage annually in Nigeria. This entails that energy consumption increases the level of CO₂ in the country. Therefore, there is a need for Nigerian policymakers to design extensive policies on energy use regulations and alternatives. This could be through emphasize on the use of other alternatives of low-emission energy, like solar, thermal, wind, and hydro energy that will mitigate the level of CO₂ and enhance the level of viable energy utilization for a better environment in the nation.

There is a need to review the existing energy policies to strengthen the energy regulatory framework to ensure the orderly development of the sector and ensure that the reviewed energy policies are enacted into law by the legislatures. For example, Nigeria should embrace a feasible national Renewable Energy Portfolio Standard (RPS) framework in their energy policies that would obligate a certain percentage of electricity to be sourced by renewable energy every year.

In addition, the nation should adopt policies recommended by the United Nations on the mitigation of CO₂ emissions toward achieving sustainable development related to

economic growth and energy use. This will help in the mitigation of CO₂ discharge and improve the environmental quality in Nigeria. Foreign direct investment and financial development have a significant negative impact on the level of CO₂ discharge in Nigeria it will be paramount that the policymakers should emphasize more appropriate policies that will consider financial reform policy, smooth industrial policies, and all avenues that will attract clean foreign investment to stimulates sustainable development in this nation. This could be through further control of the high explosion of CO₂ by making the availability of low emissions technologies through FDI, provision of financial incentives that will encourage the use of low CO₂ technology, and removing trade barriers that will attract foreign investment, human capital development, and research in the country. Consequently, policy on the restructuring of financial and industrial sectors should meet up with the designed goals to enhance the level of environmental quality.

6.4 Recommendations

From the study's findings, it is clear that there is a need for Nigeria to pursue environmentally sustainable economic growth. Having conducted an empirical investigation of economic growth and energy consumption in Nigeria, the following recommendations were offered strictly based on the study findings. Based on the study findings economic growth and energy consumption, FDI, and trade increase the level of environmental degradation in Nigeria. However, financial development reduces environmental degradation. Therefore, Nigeria's government and policymakers should consider the following:

- To design economic policies with environmental control measures to ensure environmental quality in light of economic progress. Similarly, Nigeria's government should establish environmental quality institutions that will control and overlook the extent to which households and industries discharge CO₂ emissions and at the same time put restrictions on the importation of high CO₂ emission technologies to this country.
- To design policies on energy use regulations and alternatives. This could be through emphasize on the use of other alternatives of low-emission energy, like solar, thermal, wind, and hydro energy that will mitigate the level of CO₂ and enhance the level of viable energy utilization for a better environment in the nation.
- To provide financial incentives, especially to industries that will encourage the use of low emissions technology and industrial sector's restructuring to meet up with the designed goals to enhance the level of environmental quality and to achieve sustainable development.
- To provide an enabling and conducive condition for domestic investment, removing trade barriers to attract foreign investment through improved economic and infrastructural development for a better environment in Nigeria.
- In the light of the study's outcome of the forecast analysis and causality, it all indicates that economic growth and energy consumption increase environmental degradation in the future time and found that economic progress and energy use cause environmental pollution in Nigeria, hence, Environmentalists and stakeholders should educate individuals and owners of industries in the country on the need to mitigate CO₂ for sustainable economic development.

6.5 Limitations of the Study

This study is not free from limitations despite the efforts made at obtaining robust reasonable findings. One probable inherent limitation of the study is the unavailability of data on some important variables. In addition, this shortage of data availability has prevented further disaggregation of some variables into different components and their inclusion in the models. This constraint is recognized in the course of pursuing this research. However, an attempt was made to overcome this to a reasonable extent and it is believed that the study can provide useful information to the understanding of the impact of energy consumption and economic performance in determining CO₂ discharge in Nigeria as well as a signal to future studies in the area

The study utilized variables like fossil fuel, domestic credit, GDP, and FDI that explain the dependents variable. Nevertheless, certain variables such as banks' liquidity ratio, energy prices, and other disaggregated energy variables that have been used in the earlier studies were not considered in this study. The study also considered the use of time series analysis because it provides efficient and unbiased estimation. Nonetheless, The analysis was limited to the period 1980 to 2020 due to the unavailability of data for a long period, especially on the CO₂ emission variable. Furthermore, the study was limited to only Nigeria due to the unavailability of data employed especially data on CO₂ and energy consumption.

6.6 Suggestions for Further Research

Following the limitations of this study, the study suggests that further research should consider the following issues. Firstly, future studies should expand the coverage by

extending the data set to cover some sub-Saharan African countries (SSA) countries if data is available on the issue of CO₂, energy consumption is not only limited to the sampled nations. Furthermore, the study only examines economic growth as well as energy consumption and their relationship with CO₂ by including financial development and FDI and trade as the determinants of CO₂ discharge. However, other factors determine CO₂, which were not included in this study. Therefore, future research should look into these other factors such as energy prices and population density, and integrate them into the relationship to see how they affect CO₂. This will require a large data set that will include some of the nations in SSA.

Finally, this study employed the ARDL technique. Future studies may consider other approaches in terms of panel analysis such as GMM, FMOLS, and DOLS to study energy consumption, economic performance, and CO₂ in SSA nations. Besides, future research should expand the scope of this study by making a comparison with other continents in the world to see the extent to which the result differs across different continents.

6.7 Conclusion

The present study empirically examines the effect of economic growth and energy consumption on the environment in Nigeria by applying the ARDL, OLS, and Toda-Yamamoto causality techniques from 1980 to 2020. The results of the bound test show that the variables used in the models of the study have a long-run association. The finding of the study reveals the positive impact of economic growth and energy consumption on CO₂ in Nigeria. However, financial development has a negative impact on CO₂ in the country. The findings provide broader information concerning the contribution of energy consumption and economic performance on CO₂ in the nation. Hence, the research is

significant to Nigerian policymakers on the policies aimed at mitigating CO₂. Various studies in the literature have analyzed the effect of economic growth and energy consumption on CO₂. However, the influence of the interaction effect of economic performance with energy use on the environment in Nigeria has been left un-investigated. Therefore, the findings of this study contribute to the existing literature as none of the studies investigates the interaction effects of economic growth with energy use on the environment in Nigeria.

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APPENDIX

Descriptive statistics

	CO2	ENC	ENC_GDP	FD	FDI	GDP	TO
Mean	86.80558	0.944420	1516.743	15.22784	1.700663	1354.427	31.86590
Median	91.64342	0.831487	671.7919	13.52085	1.608284	902.2159	34.18262
Maximum	119.1077	1.786820	6416.394	38.38656	5.790847	3590.956	53.27796
Minimum	55.44403	0.417107	215.6482	8.709660	-1.150856	270.2240	6.236631
Std. Dev.	17.06311	0.367691	1590.465	5.977005	1.292739	940.5973	13.35954
Skewness	-0.425473	0.848059	1.422413	2.322634	0.976722	0.673450	-0.355020
Kurtosis	2.241100	2.610614	4.132888	8.735778	4.800713	2.210911	2.022650
Jarque-Bera	2.220897	5.173584	16.01814	93.06602	12.05828	4.162866	2.493093
Probability	0.329411	0.075261	0.000332	0.000000	0.002408	0.124751	0.287496
Sum	3559.029	38.72124	62186.44	624.3415	69.72719	55531.51	1306.502
Sum Sq. Dev.	11645.99	5.407877	1.01E+08	1428.984	66.84699	35388928	7139.096
Observations	41	41	41	41	41	41	41

Objective one

ARDL Bounds Test

Date: 10/25/22 Time: 09:48

Sample: 1984 2020

Included observations: 37

Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	9.411737	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10 per cent	2.45	3.52
5 per cent	2.86	4.01
2.5 per cent	3.25	4.49
1 per cent	3.74	5.06

Test Equation:
 Dependent Variable: D(CO2)
 Method: Least Squares
 Date: 10/25/22 Time: 09:48
 Sample: 1984 2020
 Included observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	-0.139426	0.142791	-0.976431	0.3454
D(CO2(-2))	0.087140	0.141749	0.614748	0.5486
D(CO2(-3))	0.306878	0.102488	2.994291	0.0097
D(FD)	-0.948027	0.206238	-4.596767	0.0004
D(FD(-1))	1.188181	0.333879	3.558716	0.0031
D(FD(-2))	0.560876	0.271103	2.068871	0.0575
D(FDI)	3.301429	0.911506	3.621950	0.0028
D(FDI(-1))	1.541041	1.296674	1.188457	0.2544
D(FDI(-2))	1.602083	1.114494	1.437497	0.1726
D(FDI(-3))	2.132854	0.888113	2.401558	0.0308
D(GDP)	0.018453	0.002802	6.585551	0.0000
D(GDP(-1))	0.011189	0.005199	2.152021	0.0493
D(GDP(-2))	-0.010406	0.006183	-1.682979	0.1145
D(TO)	0.188319	0.131687	1.430059	0.1746
D(TO(-1))	-0.065671	0.118941	-0.552131	0.5896
D(TO(-2))	-0.116978	0.119539	-0.978572	0.3444
D(TO(-3))	-0.188125	0.093300	-2.016347	0.0634
C	64.58348	11.76529	5.489324	0.0001
FD(-1)	-2.125723	0.399974	-5.314654	0.0001
FDI(-1)	2.074279	1.751222	1.184475	0.2559
GDP(-1)	0.011235	0.002357	4.766343	0.0003
TO(-1)	0.490747	0.163322	3.004778	0.0095
CO2(-1)	-0.757657	0.133122	-5.691458	0.0001
R-squared	0.924090	Mean dependent var		1.388536
Adjusted R-squared	0.804802	S.D. dependent var		9.417181
S.E. of regression	4.160628	Akaike info criterion		5.960592
Sum squared resid	242.3516	Schwarz criterion		6.961973
Log likelihood	-87.27095	Hannan-Quinn criter.		6.313626
F-statistic	7.746719	Durbin-Watson stat		2.640296
Prob(F-statistic)	0.000143			

ARDL Cointegrating And Long Run Form

Dependent Variable: CO2

Selected Model: ARDL(4, 3, 4, 3, 4)

Date: 10/25/22 Time: 09:50

Sample: 1980 2020

Included observations: 37

Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	-0.139426	0.142791	-0.976431	0.3454
D(CO2(-2))	0.087140	0.141749	0.614748	0.5486
D(CO2(-3))	0.306878	0.102488	2.994291	0.0097
D(FD)	-0.948027	0.206238	-4.596767	0.0004
D(FD(-1))	0.627304	0.272690	2.300433	0.0373
D(FD(-2))	0.560876	0.271103	2.068871	0.0575
D(FDI)	3.301429	0.911506	3.621950	0.0028
D(FDI(-1))	-0.061042	0.873653	-0.069870	0.9453
D(FDI(-2))	-0.530772	0.901970	-0.588458	0.5656
D(FDI(-3))	2.132854	0.888113	2.401558	0.0308
D(GDP)	0.018453	0.002802	6.585551	0.0000
D(GDP(-1))	0.021595	0.007881	2.740263	0.0159
D(GDP(-2))	-0.010406	0.006183	-1.682979	0.1145
D(TO)	0.188319	0.131687	1.430059	0.1746
D(TO(-1))	0.051307	0.126997	0.404000	0.6923
D(TO(-2))	0.071148	0.134074	0.530660	0.6040
D(TO(-3))	-0.188125	0.093300	-2.016347	0.0634
CointEq(-1)	-0.757657	0.133122	-5.691458	0.0001

$$\text{Cointeq} = \text{CO2} - (-2.8057 \cdot \text{FD} + 2.7378 \cdot \text{FDI} + 0.0148 \cdot \text{GDP} + 0.6477 \cdot \text{TO} + 85.2410)$$

Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
FD	-2.805652	0.422713	-6.637255	0.0000
FDI	2.737754	2.028811	1.349437	0.1986
GDP	0.014829	0.001727	8.588944	0.0000
TO	0.647717	0.206510	3.136495	0.0073
C	85.241010	9.954388	8.563160	0.0000

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	4.431071	Prob. F(2,12)	0.0362
Obs*R-squared	15.71743	Prob. Chi-Square(2)	0.0004

Test Equation:
 Dependent Variable: RESID
 Method: ARDL
 Date: 10/25/22 Time: 09:52
 Sample: 1984 2020
 Included observations: 37
 Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2(-1)	0.175891	0.195829	0.898187	0.3868
CO2(-2)	0.155948	0.210429	0.741095	0.4729
CO2(-3)	-0.149740	0.139750	-1.071483	0.3050
CO2(-4)	-0.002824	0.085076	-0.033196	0.9741
FD	-0.086704	0.172590	-0.502370	0.6245
FD(-1)	-0.008033	0.246403	-0.032601	0.9745
FD(-2)	0.315375	0.247311	1.275215	0.2264
FD(-3)	0.174241	0.229917	0.757841	0.4632
FDI	-0.252616	0.753000	-0.335480	0.7431
FDI(-1)	-0.426723	0.787922	-0.541580	0.5980
FDI(-2)	-0.354775	0.796149	-0.445614	0.6638
FDI(-3)	0.129573	0.782139	0.165665	0.8712
FDI(-4)	0.035013	0.733255	0.047750	0.9627
GDP	7.61E-05	0.002476	0.030749	0.9760
GDP(-1)	-0.005296	0.005075	-1.043649	0.3172
GDP(-2)	-0.000357	0.007626	-0.046849	0.9634
GDP(-3)	0.002754	0.005567	0.494591	0.6298
TO	-0.066823	0.111166	-0.601106	0.5590
TO(-1)	-0.037609	0.118073	-0.318527	0.7556
TO(-2)	0.082631	0.108357	0.762580	0.4604
TO(-3)	0.000469	0.109913	0.004269	0.9967
TO(-4)	-0.021443	0.077727	-0.275881	0.7873
C	-15.40915	11.08935	-1.389546	0.1899
RESID(-1)	-0.885212	0.337808	-2.620457	0.0224
RESID(-2)	-0.761777	0.396456	-1.921464	0.0787

R-squared	0.424795	Mean dependent var	-7.11E-15
Adjusted R-squared	-0.725614	S.D. dependent var	2.594608
S.E. of regression	3.408345	Akaike info criterion	5.515671
Sum squared resid	139.4018	Schwarz criterion	6.604129
Log likelihood	-77.03991	Hannan-Quinn criter.	5.899403
F-statistic	0.369256	Durbin-Watson stat	2.149166
Prob(F-statistic)	0.981789		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	4.726495	Prob. F(22,14)	0.0022
Obs*R-squared	32.60953	Prob. Chi-Square(22)	0.0676
Scaled explained SS	4.182282	Prob. Chi-Square(22)	1.0000

Test Equation:
 Dependent Variable: RESID^2
 Method: Least Squares
 Date: 10/25/22 Time: 09:53
 Sample: 1984 2020
 Included observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	21.45289	13.88360	1.545196	0.1446
CO2(-1)	-0.773360	0.211284	-3.660281	0.0026
CO2(-2)	0.860520	0.200272	4.296748	0.0007
CO2(-3)	0.000902	0.177206	0.005090	0.9960
CO2(-4)	-0.109126	0.120940	-0.902310	0.3822
FD	0.551768	0.243370	2.267196	0.0397
FD(-1)	-0.811550	0.325737	-2.491426	0.0259
FD(-2)	-0.176333	0.321787	-0.547979	0.5923
FD(-3)	0.313279	0.319914	0.979262	0.3441
FDI	0.156579	1.075620	0.145571	0.8863
FDI(-1)	0.317959	1.052712	0.302037	0.7671
FDI(-2)	-2.409302	1.030953	-2.336966	0.0348
FDI(-3)	-0.694903	1.064368	-0.652878	0.5244
FDI(-4)	-0.020842	1.048016	-0.019888	0.9844
GDP	0.006113	0.003307	1.848668	0.0857
GDP(-1)	0.023119	0.006574	3.516890	0.0034
GDP(-2)	-0.033988	0.009300	-3.654806	0.0026
GDP(-3)	-0.000985	0.007296	-0.135048	0.8945
TO	-0.129603	0.155396	-0.834015	0.4183
TO(-1)	-0.171497	0.163938	-1.046104	0.3132
TO(-2)	-0.144475	0.149862	-0.964055	0.3514
TO(-3)	-0.068470	0.158214	-0.432768	0.6718
TO(-4)	0.543136	0.110099	4.933172	0.0002
R-squared	0.881339	Mean dependent var		6.550043
Adjusted R-squared	0.694871	S.D. dependent var		8.888262
S.E. of regression	4.909741	Akaike info criterion		6.291702
Sum squared resid	337.4778	Schwarz criterion		7.293083
Log likelihood	-93.39649	Hannan-Quinn criter.		6.644736
F-statistic	4.726495	Durbin-Watson stat		2.738465
Prob(F-statistic)	0.002174			

Objective 2

ARDL Bounds Test

Date: 10/25/22 Time: 09:57

Sample: 1985 2020

Included observations: 36

Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	4.560779	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10 per cent	2.45	3.52
5 per cent	2.86	4.01
2.5 per cent	3.25	4.49
1 per cent	3.74	5.06

Test Equation:

Dependent Variable: D(CO2)

Method: Least Squares

Date: 10/25/22 Time: 09:57

Sample: 1985 2020

Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.545374	0.205382	2.655407	0.0167
D(CO2(-2))	0.199038	0.103570	1.921778	0.0716
D(CO2(-3))	0.045081	0.118997	0.378845	0.7095
D(CO2(-4))	0.246448	0.116743	2.111024	0.0499
D(ENC)	57.49127	9.041792	6.358393	0.0000
D(ENC(-1))	-29.78960	14.55756	-2.046332	0.0565
D(FD)	0.022774	0.178989	0.127239	0.9002
D(FD(-1))	0.459884	0.206519	2.226831	0.0398
D(FDI)	1.694638	0.751919	2.253752	0.0377
D(FDI(-1))	-1.140965	0.880068	-1.296451	0.2121
D(TO)	0.173513	0.100231	1.731121	0.1015
D(TO(-1))	-0.200557	0.126133	-1.590044	0.1302
D(TO(-2))	-0.304330	0.108345	-2.808890	0.0121
C	36.28117	8.316577	4.362513	0.0004
ENC(-1)	23.69664	8.145102	2.909312	0.0098
FD(-1)	-0.416606	0.167024	-2.494292	0.0232
FDI(-1)	3.584700	1.376987	2.603293	0.0186
TO(-1)	0.421086	0.152266	2.765461	0.0132
CO2(-1)	-0.835740	0.228948	-3.650353	0.0020
R-squared	0.917721	Mean dependent var		1.340193
Adjusted R-squared	0.830601	S.D. dependent var		9.546107
S.E. of regression	3.928994	Akaike info criterion		5.879894
Sum squared resid	262.4289	Schwarz criterion		6.715640

Log likelihood	-86.83809	Hannan-Quinn criter.	6.171592
F-statistic	10.53406	Durbin-Watson stat	2.323386
Prob(F-statistic)	0.000006		

ARDL Cointegrating And Long Run Form

Dependent Variable: CO2

Selected Model: ARDL(5, 2, 2, 2, 3)

Date: 10/25/22 Time: 09:58

Sample: 1980 2020

Included observations: 36

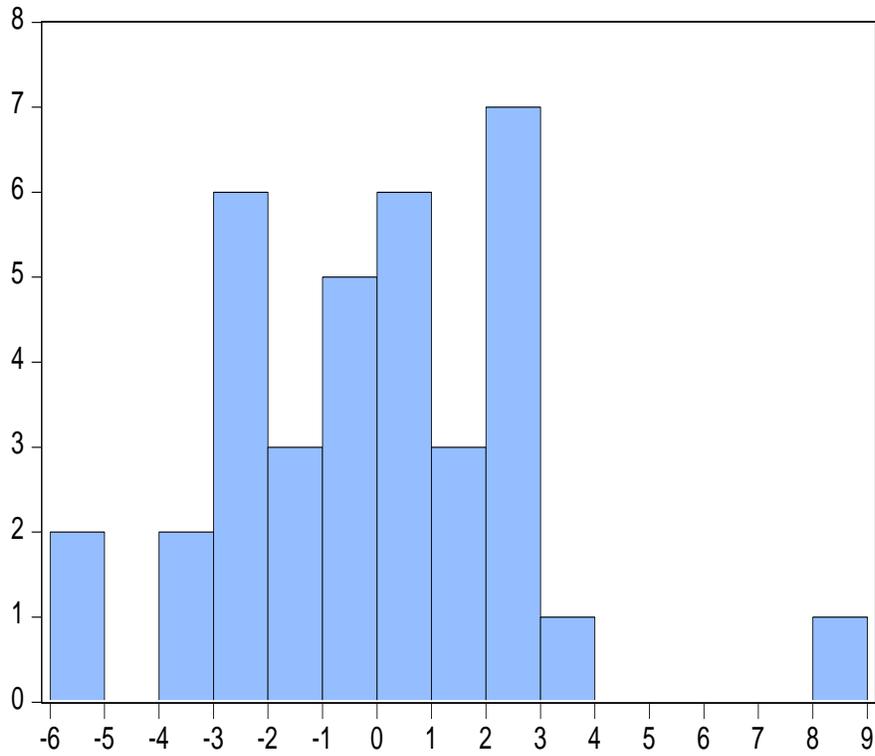
Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.545374	0.205382	2.655407	0.0167
D(CO2(-2))	0.199038	0.103570	1.921778	0.0716
D(CO2(-3))	0.045081	0.118997	0.378845	0.7095
D(CO2(-4))	0.246448	0.116743	2.111024	0.0499
D(ENC)	57.491273	9.041792	6.358393	0.0000
D(ENC(-1))	-29.789596	14.557559	-2.046332	0.0565
D(FD)	0.022774	0.178989	0.127239	0.9002
D(FD(-1))	0.459884	0.206519	2.226831	0.0398
D(FDI)	1.694638	0.751919	2.253752	0.0377
D(FDI(-1))	-1.140965	0.880068	-1.296451	0.2121
D(TO)	0.173513	0.100231	1.731121	0.1015
D(TO(-1))	0.103774	0.119692	0.867007	0.3980
D(TO(-2))	-0.304330	0.108345	-2.808890	0.0121
CointEq(-1)	-0.835740	0.228948	-3.650353	0.0020

$$\text{Cointeq} = \text{CO2} - (28.3541 \cdot \text{ENC} - 0.4985 \cdot \text{FD} + 4.2893 \cdot \text{FDI} + 0.5038 \cdot \text{TO} + 43.4121)$$

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENC	28.354098	3.435399	8.253509	0.0000
FD	-0.498488	0.243066	-2.050831	0.0560
FDI	4.289255	1.203492	3.564009	0.0024
TO	0.503848	0.103165	4.883888	0.0001
C	43.412053	6.430118	6.751362	0.0000



Series: Residuals	
Sample 1985 2020	
Observations 36	
Mean	8.88e-15
Median	0.056370
Maximum	8.909525
Minimum	-5.638790
Std. Dev.	2.738242
Skewness	0.541084
Kurtosis	4.600758
Jarque-Bera	5.600272
Probability	0.060802

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.797079	Prob. F(2,15)	0.4688
Obs*R-squared	3.458426	Prob. Chi-Square(2)	0.1774

Test Equation:
 Dependent Variable: RESID
 Method: ARDL
 Date: 10/25/22 Time: 09:59
 Sample: 1985 2020
 Included observations: 36
 Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2(-1)	0.288744	0.315092	0.916380	0.3740
CO2(-2)	-0.207668	0.310833	-0.668102	0.5142
CO2(-3)	-0.013159	0.148109	-0.088847	0.9304
CO2(-4)	0.045588	0.163428	0.278948	0.7841
CO2(-5)	0.013400	0.119021	0.112582	0.9119
ENC	2.995855	9.815558	0.305215	0.7644
ENC(-1)	-15.63444	20.84809	-0.749922	0.4649
ENC(-2)	9.447938	16.95648	0.557188	0.5856
FD	0.015821	0.222965	0.070957	0.9444
FD(-1)	0.070987	0.278727	0.254682	0.8024
FD(-2)	0.003123	0.229573	0.013603	0.9893
FDI	-0.076203	0.767060	-0.099345	0.9222
FDI(-1)	-0.198353	0.844909	-0.234762	0.8176
FDI(-2)	-0.246641	0.916228	-0.269192	0.7914
TO	-0.013552	0.107205	-0.126416	0.9011
TO(-1)	-0.041421	0.110331	-0.375424	0.7126
TO(-2)	0.015553	0.124717	0.124706	0.9024
TO(-3)	-0.027819	0.112839	-0.246538	0.8086
C	-6.191480	9.807315	-0.631313	0.5373
RESID(-1)	-0.514725	0.408509	-1.260011	0.2269
RESID(-2)	0.026444	0.443528	0.059621	0.9532

R-squared	0.096067	Mean dependent var	8.88E-15
Adjusted R-squared	-1.109176	S.D. dependent var	2.738242
S.E. of regression	3.976750	Akaike info criterion	5.890005
Sum squared resid	237.2181	Schwarz criterion	6.813724
Log likelihood	-85.02008	Hannan-Quinn criter.	6.212407
F-statistic	0.079708	Durbin-Watson stat	1.926400
Prob(F-statistic)	1.000000		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.512385	Prob. F(18,17)	0.9154
Obs*R-squared	12.66164	Prob. Chi-Square(18)	0.8113
Scaled explained SS	5.083314	Prob. Chi-Square(18)	0.9987

Test Equation:
 Dependent Variable: RESID^2
 Method: Least Squares
 Date: 10/25/22 Time: 10:00
 Sample: 1985 2020
 Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	15.89700	34.30679	0.463378	0.6490
CO2(-1)	-0.120872	0.816626	-0.148013	0.8841
CO2(-2)	0.287811	0.867031	0.331950	0.7440
CO2(-3)	-0.405808	0.527514	-0.769284	0.4523
CO2(-4)	0.682593	0.641928	1.063349	0.3025
CO2(-5)	-0.285637	0.481580	-0.593125	0.5609
ENC	0.356963	37.29838	0.009570	0.9925
ENC(-1)	-40.79456	62.97326	-0.647808	0.5258
ENC(-2)	27.90772	60.05152	0.464730	0.6480
FD	0.349015	0.738350	0.472695	0.6424
FD(-1)	-1.463179	1.007107	-1.452854	0.1645
FD(-2)	0.459158	0.851915	0.538971	0.5969
FDI	0.574903	3.101747	0.185348	0.8551
FDI(-1)	-3.425687	3.342074	-1.025018	0.3197
FDI(-2)	-0.472883	3.630376	-0.130257	0.8979
TO	-0.111597	0.413465	-0.269906	0.7905
TO(-1)	-0.670224	0.425509	-1.575113	0.1337
TO(-2)	0.648105	0.493742	1.312638	0.2068
TO(-3)	0.350939	0.446937	0.785210	0.4431
R-squared	0.351712	Mean dependent var		7.289693
Adjusted R-squared	-0.334710	S.D. dependent var		14.02889
S.E. of regression	16.20753	Akaike info criterion		8.714079
Sum squared resid	4465.629	Schwarz criterion		9.549825
Log likelihood	-137.8534	Hannan-Quinn criter.		9.005777
F-statistic	0.512385	Durbin-Watson stat		2.112309
Prob(F-statistic)	0.915393			

Objective 3

ARDL Bounds Test
 Date: 10/25/22 Time: 10:02
 Sample: 1984 2020
 Included observations: 37
 Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	3.967568	6

Critical Value Bounds

Significance	I0 Bound	I1 Bound
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10 per cent	2.12	3.23
5 per cent	2.45	3.61
2.5 per cent	2.75	3.99
1 per cent	3.15	4.43

Test Equation:
 Dependent Variable: D(CO2)
 Method: Least Squares
 Date: 10/25/22 Time: 10:02
 Sample: 1984 2020
 Included observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ENC_GDP)	-0.021502	0.006561	-3.277121	0.0096
D(ENC_GDP(-1))	0.001205	0.009824	0.122704	0.9050
D(ENC_GDP(-2))	-0.003016	0.005856	-0.514956	0.6190
D(ENC_GDP(-3))	0.009195	0.006600	1.393265	0.1970
D(ENC)	107.8266	17.46123	6.175198	0.0002
D(ENC(-1))	33.62695	28.23087	1.191141	0.2641
D(ENC(-2))	7.044115	19.14659	0.367904	0.7214
D(ENC(-3))	-41.53190	23.47962	-1.768849	0.1107
D(FD)	-0.863780	0.293394	-2.944100	0.0164
D(FD(-1))	2.849912	0.702291	4.058021	0.0029
D(FD(-2))	2.471710	0.624006	3.961034	0.0033
D(FD(-3))	0.802606	0.371744	2.159029	0.0592
D(FDI)	2.710593	0.682412	3.972075	0.0032
D(FDI(-1))	-1.446426	0.767364	-1.884928	0.0921
D(GDP)	0.031413	0.010384	3.025162	0.0144
D(GDP(-1))	0.004747	0.012955	0.366439	0.7225
D(GDP(-2))	0.013849	0.009496	1.458410	0.1787
D(GDP(-3))	-0.009913	0.005797	-1.710146	0.1214
D(TO)	-0.138819	0.146794	-0.945672	0.3690
D(TO(-1))	0.197958	0.106875	1.852234	0.0970
C	82.09218	21.67866	3.786773	0.0043
ENC_GDP(-1)	-0.030389	0.010458	-2.905817	0.0174
ENC(-1)	57.49814	21.97269	2.616800	0.0280
FD(-1)	-4.302875	1.020900	-4.214787	0.0023
FDI(-1)	7.273435	1.719569	4.229800	0.0022
GDP(-1)	0.048469	0.013559	3.574568	0.0060
TO(-1)	-0.195346	0.165468	-1.180564	0.2680
CO2(-1)	-1.114249	0.234452	-4.752571	0.0010

R-squared	0.974915	Mean dependent var	1.388536
Adjusted R-squared	0.899661	S.D. dependent var	9.417181
S.E. of regression	2.983013	Akaike info criterion	5.123565
Sum squared resid	80.08531	Schwarz criterion	6.342638
Log likelihood	-66.78595	Hannan-Quinn criter.	5.553345
F-statistic	12.95499	Durbin-Watson stat	2.229510
Prob(F-statistic)	0.000192		

ARDL Cointegrating And Long Run Form

Dependent Variable: CO2

Selected Model: ARDL(1, 4, 4, 4, 2, 4, 2)

Date: 10/25/22 Time: 10:03

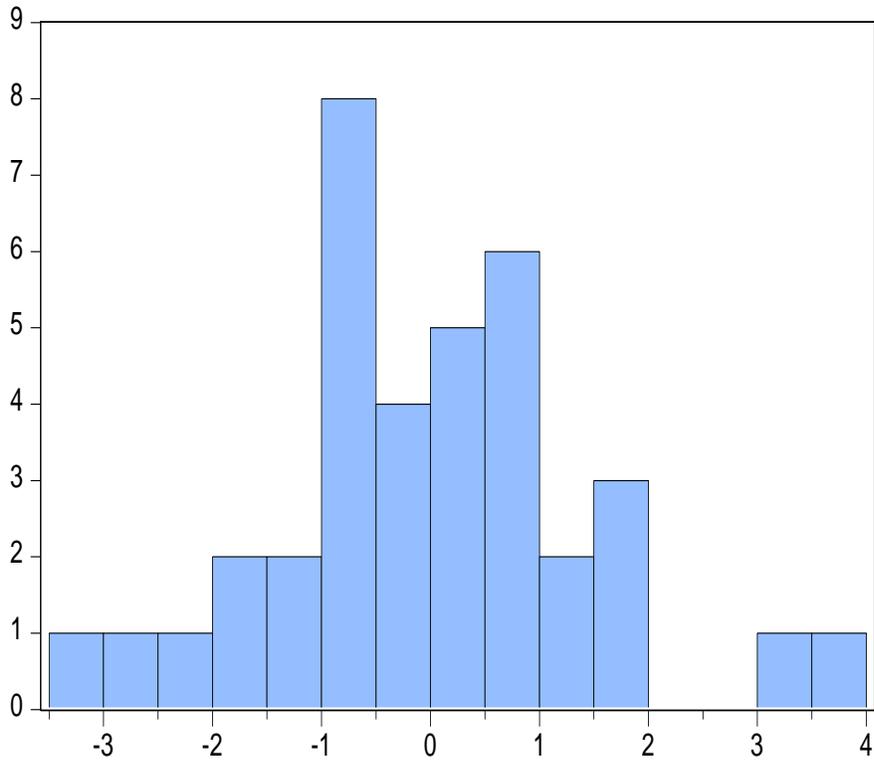
Sample: 1980 2020

Included observations: 37

Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ENC_GDP)	-0.021502	0.006561	-3.277121	0.0096
D(ENC_GDP(-1))	0.004221	0.010329	0.408661	0.6923
D(ENC_GDP(-2))	-0.012211	0.008040	-1.518725	0.1631
D(ENC_GDP(-3))	0.009195	0.006600	1.393265	0.1970
D(ENC)	107.826584	17.461235	6.175198	0.0002
D(ENC(-1))	26.582833	24.346313	1.091863	0.3033
D(ENC(-2))	48.576013	20.507481	2.368697	0.0420
D(ENC(-3))	-41.531898	23.479623	-1.768849	0.1107
D(FD)	-0.863780	0.293394	-2.944100	0.0164
D(FD(-1))	0.378202	0.260341	1.452721	0.1803
D(FD(-2))	1.669103	0.393853	4.237886	0.0022
D(FD(-3))	0.802606	0.371744	2.159029	0.0592
D(FDI)	2.710593	0.682412	3.972075	0.0032
D(FDI(-1))	-1.446426	0.767364	-1.884928	0.0921
D(GDP)	0.031413	0.010384	3.025162	0.0144
D(GDP(-1))	-0.009102	0.015664	-0.581107	0.5754
D(GDP(-2))	0.023763	0.012201	1.947654	0.0833
D(GDP(-3))	-0.009913	0.005797	-1.710146	0.1214
D(TO)	-0.138819	0.146794	-0.945672	0.3690
D(TO(-1))	0.197958	0.106875	1.852234	0.0970
CointEq(-1)	-0.714249	0.234452	-4.752571	0.0010

$$\text{Cointeq} = \text{CO2} - (-0.0273*\text{ENC_GDP} + 51.6026*\text{ENC} - 3.8617*\text{FD} + 6.5277 * \text{FDI} + 0.0435*\text{GDP} - 0.1753*\text{TO} + 73.6749)$$

Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENC_GDP	-0.027273	0.008224	-3.316151	0.0090
ENC	51.602608	17.582650	2.934860	0.0166
FD	-3.861683	0.641435	-6.020382	0.0002
FDI	6.527658	0.694042	9.405274	0.0000
GDP	0.043499	0.009310	4.672098	0.0012
TO	-0.175316	0.156818	-1.117960	0.2925
C	73.674921	14.399458	5.116507	0.0006



Series: Residuals	
Sample 1984 2020	
Observations 37	
Mean	-3.92e-14
Median	-0.091887
Maximum	3.924131
Minimum	-3.374886
Std. Dev.	1.491507
Skewness	0.170481
Kurtosis	3.544436
Jarque-Bera	0.636194
Probability	0.727532

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.035883	Prob. F(2,7)	0.4036
Obs*R-squared	8.449880	Prob. Chi-Square(2)	0.1467

Test Equation:
 Dependent Variable: RESID
 Method: ARDL
 Date: 10/25/22 Time: 10:04
 Sample: 1984 2020
 Included observations: 37
 Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2(-1)	0.155539	0.275174	0.565240	0.5896
ENC_GDP	0.001581	0.006696	0.236152	0.8201
ENC_GDP(-1)	-0.000283	0.013021	-0.021712	0.9833
ENC_GDP(-2)	-0.003479	0.010819	-0.321603	0.7571
ENC_GDP(-3)	0.001485	0.008282	0.179319	0.8628
ENC_GDP(-4)	-0.000325	0.006694	-0.048590	0.9626
ENC	-1.250257	18.70186	-0.066852	0.9486
ENC(-1)	-7.164450	30.83674	-0.232335	0.8229
ENC(-2)	9.591869	25.27116	0.379558	0.7155
ENC(-3)	-3.521367	20.88673	-0.168594	0.8709
ENC(-4)	1.554975	25.58741	0.060771	0.9532
FD	-0.006006	0.346031	-0.017357	0.9866
FD(-1)	-0.006493	0.289155	-0.022454	0.9827
FD(-2)	0.078592	0.267277	0.294049	0.7772
FD(-3)	0.077834	0.442396	0.175936	0.8653
FD(-4)	0.077774	0.378960	0.205229	0.8432
FDI	0.151086	0.729828	0.207016	0.8419
FDI(-1)	-0.425757	1.097513	-0.387928	0.7096
FDI(-2)	-0.340053	0.835433	-0.407038	0.6961
GDP	-0.003153	0.010577	-0.298152	0.7742
GDP(-1)	0.000484	0.022186	0.021813	0.9832
GDP(-2)	0.003278	0.016919	0.193760	0.8519
GDP(-3)	-0.000920	0.013099	-0.070197	0.9460
GDP(-4)	0.000187	0.006011	0.031086	0.9761
TO	-0.032275	0.159697	-0.202103	0.8456
TO(-1)	-0.027815	0.102933	-0.270220	0.7948
TO(-2)	-0.012215	0.110783	-0.110256	0.9153
C	-11.08343	23.02364	-0.481394	0.6449
RESID(-1)	-0.346704	0.531244	-0.652627	0.5348
RESID(-2)	-0.605466	0.457674	-1.322919	0.2274

R-squared	0.228375	Mean dependent var	-3.92E-14
Adjusted R-squared	-2.968356	S.D. dependent var	1.491507
S.E. of regression	2.971191	Akaike info criterion	4.972416
Sum squared resid	61.79581	Schwarz criterion	6.278566
Log likelihood	-61.98970	Hannan-Quinn criter.	5.432895
F-statistic	0.071440	Durbin-Watson stat	2.115902
Prob(F-statistic)	1.000000		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.575835	Prob. F(27,9)	0.8712
Obs*R-squared	23.43448	Prob. Chi-Square(27)	0.6615
Scaled explained SS	1.764000	Prob. Chi-Square(27)	1.0000

Test Equation:
 Dependent Variable: RESID^2
 Method: Least Squares
 Date: 10/25/22 Time: 10:05
 Sample: 1984 2020
 Included observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	35.23356	30.80500	1.143761	0.2822
CO2(-1)	-0.006847	0.333152	-0.020551	0.9841
ENC_GDP	-0.010085	0.009323	-1.081720	0.3075
ENC_GDP(-1)	0.000963	0.018570	0.051867	0.9598
ENC_GDP(-2)	-6.73E-05	0.014677	-0.004589	0.9964
ENC_GDP(-3)	0.008097	0.011425	0.708658	0.4965
ENC_GDP(-4)	-0.002804	0.009378	-0.298997	0.7717
ENC	40.66049	24.81211	1.638736	0.1357
ENC(-1)	-31.91893	40.99029	-0.778695	0.4561
ENC(-2)	-36.93782	34.59568	-1.067700	0.3135
ENC(-3)	-19.60599	29.14077	-0.672803	0.5180
ENC(-4)	44.20655	33.36413	1.324972	0.2178
FD	-0.254184	0.416907	-0.609689	0.5571
FD(-1)	-0.507035	0.408880	-1.240059	0.2463
FD(-2)	0.347945	0.369939	0.940546	0.3715
FD(-3)	-0.989539	0.559658	-1.768114	0.1108
FD(-4)	0.034954	0.528242	0.066171	0.9487
FDI	-1.247302	0.969696	-1.286282	0.2304
FDI(-1)	0.661699	1.499516	0.441275	0.6694
FDI(-2)	-0.480897	1.090411	-0.441024	0.6696
GDP	0.009194	0.014755	0.623094	0.5487
GDP(-1)	0.005843	0.031631	0.184729	0.8575
GDP(-2)	0.015290	0.022258	0.686959	0.5094
GDP(-3)	-0.025526	0.017337	-1.472370	0.1750
GDP(-4)	0.003817	0.008237	0.463432	0.6541
TO	-0.285269	0.208592	-1.367596	0.2046
TO(-1)	-0.155567	0.144234	-1.078569	0.3088
TO(-2)	0.139772	0.151868	0.920357	0.3814
R-squared	0.633364	Mean dependent var		2.164468
Adjusted R-squared	-0.466542	S.D. dependent var		3.500230
S.E. of regression	4.238809	Akaike info criterion		5.826262
Sum squared resid	161.7075	Schwarz criterion		7.045335
Log likelihood	-79.78584	Hannan-Quinn criter.		6.256042
F-statistic	0.575835	Durbin-Watson stat		2.295774
Prob(F-statistic)	0.871154			

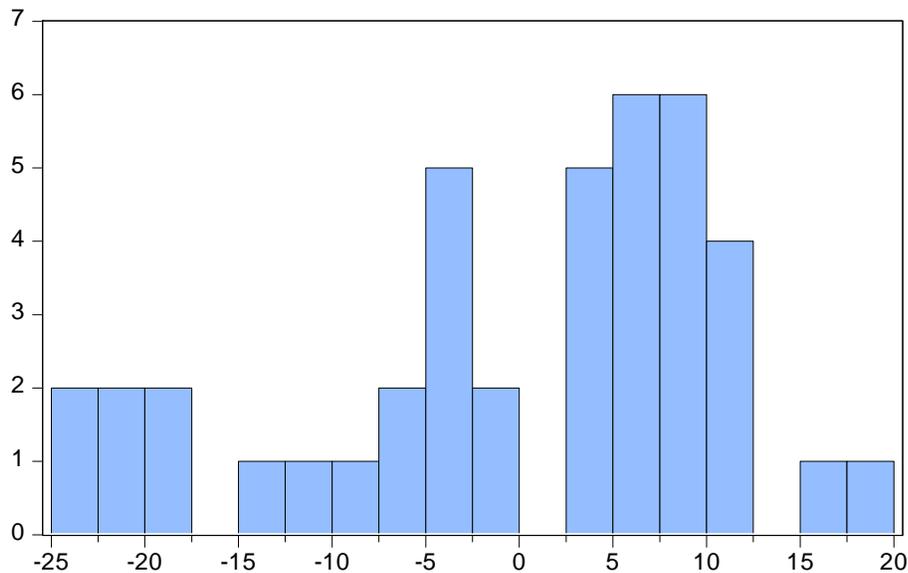
Robust estimation

Dependent Variable: CO2
 Method: Least Squares
 Date: 05/26/23 Time: 08:19
 Sample: 1980 2020

Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	0.011578	0.002258	5.128020	0.0000
FD	-0.856885	0.352518	-2.430755	0.0202
FDI	6.374338	1.571433	4.056385	0.0003
TO	0.392410	0.149625	2.622616	0.0127
C	60.82709	7.830303	7.768165	0.0000

R-squared	0.563066	Mean dependent var	86.80558
Adjusted R-squared	0.514518	S.D. dependent var	17.06311
S.E. of regression	11.88899	Akaike info criterion	7.902951
Sum squared resid	5088.528	Schwarz criterion	8.111924
Log likelihood	-157.0105	Hannan-Quinn criter.	7.979048
F-statistic	11.59808	Durbin-Watson stat	0.914913
Prob(F-statistic)	0.000004		



Series: Residuals	
Sample 1980 2020	
Observations 41	
Mean	-1.26e-15
Median	3.811551
Maximum	18.43309
Minimum	-23.24827
Std. Dev.	11.27888
Skewness	-0.691089
Kurtosis	2.518678
Jarque-Bera	3.659396
Probability	0.160462

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	8.110083	Prob. F(2,34)	0.0013
Obs*R-squared	13.24223	Prob. Chi-Square(2)	0.3130

Test Equation:

Dependent Variable: RESID

Method: Least Squares

Date: 05/26/23 Time: 08:22

Sample: 1980 2020

Included observations: 41

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	0.000656	0.001920	0.341580	0.7348
FD	-0.197664	0.309717	-0.638207	0.5276

FDI	-0.967108	1.364870	-0.708572	0.4834
TO	-0.054707	0.128037	-0.427275	0.6719
C	5.621240	6.972508	0.806201	0.4257
RESID(-1)	0.619196	0.171069	3.619575	0.0009
RESID(-2)	-0.037429	0.175633	-0.213109	0.8325

R-squared	0.322981	Mean dependent var	-1.26E-15
Adjusted R-squared	0.203507	S.D. dependent var	11.27888
S.E. of regression	10.06600	Akaike info criterion	7.610456
Sum squared resid	3445.030	Schwarz criterion	7.903017
Log likelihood	-149.0144	Hannan-Quinn criter.	7.716991
F-statistic	2.703361	Durbin-Watson stat	1.938975
Prob(F-statistic)	0.029611		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	2.858958	Prob. F(4,36)	0.0372
Obs*R-squared	9.884282	Prob. Chi-Square(4)	0.0424
Scaled explained SS	5.786528	Prob. Chi-Square(4)	0.2157

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 05/26/23 Time: 08:23

Sample: 1980 2020

Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	28.23310	93.65125	0.301471	0.7648
GDP	0.090788	0.027004	3.362030	0.0018
FD	-4.856984	4.216151	-1.151995	0.2569
FDI	13.90720	18.79451	0.739961	0.4641
TO	0.728713	1.789534	0.407208	0.6863

R-squared	0.241080	Mean dependent var	124.1104
Adjusted R-squared	0.156756	S.D. dependent var	154.8471
S.E. of regression	142.1935	Akaike info criterion	12.86610
Sum squared resid	727884.0	Schwarz criterion	13.07508
Log likelihood	-258.7551	Hannan-Quinn criter.	12.94220
F-statistic	2.858958	Durbin-Watson stat	1.371422
Prob(F-statistic)	0.037241		

objective 2

Dependent Variable: CO2

Method: Least Squares

Date: 05/26/23 Time: 08:24

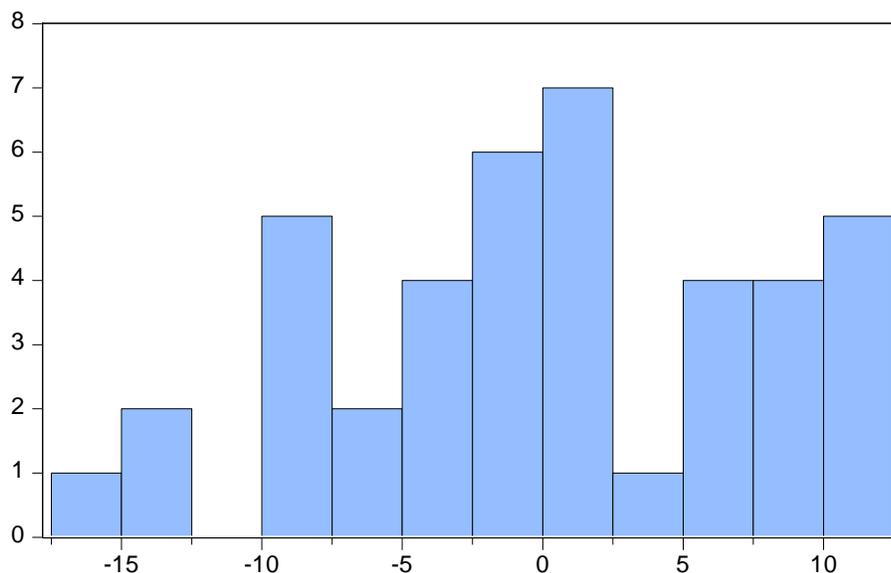
Sample: 1980 2020

Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
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ENC	35.03183	3.355726	10.43942	0.0000
FD	-0.240977	0.212308	-1.135035	0.2639
FDI	4.041666	0.992733	4.071250	0.0002
TO	0.377659	0.098057	3.851410	0.0005
C	38.48242	5.832840	6.597544	0.0000

R-squared	0.812255	Mean dependent var	82.61788
Adjusted R-squared	0.791395	S.D. dependent var	17.06311
S.E. of regression	7.793288	Akaike info criterion	7.058252
Sum squared resid	2186.472	Schwarz criterion	7.267224
Log likelihood	-139.6942	Hannan-Quinn criter.	7.134348
F-statistic	38.93747	Durbin-Watson stat	1.150089
Prob(F-statistic)	0.000000		



Series: Residuals
Sample 1980 2020
Observations 41

Mean 9.46e-15
Median 0.634635
Maximum 11.08793
Minimum -15.93714
Std. Dev. 7.393362
Skewness -0.249924
Kurtosis 2.227925

Jarque-Bera 1.445161
Probability 0.485498

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	4.269209	Prob. F(2,34)	0.0222
Obs*R-squared	8.229622	Prob. Chi-Square(2)	0.1163

Test Equation:

Dependent Variable: RESID

Method: Least Squares

Date: 05/26/23 Time: 08:24

Sample: 1980 2020

Included observations: 41

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENC	1.080217	3.153957	0.342496	0.7341
FD	-0.080632	0.213415	-0.377818	0.7079
FDI	-0.359722	0.936910	-0.383945	0.7034
TO	-0.037913	0.091251	-0.415486	0.6804
C	2.055161	5.521468	0.372213	0.7120

RESID(-1)	0.495982	0.174022	2.850113	0.0074
RESID(-2)	-0.086950	0.199258	-0.436371	0.6653
R-squared	0.200722	Mean dependent var		9.46E-15
Adjusted R-squared	0.059674	S.D. dependent var		7.393362
S.E. of regression	7.169375	Akaike info criterion		6.931766
Sum squared resid	1747.598	Schwarz criterion		7.224327
Log likelihood	-135.1012	Hannan-Quinn criter.		7.038300
F-statistic	1.423070	Durbin-Watson stat		1.937947
Prob(F-statistic)	0.234533			

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	2.995775	Prob. F(4,36)	0.0312
Obs*R-squared	10.23917	Prob. Chi-Square(4)	0.0366
Scaled explained SS	4.846676	Prob. Chi-Square(4)	0.3034

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 05/26/23 Time: 08:25

Sample: 1980 2020

Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-42.15512	40.88398	-1.031091	0.3094
ENC	56.48900	23.52120	2.401620	0.0216
FD	-0.569100	1.488126	-0.382427	0.7044
FDI	1.398109	6.958342	0.200926	0.8419
TO	1.519580	0.687311	2.210908	0.0335

R-squared	0.249736	Mean dependent var	53.32858
Adjusted R-squared	0.166373	S.D. dependent var	59.82848
S.E. of regression	54.62530	Akaike info criterion	10.95272
Sum squared resid	107421.2	Schwarz criterion	11.16169
Log likelihood	-219.5308	Hannan-Quinn criter.	11.02882
F-statistic	2.995775	Durbin-Watson stat	1.924530
Prob(F-statistic)	0.031178		

objective 3

Dependent Variable: CO2

Method: Least Squares

Date: 05/26/23 Time: 08:29

Sample: 1980 2020

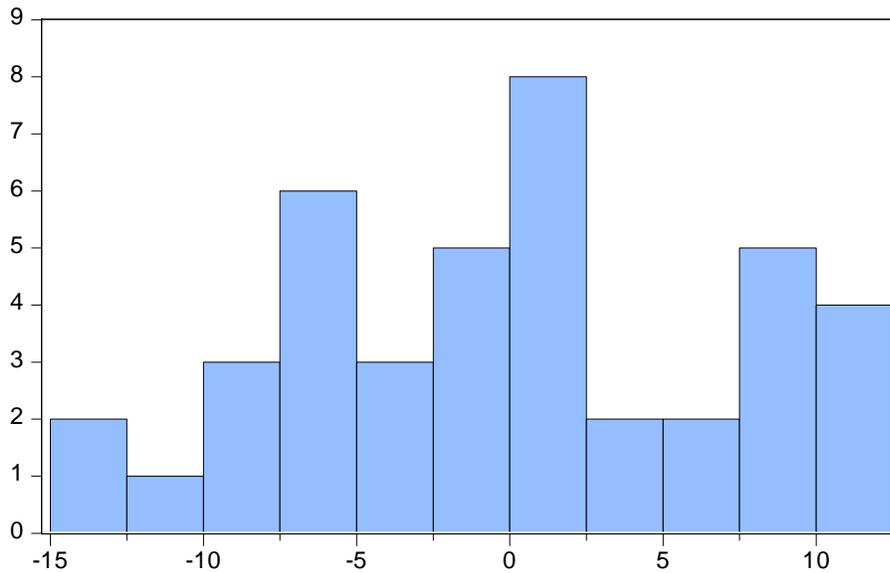
Included observations: 41

No d.f. adjustment for standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENC_GDP	0.006474	0.004590	1.410438	0.1675

ENC	23.66988	10.77627	2.196481	0.0350
GDP	-0.007587	0.004996	-1.518540	0.1381
FD	-0.136542	0.230461	-0.592471	0.5575
FDI	3.737713	0.999208	3.740674	0.0007
TO	0.438077	0.099682	4.394761	0.0001
C	46.66972	8.585104	5.436127	0.0000

R-squared	0.822289	Mean dependent var	79.28712
Adjusted R-squared	0.790929	S.D. dependent var	17.06311
S.E. of regression	7.801993	Akaike info criterion	7.100887
Sum squared resid	2069.617	Schwarz criterion	7.393449
Log likelihood	-138.5682	Hannan-Quinn criter.	7.207422
F-statistic	26.22036	Durbin-Watson stat	1.068338
Prob(F-statistic)	0.000000		



Series: Residuals	
Sample 1980 2020	
Observations 41	
Mean	-4.59e-15
Median	0.120932
Maximum	12.41053
Minimum	-14.93052
Std. Dev.	7.193082
Skewness	-0.113053
Kurtosis	2.256068
Jarque-Bera	1.032789
Probability	0.596668

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	5.618823	Prob. F(2,32)	0.0081
Obs*R-squared	10.65607	Prob. Chi-Square(2)	0.0049

Test Equation:

Dependent Variable: RESID

Method: Least Squares

Date: 05/26/23 Time: 08:30

Sample: 1980 2020

Included observations: 41

No d.f. adjustment for standard errors & covariance

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENC_GDP	0.003837	0.004178	0.918381	0.3653
ENC	-8.430436	9.720359	-0.867297	0.3922
GDP	-0.002895	0.004420	-0.654896	0.5172
FD	-0.219948	0.224554	-0.979491	0.3347

FDI	-0.348408	0.867348	-0.401693	0.6906
TO	-0.010410	0.085979	-0.121074	0.9044
C	10.24846	8.268385	1.239476	0.2242
RESID(-1)	0.552812	0.156352	3.535687	0.0013
RESID(-2)	0.042980	0.184525	0.232922	0.8173

R-squared	0.259904	Mean dependent var	-4.59E-15
Adjusted R-squared	0.074880	S.D. dependent var	7.193082
S.E. of regression	6.918533	Akaike info criterion	6.897473
Sum squared resid	1531.715	Schwarz criterion	7.273623
Log likelihood	-132.3982	Hannan-Quinn criter.	7.034446
F-statistic	1.404706	Durbin-Watson stat	1.955482
Prob(F-statistic)	0.232304		

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.753106	Prob. F(6,34)	0.1387
Obs*R-squared	9.687273	Prob. Chi-Square(6)	0.1385
Scaled explained SS	4.183836	Prob. Chi-Square(6)	0.6518

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 05/26/23 Time: 08:30

Sample: 1980 2020

Included observations: 41

No d.f. adjustment for standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-73.15369	59.74117	-1.224511	0.2292
ENC_GDP	-0.035317	0.031943	-1.105626	0.2767
ENC	91.60804	74.98886	1.221622	0.2303
GDP	0.048626	0.034766	1.398670	0.1710
FD	-1.244714	1.603710	-0.776146	0.4430
FDI	10.16069	6.953190	1.461299	0.1531
TO	0.831502	0.693655	1.198725	0.2389

R-squared	0.236275	Mean dependent var	50.47847
Adjusted R-squared	0.101500	S.D. dependent var	57.27626
S.E. of regression	54.29173	Akaike info criterion	10.98087
Sum squared resid	100218.1	Schwarz criterion	11.27343
Log likelihood	-218.1079	Hannan-Quinn criter.	11.08741
F-statistic	1.753106	Durbin-Watson stat	1.814430
Prob(F-statistic)	0.138716		