

**ENERGY CONSUMPTION, ECONOMIC GROWTH, FINANCIAL
DEVELOPMENT, INSTITUTIONAL QUALITY AND CARBON EMISSIONS
IN SUB-SAHARAN AFRICA**

BY

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THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN
ECONOMICS**

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2025

DECLARATION

Declaration by the Candidate

I declare that this thesis is my original work and has not been presented to any other institution. No part of this work may be reproduced without prior or express permission of the author and/or Moi University.

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Declaration by the Supervisors

This thesis is submitted for presentation with our approval as supervisors

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DEDICATION

I would like to express my heartfelt gratitude and dedication to my fiancée Gwen Maina and my parents, Mr. Benerd Kinuthia and Mrs. Hannah Wangui, as well as my siblings: Ibrahim Wainaina, Wilson Wanyoike, David Mwangi, Goefrey Kimani, Vero Waruguru, Rahab Ndiko, Edith Wambui, Maria Njeri, and Mary Wanjiru. Your unwavering support and understanding have been instrumental in the conception and development of this research proposal. In times of both challenge and success, your love has been a guiding force, providing the foundation upon which this proposal was built.

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ABSTRACT

Global warming is arguably among the most pressing problems affecting almost all countries of the world—developed or developing due to its deleterious consequences on the environment. Global warming has often been attributed to carbon emissions onto the atmosphere, which has seen an astronomical increase in the last century. Renewable energy has gained significant attention during the last decade because it has been the fastest growing energy source in the world since the late 2000s. Despite this, a significant proportion of the existing studies emphasize energy consumption more, without disaggregating the discussion in line with both renewable and non-renewable energy sources. This leaves a gap in understanding how each type of energy consumption affects carbon emission. Financial development, economic growth and institutional quality have also been the focus of a heated debate between researchers and economists because institutions have a direct and indirect effect on the relationship between them and climate change. The aim of this study was to investigate the moderating role of institutional quality on the relationship between energy consumption, economic growth, financial development and carbon emissions in Sub-Saharan Africa. The specific objectives of the study were to establish whether: the two dimensions of energy consumption; renewable and non-renewable energy consumption and economic growth, financial development have an effect on carbon emissions. Additionally, the study investigated whether institutional quality moderates the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions. The study was guided by environmental Kuznets curve, energy transition and institutional theories. The study adopted explanatory and longitudinal research designs and used panel data to establish the causal relationship among the study variables. The target population comprised 48 countries in Sub-Saharan Africa. The inclusion/exclusion criteria were based on whether the country consistently had available data from 2000 to 2023 and this led to a final sample of 552 country-year observations. Data was collected from the World Bank database and was analyzed using both descriptive and inferential statistics. The results of the regression model were used to test the hypotheses. The study established that renewable energy consumption ($\beta = 0.0342$, p -value < 0.05) non-renewable energy consumption ($\beta = 0.0027$, $p < 0.05$) economic growth ($\beta = 0.7026$, p -value < 0.05) and financial development ($\beta = 0.0441$, $p < 0.05$) had a positive and significant effect on carbon emissions with an R-square of 94.46 percent. Further, the study found that institutional quality had an antagonistic moderation on the relationship between renewable energy consumption ($\beta = -0.0075$, p -value < 0.05) non-renewable energy consumption ($\beta = -0.0022$, $p < 0.05$) economic growth ($\beta = -0.4327$, p -value < 0.05), financial development ($\beta = -0.0378$, $p < 0.05$) and carbon emissions with an R-square of 95.14 percent. Generalized method of moment results confirmed the fixed effect model results. Based on the results, the study concluded that institutional quality moderated the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions. The findings have several implications; policymakers should prioritize strengthening institutional quality through improved governance, regulatory frameworks, and transparency. Moreover, policymakers should integrate renewable energy with institutional reforms. This includes implementing strict emission controls on fossil fuel consumption and providing financial incentives for industries to shift towards cleaner energy alternatives. Financial development must be directed towards green investments. Future research could adopt a comparative approach by analyzing the relationship between energy consumption, economic growth, financial development, and carbon emissions in SSA relative to other regions, such as Europe, Asia, and America.

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ACRONYMS AND ABBREVIATIONS

AERC:	African Economic Research Consortium
ARDL:	Autoregressive distributed lag
BRI:	Belt and Road Initiative
BRIC:	Brazil, Russia, India, and China
COP:	Conference of Parties
EKC:	Environmental Kuznets Curve
ESG:	Environmental, social and governance
EU:	European Union
FDI:	Foreign Direct Investment
GDP:	Gross domestic product
GHG:	Greenhouse Gas
ICT:	Information communication technology
IPCC:	Intergovernmental Panel on Climate Change
KP:	Kyoto protocol
SSA:	Sub-Saharan Africa
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change

OPERATIONAL DEFINITION OF TERMS

- Carbon emissions:** The release of carbon dioxide (CO₂) and other greenhouse gases into the atmosphere, primarily from human activities such as burning fossil fuels and deforestation, contributing to global warming and climate change (IPCC, 2018).
- Economic growth:** The sustained increase in a country's production of goods and services over time, typically measured by changes in gross domestic product (GDP), reflecting improvements in living standards and well-being (Mankiw et al., 2019).
- Financial development:** Financial development entails the enhancement and sophistication of financial intermediation, encompassing banking, securities, and insurance markets, crucial for fostering economic growth and stability (Beck & Cull, 2018).
- Foreign direct investment (FDI):** Investment made by a company or individual from one country in business interests in another country, typically involving a long-term relationship and a significant degree of control over the foreign enterprise (Caves, 2018).
- Industrialization:** The process of economic development characterized by the growth of manufacturing industries and the transition from agrarian economies to urbanized, industrial societies (Fiori & Vecchi, 2019).

Institutional quality: The effectiveness, transparency, and reliability of institutions within a society, including governance structures, the rule of law, and regulatory frameworks, influencing economic and social outcomes (World Bank, 2020).

Non-renewable energy consumption: The utilization of energy derived from finite sources such as fossil fuels (coal, oil, and natural gas) and nuclear fuels, leading to environmental degradation and resource depletion (IEA, 2018).

Population: The total number of individuals inhabiting a specified area, often considered in relation to factors such as resource consumption and environmental impact (World Population Review, 2019).

Renewable energy consumption: The utilization of energy derived from naturally replenishable sources such as sunlight, wind, and water, contributing to sustainable energy practices (REN21, 2019).

CHAPTER ONE

INTRODUCTION

1.1 Overview

In this chapter the background information to the study, statement of the research problem, objectives of the study, and significance of the study, research hypotheses and the scope of the study have been discussed.

1.2 Background to the Study

Global warming and climate change remain the most important problems in the world (Stepanov *et al.*, 2023). Fossil fuels (oil, natural gas, coal) combustion emits large amounts of greenhouse gases (GHGs) such as carbon dioxide, causing environmental problems (Wang & Azam, 2024). Drought, natural disasters such as floods, and health hazards are all caused by climate change (Pizzorni, Innocenti & Tollin, 2024). Carbon emissions from fossil fuel combustion are the principal cause of climate change and a major source of harmful air pollution. Annually, more than seven million individuals succumb to the effects of air pollution both indoors and outdoors in their homes (WHO, 2017).

In recent years, greenhouse gas (GHG) emissions, and more specifically carbon dioxide, have received much attention for their adverse impacts on climate change and global warming (Ramirez-Corredores, Goldwasser & Falabella 2023). The importance of reducing environmental pollution and carbon dioxide emissions has grown more and more important (Kwakwa, 2023). The target greenhouse gas emissions are identified in the Kyoto Protocol signed in 1997. The main goal of this agreement is to keep global warming under 2 °C by reducing greenhouse gas emissions. After the Kyoto Protocol, nations have started to adopt the more sustainable energy sources (Eskander & Fankhauser, 2020). This protocol was further advocated at the 2015 Paris Conference

on Climate Change (the 21st Conference of the Parties, COP21), which was supported by the whole world and signed by 195 nations. The aim of the Paris Agreement is to limit the increase in global average temperature to below 2 °C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5 °C. It also aims to enable nations to fight climate change more effectively. Utilizing renewable energy resources to the maximum degree possible, rather than fossil fuels, is the most significant action. According to Gielen *et al.* (2019), renewable energy resources will meet 2/3 of the global energy demand by 2050. That will greatly reduce greenhouse gas emissions.

According to the EKC model, environmental pollution and economic growth have an inverse U-shaped relationship (Weimin *et al.*, 2022). Growth of GDP increases carbon emissions up to a certain point, after which they start to decrease. Numerous research has already examined the validity of the EKC theory; nonetheless, the results are still insufficient. Following the groundbreaking study of Kraft and Kraft (1978), the correlation between energy use and economic growth has been carefully investigated. All of the studies, however, either focus on developed countries or include both developed and developing country categories. However, developing countries receive less attention.

Rising nations in Sub-Saharan Africa still rely on more oil, coal and gas to achieve significant economic growth (Copinschi, 2022). However, this heavy use of fossil fuels is causing some problems of weak economic development (Baz *et al.*, 2021). The use of non-renewable energy has enhanced the economy, but the waste products from burning fossil fuels (Wolde-Rufael 2005; Narayan and Smyth 2005; Halicioglu 2011) have adversely affected the region's biological life and ecology. Although they know that their use will worsen the environment, developing economies are compelled to use

the readily available and cheap nonrenewable energy resources to achieve economic progress. These countries are reluctant to stop using non renewable energy sources since the eradication of poverty, food insecurity and economic expansion are prioritized over environmental quality (Sadorsky 2012; Bekhet and Harun 2012). The use of fossil fuels by developing nations has been consistently disregarded with regard to the environmental consequence of the use of fossil fuels for economic expansion, with the emission of harmful gases into the atmosphere (Hanif and Gago-de-Santos 2017; Hanif 2017).

Nigeria, Ghana, Cameroon, Madagascar, Mauritius, Uganda, and South Africa are highly rated among Sub-Saharan Africa's emerging nations as far as carbon dioxide emissions and other pollutants that are currently causing considerable biological harm are concerned (Byaro, Nkonoki & Mafwolo, 2023). It is alarming that air pollution alone kills about half a million people in Sub-Saharan Africa each year (World Health Organization 2016). Industrialization in developing countries is an important production of energy, but the high reliance on fossil fuels is causing air pollution, health problems, and land degradation (Bailis *et al.* 2005; Arouri *et al.* 2012; Al-Mulali and Sab 2012; Kiviyiro and Arminen 2014). However, most countries in Sub-Saharan Africa are heavily dependent on fossil fuels and other non-renewable energy sources to fuel their economies. In Sub-Saharan Africa and many other parts of the world, fossil fuels remain the most cost-effective energy sources for generation and are extensively used in the industrial sectors (Destek and Aslan 2017). But greenhouse gases are not part of the cost of manufacturing, as is traditional economic theory, and pollution of the environment is a negative externality that has to be reduced by stronger government regulations. Meanwhile, the increasingly severe effects of climate change are impacting society, the economy and the environment. These consequences are intimately linked

to the development patterns common to developing countries in Sub-Saharan Africa (Kiviyiro and Arminen 2014; Menyah and Wolde-Rufael 2010; Sebri and Ben-Salha 2014; Ezzo and Keho 2016). To overcome these environmental challenges, they must adopt a more sustainable type of economic progress. Given this, they may develop a sustainable development strategy to decrease their exposure to environmental issues and seek strategies that are more socially and equally cohesive (Hanif and Gago-de-Santos 2017).

In the case of Sub-Saharan Africa, the perspective of climate change has been skewed (Belianska *et al.*, 2022). That position and the extraordinary sensitivity of biodiversity make the region especially vulnerable to climate change. On average, oil is the primary fuel chosen to meet energy needs, and its carbon emissions increased at a rate of 2.6% between 2005 and 2015 in other regions of the world (World Health Organization 2016). At the same time, little has been studied regarding the link between economic growth, non-renewable energy use, and the results of African governments' steps (Cole 2004; Collier *et al.* 2008; Sulemana *et al.* 2017). Emerging countries that produce oil for such controlling CO₂ emissions may be difficult because whatever is done could ultimately choke off economic progress in regions where the production of natural gas and petroleum are major drivers of economic growth. Algeria, Angola, Egypt, Gabon, Nigeria, and other countries saw an increase in their average natural gas consumption from around 107.9 billion cubic feet in 1980 to about 327 billion cubic feet in 2000 and 759.5 billion cubic feet in 2015. This suggests that these countries' average natural gas consumption in 2015 increased by almost 604% and 133%, respectively, when compared to 1990 and 2000 numbers. From an average of 116.4 thousand barrels per day in 1980 and 213.2 thousand barrels per day in 2000 to roughly 339.2 thousand barrels per day in 2015, these countries used more petroleum products; these increases

corresponded to increases of roughly 191% and 59%, respectively, over their 1980 and 2000 figures. This shows that these economies' average GDP per capita increased by 15% between 1990 and 2015, while average carbon emissions increased by about 144% during the same period.

Anwar, Shabir & Hussain, (2011) have shown that the financial industry can have an impact on sustainability and economic development since the 2000s. There is conflicting data about the relationship between environmental quality and financial sector development (FD). FD makes investments in green technology more affordable for businesses and consumers (Gök 2020). Green practices and technology that reduce greenhouse gas emissions are adopted by people and businesses when the financial sector is established (Anger and Barker 2015; Atsu *et al.* 2021; Omoke *et al.* 2020a; Kim *et al.* 2023; Qayyum *et al.* 2021; Meo and Karim 2022). A well-developed financial sector could put the environment at risk by encouraging industrial and manufacturing processes, which would raise CO₂ emissions. Consumers may use energy-intensive equipment due to financial reasons as well (Gök 2020; Jiang and Ma 2019; Yao and Zhang 2021). Using commodities that need a lot of energy puts the environment in danger.

The standard proxies for financial development are the GDP's stock market capitalization or the percentage of private credit (Omoke *et al.* 2020a, b; Vo *et al.* 2021). However these metrics fail to take into account how complicated financial success is. According to Bayar *et al.* (2020) and Svirydzenka (2016), the IMF's Financial Development Index (FD) (IMF 2020a) provides an overview of the financial markets and institutions that, in contrast to other measures of the development of the financial sector, measure the size and liquidity of the financial sector; access: how simple it is

for individuals or businesses to obtain financial services; and efficiency: how well financial institutions are able to compete for business, generate sustainable profits from their services, and monitor the level of activity of the capital markets.

Underlying Sub-Saharan Africa's energy landscape is a dichotomy of enormous potential and serious economic obstacles (Sackeyfio, Sackeyfio & Pusca, 2018). A high rate of energy poverty and poor infrastructure plague the area even though it is rich in renewable resources, such as hydropower, wind, and solar energy. As mentioned, conventional biomass is still widely used as a fuel and is linked to both environmental damage and health problems (Moyo *et al.*, 2014). Stagnating growth and development in the region, the dependence on non-renewable energy sources exacerbates pre-existing vulnerabilities. Nonetheless, recent developments are encouraging; rising investment in renewable energy and declining costs due to technology breakthroughs have established these resources as potential economic drivers. Studies show that investments in renewable energy boost productivity across all sectors and create new jobs right now, which eventually contributes to GDP growth (Oyegbile *et al.*, 2024). Energy security and economic stability in Sub-Saharan Africa so depend on tackling the energy shortfall through sustainable means.

There are many reasons why this study decided to focus on Sub-Saharan Africa. Notable energy-related obstacles, such as a notable dependence on non-renewable energy sources and an insufficient infrastructure for renewable energy (International Energy Agency, 2019), are faced by the region in question. The relationship between energy, economic growth, and the environment is a crucial case to do research because the direct effects of the region's energy consumption habits on environmental sustainability and economic growth are felt in Sub-Saharan Africa. Second, many Sub-

Saharan African nations are rapidly industrializing and increasing their populations, which increases the pressure on the region's energy supplies and increases carbon emissions. Therefore, it is essential to investigate whether renewable energy can support sustainable growth and stop environmental damage. Finally, Sub-Saharan Africa's financial development remains uneven, and there is little understanding of how it might spur long term economic growth and clean energy investments. The purpose of concentrating on this area is to provide insights that can inform policy choices regarding environmental sustainability, energy use, and economic growth.

Financial institutions matter a great deal in determining both renewable energy consumption and carbon emissions. Financial depth is the extent to which financial institutions (such as banks and stock markets) contribute to the GDP of an economy (Tchamyou *et al.*, 2019). The more financial depth, the more likely financial resources will be allocated to sustainable projects that will increase renewable energy consumption and reduce carbon emissions, according to studies. Private credit and loans allocated to fund green initiatives are especially true (Xu *et al.*, 2022; M. Usman *et al.*, 2023). Nevertheless, the literature on the effects of financial depth on carbon emissions and renewable energy consumption in developing countries is still limited. As noted by Emenekwe *et al.* (2022a), this topic has received very little attention in developing nations. There have been only a few studies that looked at the relationship between financial depth, renewable energy, and carbon emissions in these regions. This research attempts to fill this gap by investigating whether similar patterns are present in countries with large financial depth.

In the Sub-Saharan African (SSA) region, where most countries have been pursuing democratic governance over the past four decades to support inclusive growth and development, the political landscape is especially important. Although the democracy

standards of SSA countries may not match those of more developed nations, many SSA countries have advanced in building democratic institutions that are important in assessing the effect of democracy on environmental degradation. According to Freedom House (2018), five of the eleven least effective democracies in the world are located in Africa: South Sudan, the Central African Republic, Somalia, Equatorial Guinea, Eritrea. According to Freedom House (2017), some 51 per cent of Africa's population, which exceeds one billion, live in countries that are free or partly free, up from 37 per cent in 2010 (Freedom House, 2010).

The theoretical foundation for democracy's environmental outcomes rests on the belief that democratic systems promote civic competence and empower citizens to participate in public dialogue so they can differentiate between collective and individual interests (Fiorino, 1990, p. 229). Environmental policies in democratic systems are shaped by the preferences of the median voter. Democratic systems adopt more stringent environmental standards because the median voter bears lower personal costs of environmental regulation than other groups of higher wealth or greater political privilege (Farzanegan and Markwardt, 2018; Bernauer and Koubi, 2009). They argue (Farzin and Bond 2006) that democratization increases citizen understanding of environmental issues, improves their ability to organize, and promotes activism, resulting in greater government accountability for environmental protection. In democratic settings, citizens are given the power to express their preferences and help influence the government decisions, so they are aware that there is a need for environmental preservation among the political leaders. Therefore, democratic governments tend to involve citizens in creating policies that foster community participation, social equity and sustainable behaviour (Freedom House, 2018).

Research further supports this relationship between democracy and environmental policy by showing that global policymakers are inclined to support environmental policies consistent with their ideological beliefs and thus influence the future course of climate policy (Scruggs, 1999). As confirmed by Harrison and Sundstrom (2007), the main determinants of whether environmental policies such as the Kyoto Protocol are adopted and implemented are the (ideological) positions of the political parties. On the other hand, scholars say that non democratic regimes tend to provide fewer public goods, and therefore are less likely to enforce stringent environmental standards (Deacon, 2009; Dizaji *et al.*, 2016; Lake and Baum, 2001; McGuire and Olson, 1996). In non-democratic states, such a small ruling elite often disproportionately carries the costs of improving environmental quality, thereby decreasing their incentive to enact effective environmental regulations (Farzanegan and Markwardt, 2018). As Dasgupta *et al.* (2002) also propose, institutional development is a slow process, but improving governance and supervision is crucial to reduce pollution and mitigate its adverse effects (Wang *et al.*, 2018).

Empirical research using different econometric methods and institutional proxies documents the large impact of institutions on the economic growth of countries (Acemoglu, Johnson, Robinson, & Thaicharoen, 2003; Esfahani & Ramírez, 2003; Flachaire, García-Peñalosa, & Konte, 2014; Fosu, 1992; Rodrik, Subramanian, & Trebbi, 2004). This large body of literature teaches the main lesson that countries with extractive institutions grow more slowly than those with growth supporting and efficient institutions.

A body of institutional economists has argued that differences in institutions among countries generate differences in economic development. Countries colonized by different European powers inherited different institutional frameworks during

colonization, according to North (1989, 1992), North, Summerhill and Weingast (2000), and Shirley (2008). The result has been divergent economic growth trajectories after colonization. For example, countries that were previously colonized by the British adopted British style institutions, while those that were previously colonized by the French inherited French institutional frameworks. This means that former British and former French colonies tend to have different levels of economic growth and institutional quality. Scholars such as Bertocchi and Canova (2002) and Grier (1999) have empirically supported this theoretical argument. La Porta, Lopez-de-Silanes, and Shleifer (2008, p. 286) assert that countries with British legal systems have better protection of property rights, better outcomes for private markets, stronger contract enforcement, and lower levels of judicial formalism. On the other hand, countries with French, German, or Scandinavian institutional origins have higher levels of government ownership and regulation, weaker property rights protection, and less effective contract enforcement. Building on these findings, this research departs from the assumption of institutional uniformity across nations.

The relationship between institutional quality, financial development, and carbon emissions is complicated in SSA. Financial development often contributes to economic growth which subsequently causes increased carbon emissions, but robust institutions can mitigate this outcome by encouraging cleaner technologies and sustainable practices (Sarkodie & Adams, 2018). In SSA, regions with better institutional quality are more likely to enforce effective environmental regulation that caps carbon emissions and promotes the uptake of renewable energy (Adu & Denkyirah, 2018). One of the biggest carbon emitters in the region, South Africa has made important progress in cutting its carbon footprint through institutional reforms and investments in renewable energy (Bhorat *et al.*, 2014). Financial development is usually worse for

environmental degradation in weaker institutional contexts, as economic pursuits are made without much regard for environmental sustainability (Asongu & Odhiambo, 2020).

In general, the institutional approach to renewable energy in SSA is characterized by an intermingling of supportive regulations and numerous obstacles to implementation. The possibilities renewable energy offers to help solve energy deficits and attain sustainable development are becoming clearer to governments in the region. Many countries have adopted policies to support investment in renewable energy, like feed-in tariffs, tax incentives and public private partnerships (Eberhard *et al.*, 2017). However, the effectiveness of these policies is often hindered by weak institutional capacity, bureaucratic inefficiencies, and inadequate infrastructure Hickey (2019). For instance, countries like Kenya and South Africa have been more successful in renewable energy efforts than others due to comparatively stronger institutional frameworks compared to those that struggle with inconsistent policy application and inadequate regulatory enforcement (Hansen *et al.*, 2020).

Resources mobilization through financial development is important for supporting renewable energy projects and sustainable development in SSA. The financial sector is expanding in many SSA countries, taking advantage of advances in banking, capital markets, and financial inclusion (Allen, Carletti, Cull, Qian, Senbet, & Valenzuela, 2021). The degree of financial development within the region is very variable, which is due to the robustness of financial institutions and the complete macroeconomic environment. Countries like South Africa and Nigeria have a higher level of financial system development, and accordingly, a higher availability of credit and financial services that can support investments in renewable energy and a range of green technologies. Although (Allen *et al.*, 2020) financial markets in many countries of Sub-

Saharan Africa are underdeveloped, which prevents access to financing for renewable energy initiatives, thereby limiting the region's potential for reducing carbon emissions (Yoshino, Taghizadeh-Hesary, & Nakahigashi, 2019).

The variable quality of institutions is critical in determining the effectiveness of policies on renewable energy consumption and financial development in SSA. Transparency, accountability, the rule of law, and effective regulation enforcement are distinguishing characteristics of quality institutions (Kaufmann, Kraay, & Mastruzzi, 2010). In SSA, the disparity in institutional quality is very pronounced, as some countries have resilient governance structures, while others struggle with corruption, political instability and weak regulatory frameworks. Often Botswana stands out as a case in point, because of its advanced institutional quality that has allowed for better governance of natural resources and the development of sustainable energy projects (Acemoglu & Robinson, 2010). On the contrary, the institutional quality of nations is deficient, especially in countries that are experiencing ongoing conflict or pervasive corruption, and they face great challenges to effective financial development and adoption of renewable energy technologies (Asongu & Odhiambo, 2020).

1.2.1 Economics of carbon emission

Carbon emissions, particularly carbon dioxide (CO₂), are at the core of the global climate crisis and represent a classic example of a negative externality in economic theory. Negative externalities occur when the social costs of a particular activity—such as pollution—are not reflected in market prices. In the case of carbon emissions, the producers of emissions (industries, vehicles, energy producers) do not bear the full societal cost of their environmental impact, leading to overproduction and overconsumption of fossil fuels (Stern, 2007). The consequence is a range of costly effects: public health deterioration due to poor air quality, climate-induced damages to

infrastructure, loss of biodiversity, and productivity losses in agriculture. These impacts disproportionately affect developing nations, further complicating efforts toward equitable global development.

To address these economic distortions, governments and policymakers have adopted market-based instruments aimed at internalizing the cost of emissions. Carbon taxes and cap-and-trade systems are two primary mechanisms used to realign economic incentives with environmental outcomes. Carbon taxes directly price emissions, creating a cost for carbon-intensive activities. Countries such as Sweden have demonstrated the success of this approach—its carbon tax, initiated in the early 1990s, significantly reduced emissions while maintaining steady GDP growth (Andersson, 2019). Cap-and-trade systems, such as the European Union Emissions Trading System (EU ETS), work by placing a limit on total emissions and allowing firms to trade emission permits. This creates a financial incentive to reduce emissions where it is most cost-effective (Ellerman, Convery, & de Perthuis, 2010). These instruments align private costs with social costs, enhancing overall economic efficiency and reducing emissions.

Carbon emissions intersect significantly with numerous United Nations Sustainable Development Goals (SDGs), reflecting their broad economic, social, and environmental impact. SDG 13, “Climate Action,” is the most directly related to carbon emissions, urging countries to take urgent steps to combat climate change and its effects. Emission reduction strategies such as carbon pricing, transition to renewable energy, and energy efficiency measures directly contribute to achieving SDG 13 (UNFCCC, 2015). These actions also bolster resilience and adaptive capacities in vulnerable regions, mitigating the worst impacts of climate volatility.

The relationship between carbon emissions and SDG 7, “Affordable and Clean Energy,” is also significant. A major source of emissions is energy production from fossil fuels. Replacing these sources with renewable alternatives such as wind, solar, and hydroelectric power reduces emissions while ensuring sustainable energy access. This transition not only mitigates environmental harm but also offers economic opportunities through green jobs and investment in clean energy infrastructure (IRENA, 2020). Similarly, SDG 9, which focuses on industry, innovation, and infrastructure, emphasizes the importance of building resilient infrastructure and promoting inclusive, sustainable industrialization. Innovation in carbon capture, low-emission manufacturing processes, and smart infrastructure plays a vital role in decarbonizing economic activities and fostering sustainable growth (OECD, 2017).

Urbanization, captured under SDG 11, “Sustainable Cities and Communities,” is another crucial area of intersection. Cities are responsible for a significant proportion of global emissions due to high energy demand, transport emissions, and waste. Sustainable urban planning, improved public transportation, and energy-efficient building standards can substantially reduce carbon footprints in urban settings (UN-Habitat, 2016). Moreover, responsible consumption and production, the focus of SDG 12, directly addresses unsustainable practices that drive high emission levels. Promoting circular economies, waste reduction, and sustainable supply chains are all strategies that contribute to both SDG 12 and global emission reduction efforts (UNEP, 2011).

SDG 8, which advocates for decent work and economic growth, connects with the carbon agenda through the transition to a low-carbon economy. Green sectors—such as renewable energy, sustainable agriculture, and energy efficiency—present considerable employment opportunities. Studies from the International Labour Organization (ILO,

2018) estimate that adopting greener practices can result in a net positive impact on employment globally, supporting both economic and environmental sustainability.

The effects of carbon emissions on human health establish a link with SDG 3, “Good Health and Well-being.” Air pollution caused by the burning of fossil fuels leads to respiratory diseases, cardiovascular conditions, and premature deaths, especially in densely populated or low-income areas. Reducing emissions, therefore, has the co-benefit of improving air quality and health outcomes (WHO, 2018). In turn, this reduces healthcare costs and increases productivity, contributing to broader economic and developmental gains.

Agriculture is both a victim and contributor to carbon emissions, which ties into SDG 2, “Zero Hunger.” Changes in climate patterns—resulting from elevated CO₂ levels—threaten crop yields, alter growing seasons, and increase the frequency of extreme weather events like droughts and floods. Carbon mitigation helps stabilize climatic conditions, supporting sustainable food production and rural livelihoods (FAO, 2016). This is particularly important in sub-Saharan Africa and parts of Asia, where food insecurity remains a pressing challenge.

Water systems are also under threat due to climate-induced variability in precipitation, drought, and water pollution. These impacts are central to SDG 6, “Clean Water and Sanitation.” Carbon emission reductions contribute to mitigating water scarcity risks by stabilizing climate conditions and reducing temperature extremes that exacerbate water stress (UN-Water, 2018). These measures support integrated water resource management and the sustainability of water ecosystems.

Lastly, carbon emissions and climate change contribute to biodiversity loss and the degradation of terrestrial ecosystems, making them highly relevant to SDG 15, “Life

on Land.” Forests, wetlands, and other ecosystems act as carbon sinks but are also vulnerable to the impacts of climate change. Preserving these systems not only aids in carbon sequestration but also supports biodiversity, ecosystem services, and livelihoods dependent on natural resources (IPBES, 2019). The interdependence between carbon emissions and biodiversity preservation underscores the need for integrated solutions that address ecological and climate priorities simultaneously.

1.3 Statement of the Problem

Sub-Saharan Africa is pursuing rapid structural transformation under persistent energy poverty, yet its growth trajectory is increasingly carbon-constrained (Armah & Baek, 2018). Africa emitted about 1,261.7 MtCO₂ from fuel combustion in 2023, accounting for 3.6% of global CO₂ emissions with emissions concentrated in a few large economies, but rising energy demand across the region (International Energy Agency, 2023). At the same time, many SSA countries still have very low per-capita emissions approximately 0.1 tCO₂/person/year in some of the poorest SSA states, underscoring that low emissions often reflect limited modern energy use rather than low-carbon development (Ritchie & Roser, n.d.). This creates a policy dilemma: expanding energy consumption to support economic growth and financial deepening may accelerate fossil-based emissions if institutions and energy systems do not guide investment toward cleaner technologies (IEA, 2023).

Empirically, the carbon-growth-energy linkage remains unsettled in SSA. Panel evidence shows that economic growth and energy consumption significantly raise CO₂ emissions; for example, a 1% increase in economic growth is associated with ~0.02% higher CO₂ emissions in a multi-country SSA sample (Alaganthiran & Anaba, 2022). However, causality patterns can vary across regions and contexts, implying that a single narrative about growth–energy–emissions may be misleading (Acheampong, 2018).

Findings are also mixed on financial development (FD): some studies report that FD increases emissions including evidence that population growth and FD raise CO₂ in SSA (Acheampong et al., 2019), while others find that aggregate FD reduces emissions over the long run (Emenekwe et al., 2022). Likewise, institutional quality shows ambiguous direct effects sometimes neutral-yet becomes important through interaction channels where stronger institutions can shift activities toward lower-carbon outcomes (Maji et al., 2023).

These contradictions point to a conceptual gap where there is limited integration of energy consumption, economic growth, FD, and institutional quality jointly, and insufficient treatment of institutional quality as a moderator, and a methodological gap where many studies rely on single estimators despite endogeneity and unobserved heterogeneity. Addressing this requires designs that combine fixed effects to control time-invariant country heterogeneity with GMM/System-GMM robustness to mitigate simultaneity and dynamic endogeneity, while explicitly modelling the moderating role of institutional quality to explain why the same drivers can yield divergent emissions outcomes across SSA (Acheampong et al., 2021; Acheampong et al., 2019).

1.4 Objectives

1.4.1 Specific Objectives

The aim of the study was to investigate the moderating role of institutional quality on the relationship between Energy consumption, Economic Growth, Financial development and Carbon emissions in Sub-Saharan Africa.

1.4.2 Specific Objectives

The study was guided by several specific objectives as show below.

- a) To determine the effect of renewable energy consumption on carbon emissions in Sub-Saharan Africa
- b) To assess the effect of non-renewable energy consumption on carbon emissions in Sub-Saharan Africa
- c) To Investigate the effect of economic growth on carbon emissions in Sub-Saharan Africa
- d) To determine the effect of financial development on carbon emissions in Sub-Saharan Africa
- e) To establish the moderating effect of institutional quality on the relationship between;
 - i. Renewable energy consumption and carbon emissions in Sub-Saharan Africa
 - ii. Non-renewable energy consumption and carbon emissions in Sub-Saharan Africa
 - iii. Economic growth and carbon emissions in Sub-Saharan Africa
 - iv. Financial development and carbon emissions in Sub-Saharan Africa

1.5 Hypotheses of the Study

This study was guided by the following hypotheses:

- H₀₁:** Renewable energy consumption has no significant effect on Carbon emissions in Sub-Saharan Africa
- H₀₂:** Non-renewable energy consumption has no significant effect on Carbon emissions in Sub-Saharan Africa

- H03:** Economic growth has no significant effect on Carbon emissions in Sub-Saharan Africa
- H04:** Financial development has no significant effect on Carbon emissions in Sub-Saharan Africa
- H05:** Institutional quality does not moderate the relationship between;
- H05a:** Renewable energy consumption and Carbon emissions in Sub-Saharan Africa
- H05b:** Non-renewable energy consumption and Carbon emissions in Sub-Saharan Africa
- H05c:** Economic growth and Carbon emissions in Sub-Saharan Africa
- H05a:** Financial development and Carbon emissions in Sub-Saharan Africa

1.6 Significance of the Study

Investors are increasingly recognizing the importance of sustainability and environmental considerations in their decision-making processes. Understanding the dynamics of energy consumption choices, institutional quality, carbon emissions, and economic growth in Sub-Saharan Africa can provide valuable insights for investors seeking opportunities in the region. By assessing the environmental sustainability of investment projects, identifying emerging trends in renewable energy adoption, and evaluating the impact of institutional factors on investment risks, investors can make more informed decisions that align with their environmental, social, and governance (ESG) criteria. Moreover, insights from the study can help investors identify potential areas for sustainable investment and contribute to the transition towards a low-carbon economy in Sub-Saharan Africa.

Policymakers play a crucial role in shaping energy policies, regulatory frameworks, and institutional reforms that influence energy consumption patterns, carbon emissions, and economic growth. Understanding the complex interrelationships between these factors in Sub-Saharan Africa can inform the design and implementation of effective policies to promote sustainable development. Policymakers can use insights from the study to develop strategies for enhancing institutional quality, fostering investment in renewable energy infrastructure, and promoting energy efficiency initiatives. By addressing institutional weaknesses, strengthening regulatory frameworks, and incentivizing clean energy investments, policymakers can create an enabling environment for sustainable development and climate action in the region.

Academia plays a vital role in advancing knowledge and understanding in areas related to energy, sustainability, and economic development. Research on energy consumption choices, institutional quality, carbon emissions, and economic growth in Sub-Saharan Africa contributes to academic scholarship by generating new insights, theories, and empirical evidence. Academics can use findings from the study to develop theoretical frameworks, test hypotheses, and refine methodologies for studying complex socio-economic and environmental issues. Moreover, academic research can inform interdisciplinary collaborations, policy debates, and capacity-building efforts aimed at addressing the region's energy and sustainability challenges. By engaging with stakeholders and disseminating research findings, academia can facilitate evidence-based policymaking and contribute to sustainable development goals in Sub-Saharan Africa and beyond.

1.7 Justification of the Study

Sub-Saharan Africa faces significant energy access challenges, with millions of people lacking access to reliable and affordable energy sources. Understanding energy

consumption patterns and their implications for economic growth can help identify strategies to improve energy access, promote industrialization, and stimulate economic development in the region. By examining how institutional factors influence energy consumption choices and economic outcomes, research can inform policy interventions aimed at enhancing energy security and fostering sustainable development.

Sub-Saharan Africa is particularly vulnerable to the impacts of climate change, including extreme weather events, droughts, and food insecurity. Addressing carbon emissions and promoting sustainable energy practices are essential for mitigating climate change and building resilience to its adverse effects. Research on carbon emissions, institutional quality, and economic growth can provide valuable insights into the drivers of environmental degradation and opportunities for transitioning towards cleaner and more sustainable energy systems in the region. By identifying policy measures to reduce carbon emissions while promoting economic growth, research can contribute to global efforts to combat climate change and achieve sustainable development goals.

Institutional quality plays a critical role in shaping energy policies, regulatory frameworks, and investment climates in Sub-Saharan Africa. Weak governance structures, corruption, and regulatory barriers often hinder investment in renewable energy infrastructure and sustainable development initiatives. Research on institutional quality and its impact on energy consumption choices and economic growth can help identify areas for institutional reforms, capacity-building, and governance improvements. By strengthening institutions, enhancing transparency, and promoting accountability, research can support efforts to create an enabling environment for sustainable development and attract investment in clean energy technologies.

The energy and sustainability challenges facing Sub-Saharan Africa have regional and global implications, including energy security, migration, and geopolitical stability. Understanding the dynamics of energy consumption, carbon emissions, and economic growth in the region can provide insights into regional energy dynamics, trade patterns, and geopolitical risks. Research can also inform international collaborations, technology transfers, and financial mechanisms aimed at supporting clean energy transitions and sustainable development in Sub-Saharan Africa. By engaging with stakeholders and sharing best practices, research can contribute to regional cooperation and global efforts to address climate change and promote sustainable development

1.8 Scope of the Study

The study covered energy consumption, institutional quality, carbon emissions and economic growth. The study was limited to the two main energy consumption type that is, renewable energy consumption and non-renewable energy consumption. The study focused on 49 countries in Sub-Saharan Africa between the years 2000 to 2023. The study employed secondary data and panel approach as it involved observing a broad cross section of countries over time. Inclusion/Exclusion criteria led a final sample of 552 country year observations. The study employed environmental Kuznets curve as the main theory and energy transition and institutional theories as supplementary theories.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter discusses the concepts, theories, empirical and conceptual framework of the research.

2.2 Concepts of study

2.2.1 Carbon dioxide emissions

Carbon emissions refer to the release of carbon dioxide (CO₂) and other greenhouse gases into the atmosphere, primarily as a result of human activities such as burning fossil fuels, deforestation, and industrial processes (Intergovernmental Panel on Climate Change [IPCC], 2019). These emissions contribute to the greenhouse effect, trapping heat in the Earth's atmosphere and leading to global warming and climate change.

Carbon emissions originate from various sources, with the burning of fossil fuels for energy production being the largest contributor (IPCC, 2019). Activities such as electricity generation, transportation, industrial manufacturing, and residential heating all release significant amounts of CO₂ into the atmosphere. Additionally, deforestation and land-use changes disrupt the natural carbon cycle, releasing stored carbon from vegetation and soil into the atmosphere.

The accumulation of carbon emissions in the atmosphere has far-reaching environmental, social, and economic consequences. Rising temperatures and changes in precipitation patterns lead to more frequent and severe weather events, sea-level rise, loss of biodiversity, and disruptions to ecosystems and agriculture (IPCC, 2019). These

impacts disproportionately affect vulnerable communities, exacerbating inequalities and threatening food security, water resources, and human health.

Addressing carbon emissions is a critical component of global efforts to mitigate climate change and transition towards a low-carbon economy. Mitigation strategies include increasing energy efficiency, transitioning to renewable energy sources, implementing carbon pricing mechanisms, and promoting sustainable land-use practices (IPCC, 2019). Additionally, efforts to enhance carbon capture and storage technologies and restore ecosystems can help offset emissions and achieve carbon neutrality.

2.2.2 Renewable energy

Renewable energy refers to energy derived from natural resources that are replenished continuously or on a human timescale. These resources include sunlight, wind, rain, tides, waves, and geothermal heat (Renewable Energy Policy Network for the 21st Century [REN21], 2017). Unlike fossil fuels, which are finite and contribute to environmental degradation, renewable energy sources offer a sustainable and environmentally friendly alternative for meeting energy demands.

Renewable energy encompasses various sources, each with distinct characteristics and applications. Solar energy, obtained from sunlight through photovoltaic cells or solar thermal systems, is one of the most abundant and widely utilized renewable energy sources (REN21, 2017). Wind power harnesses the kinetic energy of wind to generate electricity through turbines, while hydropower relies on the gravitational force of flowing or falling water to drive turbines and produce electricity. Additionally, biomass energy utilizes organic materials such as wood, agricultural residues, and waste to generate heat or electricity through combustion or biochemical processes.

The adoption of renewable energy offers numerous benefits, including mitigating climate change, enhancing energy security, and promoting economic development (REN21, 2017). By reducing greenhouse gas emissions and dependency on fossil fuels, renewable energy technologies contribute to global efforts to combat climate change and minimize environmental degradation. Moreover, investing in renewable energy infrastructure creates job opportunities, fosters innovation, and stimulates economic growth, particularly in regions with abundant renewable resources.

Despite its potential, the widespread deployment of renewable energy faces several challenges, including intermittency, grid integration, and initial investment costs (REN21, 2017). Intermittent energy sources such as solar and wind pose challenges for grid stability and reliability, necessitating advancements in energy storage and grid management technologies. Additionally, the upfront costs of renewable energy installations, although declining, remain a barrier to adoption for some countries and communities. However, ongoing technological advancements, supportive policies, and international cooperation offer opportunities to overcome these challenges and accelerate the transition towards a sustainable energy future.

2.2.3 Non-renewable energy

Non-renewable energy refers to energy sources that are finite and cannot be replenished on a human timescale, typically extracted from fossil fuels such as coal, oil, and natural gas, as well as nuclear fuels like uranium (United Nations, 2017). Unlike renewable energy sources, which are continuously replenished by natural processes, non-renewable energy reserves are finite and will eventually be depleted with continued consumption.

Non-renewable energy sources are categorized into several types, primarily fossil fuels and nuclear energy. Fossil fuels, including coal, oil, and natural gas, are formed from the remains of ancient plants and animals that were buried and subjected to geological processes over millions of years (United Nations, 2017). These fuels are extracted from underground deposits and converted into energy through combustion or other industrial processes. Nuclear energy, on the other hand, is generated by nuclear reactions, primarily through the fission of uranium isotopes in nuclear power plants.

While non-renewable energy sources have played a crucial role in powering modern industrial societies, their extraction, processing, and combustion pose significant environmental and socio-economic challenges (United Nations, 2017). The burning of fossil fuels releases greenhouse gases and other pollutants into the atmosphere, contributing to climate change, air pollution, and adverse health effects. Moreover, the extraction of fossil fuels often involves destructive mining practices, habitat destruction, and water pollution, leading to environmental degradation and ecosystem disruption. Additionally, the finite nature of non-renewable energy reserves raises concerns about energy security, price volatility, and geopolitical tensions associated with resource extraction and distribution.

Given the environmental and socio-economic challenges posed by non-renewable energy sources, there is increasing global momentum towards transitioning to renewable energy alternatives (United Nations, 2017). Renewable energy technologies offer a sustainable and environmentally friendly alternative to fossil fuels, with the potential to mitigate climate change, enhance energy security, and promote socio-economic development. By investing in renewable energy infrastructure, implementing supportive policies, and fostering innovation, countries can accelerate the transition towards a more sustainable and resilient energy future.

2.2.4 Economic growth

Economic growth refers to the sustained increase in an economy's production of goods and services over time, usually measured by the rise in gross domestic product (GDP). It signifies the expansion of an economy's capacity to produce goods and services, reflecting an improvement in the standard of living and well-being of its citizens (Mankiw, 2015).

Several factors contribute to economic growth, including technological advancement, investment in physical and human capital, innovation, and efficient allocation of resources (Acemoglu & Robinson, 2015). Technological progress, in particular, plays a pivotal role in stimulating productivity gains and fostering long-term economic growth by enabling firms to produce more output with the same level of inputs.

Economic growth generates numerous positive outcomes for a society, such as higher incomes, increased employment opportunities, and enhanced living standards (Barro & Sala-i-Martin, 2015). It allows nations to address various socio-economic challenges by generating resources for public investment in infrastructure, education, healthcare, and social welfare programs.

However, sustainable economic growth requires careful consideration of environmental concerns and inclusive development strategies (Stiglitz, Sen, & Fitoussi, 2015). Policymakers must prioritize policies that promote environmental sustainability, reduce income inequality, and ensure equitable access to economic opportunities to foster inclusive growth and mitigate adverse social consequences.

2.2.5 Financial development

Financial development refers to the process of enhancing and deepening financial systems within an economy, encompassing various aspects such as the growth and

sophistication of financial institutions, the expansion of financial markets, the development of regulatory frameworks, and the improvement of financial infrastructure. It plays a pivotal role in facilitating economic growth, reducing poverty, and promoting stability by efficiently mobilizing savings, allocating capital, facilitating investments, managing risks, and fostering innovation and entrepreneurship (Beck & Cull, 2018; Claessens & Perotti, 2018).

Financial development involves the improvement of financial intermediation mechanisms, such as banks and other financial institutions, in efficiently channeling funds from savers to investors. This process includes enhancing access to credit, reducing information asymmetries, improving corporate governance practices, and strengthening risk management frameworks (Demirgüç-Kunt & Levine, 2018; Allen & Carletti, 2018).

Financial development also entails the expansion and deepening of financial markets, including equity, bond, and derivative markets, to provide diverse investment opportunities and facilitate efficient price discovery. A well-developed financial market enables firms to raise capital, investors to diversify portfolios, and households to manage risks through insurance and pension products (Levine, 2018; Panetta et al., 2018).

Effective regulatory frameworks are essential for ensuring the stability, integrity, and efficiency of financial systems. Financial development involves the establishment and enforcement of prudential regulations, market conduct rules, and consumer protection measures to mitigate systemic risks, prevent financial fraud and misconduct, and promote fair and transparent financial practices (Claessens & Perotti, 2018; Demirgüç-Kunt & Levine, 2018).

Financial development encompasses the enhancement of financial infrastructure, including payment systems, credit information registries, and legal frameworks, to reduce transaction costs, enhance transparency, and facilitate the smooth functioning of financial markets and intermediaries (Allen & Carletti, 2018; Claessens & Perotti, 2018).

2.2.6 Institutional Quality

Institutional quality refers to the effectiveness, efficiency, and credibility of institutions within a society, encompassing the rule of law, property rights protection, government accountability, regulatory frameworks, and governance structures (World Bank, 2019). High institutional quality fosters trust, stability, and predictability, facilitating economic development, social cohesion, and overall well-being within a country.

The quality of institutions is a crucial determinant of a country's economic performance and social progress (World Bank, 2019). Strong institutions provide a conducive environment for investment, entrepreneurship, and innovation, fostering economic growth and poverty reduction. Indicators of institutional quality include the level of corruption, judicial independence, regulatory efficiency, government transparency, and the effectiveness of public services.

Institutional quality influences various aspects of development, shaping the distribution of resources, the efficiency of markets, and the effectiveness of public policies (Acemoglu & Robinson, 2019). Countries with well-functioning institutions tend to attract higher levels of investment, promote business confidence, and achieve more equitable distribution of wealth. Conversely, weak or corrupt institutions hinder economic activity, perpetuate inequality, and undermine social trust and cohesion.

Improving institutional quality often requires comprehensive reforms aimed at enhancing the rule of law, strengthening regulatory frameworks, and combating corruption (World Bank, 2019). However, institutional reforms face numerous challenges, including resistance from vested interests, capacity constraints, and political obstacles. Nonetheless, successful efforts to improve institutional quality can yield significant dividends in terms of economic growth, poverty reduction, and overall societal well-being.

2.3 Theoretical literature

This section outlines the theories that will be used in this study. The study will be guided by the following theories: The environmental Kuznet curve theory, Energy transition theory and Institutional theory.

2.3.1 The Environmental Kuznets Curve (EKC) theory

The Environmental Kuznets Curve (EKC) theory posits a nonlinear relationship between environmental degradation and economic development, suggesting that environmental quality initially deteriorates as economies grow but improves beyond a certain income level. During the early stages of economic development in SSA countries, there might be an increase in CO₂ emissions due to industrialization and growing energy demands, often met by conventional and fossil fuel-based energy sources (Stern, 2004). As income levels rise, so does the consumption of energy, and this could contribute to a rise in emissions.

However, as economies in SSA progress and reach a certain income threshold, there is an opportunity for a transition to cleaner and more sustainable energy sources. Countries may invest in renewable energy technologies and, in some cases, nuclear energy, as part of a strategy to decouple economic growth from environmental

degradation (Grossman & Krueger, 1995). This transition aligns with the descending portion of the EKC, where environmental quality improves as income continues to rise.

Several studies have explored the applicability of the EKC theory to SSA. For instance, Paul and Guilhoto (2005) found evidence supporting an EKC for CO₂ emissions in South Africa, indicating a potential turning point where economic growth could lead to environmental improvement. Similarly, Mert, Arik, and Senses (2016) observed an inverted U-shaped relationship between economic growth and environmental degradation in African countries.

The adoption of cleaner technologies and policies that promote sustainability could expedite the shift towards the declining phase of the EKC. Policies promoting renewable energy sources and, where applicable, nuclear energy, become crucial in determining the turning point in the environmental-economic relationship (Jayanthakumaran et al., 2012)

2.3.2 Energy Transition Theory

The transition involves a shift from centralized, fossil fuel-based power generation to decentralized, cleaner alternatives. Renewable energy sources such as solar, wind, and hydropower contribute to diversifying the energy mix (IRENA, 2021). Nuclear energy, while controversial, is considered by some countries as a low-carbon option to meet growing energy demands (World Nuclear Association, 2021).

The economic aspect of energy transition in SSA is crucial. The adoption of renewable and nuclear energy is not merely an environmental imperative but is closely intertwined with economic growth. Renewable energy investments can stimulate economic activities, create jobs, and enhance energy access (IRENA, 2019). Similarly, the

development of nuclear energy infrastructure can contribute to technological advancement and economic diversification (World Nuclear Association, 2021).

The success of energy transition in SSA is contingent on various factors, including policy frameworks, technological advancements, and international cooperation. Adequate policies should incentivize the private sector to invest in renewable and nuclear projects, ensuring a sustainable and resilient energy future for the region (IRENA, 2021). Additionally, capacity building and knowledge transfer are essential components for fostering a skilled workforce capable of managing and sustaining these technologies (World Nuclear Association, 2021).

In conclusion, energy transition theory provides a conceptual framework for understanding the ongoing changes in the energy sector of Sub-Saharan Africa. The adoption of renewable and nuclear energy is not only an environmental necessity but a strategic pathway toward achieving economic growth while mitigating carbon emissions.

2.3.3 Institutional Theory

Institutional quality theory, pioneered by scholars like Daron Acemoglu and James A. Robinson, posits that the quality of institutions within a society profoundly influences its economic performance and development trajectory (Acemoglu & Robinson, 2012). Institutional quality encompasses the effectiveness of governance structures, the rule of law, property rights protection, regulatory frameworks, and the absence of corruption. Within the context of energy consumption choices and their impact on economic growth, institutional quality plays a pivotal moderating role.

Acemoglu and Robinson argue that high-quality institutions create an enabling environment conducive to investment, innovation, and entrepreneurship, thereby

fostering economic growth (Acemoglu & Robinson, 2012). In the realm of energy consumption choices, institutional quality influences the efficiency and effectiveness of resource allocation, infrastructure development, and policy formulation. Countries with strong institutions are better equipped to implement sound energy policies, attract investment in renewable energy technologies, and promote energy efficiency measures, leading to sustainable economic growth (Acemoglu & Robinson, 2012).

Furthermore, Strong institutions can enforce environmental regulations, incentivize the adoption of cleaner energy sources, and facilitate international cooperation on climate change mitigation efforts (Acemoglu & Robinson, 2012). Conversely, countries with weak institutions may struggle to implement and enforce environmental policies, leading to higher levels of carbon emissions associated with energy production and consumption (Acemoglu & Robinson, 2012).

For instance, countries with robust institutional frameworks, such as Norway and Sweden, have successfully transitioned towards renewable energy sources and implemented carbon pricing mechanisms, resulting in lower carbon emissions per unit of GDP (Acemoglu & Robinson, 2012; IEA, 2020). In contrast, countries with weaker institutional quality, such as some Sub-Saharan African nations, face challenges in promoting clean energy transitions due to regulatory inconsistencies, corruption, and limited enforcement capacity (Transparency International, 2020). As a result, they may continue to rely heavily on fossil fuels, contributing to higher carbon emissions and environmental degradation (IEA, 2020).

2.4 Empirical literature

This study discusses empirical literature regarding renewable energy consumption, non-renewable energy consumption, economic growth, financial development and

carbon emissions. Institutional quality and carbon emissions. Population, industrialization, foreign direct investment and carbon emissions.

2.4.1 Direct Effect

2.4.1.1 Renewable energy consumption and Carbon emissions

Abbasi, *et al.*, (2021) reported that Thailand's Nationally Determined Contribution (NDC) aimed to reduce CO₂ emissions by 20-25%. In order to successfully reach the long-term goal of the Paris Agreement, which is to keep global temperature rise well below 2 °C, it is imperative to take bold and proactive measures for reducing greenhouse gas emissions beyond the year 2030. The study investigated the influence of the rate at which energy is depleted, the consumption of renewable energy, the rate at which non-renewable energy is depleted, and the GDP on CO₂ emissions in Thailand from 1980 to 2018, considering their significance. The study employed a novel dynamic ARDL simulations model [1] and conducted a frequency domain causality (FDC) test. The empirical results showed that the rate of depletion had a substantial negative effect on CO₂ emissions, both in the long term and the short term. In addition, our findings indicated that renewable energy had a significant and negative effect on CO₂ emissions in the short term. Nevertheless, the rate at which non-renewable energy is being used up and the gross domestic product (GDP) have been found to have a significant and positive impact on carbon dioxide (CO₂) emissions, both in the short term and in the long term, according to statistical analysis. The FDC test has verified the presence of causality in the short, medium, and long term between DR, RE, DRNRE, and CO₂ emission.

In their study, Yuping, *et al.*, (2021) aimed to assess the impact of globalization, renewable energy consumption, non-renewable energy consumption, and economic growth on carbon dioxide emissions in Argentina from 1970 to 2018. The econometric

methodology employed in this study utilized robust methods to address structural break issues in the data. The Maki cointegration analysis, which accounted for multiple structural breaks, identified significant long-term relationships between carbon-dioxide emissions, renewable and non-renewable energy consumption, globalization, and economic growth. The Autoregressive Distributed Lag analysis of models revealed that renewable energy consumption and globalization have a negative impact on emissions, while non-renewable energy consumption has a positive impact on emissions, both in the short- and long-term. In addition, it was discovered that the combination of globalization and renewable energy consumption led to a decrease in emissions. Conversely, the combination of globalization and non-renewable energy consumption led to an increase in emissions, but only in the long-term.

Saidi and Omri (2020) conducted a study to analyze the effects of renewable and nuclear energy consumption on CO₂ emissions in 15 OECD countries from 1990 to 2018. They used two estimation methods, namely the Fully Modified OLS (FMOLS) and the vector error correction model approach (VECM), to examine both the short-term and long-term impacts. The findings from the FMOLS analysis indicated that investment in nuclear energy led to a decrease in CO₂ emissions in several countries including Canada, Netherlands, Japan, Switzerland, Czech Republic, and UK. On the other hand, investment in renewable energy resulted in a decrease in CO₂ emissions in Belgium, Canada, France, Germany, Sweden, UK, US, Japan, Switzerland, Finland, and Czech Republic, but it led to an increase in CO₂ emissions in Netherlands and South Korea. Furthermore, both nuclear and renewable energy consumption contributed to a reduction in carbon emissions based on the panel estimations. Furthermore, the findings from the VECM approach demonstrated that nuclear and renewable energies have a long-term effect in decreasing CO₂ emissions.

Chen, *et al.*, (2022) conducted a comprehensive analysis of the relationship between energy and economic growth and carbon dioxide (CO₂) emissions per capita in response to growing concerns about climate change. This study contributed to the existing body of literature on the subject. Most of the previous studies used different linear panel estimation methods without considering the possible nonlinear impacts of energy and income on per capita CO₂ emissions. In order to address this deficiency, this research employed panel data encompassing 97 countries from 1995 to 2015. It investigated the non-linear effects of renewable and non-renewable energy consumption, as well as economic growth, on per capita CO₂ emissions. This investigation utilized a dynamic panel threshold model that is resilient to cross-section dependence. The results of our study showed that there is a negative and significant relationship between the increase in per capita renewable energy consumption and the growth of per capita CO₂ emissions, but only when countries exceed a certain threshold of renewable energy consumption.

In their study, Jamil, *et al.*, (2022) aimed to conduct a comparative analysis of CO₂ emissions, renewable energy usage, trade openness, gross domestic product (GDP), financial development (FD), and remittance in a specific group of G-20 countries. The study utilized fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) models to estimate annual data from 1990 to 2019. The LM tests identified the presence of cross-section dependability, while the stationarity of the variables was assessed using the Levin-Lin-Chu and Im-Pesaran-Shin tests, as well as Hansen's Covariate-Augmented Dickey Fuller (CADF) test, considering the existence of cross-section dependency. The panel unit root tests indicated that all variables achieved stationarity after being transformed into their first differences. The Panel Cointegration and Wester-Lund test investigated whether there is a long-term

equilibrium relationship among specific variables in the G-20 countries. The study's results revealed a substantial and adverse correlation between renewable energy and CO₂ emissions. Two models demonstrated a positive correlation between the economic growth of specific G-20 countries and their CO₂ emissions. Moreover, the results revealed that the financial development coefficient has a positive and significant effect on CO₂ emissions. The remittances had a substantial and beneficial impact on CO₂ emissions, while trade openness had a negligible effect on CO₂ emissions across the two models.

Namahoro, *et al.*, (2021) conducted a study to investigate the relationship between energy consumption, economic growth, and CO₂ emissions at both regional and global levels, taking into account different levels of development. Only a small number of studies conducted at the African level failed to consider the variations in regions and income levels among the countries included in the research. This study conducted an empirical analysis to investigate the long-term effects of energy intensity, renewable energy consumption, and economic growth on CO₂ emissions in 50 African countries across different regions and income levels from 1980 to 2018. State-of-the-art panel estimators, causality tests, and analysis of impulse response and variance decomposition were utilized. The panel estimators' findings indicated that the consumption of renewable energy significantly helped to reduce CO₂ emissions. However, energy intensity was found to increase emissions across different regions and income levels, including at the African level. Economic growth had a detrimental negative impact on CO₂ emissions at the African level, although the effect varied across regions and income levels. The causality test has confirmed the presence of bi-directional causations between CO₂ emissions and its determinants in various regions and income levels in Africa.

Dong, *et al.*, (2020) argue that previous studies often overlooked the substantial disparity in the relationship between emissions and renewable energy across countries with varying income levels. An empirical study was conducted to examine whether the impact of renewable energy consumption on carbon dioxide (CO₂) emissions varies among countries with different income levels. The study analyzed a global panel of 120 countries and divided them into four subpanels based on income levels. The data covered the period from 1995 to 2015. By taking into account the possible cross-sectional dependence and variation in slopes, a range of econometric methods that accommodate cross-sectional dependence and slope heterogeneity are employed. Both the global panel and all four subpanels exhibit confirmed cross-sectional dependence and slope heterogeneity. The validity of the environmental Kuznets curve (EKC) hypothesis was observed only in the global panel, high-income subpanel, and upper-middle-income subpanel. While renewable energy consumption does have a negative impact on CO₂ emissions, its influence is not substantial.

Saidi and Omri (2020) did a study to analyze the impact of renewable energy on economic growth and carbon emissions in 15 major renewable energy-consuming countries. This will be done using fully modified ordinary least square (FMOLS) and vector error correction model (VECM) estimation techniques. The FMOLS technique results demonstrated the effectiveness of renewable energy in enhancing economic growth and decreasing carbon emissions. The VECM Granger causality test revealed bidirectional causality between economic growth and renewable energy in both short- and long-run for both estimated functions, confirming the feedback hypothesis. Additionally, it shows there is no causal connection between the emissions of carbon dioxide and renewable energy in the long-run, but there is a bidirectional causal connection between the two variables in the short-run.

Adams & Acheampong (2019) did a study to investigate how democracy and renewable energy affect carbon emissions in 46 sub-Saharan African nations utilizing imbalanced data from 1980 to 2015. The study utilized an instrumental variable generalized method of moments to determine that democracy and renewable energy had an improving impact on carbon emissions. Foreign direct investment, trade openness, population, and economic growth were the factors driving carbon emissions in sub-Saharan Africa. Accounting for democracy leads to a decrease in carbon emissions despite economic development. No evidence supporting the existence of the Environmental Kuznets curve was discovered. The studies also showed that the influence of urbanization on carbon emissions is uncertain.

According to Dogan and Seker (2016), recent decades have seen a significant rise in carbon dioxide (CO₂) emissions, leading to several research in the field of energy-growth-environment that aim to pinpoint the factors influencing CO₂ emissions. The study acknowledged a significant critique about the choice of panel estimation methods in the current investigations. Most studies utilized panel methods that overlook cross-sectional dependency, despite the high probability of heterogeneity and cross-sectional dependence among nations in the panel. Most current studies analyzed overall energy use and do not distinguish the environmental implications of energy consumption from different sources. This empirical study examined how real income, renewable energy consumption, non-renewable energy consumption, trade openness, and financial development impact CO₂ emissions in the EKC model for top countries in the Renewable Energy Country Attractiveness Index. The study uses heterogeneous panel estimation techniques with cross-section dependence to address gaps in the literature. After doing the CADF and CIPS unit root tests, the study sawed that the variables achieved stationarity in their initial differences. Additionally, the LM

bootstrap cointegration test indicated that the variables are cointegrated. FMOLS and DOLS analyses reveal that higher levels of renewable energy consumption, trade openness, and financial development lead to a decrease in carbon emissions. Conversely, an increase in non-renewable energy consumption is associated with higher emissions. The EKC hypothesis is confirmed for the leading renewable energy countries.

Jin & Kim (2018) studied the factors influencing carbon emissions by examining energy consumption statistics from 30 nations that utilize nuclear energy between 1990 and 2014. Renewable energy and nuclear energy consumption are considered as factors, while real coal price and real GDP are included as additional variables. Panel cointegration analysis and Granger causality tests are performed to explore the link between the variables. The panel cointegration test indicated the presence of a long-term equilibrium link between carbon emissions, renewable energy consumption, and nuclear energy consumption. The long-term cointegrating vector and Granger causality tests showed that nuclear energy does not aid in reducing carbon emissions, unlike renewable energy.

A study by Nguyen and Kakinaka (2019) analyzed the correlation between renewable energy usage and carbon emissions in 107 countries from 1990 to 2013, using panel cointegration analysis to consider the development stage. The data demonstrated considerable disparities between the low- and high-income country groupings. Renewable energy usage in low-income nations had both a positive and negative correlation with carbon emissions and output, respectively. In high-income countries, there was a mixed relationship between renewable energy usage and carbon emissions as well as output.

Adams and Nsiah (2019) utilized panel cointegration methods to study the correlation between renewable energy and carbon dioxide emissions across 28 Sub-Saharan African nations from 1980 to 2014. The results from the Fully Modified OLS and GMM estimation methods indicated that both renewable and nonrenewable energy sources impact carbon dioxide emissions in the studied countries over time. However, only nonrenewable energy had a significant favorable effect on carbon dioxide emissions in the short term. An increase in nonrenewable energy use results in a 1.07% rise in CO₂ emissions in the near term and a 1.9% increase in the long run. Economic growth leads to environmental degradation, and urbanization negatively impacts carbon dioxide emissions. An increase in GDP resulted in a 1.3% rise in emissions in the short term and a 1.82% increase in the long term.

Isun *et al.*, 2022 MENA investigated the connections between the consumption of renewable energy, urbanization, economic growth, and carbon emissions (CE) in the Middle East and North Africa region from 1991 to 2019. Using bias-corrected methodologies that were continually updated, fully adjusted, and continuously updated, this study demonstrated that the existence of the environmental Kuznets curve hypothesis over the course of a lengthy period of time. In addition, fast urbanization and economic growth were among the factors that contributed to higher CE, whereas the consumption of renewable energy was discovered to be the most effective method to mitigate CE.

Akram *et al.*, (2020) examined how energy efficiency (EE), renewable energy (RE), and other factors impact carbon emissions in 66 developing nations from 1990 to 2014, including the environmental Kuznets curve (EKC) theory. This study examined the impact of environmental education in developing the Environmental Kuznets Curve hypothesis, a factor overlooked in prior research. Through the application of panel

ordinary least squares and fixed-effect panel quantile regression (PQR), we have determined that the influence of key factors on CO₂ emissions varies among different quantiles. EE reduced CO₂ emissions at all levels, with the most significant impact shown at the 90th quantile. Renewable energy reduced carbon dioxide emissions and has a significant impact at the 10th percentile. Nuclear energy used decreases CO₂ emissions, impacting carbon emissions substantially at the 50th percentile. An increase in GDP leads to an increase in CO₂ emissions, with a more pronounced effect observed at higher quantiles of GDP. Squaring GDP decreases CO₂ emissions and has the most significant impact on reducing emissions at higher quantiles. The quantile coefficients for Y and Y² confirmed the presence of the Environmental Kuznets Curve (EKC) hypothesis in emerging countries, with Y showing considerably positive coefficients and Y² showing significantly negative coefficients. Overall, Energy Efficiency (EE) and Renewable Energy (RE) helped decrease carbon emissions in developing nations.

According to Yuan *et al.*, (2022), the global shift towards green and low-carbon practices involved using clean and renewable energy sources which included wind, hydro, and solar power as an alternative to existing energy sources. The renewable energy sector holds significant promise and has emerged as a focal point in the worldwide energy sector. This study discussed the rolling-window Granger causality test to investigate the impact of renewable energy (RE) on reducing greenhouse gas emissions. Through analyzing the relationship between renewable energy consumption and carbon dioxide emissions, it was evident that renewable energy's ability to replace traditional sources has significantly increased, leading to a significant reduction in carbon emissions.

Salem *et al.*, (2021) choose the top ten nations with large carbon emissions to analyze the trends in renewable energy usage from 1991 to 2018. Developed renewable energy

companies were a gradual process that does not happen quickly. Additionally, it involved a period of infrastructure building that could lead to a temporary increase in CO₂ emissions. Renewable energy consumption, including Wind, Solar, and Hydropower, were utilized to analyze the non-linear relationship with CO₂ and its variations. The empirical findings obtained by a pooled mean group (PMG) approach suggest that renewable energy consumption and hydropower exhibit an inverted U-shaped pattern, whereas wind and solar energy consumption display a U-shaped pattern.

In 2016, Bhattacharya, Paramati, Ozturk & Bhattacharya used a panel data method to investigate how renewable energy consumption affects carbon emissions across 38 countries between 1991 and 2012. To address the possible endogeneity problems, the study employed the Generalized Method of Moments (GMM) estimator. The research found that a 1 percent increase in renewable energy consumption leads to a 0.06 percent decline in carbon emissions, underlining the critical role of renewables in climate change mitigation. Sarkodie and Adams (2018) researched between the years 1990 and 2013 the impact that the consumption of renewable energy had in the carbon emissions of 28 countries in sub-Saharan Africa. To adjust for country specific influences, the authors deployed a fixed effects panel data model. The results showed that the use of renewable energy significantly reduces carbon emissions: a 1 percent increase in renewable energy consumption corresponds to a 0.05 percent decrease in carbon emissions. Renewable energy policies in the region were highlighted as being critical.

Sebri and Ben Salha (2014) examine the effect of renewable energy consumption on carbon emissions in a panel of 15 MENA countries from 1980 to 2009. Panel cointegration techniques were used to establish the long-term sustainable correlation between renewable energy consumption and carbon emissions. The findings showed

that a 1% increase in renewable energy consumption is associated with a 0.04% reduction in carbon emissions, which indicates that renewable energy has the potential to mitigate environmental impacts in the MENA region. From 1971 to 2014, the impact of renewable energy utilisation on carbon emissions in France was examined by Solarin, Shahbaz, Khan & Razali (2021). A short- and long-term relationship was investigated with an autoregressive distributed lag (ARDL) model. The results show that integrated renewable energy consumption reduces carbon emissions in the short and long term: a 1 percent increase in renewable energy consumption cuts emissions by 0.09 percent. The research made clear how effective France's renewable energy policies are at cutting emissions. Lin and Moubarak (2014) investigated the contribution of renewable energy to carbon emissions in China from 1980 to 2011. Asymmetric effects were modeled using a nonlinear autoregressive distributed lag (NARDL) model. The results show that an advantageous shift in renewable energy consumption leads to lower carbon emissions while a disadvantageous change leads to a smaller effect. This asymmetry exists because reliable renewable energy policies are important for sustaining reductions in emissions.

Jebli and Youssef (2015) examined the relationship between renewable energy consumption, trade openness, and carbon emissions in Tunisia using data from 1980 to 2009 and co-integration analysis and a vector error correction model (VECM) were used to study long-term dynamics. They found that a 1 percent increase in renewable energy consumption leads to a 0.05 percent drop in carbon emissions. In addition, the authors found that trade openness promotes renewable energy consumption in the reduction of emissions.

2.4.1.2 Non-renewable energy consumption and Carbon emissions

Zhang, *et al.*, (2023), investigated the correlation between the use of renewable and non-renewable energy, carbon dioxide emissions, and economic growth in China, India, Bangladesh, Japan, South Korea, and Singapore. They employed panel Augmented Mean Group (AMG) estimation techniques to analyze data from 1975 to 2020. The analysis revealed that the consumption of renewable energy, non-renewable energy, the employment of labor force, and capital formation all have significant effects on long-term economic growth. The study revealed that the utilization of non-renewable energy led to a substantial increase in long-term carbon emissions, whereas the usage of renewable energy resulted in a significant reduction in long-term carbon emissions. The N-type Environmental Kuznets Curve (EKC) hypothesis is supported in selected emerging economies, as both GDP and GDP3 have a notable positive effect on environmental degradation, while GDP2 has a significant negative effect.

Banday and Aneja (2020) investigated the causal connection between energy consumption (renewable and non-renewable), gross domestic product (GDP) growth, and carbon dioxide (CO₂) emissions in Brazil, Russia, India, China, and South Africa from 1990 to 2017. The study employed the bootstrap Dumitrescu and Hurlin panel causality test, which allows for heterogeneity and dependency in cross-sectional units across developing nations. The findings indicated a one-way causal relationship from GDP to CO₂ emissions in India, China, Brazil, and South Africa, while no causal relationship was observed for Russia. The causal relationships between renewable energy utilization and GDP in different countries are as follows: there is evidence of a feedback hypothesis in China and Brazil, a growth hypothesis in Russia, a conservation hypothesis in South Africa, and a neutrality hypothesis in India. Nevertheless, the findings supported the hypothesis of economic growth for India, China, Russia, and

Brazil, while supporting the hypothesis of neutrality for South Africa. Regarding the relationship between CO₂ emissions and the use of renewable and non-renewable energy, the study discovered that India, Russia, and South Africa exhibited convergence, while China and Brazil showed divergence.

Adebayo, *et al.*, (2022) state that the COVID-19 pandemic, which began in late 2019, has led to a global lockdown of an unprecedented scale. This lockdown has had a significant impact on environmental quality. The aim of this study was to investigate the impact of renewable energy, non-renewable energy, and COVID-19 cases on CO₂ emissions in the United Kingdom. To achieve this objective, various non-linear techniques were utilized, including the Fourier ADL cointegration test, Non-Linear ARDL, Markov switching regression, and the Breitung and Candelon (BC) causality test. The findings indicated that there is a long-term cointegration between the variables examined in this study. The findings indicated that an increase (decrease) in renewable energy development led to a reduction (increase) in CO₂ emissions, whereas an increase (decrease) in fossil fuel energy resulted in an increase in CO₂ emissions. Furthermore, a decreased (increased) in CO₂ emissions was observed as a result of a negative (positive) variation in COVID cases. Furthermore, a one-way causal effect was discovered to originate from all the variables that is renewable energy, fossil fuel, COVID-19 cases to CO₂ emissions impact.

Erdogan, *et al.*, (2020) asserted that the relationship between the environment and economic growth is a primary focus of contemporary researchers. Despite the existence of numerous studies in this field, a consensus has not yet been reached through discussions. This study aimed to examine the impact of economic growth, consumption of renewable and non-renewable energy, oil prices, and trade openness on CO₂ emissions in 25 Organization for Economic Co-operation and Development (OECD)

countries from 1990 to 2014. We presented empirical evidence based on panel data, utilizing both first- and second-generation estimation methods for comparison. The estimations using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods provided evidence supporting the validity of the Environmental Kuznets Curve (EKC) hypothesis in OECD countries. Nevertheless, the Augmented Mean Group (AMG) estimator demonstrated that the EKC hypothesis is not valid. The AMG estimator, being a second-generation estimator, yields robust results in the presence of cross-sectional dependence, unlike the first-generation methods. Consequently, the EKC hypothesis is deemed invalid. Our supplementary discoveries indicated that the increased in renewable energy consumption and oil prices helps to reduce CO₂ emissions, while the consumption of non-renewable energy has an adverse impact, as confirmed by all estimators. There is no evident correlation between trade openness and CO₂ emissions.

According to Akadiri and Adebayo (2022), financial globalization has been suggested to have an impact on the rise or fall of greenhouse gas emissions, and consequently, global temperature. According to the International Energy Agency (IEA), India ranks third in terms of global greenhouse gas emissions. The carbon emissions generated by the wealthy households in India are approximately seven times higher than those produced by the poorest households. This study investigated the unequal impact of financial globalization on carbon emissions, taking into account factors such as non-renewable energy usage, consumption of renewable energy, and economic growth. The study utilized annual data spanning from 1970 to 2018 and employed various econometric methods to examine these relationships. The results of the NARDL analysis revealed the following: (i) an increase (decrease) in the use of non-renewable energy led to an increase (decrease) in carbon emissions; (ii) positive (negative)

changes in renewable energy consumption resulted in a decrease in carbon emissions; (iii) a positive shock in financial development contributed to an increase in carbon emissions; and (iv) a positive shock in economic growth had a positive impact on carbon emissions.

Anwar, *et al.*, (2021) investigated the effects of energy consumption on the environment. A typical empirical study commonly employed either aggregate energy consumption data or utilized conventional econometric techniques to model the relationship between energy, income, and the environment. In order to address these deficiencies, the aim of the research was to examine the relationship between energy consumption, income, and the environment by utilizing both renewable and non-renewable energy sources. Additionally, the study employed the innovative Method of Moments Quantile Regression technique specifically for ASEAN countries. The results showed that the use of non-renewable energy led to an increase in carbon emissions throughout all levels of consumption, ranging from the 10th to the 90th percentile. Specifically, the carbon emissions at the 10th percentile were measured at 0.257, while they increased to 0.501 at the 90th percentile. The consumption of renewable energy resulted in a reduction in CO₂ emissions across all quantiles (10th to 90th). However, this correlation was not statistically significant at higher quantiles, specifically from the 60th to the 90th. The empirical results also confirmed the existence of the relationship known as the environmental Kuznets curve, which is statistically substantial from the 30th to the 90th quantiles. Furthermore, the utilization of panel estimation methods such as FMOLS, DOLS, and FE-OLS has also confirmed the presence of the Environmental Kuznets Curve (EKC) hypothesis in ASEAN countries. Their research findings indicated that a 1 percent rise in non-renewable energy consumption led to a corresponding increase in CO₂ emissions of 0.29%, 0.26%, and 0.30% in the FMOLS,

DOLS, and FE-OLS models, respectively. Conversely, a 1% increase in utilization of renewable energy results in a reduction in CO₂ emissions of 0.17%, 0.15%, and 0.17% in the FMOLS, DOLS, and FE-OLS models, respectively.

Adedoyin, *et al.*, (2021) reported that Sub-Saharan Africa, a prominent region for diverse resources related to energy and minerals in the global market, has witnessed significant economic growth over the past decade. Nevertheless, the influence of economic uncertainties on the environmental impact of energy generation has not received sufficient attention, despite the acknowledged environmental consequences of energy production. Therefore, this study examined how economic policy uncertainty affects the relationship between energy, economic growth, and emissions in 32 countries in Sub-Saharan Africa from 1996 to 2014. The findings from the one-step system-GMM analysis revealed a positive correlation between both real GDP and non-renewable energy generation with CO₂ emissions.

In their study, Khan, *et al.*, (2021) aimed to determine the immediate and long-term effects of technological innovation, finance, and foreign direct investment on renewable energy, non-renewable energy, and CO₂ emissions in 69 countries participating in the "Belt and Road Initiative (BRI)" between 2000 and 2014. The application of robust standard error regression and dynamic GMM estimators revealed that technological innovations, economic growth, and foreign direct investment (FDI) exerted a detrimental effect on renewable energy. On the other hand, financial developments were found to have a strong positive influence on the renewable energy sector in the study area. The impact of technological innovation, foreign direct investment (FDI), and economic growth on energy consumption and carbon dioxide (CO₂) emissions in the countries involved in the Belt and Road Initiative (BRI) is significantly favorable. The Granger non-causality test revealed bidirectional causal connections among

renewable energy, technological innovation, finance, and foreign direct investment (FDI).

Mahalik, *et al.*, (2021) utilized panel data from 1990-2015 for selected BRICS countries (Brazil, India, China, and South Africa) to assess the impact of primary and secondary education levels on reducing carbon emissions. The study also considered changes in energy consumption patterns, including renewable and non-renewable energy, as well as factors such as real economic growth, urbanization, and economic globalization, as additional determinants in the function of per capita CO₂ emissions. The study employed random effect and system GMM techniques to identify the factors contributing to changes in carbon emissions. The results showed that primary education and non-renewable energy use, as well as total energy consumption, economic growth, and globalization, were associated with increased carbon emissions. On the other hand, secondary education, urbanization, and usage of renewable energy were found to be linked to favorable environmental quality by reducing carbon emissions.

Aydođan and Vardar (2020) conducted a study to analyze the interconnections among per capita CO₂ emissions, economic growth, agricultural value added, and renewable and non-renewable energy consumption. The study also aimed to investigate the presence of the Environmental Kuznets Curve (EKC) hypothesis in a panel of E7 countries from 1990 to 2014. The estimates demonstrated a positive correlation between CO₂ emissions and real GDP, non-renewable energy consumption, and agricultural value added over a long period of time. Conversely, a negative correlation is observed between CO₂ emissions and the square of real GDP, as well as renewable energy consumption. The long-term estimates confirmed the presence of an inverted U-shaped Environmental Kuznets Curve (EKC) in the chosen countries. Regarding the

Granger causality analysis, there was a bi-directional relationship between non-renewable energy use and the release of CO₂ in the long term.

Saidi and Omri (2020) Aligning carbon emissions with economic growth was a key option for achieving the sustainable development goals (SDGs). Renewable energy's impact in restoring environmental and economic equilibrium was a prominent topic of dispute in current discussions. The main aim of this study was to analyze the impact of renewable energy on economic growth and carbon emissions in 15 major renewable energy-consuming countries. This will be done using fully modified ordinary least square (FMOLS) and vector error correction model (VECM) estimation techniques. The FMOLS technique results demonstrated the effectiveness of renewable energy in enhancing economic growth and decreasing carbon emissions. The VECM Granger causality test revealed bidirectional causality between economic growth and renewable energy in both short- and long-run for both estimated functions, confirming the feedback hypothesis. Additionally, it shows there is no causal connection between the emissions of carbon dioxide and renewable energy in the long-run, but there is a bidirectional causal connection between the two variables in the short-run.

Adams & Acheampong (2019) The global economy is experiencing a steady rise in carbon emissions, hindering the achievement of the Paris agreement on climate change. Understanding the factors that drive carbon emissions is essential for informing policies aimed at mitigating them. Although there is extensive literature on how economic growth affects carbon emissions, there is minimal empirical study on how democracy and renewable energy improve environmental quality in emerging nations. The aim of the study was to investigate how democracy and renewable energy affect carbon emissions in 46 sub-Saharan African nations utilizing imbalanced data from 1980 to 2015. The study utilized an instrumental variable generalized method of moments to

determine that democracy and renewable energy had an improving impact on carbon emissions. Foreign direct investment, trade openness, population, and economic growth were the factors driving carbon emissions in sub-Saharan Africa. Accounting for democracy leads to a decrease in carbon emissions despite economic development. No evidence supporting the existence of the Environmental Kuznets curve was discovered. The studies also showed that the influence of urbanization on carbon emissions is uncertain.

Dogan and Seker (2016) Recent decades have seen a significant rise in carbon dioxide (CO₂) emissions, leading to several research in the field of energy-growth-environment that aim to pinpoint the factors influencing CO₂ emissions. The study acknowledged a significant critique about the choice of panel estimation methods in the current investigations. Most studies utilized panel methods that overlook cross-sectional dependency, despite the high probability of heterogeneity and cross-sectional dependence among nations in the panel. Most current studies analyzed overall energy use and do not distinguish the environmental implications of energy consumption from different sources. This empirical study examined how real income, renewable energy consumption, non-renewable energy consumption, trade openness, and financial development impact CO₂ emissions in the EKC model for top countries in the Renewable Energy Country Attractiveness Index. The study uses heterogeneous panel estimation techniques with cross-section dependence to address gaps in the literature. After doing the CADF and CIPS unit root tests, the study sawed that the variables achieved stationarity in their initial differences. Additionally, the LM bootstrap cointegration test indicated that the variables are cointegrated. FMOLS and DOLS analyses reveal that higher levels of renewable energy consumption, trade openness, and financial development lead to a decrease in carbon emissions. Conversely, an

increase in non-renewable energy consumption is associated with higher emissions. The EKC hypothesis is confirmed for the leading renewable energy countries.

Jin & Kim (2018) studied the factors influencing carbon emissions by examining energy consumption statistics from 30 nations that utilize nuclear energy between 1990 and 2014. Renewable energy and nuclear energy consumption are considered as factors, while real coal price and real GDP are included as additional variables. Panel cointegration analysis and Granger causality tests are performed to explore the link between the variables. The panel cointegration test indicated the presence of a long-term equilibrium link between carbon emissions, renewable energy consumption, and nuclear energy consumption. The long-term cointegrating vector and Granger causality tests showed that nuclear energy does not aid in reducing carbon emissions, unlike renewable energy.

Nguyen and Kakinaka (2019) Renewable energy usage has been encouraged to address climate change issues through initiatives like the Kyoto Protocol and the Paris Agreement. A nation's selection of energy sources is determined by the equilibrium between economic growth and environmental harm, which is intricately linked to its level of development. This study analyzed the correlation between renewable energy usage and carbon emissions in 107 countries from 1990 to 2013, using panel cointegration analysis to consider the development stage. The data demonstrated considerable disparities between the low- and high-income country groupings. Renewable energy usage in low-income nations had both a positive and negative correlation with carbon emissions and output, respectively. In high-income countries, there was a mixed relationship between renewable energy usage and carbon emissions as well as output.

Adams and Nsiah (2019) Utilized panel cointegration methods to study the correlation between renewable energy and carbon dioxide emissions across 28 Sub-Saharan African nations from 1980 to 2014. The results from the Fully Modified OLS and GMM estimation methods indicated that both renewable and nonrenewable energy sources impact carbon dioxide emissions in the studied countries over time. However, only nonrenewable energy had a significant favorable effect on carbon dioxide emissions in the short term. An increase in nonrenewable energy use results in a 1.07% rise in CO₂ emissions in the near term and a 1.9% increase in the long run. Economic growth leads to environmental degradation, and urbanization negatively impacts carbon dioxide emissions. An increase in GDP resulted in a 1.3% rise in emissions in the short term and a 1.82% increase in the long term.

ISun *et al.*, 2022 MENA economies was highly urbanized and resource-rich economies. They were also known as the Middle East and North African economies. On the other hand, these economies were facing significant challenges imposed on by climate change. In light of this, the purpose of this study was to investigated the connections between the consumption of renewable energy, urbanization, economic growth, and carbon emissions (CE) in the Middle East and North Africa region from 1991 to 2019. Using bias-corrected methodologies that were continually updated, fully adjusted, and continuously updated, this study demonstrated that the existence of the environmental Kuznets curve hypothesis over the course of a lengthy period of time. In addition, fast urbanization and economic growth were among the factors that contributed to higher CE, whereas the consumption of renewable energy was discovered to be the most effective method to mitigate CE.

Akram *et al.*, (2020) Utilizing energy-efficient and renewable energy sources is essential for decreasing greenhouse gas emissions. The study examined how energy

efficiency (EE), renewable energy (RE), and other factors impact carbon emissions in 66 developing nations from 1990 to 2014, including the environmental Kuznets curve (EKC) theory. This study examined the impact of environmental education in developing the Environmental Kuznets Curve hypothesis, a factor overlooked in prior research. Through the application of panel ordinary least squares and fixed-effect panel quantile regression (PQR), we have determined that the influence of key factors on CO₂ emissions varies among different quantiles. EE reduced CO₂ emissions at all levels, with the most significant impact shown at the 90th quantile. Renewable energy reduced carbon dioxide emissions and has a significant impact at the 10th percentile. Nuclear energy used decreases CO₂ emissions, impacting carbon emissions substantially at the 50th percentile. An increase in GDP leads to an increase in CO₂ emissions, with a more pronounced effect observed at higher quantiles of GDP. Squaring GDP decreases CO₂ emissions and has the most significant impact on reducing emissions at higher quantiles. The quantile coefficients for Y and Y² confirmed the presence of the Environmental Kuznets Curve (EKC) hypothesis in emerging countries, with Y showing considerably positive coefficients and Y² showing significantly negative coefficients. Overall, Energy Efficiency (EE) and Renewable Energy (RE) helped decrease carbon emissions in developing nations.

Yuan *et al.*, (2022) The global shift towards green and low-carbon practices involved using clean and renewable energy sources which included wind, hydro, and solar power as an alternative to existing energy sources. The renewable energy sector holds significant promise and has emerged as a focal point in the worldwide energy sector. This study discussed the rolling-window Granger causality test to investigate the impact of renewable energy (RE) on reducing greenhouse gas emissions. Through analyzing the relationship between renewable energy consumption and carbon dioxide

emissions, it was evident that renewable energy's ability to replace traditional sources has significantly increased, leading to a significant reduction in carbon emissions.

Salem *et al.*, (2021) Rising energy consumption signified a boost in economic activity; the resulting prosperity hinges on the sustainability and reliability of the energy source. The study has chosen the top ten nations with large carbon emissions to analyze the trends in renewable energy usage from 1991 to 2018. Developed renewable energy companies were a gradual process that does not happen quickly. Additionally, it involved a period of infrastructure building that could lead to a temporary increase in CO₂ emissions. Renewable energy consumption, including Wind, Solar, and Hydropower, were utilized to analyze the non-linear relationship with CO₂ and its variations. The empirical findings obtained by a pooled mean group (PMG) approach suggest that renewable energy consumption and hydropower exhibit an inverted U-shaped pattern, whereas wind and solar energy consumption display a U-shaped pattern.

Pata (2021) examined the impact of economic complexity, globalization, and the utilization of renewable and non-renewable energy on CO₂ emissions and ecological footprint in relation to the EKC hypothesis in the United States. The integrated cointegration test and three separate estimators were utilized for the period from 1980 to 2016. The study's principal result indicated that the inverted U-shaped Environmental Kuznets Curve relationship between economic complexity and environmental pollution is relevant to the USA. Moreover, environmental pollution diminishes due to globalization and the utilization of renewable energy, but the usage of non-renewable energy exacerbates environmental stress.

Zhang *et al.* (2023) examined the relationship among renewable and non-renewable energy consumption, carbon dioxide emissions, and economic growth in China, India,

Bangladesh, Japan, South Korea, and Singapore. Data spanning from 1975 to 2020 was utilized for analysis, employing panel Augmented Mean Group (AMG) estimation techniques. The research indicated that prolonged carbon emissions increased markedly with the utilization of non-renewable energy, whereas prolonged carbon emissions decreased considerably upon the adoption of renewable energy. Banday and Aneja (2020) examined the causal relationship among energy consumption (including renewable and non-renewable), gross domestic product (GDP) growth, and carbon dioxide (CO₂) emissions in Brazil, Russia, India, China, and South Africa from 1990 to 2017. The study utilized the bootstrap Dumitrescu and Hurlin panel causality test, appropriate for the heterogeneity and interconnectedness of cross-sectional units in developing countries. The findings indicated a unidirectional causal relationship from GDP to CO₂ emissions in India, China, Brazil, and South Africa, but no causal association was found for Russia. The causal linkages between renewable energy consumption and GDP in different countries are as follows: a feedback hypothesis in China and Brazil, a growth hypothesis in Russia, a conservation hypothesis in South Africa, and a neutrality theory in India. Nevertheless, the findings validated the hypothesis of economic growth for India, China, Russia, and Brazil, while confirming the hypothesis of neutrality for South Africa. The analysis indicated that India, Russia, and South Africa shown convergence in the relationship between CO₂ emissions and the use of renewable and non-renewable energy, whereas China and Brazil showed divergence.

2.4.1.3 Economics growth and Carbon emissions

Ghazouani & Maktouf (2024) studied the effects of natural resource exploitation, trade openness, and economic growth on carbon emissions in oil-exporting countries from 1971 to 2014. the study analyzed this association using the panel autoregressive

distributed lag model and several econometric techniques that consider cross-sectional dependence. The study showed that the depletion of natural resources and increased trade have a lasting adverse effect on environmental quality. The findings showed the validity of the Kuznets Environmental Curve for oil-exporting nations. An analysis of causation showed a two-way connection between natural resources, economic growth, and CO₂ emissions, and a one-way connection between trade openness and CO₂ emissions.

Mehboob *et al.*, (2024) studied how nuclear energy consumption and environmental tax impact consumer-based carbon emission reduction in the top five emitter nations from 1990 to 2020, within the framework of trade globalization. The study employed different empirical methods such as preliminary analysis to verify stationarity and cointegration, CS-ARDL for long-term analysis, CCEMG, AMG for robustness, and D-H causality test for short-term pairwise causation. The findings showed that nuclear energy use, environmental tax, and trade globalization reduce consumption-based carbon emissions, but economic growth and population density increase carbon emissions. Moreover, the data indicated a bidirectional causal relationship between nuclear energy usage, population density, and consumption-based emissions of greenhouse gases.

Li *et al.*, (2024) did an extensive study on economic, social, and energy-related variables due to the worldwide need to reduce carbon emissions for sustainable development. Past research showed a complicated scenario with varying results on how geopolitical risk, natural resource rents, corrupt governance, and energy intensity affect each other. The study created a research model based on the Environmental Kuznets Curve using panel data from 38 nations between 2002 and 2020 to clarify this uncertainty. The study used panel quantile regression models to directly evaluate the

influence of indicated components. The results confirmed the correlation between economic growth and carbon emissions, endorsing the Environmental Kuznets Curve theory. Increased geopolitical risk and energy intensity are positively associated with higher carbon emissions, but corruption governance and natural resource rents have a reducing impact. Our study also investigated the indirect effects of these factors with a panel threshold regression model. The results showed a decreasing impact of economic expansion on carbon emissions.

Gyimah *et al.*, (2023) did a study that used Two-stage least squares to analyze the impact of energy sources (renewable and fossil energy) and economic growth on carbon emissions in Ghana. the study used Robustness Least Square and Generalized Method of Moments to verify the quality of our result. The study's data spans from 1990 to 2018. The study's findings showed that both renewable energy and fossil fuels contribute to carbon emissions in Ghana over the years analyzed. Economic growth does not have a significant impact on carbon emissions.

Choudhury *et al.*, (2023) investigated the impact of carbon emissions on the economic growth of the world's top five most polluted economies. The study employed a Panel Autoregressive Distributed Lag (PARDL) technique to provide an empirical estimate. Following a disturbance, the system moved towards a stable long-term balance, shown by the negative and statistically significant ECM value in the findings. Empirical evidence demonstrated a positive and strong correlation between energy consumption and GDP with carbon dioxide emissions in both the short and long term. Furthermore, the GDP2 effect demonstrated the presence of the Environmental Kuznets Curve (EKC) effect in the top five most polluted countries. Short-term industrial production is favorably associated with CO₂ emissions, whereas in the long term, the correlation is negative and statistically negligible.

Chen *et al.*,. (2023) study examined how petroleum consumption, economic growth, and technological innovation affect carbon emissions in Bangladesh by analyzing quarterly data from 1972Q1 to 2020Q4. The regression results confirmed that increased consumption of petroleum and economic growth contribute to environmental degradation by increasing carbon dioxide emissions, while technological innovation helped improve environmental conditions by reducing Bangladesh's emission levels.

Li and Wei (2021) analyzed the influence of carbon emissions on economic growth in 30 Chinese provinces from 1987 to 2017 using balanced panel data and the panel smooth transition regression model. Estimation was performed using the entire sample as well as separate subsamples for the northern and southern regions. Empirical findings demonstrated the presence of non-linear connections between carbon emissions, financial development, openness, innovation, and economic growth. Additionally, carbon emissions diminish the positive impacts of financial development and innovation on economic growth, a relationship supported by the use of energy consumption as a transitional factor. Subsample analyzed revealed significant regional disparities in the influence of carbon emissions on economic growth, with the northern region exhibiting a lower carbon emissions threshold but a faster transition rate.

Sharif & Tauqir (2021) investigated carbon emissions from various sectors to assess the environmental impact in Pakistan and its correlation with the country's transportation infrastructure. Road transport is the primary contributor to carbon emissions in Pakistan, accounting for almost 70% of greenhouse gas emissions in 2014. The study utilized fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) methodologies to examine the impact of carbon emissions (both aggregate and disaggregate) and road infrastructure on economic growth from 1972 to 2017. Prior to the primary analysis, this study additionally examined the co-integrating

relationships. The research indicated a clear positive correlation between road infrastructure and economic growth. Carbon emissions, regardless of whether they are in aggregate or disaggregate forms, have an unfavorable influence on economic growth.

Obobisa, *et al.*, (2022) investigated the lasting impact of green technological innovation, institutional quality, renewable energy, fossil fuel energy, and economic growth on CO₂ emissions in 25 African countries between 2000 and 2018. The study employed second-generation panel methodologies to investigate the association connecting the variables, taking into account the possibility of residual cross-sectional dependence and heterogeneity. The empirical results obtained from the augmented mean group (AMG) and common correlated effects mean group (CCEMG) estimators demonstrate that green technological innovation and renewable energy usage exhibit a statistically significant negative influence on CO₂ emissions. Conversely, CO₂ emissions were positively influenced by factors such as institutional quality, economic growth, and the use of energy generated from fossil fuels.

Islam, *et al.*, (2021) argued that Bangladesh's recent impressive economic growth can be attributed to various factors, including globalization, foreign direct investment (FDI), trade, urbanization, energy usage, innovation, and institutional quality. These factors have also had an impact on the country's natural environment. Prior research rarely integrated these dynamics, specifically innovation and institutional quality, to analyze their effects on environmental degradation in Bangladesh. This study aimed to analyze the impact of globalization, foreign direct investment, economic growth, trade, innovation, urbanization, and consumption of energy on CO₂ emissions in Bangladesh from 1972 to 2016. The study utilized a dynamic ARDL simulations model developed by Jordan and Philips (2018) to examine the relationship between these factors and CO₂ emissions, taking into account the influence of institutional quality. The findings of the

investigation revealed that globalization, foreign direct investment, and innovation had an adverse impact on CO₂ emissions, leading to a decline in environmental quality. On the other hand, economic growth, trade, energy consumption, and urbanization had a positive effect on CO₂ emissions, thereby contributing to environmental degradation in both the short and long term. In addition, the level of institutional quality, as measured by the political terror scale (PTS), had a positive impact on CO₂ emissions, leading to a deterioration in environmental quality over both the short and long term.

According to Acheampong, *et al.*, (2021), renewable energy is considered the most advantageous substitute for fossil fuels and is widely recognized as the most effective approach to addressing climate change. Nevertheless, the expenses associated with implementing renewable energy sources are substantial. It seems that the prosperity of nations, the various levels of economic advancement and progress, and the willingness and quality of institutions play a crucial role in successfully addressing this global challenge. Nevertheless, there was a scarcity of comprehensive data regarding the complex connection between all the factors that are considered crucial in driving the global transition towards the utilization of renewable energy sources to fulfill the majority of both domestic and industrial energy requirements. This study examined the cause-and-effect relationship over time between institutions, renewable energy, carbon emissions, and economic growth in 45 sub-Saharan African countries. The study used annual data from 1960 to 2017. We employed the generalized method of moment panel vector autoregression (GMM-PVAR) technique to investigate the connections. Overall, the findings indicated that there does not exist a direct cause-and-effect relationship between institutions and economic growth. However, there is a two-way causal relationship between economic growth and renewable energy. Our findings suggested that there is a positive relationship between economic growth and carbon

emissions. Additionally, institutions are more inclined to address carbon emissions and promote renewable energy. However, our analysis did not find any evidence of a causal relationship between carbon emissions and renewable energy.

Muhammad, (2021) aims to examine the moderating role of natural assets in the relationship between institutional quality and carbon dioxide (CO₂) emissions in 106 countries that were developing between 1996 and 2017. The study applies robustness estimators such as the instrumental time fixed effect, instrumental fixed effect, and generalized method of moments (GMM) as well as dynamic fixed effect and system GMM estimators. We used dynamic models and instrumental system GMM to eliminate biases from superfluous data, address potential endogeneity problems, and lessen the effect of autocorrelation rising due to model misspecification. The empirical findings demonstrate that although natural resources and economic growth are the main drivers of CO₂ emissions in developing nations, financial development, trade, and institutional factors—corruption perception control, government effectiveness, political stability, regulatory quality, rule of law, voice and accountability—all play a critical role in reducing CO₂ emissions. Conversely, the indirect effect of institutional quality on CO₂ emissions in developing nations was enhanced by natural resources. According to Salahodjaev and Isaeva (2022), The severe effects of climate change may be greatly intensified by the abundance of natural resources, growth-oriented strategies, and low level of environmental concern in post-Soviet states. This study examined the correlation between carbon dioxide (CO₂) emissions, economic growth, foreign investment inflows, trade, and energy consumption in 20 countries that were formerly part of the Soviet Union. The study analyzed data from the years 1995 to 2017. A panel cointegration test confirmed the existence of a long-term cointegrating relationship among the variables. The longer-term elasticities are determined through the

application of Dynamic Ordinary Least Squares and Fully Modified Ordinary Least Squares regressions. These methods produced comparable outcomes, indicating that GDP per capita, foreign direct investment (FDI) inflows, trade, and energy consumption is positively associated with CO₂ emissions per capita in the long term. A panel causality test revealed significant unidirectional causality from CO₂ emissions to consumption of energy at a significance level of $p < 0.01$. Put simply, increased economic activity, such as the inflow of foreign capital, higher trade volumes, increased energy consumption, and economic growth, have negative consequences for the environment by causing a rise in CO₂ emissions. This also highlights the urgency for increased attention to issues related to climate change and the environment.

Rahaman, *et al.*, (2022) conducted a study to examine the influence of foreign direct investment (FDI), tourism, electricity consumption, and economic development on CO₂ emissions in Bangladesh from 1990 to 2019. The empirical findings indicated that variables such as foreign direct investment (FDI), energy use, and economic development have a substantial and positive impact on carbon dioxide (CO₂) emissions in the long run. Conversely, tourism has a detrimental impact in the long run. The GDP variable exhibits a significant negative coefficient when squared. This suggests that in Bangladesh, there is an inverted U-shaped relationship between CO₂ emissions and economic development. Consequently, the EKC postulate has been validated. CO₂ emissions were not significantly impacted by energy use, economic development, GDP², and tourism in the short term. The only variables that exhibit negative and statistically significant coefficients are those related to FDI. The anticipated ECM coefficients are both unfavorable and significant in statistical terms. Based on this data, the entire system adapts at a rate of 60%. The Granger causality analysis demonstrated a unidirectional causal relationship between energy use and CO₂ emissions, CO₂

emissions and economic development, electricity consumption and economic development, FDI, and CO₂ emissions.

Onofrei, *et al.*, (2022) conducted a study to examine the connection between economic growth and CO₂ emissions in the 27 EU member states from 2000 to 2017 using a panel approach. We employed a qualitative sequential methodology, which involved empirical analysis to ensure consistency and validity in our study. Additionally, we utilized quantitative methods such as Dynamic Ordinary Least Squares (DOLS), unit root tests, and cointegration techniques. The findings indicated a persistent cointegrating relationship between growth and CO₂ emissions in EU countries. The DOLS method demonstrated a statistically significant influence of economic growth on CO₂ emissions for both versions of estimators. Specifically, it revealed that, on average, a 1% change in GDP results in a 0.072 change in CO₂ emissions.

Fávero, *et al.*, (2022), examined the global correlation between economic growth and CO₂ emissions. After conducting a thorough analysis of multiple comparable studies, we developed a new quantitative methodological approach that effectively captures the contextual perspectives of 187 countries from 1800 to 2016. The multilevel model proposed in this study effectively accounted for the relationships between fixed and random effects parameters pertaining to GDP and carbon dioxide emissions. Furthermore, it presented new evidence regarding the trends of occurrence for the phenomenon under study across different countries and over time, while taking into account the variations in these observations. The model not only confirmed the positive and statistically significant correlation between economic development and carbon emissions per country, but also emphasized the positive effects of linear and cubic income on CO₂ emissions, as well as the negative effect of quadratic income. This highlights the validity of the traditional N-shaped curve for the analyzed period.

Banday and Aneja (2019) studied the relationship between energy, growth and CO₂ emissions for G7 nations between 1971 and 2014. The causality was investigated by employing an autoregressive distributed lagged model (ARDL) and the methodologies of Dumitrescu and Hurlin (2012) and Toda and Yamamoto (1995). The ARDL model revealed the long run relationship between energy, growth, and CO₂ emissions. Causality results are important for Japan and the UK, but not for other countries, with regard to non-renewable resources and economic growth. The analysis does not find a causal relationship between non-renewable resource use and CO₂ emissions in other countries, but does find strong effects for Germany, Italy and the UK. For Germany, Italy, the UK and the USA, the causal relationship between economic progress and CO₂ emissions is unidirectional.

Apergis *et al.* (2010) employed a panel error correction mechanism (ECM) model for 19 developed and developing nations over the period 1984 to 2007. The results show a long run relationship between CO₂ emissions, financial development and energy consumption. The short run causality test shows bi directional causality between economic development and energy consumption as per the feedback hypothesis, and the long run analysis shows unidirectional causality as per the growth hypothesis. The results show that renewable energy is positively correlated with economic growth, and negatively correlated with nuclear energy consumption.

Shahbaz *et al.* (2012) found that carbon emissions are unidirectionally caused by economic growth, and that energy consumption increases carbon emissions in the short and long run. But they argue that green energy is necessary for economic growth, while in Pakistan, all sectors are dependent on fossil fuels, and carbon emissions are on the rise.

The validity of the EKC hypothesis was found in Turkey by Seker, Ertugrul, and Cetin (2015) who analyzed the effects of energy consumption, foreign direct investment, GDP and the square of GDP on emissions. The study of Ahmad *et al.* (2016) utilized India as an argument study and concluded a positive correlation between energy consumption and environmental degradation, and also validated the Environmental Kuznets Curve (EKC) hypothesis. From 1976 to 2009, Tang & Tan (2015) concluded that energy consumption adversely affects the environment in Vietnam and validated the Environmental Kuznets Curve hypothesis. In their study of the Environmental Kuznets Curve (EKC) hypothesis, Pal and Mitra (2017) investigated the relation between trade, CO₂ emissions and energy consumption in China and India and found that the EKC hypothesis is valid in these economies.

2.4.1.4 Financial development and Carbon emissions

According to Zhao and Yang (2020), it is crucial to reduce CO₂ emissions in China, as it is the largest contributor to CO₂ emissions. The primary objective of this study was to examine the relationship between financial development and CO₂ emissions at the local level in China through static and dynamic analysis, a topic that has received limited attention. Principal Component Analysis (PCA) is utilized to mitigate the issue of indicator correlation that commonly arises in previous studies. Its purpose is to create a provincial financial development index for China starting from the year 2001. By conducting a static panel analysis, it was determined that a single unit increase in the provincial financial development level leads to an average reduction of 4%–5% in CO₂ emissions. However, this relationship does not hold true for the provinces of Zhejiang, Fujian, Sichuan, Yunnan, Shaanxi, and Xinjiang, as their CO₂ emissions actually increase. Over the long term, there is evidence of an inverse association between regional financial development and CO₂ emissions, although this is not the case in the

short term. The dynamic analysis results indicated that the progress of regional financial development has had a substantial negative impact on CO₂ emissions.

Lv, *et al.*, (2021) utilized panel data from 97 countries spanning the years 2000 to 2014. It employed the spatial econometric model to reassess the impact of financial development on CO₂ emissions. The findings demonstrated a spatial correlation among countries' CO₂ emissions during this time frame. Significantly, it was discovered that the financial development of neighboring countries can have an impact on a country's CO₂ emissions. The negative impact of financial development on CO₂ emissions outweighed the positive direct impact, resulting in a significant cumulative negative effect.

Habiba and Xinbang (2022) conducted a study to examine the influence of financial market development, institution development, and their sub-indices on CO₂ emissions. The study recognized the complex and multifaceted nature of financial development. In order to enhance our understanding of the relationship between financial development and CO₂ emissions, we utilize four financial market indices (overall financial market development, FM-access, FM-depth, and FM-efficiency) and four financial institution indices (overall financial institution development, FI-access, FI-depth, and FI-efficiency). The study employed a two-stage system Generalized Method of Moments (GMM) approach and utilized panel data from both developed and emerging countries spanning the years 2000 to 2018. The empirical findings demonstrated that the general development of the financial market, as well as its specific components (FM-access, FM-depth, and FM-efficiency), led to a decrease in CO₂ emissions in both developed and emerging nations.

Raheem, *et al.*, (2020) examined the impact of information and communication technology (ICT) and financial development (FD) on carbon emissions and economic growth in the G7 countries from 1990 to 2014. Through the utilization of PMG, it was discovered that Information and Communication Technology (ICT) has a significant and lasting positive impact on emissions. On the other hand, Foreign Direct Investment (FD) has been found to have a limited influence on emissions. The interaction term between Information and Communication Technology (ICT) and Financial Development (FD) yields negative coefficients. Furthermore, it has been observed that both variables have a detrimental effect on economic growth.

According to Shoaib, *et al.*, (2020), financial development played a crucial role in promoting both rapid economic growth and the emission of CO₂ into the environment. The objective of this study was to examine the causal relationship between financial development and CO₂ emissions in G8 and D8 countries from 1999 to 2013. The study employed Principal Component Analysis (PCA) to construct a financial development index based on its five constituent sub-components. Second-generation panel unit root tests are utilized to assess the stationary level and address the existence of cross-sectional dependence in panel data. The empirical findings from the PMG-panel ARDL technique indicated that there is a significant and positive relationship between financial development and carbon emissions at a 1% statistical significance level in both panels over the long-term. The influence of financial development is more pronounced in D8 countries, while energy consumption has a stronger effect in G8 countries. Energy consumption and trade liberalization have a positive impact, while GDP has a significant negative effect on carbon emissions at a 1% statistical significance level. The D-H causality test results indicated that most variables exhibit one-way causality towards CO₂ emission in both panels, with the exception of financial

development and energy use, which demonstrate two-way causality in the G8 panel exclusively.

Abid, *et al.*, (2022) have extensively studied the relationship between foreign direct investment and economic growth in the field of environmental economics. However, there is a lack of research on the impact of financial development and technological innovation on the environment. The G8 countries (UK, USA, Canada, Germany, France, Italy, Russia, Japan) have experienced a significant rise in urbanization due to their rapid economic growth. This urbanization has led to a substantial increase in energy consumption, which in turn is responsible for the current environmental degradation. This study aimed to assess the influence of technological innovation, financial development, foreign direct investment, energy consumption, and urbanization on carbon emissions in G8 member countries. The analysis was conducted using data from 1990 to 2019. The findings revealed a significant cross-sectional interdependence among the countries in the panel. The FMLOS estimator has identified a significant and negative correlation between foreign direct investment, financial development, and technological innovation in G8 countries with CO₂ emissions. A study has discovered an inverse correlation over a long period of time between economic growth, financial development, urbanization, trade openness, CO₂ emission, and energy use. Conversely, there is a one-way relationship between carbon emission and foreign direct investment.

In their study, Rafique, *et al.*, (2020) found that previous research on the relationship between foreign direct investment and economic growth failed to consider the significant influence of technological innovation and financial development on environmental costs. The significant economic growth and subsequent rapid urbanization in BRICS countries have resulted in a substantial increase in energy

demands, which has led to environmental degradation. The study aimed to investigate the impact of foreign direct investment, technological innovation, and financial development on carbon emissions in BRICS member countries using data from 1990 to 2017. The results confirmed a significant cross-sectional interdependence among the countries in the panel. The Augmented Mean Group (AMG) estimator revealed a negative and statistically significant long-term relationship between foreign direct investment, technological innovation, and financial development in the BRICS countries and CO₂ emissions. On the other hand, economic growth, trade openness, urbanization, and consumption of energy were found to have a statistically significant and positive impact on carbon emissions. The present study opted to utilize the Dumitrescu and Hurlin panel causality test to investigate the direction of causality. The findings indicated that there is a two-way causal relationship over a long period of time between financial development, economic growth, trade openness, urbanization, energy use, and CO₂ emissions. However, there is only a one-way causal relationship between foreign direct investment and carbon emissions.

Xu, *et al.*, (2018) conducted a study to investigate the impact of financial development on environmental degradation in Saudi Arabia from 1971 to 2016. The study controlled for the effects of globalization and electricity consumption in the model. The autoregressive distributive lag (ARDL) method was used to analyze long-run relationships, while the vector error correction method (VECM) is used to examine causal relationships. The empirical findings demonstrated that the advancement of financial systems had a direct impact on the increase of CO₂ emissions and the deterioration of environmental conditions. The findings further indicated that the impact of globalization on environmental degradation is negligible, while electricity consumption emerges as the primary factor driving the increase in CO₂ emissions in

Saudi Arabia. Furthermore, there was an inverse connection between globalization and CO₂ emissions over an extended period of time, and there is a mutual causal relationship between financial development and CO₂ emissions.

In their study, Khan, *et al.*, (2018) investigated the impact of financial development, inequality of income, consumption of energy, and per capita GDP on carbon dioxide (CO₂) emissions, as well as the presence of the environmental Kuznets curve (EKC), in three developing Asian countries: Bangladesh, India, and Pakistan. The empirical investigation utilized panel data from 1980 to 2014 and employed the Fully Modified Ordinary Least Squares (FMOLS) method to analyze the Stochastic Impacts by Regression on Population, Affluence, and Technology model. The findings indicated a notable inverse correlation between financial development and CO₂ emissions in the three chosen Asian nations, except for India. The findings additionally demonstrated that income inequality in Pakistan and India led to a decrease in CO₂ emissions, whereas the outcome for Bangladesh was the opposite. In addition, energy consumption had a notable and favorable impact on carbon dioxide (CO₂) emissions in Bangladesh, Pakistan, and India. The results of our empirical analysis, which involved evaluating the long-run and short-run elasticity, indicate that the Environmental Kuznets Curve (EKC) holds true in both Pakistan and India.

In a study of the BRICS nations (Brazil, Russia, India, China, and South Africa), Baloch *et al.* (2019) studied the link between financial development and carbon emissions. In their study, the authors used panel data and applied Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) techniques to identify the long term relationship between financial development and carbon emissions for the period 1990 to 2014. The first indicator of financial development used was the ratio of domestic credit to GDP. The study results showed that increased financial development

in the BRICS countries results in rising carbon emissions due to the increase in industrial activity that is generally financed by the financial sector. The authors argue that while financial development is important for economic growth, it is equally important to implement policies that encourage green investments and the progress of low carbon technologies to offset the environmental effects of financial development. In Sahoo and Sethi (2022), various methodological estimations were empirically used to study the relationship between energy consumption and financial development in India from 1980 to 2017. Results showed that, financial development is detrimental to energy consumption.

Khan, Khan, and Binh (2020) use different estimation methods to investigate the heterogeneity of renewable energy consumption, CO₂ emissions, and financial development for a panel of 192 countries. The study shows that there is a negative correlation between the utilisation of renewable energy and carbon emissions while financial development has a strong positive relationship with carbon emissions. Xu *et al.* (2024) show that a robust financial market leads to a reduction in carbon emissions and a decrease in use of renewable energy (Xu *et al.* 2024). The results show that financial development plays an important role in reducing carbon emissions and energy consumption in China (Xu *et al.* 2021) but has no significant impact on carbon emissions in the MENA region (Wu *et al.* 2022). In China, carbon emissions per unit of GDP are overall reduced. Ji and El-Halwagi (2020) find a positive correlation between carbon emissions in China and the financial sector of China. Although there are many empirical studies on the impact of financial development on environmental degradation (Paramati, Alam, and Apergis 2018; Abbasi & Riaz, 2016; Wang *et al.* 2015), none have studied the impact of financial development on the correlation

between renewable energy consumption and carbon emissions in developing economies.

2.4.2 Moderating role of Institutional Quality

A moderating variable is a type of variable that affects the relationship between a dependent variable and an independent variable. When performing regression analysis, understanding how changes in an independent variable affect a dependent variable can be done using a moderator. This study will use institution quality as the potential moderator.

2.4.2.1 Institutional quality and Carbon emissions

In their study, Bakhsh, et al., (2021) investigated how institutional quality and technological innovation influence the relationship between foreign direct investment (FDI) inflows and four CO₂ emissions indicators in 40 Asian countries from 1996 to 2016. They employed the generalized method of moment (GMM) estimation to analyze the data. Empirical findings indicated that FDI inflows have a positive effect on CO₂ emissions, particularly in the context of non-interactive regression. However, we have also determined that the role of institutional quality and technological innovation is essential in influencing the relationship between FDI and CO₂ emissions. Specifically, the interaction between institutional quality measures and FDI inflows was found to significantly decrease the level of CO₂ emissions. Moreover, there is a notable moderating impact of technological innovation on the relationship between foreign direct investment (FDI) and carbon dioxide (CO₂) emissions.

In their study, Khan and Rana (2021) investigated the impact of trade, institutional quality, and their interactions on carbon dioxide emissions in a panel sample of 40 Sub-Saharan African countries. The study employed the system generalized method of

moments to analyze the data. The findings indicated that institutional reforms have a clear and undeniable positive impact on the environment. Conversely, the effects of trade on the environment are contingent upon the institutional framework of a nation. To be more precise, trade openness has a detrimental effect on the environment in countries that have poor institutional quality, while it has a positive impact on the environment in countries with high institutional quality. This implies that countries with low institutional quality must undergo institutional reforms in order to fully realize the positive impact of trade on their environment.

Khan and Rana (2021) examined the cause-and-effect connection between economic growth, energy usage, openness to trade, development of the financial sector, foreign direct investment, government spending, institutional quality, and pollution emissions in 41 Asian economies from 1996 to 2015. In addition, we conduct separate tests to assess the influence of political and economic institutions on pollution emissions in the economies included in our sample. The results obtained from the analysis using the panel cointegration method and panel vector error correction models (VECM) confirmed the existence of a cointegration relationship among all the variables selected. Although economic development, energy consumption, trade openness, and foreign direct investment contribute to environmental degradation, financial development and improved economic institutions assist the selected countries in reducing their pollution emissions. Furthermore, improved economic and political institutions play a role in mitigating the negative effects of income, trade openness, and foreign direct investment (FDI) on pollution emissions. According to the VECM model, per capita GDP is the sole variable that has a causal impact on pollution emissions in all of the models. The causal effect is significant only in a few cases for all the other variables.

In their study, Haldar and Sethi (2021) examined how the quality of institutions affects the relationship between energy consumption and CO₂ emissions in 39 developing countries from 1995 to 2017. They also considered other factors such as trade, capital formation, foreign direct investment (FDI), financial development, and population. We employed various econometric techniques, namely mean group (MG), augmented mean group (AMG), common correlated effects mean group (CCEMG) estimator, dynamic system GMM, panel grouped-mean FMOLS, and panel quantile regression, to analyze the empirical results. Through various estimation techniques, we have discovered that the quality of institutions plays a moderating role in energy consumption and enhances its effectiveness in reducing carbon emissions. The joint impact of institutional quality and energy consumption by sector on emissions is substantial and adverse. Our research also validated the hypothesis of the Environmental Kuznets curve (EKC) when considering the influence of institutional quality. Renewable energy usage has been observed to substantially decrease emissions over an extended period of time.

Jahanger, et al., (2023) Although developing economies have achieved economic success, the majority of them have not yet achieved environmental sustainability. However, if these economies fail to maintain the quality of the natural environment, they will also fail to sustain their trade and industry growth. The primary objective of this study was to investigate the impact of natural resources and institutional quality on carbon emissions throughout the process of globalization. This was achieved by employing two-stage least square and panel threshold methods on a global panel consisting of 73 countries that were developing from 1990 to 2018. This study also applied these empirical models to three sub-panel regions: Asia, Africa, and Latin America. The study's findings indicated that natural resources, globalization, institutional quality, and human capital have had a detrimental effect on carbon dioxide

emissions. On the other hand, foreign investment and consumption of energy have the potential to increase emission levels. The panel threshold test revealed that economies in developing nations with natural resources scoring beneath the threshold of 3.0315 points are likely to experience an increase in environmental pollution. This study emphasized the moderating impact of institutional quality and natural resources on carbon emissions. The findings of the other study indicated that both the environmental Kuznets curve and pollution haven hypothesis were present in all countries.

In a study conducted by Yuan, et al., (2022), China's economy is under increasing pressure to decrease carbon dioxide (CO₂) emissions. This study examined the influence of green innovation and institutional quality on CO₂ emissions, and analyzed the moderating influence of institutional quality. The findings indicated that: (1) Green innovation greatly decreased the amount of CO₂ emissions. The presence of high institutional quality had an adverse impact on the correlation between green innovation and CO₂ emissions. Specifically, when institutional quality is elevated, green innovation exhibited a more pronounced decrease in CO₂ emissions. (2) Green innovation greatly decreased carbon dioxide (CO₂) emissions in both the eastern and western regions. Furthermore, as the quality of institutions improved, there is an increase in the reduction of CO₂ emissions through green innovation in the western region. The impact of green innovation on reducing CO₂ emissions was more significant during the period of 2013-2017 compared to 2005-2012.

In their study, Dada and Ajide (2021) investigated the influence of institutional quality on the relationship between the shadow economy and environmental pollution in Nigeria from 1984 to 2018. In addition, the study also identified a particular form of institutional quality which reduced the size of the shadow economy and mitigated environmental pollution. The shadow economy was quantified as a proportion of the

gross domestic product (GDP) through the utilization of the currency demand approach, while pollution to the environment is represented by the per capita emission of carbon dioxide (CO₂). The estimation technique employed was Autoregressive Distributed Lag (ARDL). The study's findings indicated that the shadow economy has a notable and positive impact on environmental pollution, both in the short and long term. Conversely, the quality of institutions was found to have an adverse influence on environmental pollution. This study demonstrated that the presence of a shadow economy has a negative impact on environmental quality, while the quality of institutions helps to reduce environmental pollution. In the long term, the correlation between the interacting term of shadow economy and institutional quality had a negative impact on environmental pollution, although this impact was not statistically significant.

Boussaidi and Hakimi (2024, January) aimed to examine the potential advantages of a more inclusive financial system for both economic growth and the environment. Additionally, it examined the moderating influence of institutional quality (IQ) on the relationship between growth and the environment. The study utilized a dataset consisting of 12 countries in the Middle East and North Africa (MENA) region, covering the period from 2004 to 2021. The analysis employed the seemingly unrelated regression (SUR) model. The results suggested that the presence of financial inclusion (FI) had a notable impact on the magnitude of CO₂ emissions. Therefore, the presence of a more comprehensive financial system has had a negative impact on the environmental conditions in the MENA region. Nevertheless, FI does not have a substantial impact on the rate of growth. Moreover, our research revealed that the correlation between FI and IQ positively influenced development and enhanced the

overall condition of the surroundings. The observed impact is more evident when the variable being measured is the quality of the environment rather than growth.

In their study, Haldar and Sethi (2021) find that institutional quality is very important in reducing the negative effect of renewable energy consumption on CO₂ emissions. In Acheampong *et al.* (2019), the impact of institutional quality on the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa (SSA) was studied. A dynamic panel data methodology, specifically the System Generalized Method of Moments (GMM), was used to investigate data from 44 SSA countries over the period 1980 to 2015. Government effectiveness, regulatory quality, and control of corruption were the indicators of institutional quality. The research found that an improvement in institutional quality greatly increases the advantage of renewable energy in reducing carbon emissions. This research finds that robust institutions are important to ensure that renewable energy investments actually lead to real decreases in carbon emissions in SSA (Acheampong *et al.*, 2019).

Bhattacharya *et al.* (2017) found a negative correlation between institutional quality and environmental degradation in Sub-Saharan African nations. Enhanced institutional quality reduces CO₂ emissions significantly according to Ibrahim and Law (2016) and Wang *et al.* (2018). On the other hand, Godil *et al.* (2020) found that institutions and governance are responsible for environmental degradation. Hunjra *et al.* (2020) investigated the relationship between financial development and CO₂ emissions in five South Asian countries using IQ as a moderating variable. Results indicate that institutional quality has a negative effect on both financial development and carbon emissions.

Sarkodie *et al.* (2020) study of 47 Sub-Saharan African countries showed that income level, governance, and renewable energy interact to increase greenhouse gas levels, but only renewable energy is shown to reduce greenhouse gas levels in these countries. The literature does not provide studies on the moderating effect of institutional quality on the relationships between renewable energy consumption and CO₂ emissions. One of our aims is to investigate how institutional quality affects the relationship between renewable energy consumption and carbon emissions.

There is a lot of information about institutions and economic growth, but very little on the effects of institutions on environmental and energy issues (Arminen and Menegaki, 2019). Bhattacharya *et al.* (2017) claim that institutions that improve property right protection promote voluntary exchange and help governments formulate and implement sustainable development policies. Therefore, the success of governmental strategies, which are based on environmental and renewable energy initiatives, is determined by the proficiency of institutions that are necessary for the successful outcome of governmental strategies. Institutions not only affect economic growth but also the effectiveness of energy policies, argues Omri (2014). In addition, better institutions enable more energy efficient energy and renewable energy implementation and stricter energy and environmental policies (Cadoret & Padovano, 2016; Fredriksson & Svensson, 2003; Fredriksson, Vollebergh, & Dijkgraaf, 2004; Stern *et al.*, 2012). Empirically, Abid (2016) shows that government effectiveness, political stability and control of corruption help mitigate the increase of CO₂ emissions in Sub-Saharan Africa, but regulatory quality and the rule of law do not reduce the increase of CO₂ emissions in Sub-Saharan Africa. Abid (2016) extends the previous research by finding that government effectiveness, political stability, control of corruption, regulatory quality and the rule of law limit the growth of CO₂ emissions in the EU, but none of

these institutional measures significantly affect CO₂ emissions in the Middle East and North Africa region. Institutional variables should be included in the study of the relationship between renewable energy, CO₂ emissions and economic growth as institutions affect economic, energy and environmental policies, which can mitigate the bias of variable omission.

2.4.3 Control variables

A control variable is a variable that remains constant during a research investigation. The variables in question, that is population, industrialization and foreign direct investment are not the primary focus of this investigation, but they are being controlled since they have the potential of affecting the results.

2.4.3.1 Population growth and Carbon emissions

According to Sulaiman and Abdul-Rahim (2018) In theory, population growth is thought to lead to an increase in greenhouse gas emissions, specifically CO₂ emissions, due to the rise in human activities. This study aimed to examine the aforementioned claim in Nigeria by employing an autoregressive distributed lag model. The analysis covered three different time periods: 1971-2000, 1971-2005, and 1971-2010, with each period being analyzed sequentially. The findings suggested that population did not have a significant impact on CO₂ emissions over the entire duration of the study. Nevertheless, it was discovered that economic growth was the sole determining factor of CO₂ emissions in the long term during the periods under study. Nevertheless, in the immediate term, nearly all the factors that explained CO₂ emissions, including population growth, economic growth, and energy consumption, and their respective delays, were found to be statistically significant.

In their study, Dong, *et al.*, (2018) examined the relationship between carbon dioxide (CO₂) emissions, economic and population growth, and renewable energy in different regions. In order to accomplish this, a dataset consisting of 128 countries over the time span of 1990-2014 is used. The dataset is unbalanced. Given the presence of cross-sectional dependence and slope homogeneity in the panel, a set of econometric techniques that account for both cross-sectional dependence and slope homogeneity is used. The cross-sectional dependence and slope homogeneity tests revealed the presence of substantial cross-sectional dependence and heterogeneity. The empirical findings of the common correlation effect mean group (CCEMG) estimator revealed that, at both the international and local scales, the size of the population and the rate of economic growth had a positive and statistically significant impact on the levels of CO₂ emissions.

According to Shaari, *et al.*, (2021), air pollution might have an impact on human health. Pollution can result from economic activity and the consumption of non-renewable resources. Previous studies commonly employed CO₂ emissions as a surrogate measure for environmental deterioration. Carbon dioxide (CO₂) emissions are increasing in most countries, including developing nations. This study aimed to investigate the effects of energy consumption, economic growth, and rural population growth on CO₂ emissions, in response to the pressing environmental concerns. This study aimed to investigate the influence of rural population growth on CO₂ emissions. The panel Autoregressive Distributed Lag (ARDL) method was utilized to analyze data from 1990 to 2015 in 9 chosen developing nations with distinct geographical regions. The findings revealed that over time, increased energy consumption and economic expansion can lead to a rise in CO₂ emissions, whereas growth in rural population has no impact on CO₂ emissions. In the short term, there is no correlation between the growth of the rural

population and the emission of CO₂. Nevertheless, in the short term, usage of energy and economic development can have harmful effects on the environment.

Shaari, *et al.*, (2021) analyzed the equivalence relation and long-term effects of five variables in Iran from 1973 to 2008: CO₂ emissions, energy use intensity, gross domestic product growth rate, urban population, and population growth. The study also examined the interactions between these variables. In order to achieve this objective, the vector autoregressive model (VAR) has been employed. The initial stability of variables has been assessed using the Dickey-Fuller test. Subsequently, the Johnson test has been employed to analyze the convergence of five variables. The findings of this study demonstrated that the intensity of energy use, gross domestic product growth rate, urban population, and population growth all had a positive impact on CO₂ emissions.

Abdouli, *et al.*, (2018), conducted a study to analyze the non-linear impact of economic growth, foreign direct investment, and population density on environmental degradation in the BRICTS countries between 1990 and 2014. Recent panel unit root tests confirmed that all the variables are stationary. By employing static (OLS, FE, and RE) and dynamic (system GMM) panel data methodologies, it was determined that there exists a correlation between CO₂-GDP, which highlights the presence of the Kuznets curve in specific instances. Indeed, the Kuznets curve held true in the BRICTS countries. This validation is enhanced by the correlation between CO₂ emissions and density of population, as well as the correlation between CO₂ emissions and FDI inflows. The comprehensive findings indicated that as the population density and FDI inflows rose, there was an initial increase in CO₂ emissions. However, once the population and FDI inflows reached a certain threshold level, the CO₂ emissions decreased. This outcome supports the FDI halo hypothesis. However, the relationship between CO₂ emissions and economic growth does not adhere to the Kuznets curve.

Chen, *et al.*, (2022) conducted a study to investigate the relationship between economic expansion, consumption of energy, urbanization, population growth, and carbon emissions in the BRICS economies from 1990 to 2019. To ensure accurate and consistent results, we utilized contemporary econometric methods that effectively account for cross-sectional dependence and variations in slopes. Based on the results, the panel that was analyzed showed a diverse range of characteristics and was interrelated across different sections. Furthermore, all the series were initially transformed to achieve stationarity through differencing, and they were found to be co-integrated in the long run. The Augmented Mean Group (AMG) and the Common Correlated Effects Mean Group (CCEMG) estimators were used to calculate the impact of the predictors on the explained variable. Both estimators showed that energy consumption negatively affected environmental quality by causing high carbon emissions. In addition, the AMG estimator confirmed that economic growth is a strong and positive factor influencing carbon emissions. Nevertheless, both estimators verified that urbanization and population growth have minimal impact on the emissivity of carbon. Regarding the causal relationships within the series, there was an inverse causality observed between economic growth and carbon emissions, between energy consumption and economic growth, between economic growth and population growth, between energy consumption and urbanization, and between economic growth and urbanization. Finally, a causal relationship between urbanization and carbon emissions emerged.

2.4.3.2 Industrialization and Carbon emissions

In their study, Mentel, *et al.*, (2022) examined the correlation between industry value added, renewable energy, and CO₂ emissions in a sample of 44 Sub-Saharan African countries from 2000 to 2015. This study provided significant contributions to existing

research. The previous research primarily examined the connection between renewable energy and CO₂ emissions. However, this current study specifically investigated how the renewables sector influences the relationship between industrialization and CO₂ emissions. Furthermore, this study examined whether the existence of environmental Kuznets curve (EKC) relationships remains valid even after taking into account structural transformations, such as the contributions of industries to gross domestic products (GDPs). Furthermore, we are currently reevaluating the validity of the Environmental Kuznets Curve (EKC) framework for the countries in Sub-Saharan Africa. Through the implementation of a two-step system GMM estimator, we have determined that the proportion of industry in the Gross Domestic Product (GDP) has a significant and favorable effect on carbon dioxide (CO₂) emissions. Conversely, the production of renewable electricity has been observed to decrease CO₂ emissions. Assuming causality, a 1% increase in renewable electricity production resulted in a 0.22% decrease in carbon emissions. Furthermore, the renewable energy sector acts as a mediator for the positive impact of industry value added on CO₂ emissions. We have also discovered evidence supporting the statistical significance of the inverted U-shaped correlation between GDP per capita and CO₂ emissions.

Mahmood, *et al.*, 2020) Maintaining a sustainable environment is consistently a significant obstacle for countries that export oil. In this scenario, the process of industrialization and the rapid expansion of urban areas can exacerbate the problem. We examined the impact of industrialization and urbanization on the per capita CO₂ emissions in Saudi Arabia over the period of 1968-2014. The findings indicated that both industrialization and urbanization have a negative impact on the environment. Industrialization has a rigid effect on emissions, while urbanization has a more flexible effect. There is also a disparity in the correlation between industrialization and

emissions. Industrialization has a greater environmental impact when it increases compared to when it decreases.

In the study conducted by Dong, *et al.*, (2019), The occurrence of peak carbon emissions in developed economies can serve as a valuable benchmark for other economies. The peak carbon intensity, per capita carbon emissions, and carbon emissions in developed economies can be divided into three distinct stages. This study examined various indicators, including gross domestic product (GDP), per capita GDP, industrialization rate, urbanization rate, and others, at each stage. An analysis of the effects of urbanization and industrialization on carbon emissions is conducted using a threshold regression model. The findings suggested that both urbanization and income level have a substantial dual-threshold impact on carbon emissions. From an urbanization standpoint, there is no substantial correlation between carbon emissions and urbanization during the early stages of urban development. Nevertheless, urbanization during the mid-urbanization stage has an adverse impact on carbon emissions. Subsequently, the suppressive impact transforms into a stimulative impact once the level of urbanization surpasses the second threshold. Industrialization played a significant role in the increase of carbon emissions, as observed from the standpoint of income level. Industrialization had a progressively greater impact on carbon emissions in the low- and intermediate-income levels. Nevertheless, this promotional impact starts to diminish among individuals with high incomes.

Raheem and Ogebe (2017) conducted a study to examine the impact of industrialization and urbanization on carbon dioxide (CO₂) emissions in 20 African countries from 1980 to 2013. To address the issue of cross-sectional dependence, this study employed the pooled mean group approach. Furthermore, the study enhanced the existing body of knowledge by quantifying the direct, indirect, and overall impacts of industrialization

and urbanization on carbon emissions. The findings indicated a direct correlation between industrialization, urbanization, and an increased rate of environmental degradation. Industrialization and urbanization were discovered to have the additional benefit of decreasing environmental degradation by indirectly increasing per capita income. Overall, the authors' conclusion suggested that the indirect impact of industrialization will outweigh the direct impact, resulting in a decrease in the overall influence of industrialization on carbon emissions. Furthermore, the beneficial direct impact of urbanization surpasses the detrimental indirect impact, thereby posing a significant long-term threat to carbon emissions.

Salahodjaev, *et al.*, (2023) examined the correlation between industrialization and CO₂ emissions in a subset of OIC member countries from 1995 to 2020. The study utilized panel data methods, specifically the two-step system GMM estimator, to address the issues of endogeneity and simultaneity. The empirical findings indicated that the process of industrialization has a beneficial impact on the levels of CO₂ emissions. Renewable energy and financial development have a contrasting effect on CO₂ emissions by inhibiting pollution. Additionally, our findings indicated that an increase in GDP and ICT usage is positively correlated with an increase in CO₂ emissions. Patel and Mehta (2023) conducted a study to examine the impact of India's economic growth, industrial development, fossil fuel energy production, financial development, and globalization on carbon dioxide (CO₂) emissions. The study employed Non-Linear Autoregressive Distributive Lag (NARDL) analysis to investigate the relationship, utilizing annual time series data spanning from 1971 to 2019. The results revealed a persistent correlation between CO₂ emissions and other variables. Industrialization and economic expansion have a significant and enduring positive effect on carbon dioxide (CO₂) levels, while globalization significantly reduces CO₂ emissions.

According to Afriyie, *et al.*, (2023), In recent decades, there have been significant changes in urbanization and economic growth in sub-Saharan Africa. Countries in this region have been actively pursuing industrialization as a means to enhance their economic growth. This study utilized panel data from 37 sub-Saharan countries spanning from 1995 to 2017. It employs panel cointegration tests and pooled mean group ARDL (PMG-ARDL) techniques, along with the Dumitrescu-Hurlin causality test, to empirically analyze the effects of urbanization, economic growth, energy consumption, and industrialization on carbon emissions. The findings from the PMG estimator indicated that there was no statistically significant influence of urbanization on carbon emissions, both in the long term and the short term. A 1% increase in energy consumption was found to have a significant impact, resulting in a 1.03% increase in carbon emissions in the long run and a 0.15% increase in the short run. This ultimately leads to a decrease in environmental quality. Additional research uncovered a strong inverse correlation between economic growth and carbon emissions, as well as between industrialization and carbon emissions. Furthermore, our causality test revealed a one-way relationship where energy consumption directly influences carbon emissions.

Ghazouani (2022), analyzed the effects of foreign direct investment (FDI) inflows, urbanization, industrialization, and technological innovation on CO₂ emissions in Tunisia. The study utilized data from the period of 1980 to 2016. In order to assess the stationarity of variables that have structural breaks, both sharp and gradual, we utilized a new unit root test called the Structural Breaks-Oriented Test (SOR). We employed the bootstrap ARDL bounds test method to verify the presence of cointegration between CO₂ and its determinants. The empirical findings highlighted that there is a long-term relationship between CO₂ emissions, FDI, urbanization, energy consumption, industrialization, technological innovation, and economic growth, as they are

cointegrated. In addition, we discovered a curvilinear relationship between CO₂ emissions and urbanization. The process of industrialization, along with the increase in real GDP and energy consumption, has a detrimental impact on the environment. FDI inflows and technological innovation have a negligible impact on CO₂ emissions, whereas the interaction between FDI inflows and technological innovation has significantly enhanced the environment in Tunisia. The vector error correction model confirmed the presence of a feedback relationship between CO₂ emissions and its constituent components.

Mentel, *et al.*, (2022) conducted a study to evaluate the influence of industrialization and the renewable energy industry on greenhouse gas emissions, specifically focusing on CO₂ emissions in Europe and Central Asia. We utilized a two-step system GMM estimator on a sample of 48 countries spanning the years 2000 to 2018. The empirical findings indicated that there is a direct correlation between industrialization and CO₂ emissions. Specifically, for every 10% increase in industry value added as a percentage of GDP, there is a corresponding increase of 2.6% in CO₂ emissions. Renewable energy, on the other hand, reduced CO₂ emissions. A 10% increase in renewable energy consumption resulted in a 2.2% reduction in CO₂ emissions per person. The coefficient for the interaction between renewable energy and industry value added is negative, indicating that the consumption of renewable energy offsets the negative impact of industrialization on environmental quality. The primary findings of our study have also validated the U-shaped inverted correlation between GDP per capita and CO₂ emissions.

2.4.3.3 Foreign Direct Investment and Carbon emissions

Bouchoucha (2024) Foreign direct investment acts as a catalyst for economic growth in developing nations. Nevertheless, foreign direct investment (FDI) introduces

industries that emit pollutants, leading to a decline in environmental conditions in developing countries, particularly in the Middle East and North Africa (MENA) region. Consequently, these nations are attempting to enhance their environmental safeguards. This study aimed to investigate how the quality of institutions affects the relationship between foreign direct investment and environmental degradation in 17 Middle East and North African (MENA) countries. We employed various econometric techniques including ordinary least squares (OLS), fixed effects (FE), random effects (RE), and system generalized moments method (S-GMM) during the time frame from 1996 to 2018. The study employed six governance dimensions, specifically, corruption control, accountability of voice, adherence to the rule of law, quality of regulation, effectiveness of governance, and political stability. The results of our study indicated that foreign direct investment (FDI) has led to an increase in carbon dioxide (CO₂) emissions in the countries of the Middle East and North Africa (MENA).

Zheng, *et al.*, (2024) The NARDL model is used to analyze the impact of FDI on China's carbon emissions by dividing FDI into two shocks, FDI+ and FDI-. The results indicated that in the short-term, positive foreign direct investment (FDI+) had a notable impact on increasing China's carbon emissions, while negative foreign direct investment (FDI-) did not have a significant effect. In the long-term, both positive and negative FDI significantly accelerated China's carbon emissions, with the promoting effect from negative FDI being considerably higher. The "Pollution Haven" effect was confirmed in both the long-term and short-term. China's carbon emissions exhibited a "U-shaped" correlation with economic progress, and were positively associated with population expansion and energy intensity.

Parmová, *et al.*, (2024) conducted a study to examine the influence of renewable energy and Foreign Direct Investment (FDI) on carbon dioxide (CO₂) emissions in 45 countries

in Europe and Central Asia from 2000 to 2019. By employing the two-step system generalized method of moments (GMM) estimator, our research uncovered that both foreign direct investment (FDI) and renewable energy have significant impacts in reducing CO₂ emissions. Countries that had a greater integration of renewable energy saw a more significant decrease in CO₂ emissions as a result of foreign direct investment (FDI). Moreover, our examination revealed a curvilinear association between GDP per capita and CO₂ emissions, suggesting a complex pattern of environmental influence alongside economic expansion. Furthermore, our research revealed a negative relationship between carbon dioxide emissions and both the agriculture sector and the size of the government.

Kim and Seok (2023) conducted a study to examine the correlation between the inflow of foreign direct investment (FDI) and carbon dioxide (CO₂) emissions in Korea. They utilized the autoregressive distributed lag model for their analysis. We conducted a study to examine the influence of Foreign Direct Investment (FDI) on carbon dioxide (CO₂) emissions, specifically focusing on the economic growth of Korea. We analyzed yearly data from 1971 to 2015. Our findings indicated that over an extended period of time, foreign direct investment (FDI) inflows have a positive impact on carbon dioxide (CO₂) emissions. Nevertheless, the magnitude of the positive impact diminished as income levels rose. Over time, the impact of foreign direct investment (FDI) inflows shifted from being beneficial to becoming detrimental, ultimately leading to an increase in GDP per capita in the long term. Therefore, although the pollution haven hypothesis is valid at a lower income threshold, the pollution halo hypothesis becomes relevant at a higher income threshold.

Pata, *et al.*, (2023) Researchers have shown interest in studying the impact of renewable energy, tourism, foreign direct investment, and income on environmental degradation.

However, no researcher has yet investigated the combined effects of these factors on CO₂ emissions in the countries of the Association of Southeast Asian Nations (ASEAN). This study seeks to examine the factors that influence carbon dioxide (CO₂) emissions in six ASEAN countries, using the environmental Kuznets curve (EKC) hypothesis. The motivation for this research stems from the existing gap in the literature on this topic. In order to achieve this objective, the study employed the panel ARDL estimator and the Dumitrescu-Hurlin panel causality test, covering the period from 1995 to 2018. The findings indicated that both tourism and foreign direct investment have a positive correlation with the increase in CO₂ emissions. (ii) Increased real income and greater trade openness have a mitigating effect on environmental degradation. (iii) The validity of the EKC hypothesis is supported by the fact that the long-run income elasticity is lower than the short-run. (iv) Renewable energy mitigates carbon emissions in the short term but does not have a lasting impact on long-term environmental quality. There is no direct cause-and-effect relationship between renewable energy and environmental degradation.

In their study, Yi, *et al.*, (2023) examined the influence of foreign direct investment (FDI) on carbon emissions in China's manufacturing industry. They analyzed statistical data spanning from 2003 to 2020 as a basis for their research. In order to accommodate the diversity of manufacturing industries, we categorized them into three distinct groups according to their input factors: resource-intensive, technology-intensive, and labor-intensive. The primary conclusions of our study are as follows: A negative correlation was observed between foreign direct investment (FDI) and carbon dioxide (CO₂) emissions in the manufacturing sector. FDI had a beneficial impact on decreasing carbon emissions in manufacturing industries that require significant capital, advanced

technology, and labor, with the most significant impact seen in industries that heavily rely on labor.

Chien, *et al.*, (2023), investigated the impact of foreign direct investment (FDI), economic development, and exploitation of resources on carbon emissions in G-7 member countries. This study employed a distinctive method of moments quantile regression model that considers both random effects variability and microeconomic heterogeneity. In addition, our model included several important control variables to mitigate potential endogeneity issues. The study findings revealed that the impact of external factors on carbon dioxide emissions varies across different quantiles. More precisely, foreign direct investment has negative effects on carbon emissions up to the 5th quantile, and then becomes significant at higher quantiles. Carbon emissions increased due to heightened energy consumption, with the most significant effects occurring at higher levels. High-emission nations experience a decrease in emissions as a result of increased financial development and population growth. The study's findings also validated the accuracy of the halo effect concept in countries with higher emissions.

Uddin, *et al.*, (2023) have highlighted that geopolitical risk (GPR) and various social indicators have brought attention to several serious environmental issues among government environmentalists and policy analysts. This study aimed to examine the influence of GPR, corruption, and governance on environmental degradation, specifically carbon emissions (CO₂), in the BRICS countries (Brazil, Russia, India, China, and South Africa). Data from 1990 to 2018 was used for analysis. Empirical analysis was conducted using the cross-sectional autoregressive distributed lag (CS-ARDL), fully modified ordinary least square (FMOLS), and dynamic ordinary least square (DOLS) methods. The panel unit root tests of both first and second generations indicated a combination of different levels of integration. The empirical results

indicated that government effectiveness, regulatory quality, the rule of law, foreign direct investment (FDI), and innovation are all factors that contribute to a decrease in CO₂ emissions. Conversely, factors such as geopolitical risk, corruption, political stability, and consumption of energy contribute to an increase in CO₂ emissions.

2.5 Research Gaps

The existing body of literature on energy consumption, economic growth, financial development, and carbon emissions has extensively explored various aspects of the relationship between these variables across different regions and time periods. However, significant gaps remain in terms of methodology, models employed, geographical focus, and the inclusion of institutional quality as a moderating variable, particularly in the context of Sub-Saharan Africa (SSA).

Several studies have employed different econometric methodologies to analyze the relationship between energy consumption, economic growth, and carbon emissions. For instance, Abbasi et al. (2021) utilized a dynamic ARDL simulations model and a frequency domain causality (FDC) test to analyze the impact of energy consumption and GDP on carbon emissions in Thailand from 1980 to 2018. Similarly, Yuping et al. (2021) used the Maki cointegration analysis and the Autoregressive Distributed Lag (ARDL) model to assess the impact of globalization and energy consumption on carbon emissions in Argentina from 1970 to 2018.

Other studies have employed various estimation techniques such as Fully Modified Ordinary Least Squares (FMOLS) and Vector Error Correction Models (VECM) (Saidi & Omri, 2020), panel Augmented Mean Group (AMG) estimation techniques (Zhang et al., 2023), and bootstrap Dumitrescu and Hurlin panel causality test (Banday & Aneja, 2020). These studies have provided valuable insights, yet they lack a consistent

methodological approach applicable to SSA. Moreover, methodologies such as Two-Stage Least Squares (Gyimah et al., 2023), nonlinear autoregressive distributed lag (NARDL) models (Adebayo et al., 2022), and panel threshold regression models (Li et al., 2024) have been used in various contexts but have not been extensively applied to SSA with a focus on institutional quality.

The present study addresses this gap by employing the Fixed Effects Model (FEM) and the Generalized Method of Moments (GMM) model to provide robust estimates. The FEM accounts for unobservable heterogeneity across countries, which is a critical issue in panel data analysis. The GMM model, as a robustness check, mitigates endogeneity concerns that arise due to potential reverse causality among the variables. This methodological combination has not been thoroughly explored in prior studies, particularly in the SSA context.

The models used in previous studies exhibit certain limitations in capturing the complex interplay between energy consumption, economic growth, financial development, and carbon emissions. For example, Mehboob et al. (2024) employed the CS-ARDL model, CCEMG, AMG, and D-H causality tests to examine the relationship between nuclear energy consumption and carbon emissions. Choudhury et al. (2023) used the Panel Autoregressive Distributed Lag (PARDL) technique, which is useful for capturing short- and long-term effects but does not adequately address potential endogeneity issues.

Moreover, studies such as Erdogan et al. (2020) used first- and second-generation estimation methods, including FMOLS and Dynamic Ordinary Least Squares (DOLS), while Zhao and Yang (2020) employed static panel analysis and Principal Component Analysis (PCA) to measure financial development. However, these models lack the

ability to capture moderating effects explicitly. The current study bridges this gap by incorporating institutional quality as a moderating variable, which has been largely ignored in previous models. By doing so, the study extends the theoretical framework and provides a more comprehensive understanding of how institutional quality influences the relationship between energy consumption, economic growth, financial development, and carbon emissions.

Much of the existing literature focuses on developed economies or specific emerging markets, with limited attention given to SSA. For instance, Saidi and Omri (2020) examined OECD countries, while Erdogan et al. (2020) focused on 25 OECD countries. Zhang et al. (2023) investigated China, India, Bangladesh, Japan, South Korea, and Singapore, whereas Banday and Aneja (2020) focused on Brazil, Russia, India, China, and South Africa (BRICS countries).

While these studies provide insights into the relationships among energy consumption, economic growth, financial development, and carbon emissions, they do not capture the unique economic, institutional, and environmental dynamics of SSA. SSA faces distinct challenges, including energy access limitations, political instability, and weak financial institutions, which significantly influence the effectiveness of energy policies and economic growth strategies. The present study fills this gap by specifically examining SSA, thereby providing policy-relevant insights tailored to the region.

The temporal coverage of previous studies varies significantly, with many focusing on older datasets that do not reflect recent developments in energy consumption and carbon emissions. For example, Gyimah et al. (2023) analyzed data from 1990 to 2018, while Zhao and Yang (2020) used data from 2001 onwards. Erdogan et al. (2020) considered data from 1990 to 2014, and Habiba and Xinbang (2022) examined the

period from 2000 to 2018. While these studies provide valuable insights, they do not capture the most recent trends, including the impact of renewable energy transitions, financial developments, and institutional reforms in SSA.

The current study addresses this gap by analyzing data from 2000 to 2023, ensuring that the findings reflect contemporary developments in energy policies, economic growth trends, and financial sector evolution. This extended time frame allows for a more comprehensive understanding of long-term trends and structural changes in energy consumption and carbon emissions in SSA.

Institutional quality has been largely overlooked in previous studies as a moderating factor in the relationship between energy consumption, economic growth, financial development, and carbon emissions. While some studies, such as Habiba and Xinbang (2022), have examined the influence of financial institutions on carbon emissions, they have not explicitly treated institutional quality as a moderating variable. Similarly, Li et al. (2024) explored the role of governance factors but did not integrate institutional quality as a central moderating factor in their model.

Institutional quality plays a crucial role in shaping energy policies, enforcing environmental regulations, and ensuring sustainable financial development. Weak institutions often lead to poor enforcement of environmental laws, inefficiencies in energy markets, and increased carbon emissions. By incorporating institutional quality as a moderator, this study provides a novel contribution to the literature, offering a more nuanced understanding of how governance and institutional frameworks influence energy consumption patterns and environmental outcomes in SSA.

Despite extensive research on the relationship between energy consumption, economic growth, financial development, and carbon emissions, significant gaps remain in

methodology, model selection, geographical focus, and temporal coverage. Previous studies have employed various econometric techniques but have not adequately addressed endogeneity concerns and moderating effects. Additionally, existing research predominantly focuses on developed and emerging economies, neglecting the unique challenges of SSA. The time periods covered in prior studies often fail to capture recent developments in energy policies and financial reforms.

By employing the Fixed Effects Model and GMM for robust estimation, analyzing data from 2000 to 2023, and incorporating institutional quality as a moderator, this study fills these critical gaps. The findings will offer valuable insights for policymakers and researchers seeking to design effective energy policies and carbon reduction strategies tailored to the SSA region.

2.6 Conceptual Framework

A conceptual framework is a diagrammatical illustration of the relationship between the research concepts and their impact on the phenomenon being investigated (Robert, Yu & Lewis 2021). While Huberman and Miles (1994) assert that, a conceptual framework shows either graphically or in a narrative form the aspects that is studied. In this study renewable energy consumption, non-renewable energy consumption, economic growth and financial development are the independent variable, institutional quality as the moderator variable, CO₂ emissions is the dependent variable.

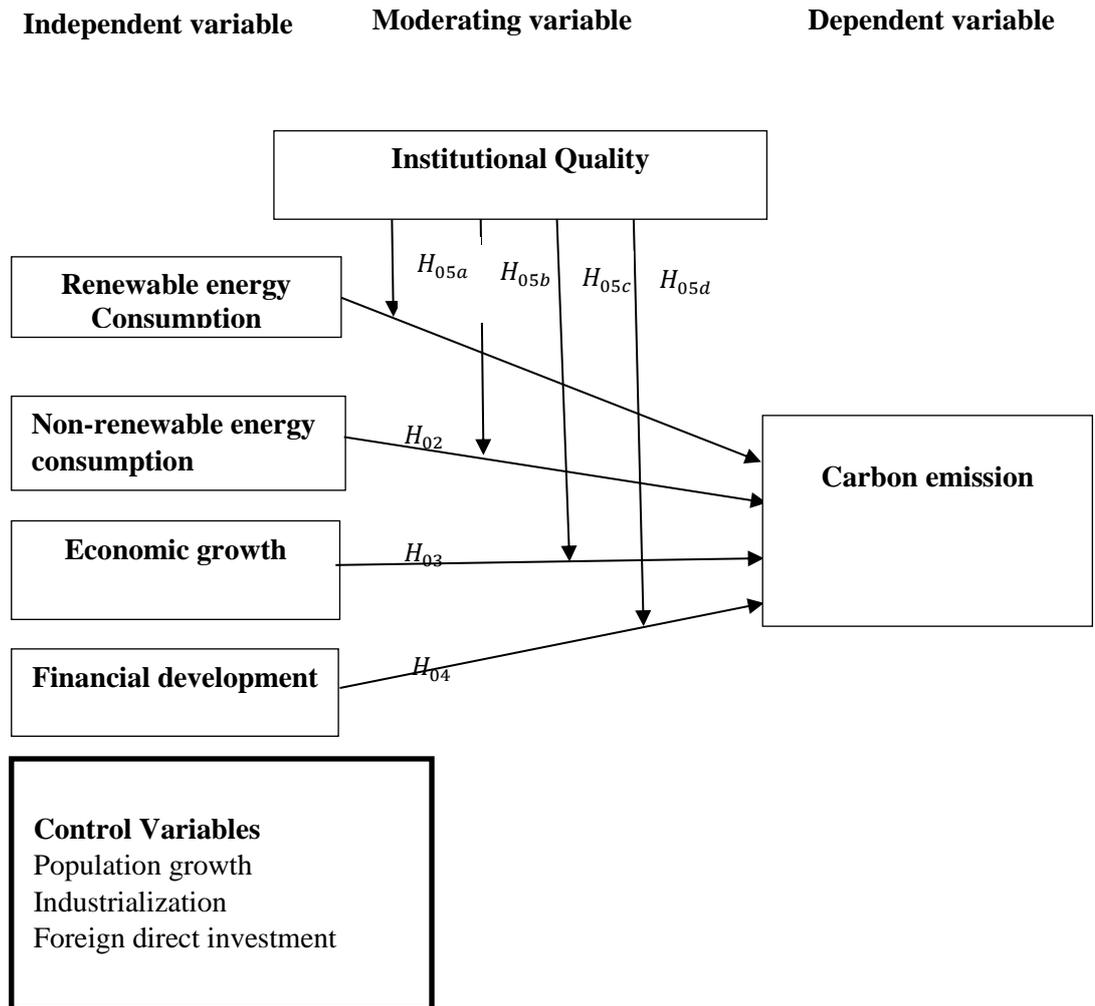


Figure 2. 1: Conceptual framework

Table 2. 1: Summary of literature

Authors	Topic	Methodology	Findings	Knowledge Gaps
Abbasi, <i>et al.</i> , (2021)	The impact of energy depletion and renewable energy on CO ₂ emissions in Thailand: fresh evidence from the novel dynamic ARDL simulation.	Novel dynamic ARDL simulations model and Frequency Domain Causality (FDC) test	The empirical results showed that the rate of depletion had a substantial negative effect on CO ₂ emissions, both in the long term and the short term. In addition, our findings indicated that renewable energy had a significant and negative effect on CO ₂ emissions in the short term. Nevertheless, the rate at which non-renewable energy is being used up and the gross domestic product (GDP) have been found to have a significant and positive impact on carbon dioxide (CO ₂) emissions, both in the short term and in the long term, according to statistical analysis. The FDC test has verified the presence of causality in the short, medium, and long term between DR, RE, DRNRE, and CO ₂ emission.	Abbasi et al. (2021) analyzed the impact of energy depletion and renewable energy on CO ₂ emissions in Thailand but did not consider institutional quality or financial development. This study fills the gap by examining the moderating role of institutional quality in Sub-Saharan Africa using panel data analysis.
Yuping, <i>et al.</i> , (2021)	the impact of globalization, renewable energy consumption, non-renewable energy consumption, and economic growth on carbon dioxide emissions in Argentina from 1970 to 2018	The findings were analysed by use Autoregressive Distributed Lag	The study revealed that renewable energy consumption and globalization have a negative impact on emissions, while non-renewable energy consumption has a positive impact on emissions, both in the short- and long-term.	Yuping et al. (2021) analyzed the impact of globalization, energy consumption, and economic growth on CO ₂ emissions in Argentina using the ARDL model, finding that renewable energy and globalization reduce emissions while non-renewable energy increases them. However, their study did not consider institutional quality or financial development and was limited to Argentina, creating a gap that this research addresses in the SSA context using panel data analysis and Gmm model
Saidi and Omri (2020)	effects of renewable and nuclear energy consumption on CO ₂ emissions in 15 OECD countries from 1990 to 2018	The study applied the Fully Modified OLS (FMOLS) and the vector error correction model approach (VECM)	Findings from the study revealed investment in nuclear energy led to a decrease in CO ₂ emissions in several countries including Canada, Netherlands, Japan, Switzerland, Czech Republic, and UK. On the other hand, investment in renewable energy resulted in a decrease in CO ₂ emissions in Belgium, Canada, France, Germany, Sweden, UK, US, Japan, Switzerland, Finland, and Czech Republic, but it led to an increase in CO ₂ emissions in Netherlands and South Korea. Furthermore, both nuclear and renewable energy consumption contributed to a reduction in carbon emissions based on the panel estimations.	Saidi and Omri (2020) study did not consider institutional quality or financial development as moderating factors and was geographically limited to OECD countries, creating a gap that this research addresses in the SSA context using panel data analysis. Additionally, they did not employ Hierarchical and GMM model in their study.

Chen, <i>et al.</i> , (2022)	It investigated the non-linear effects of renewable and non-renewable energy consumption, as well as economic growth, on per capita CO ₂ emissions	The dynamic panel threshold model.	The results indicated showed that there is a negative and significant relationship between the increase in per capita renewable energy consumption and the growth of per capita CO ₂ emissions, but only when countries exceed a certain threshold of renewable energy consumption	Chen et al. (2022) study did not incorporate institutional quality or financial development as moderating factors and was limited in methodological scope, creating a gap that this research addresses in the SSA context using hierarchical and GMM models.
Zhang <i>et al.</i> (2023)	Examined the relationship among renewable and non-renewable energy consumption, carbon dioxide emissions, and economic growth in China, India, Bangladesh, Japan, South Korea, and Singapore	Data spanning from 1975 to 2020 was utilized for analysis, employing panel Augmented Mean Group (AMG) estimation techniques.	The research indicated that prolonged carbon emissions increased markedly with the utilization of non-renewable energy, whereas prolonged carbon emissions decreased considerably upon the adoption of renewable energy.	Zhang et al. (2023) study did not consider institutional quality as moderating factor, nor did it focus on Sub-Saharan Africa, a gap that this study addresses using hierarchical and GMM models..
Ghazouani & Maktouf (2024)	effects of natural resource exploitation, trade openness, and economic growth on carbon emissions in oil-exporting countries from 1971 to 2014	The study used panel autoregressive distributed lag model and several econometric techniques that consider cross-sectional dependence.	The study showed that the depletion of natural resources and increased trade have a lasting adverse effect on environmental quality. The findings showed the validity of the Kuznets Environmental Curve for oil-exporting nations. An analysis of causation showed a two-way connection between natural resources, economic growth, and CO ₂ emissions, and a one-way connection between trade openness and CO ₂ emissions.	Ghazouani & Maktouf (2024) study did not focus on Sub-Saharan Africa or consider institutional quality and financial development, a gap this study addresses using hierarchical and GMM models..
Obobisa, <i>et al.</i> , (2022)	impact of green technological innovation, institutional quality, renewable energy, fossil fuel energy, and economic growth on CO ₂ emissions in 25 African countries between 2000 and 2018	The study employed second-generation panel.	Results revealed that CO ₂ emissions were positively influenced by factors such as institutional quality, economic growth, and the use of energy generated from fossil fuels.	Obobisa et al. (2022) study did not examine the moderating role of institutional quality in the relationship between renewable and non-renewable energy consumption, economic growth, financial development, and CO ₂ emissions, a gap this study addresses using hierarchical and GMM models..
Banday and Aneja (2019)	Studied the relationship between energy, growth and CO ₂ emissions for G7 nations between 1971 and 2014	The causality was investigated by employing an autoregressive distributed lagged model (ARDL).	The ARDL model revealed the long run relationship between energy, growth, and CO ₂ emissions. Causality results are important for Japan and the UK, but not for other countries, with regard to non-renewable resources and economic growth. The analysis did find a causal relationship between non-renewable resource use and CO ₂	Banday and Aneja (2019) study did not explore the moderating role of institutional quality or incorporate financial development as a key determinant of emissions, creating a contextual gap in Sub-Saharan

			emissions in other countries, but does find strong effects for Germany, Italy and the UK. For Germany, Italy, the UK and the USA, the causal relationship between economic progress and CO ₂ emissions is unidirectional.	Africa, which this study addresses using hierarchical and GMM models.
Zhao and Yang (2020)	The primary objective of this study was to examine the correlation between financial development and CO ₂ emissions	The study was analysed through static panel and dynamic analysis	it was determined that a single unit increase in the provincial financial development level leads to an average reduction of 4%–5% in CO ₂ emissions. However, this relationship does not hold true for the provinces of Zhejiang, Fujian, Sichuan, Yunnan, Shaanxi, and Xinjiang, as their CO ₂ emissions actually increase. Over the long term, there is evidence of an inverse association between regional financial development and CO ₂ emissions, although this is not the case in the short term. The dynamic analysis results indicated that the progress of regional financial development has had a substantial negative impact on CO ₂ emissions.	Zhao and Yang (2020) study did not consider the moderating role of institutional quality or examine the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on CO ₂ emissions in Sub-Saharan Africa, which this study addresses using hierarchical and GMM models
Lv, <i>et al.</i> , (2021)	Impact of financial development on CO ₂ emissions	It employed the spatial econometric model	it was discovered that the financial development of neighboring countries can have an impact on a country's CO ₂ emissions. The negative impact of financial development on CO ₂ emissions outweighed the positive direct impact, resulting in a significant cumulative negative effect.	Lv et al. (2021) study did not explore the moderating role of institutional quality or the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on CO ₂ emissions in Sub-Saharan Africa
Habiba and Xinbang (2022)	conducted a study to examine the influence of financial market development, institution development, and their sub-indices on CO ₂ emissions	The study employed a two-stage system Generalized Method of Moments (GMM) approach	The empirical findings demonstrated that the general development of the financial market, as well as its specific components (FM-access, FM-depth, and FM-efficiency), led to a decrease in CO ₂ emissions in both developed and emerging nations	Habiba and Xinbang (2022) study did not examine the moderating role of institutional quality or consider the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on CO ₂ emissions in Sub-Saharan Africa
Raheem, <i>et al.</i> , (2020)	examined the impact of information and communication technology (ICT) and financial development (FD) on carbon emissions and economic growth in the G7 countries from 1990 to 2014.	Utilized PMG model	The results showed that the interaction term between Information and Communication Technology (ICT) and Financial Development (FD) yields negative coefficients	Raheem et al. (2020) study did not explore the moderating role of institutional quality or consider the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on carbon emissions in Sub-Saharan Africa.

Shoab, <i>et al.</i> , (2020),	The objective of this study was to examine the causal relationship between financial development and CO ₂ emissions in G8 and D8 countries from 1999 to 2013.	The study employed PMG-panel ARDL technique	The empirical findings from the PMG-panel ARDL technique indicated that there is a significant and positive relationship between financial development and carbon emissions at a 1% statistical significance level in both panels over the long-term.	Shoab, <i>et al.</i> , (2020) study did not explore the moderating role of institutional quality or consider the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on carbon emissions in Sub-Saharan Africa
Xu, <i>et al.</i> , (2018)	The study was conducted a study to investigate the impact of financial development on environmental degradation in Saudi Arabia from 1971 to 2016	The autoregressive distributive lag (ARDL) method was used to analyze long-run relationships, while the vector error correction method (VECM) is used to examine causal relationships	The empirical findings demonstrated that the advancement of financial systems had a direct impact on the increase of CO ₂ emissions and the deterioration of environmental conditions. The findings further indicated that the impact of globalization on environmental degradation is negligible, while electricity consumption emerges as the primary factor driving the increase in CO ₂ emissions in Saudi Arabia	Xu, <i>et al.</i> , (2018) study did not consider institutional quality as a moderating factor, nor did it examine the interplay between renewable and non-renewable energy consumption, economic growth, and financial development on carbon emissions within the Sub-Saharan African context. This study addresses these gaps by employing hierarchical and GMM models to provide region-specific insights into the moderating role of institutional quality in SSA
Khan, <i>et al.</i> , (2018)	The study investigated the impact of financial development, inequality of income, consumption of energy, and per capita GDP on carbon dioxide (CO ₂) emissions, as well as the presence of the environmental Kuznets curve (EKC), in three developing Asian countries	The empirical investigation utilized panel data from 1980 to 2014 and employed the Fully Modified Ordinary Least Squares (FMOLS) method to analyze the Stochastic Impacts by Regression on Population, Affluence, and Technology model	The findings indicated a notable inverse correlation between financial development and CO ₂ emissions in the three chosen Asian nations, except for India. The findings additionally demonstrated that income inequality in Pakistan and India led to a decrease in CO ₂ emissions, whereas the outcome for Bangladesh was the opposite	Khan et al. (2018) study did not explore the moderating role of institutional quality, nor did it consider the combined effects of renewable and non-renewable energy consumption, economic growth, and financial development on carbon emissions in the Sub-Saharan African context. This study addresses these gaps by employing hierarchical and GMM models to analyze these relationships within SSA.
Bakhsh, et al., (2021)	investigated how institutional quality and technological innovation influence the relationship between foreign direct investment (FDI) inflows and four CO ₂ emissions indicators in 40 Asian countries from 1996 to 2016	The study employed the generalized method of moment (GMM) estimation to analyze the data	The interaction between institutional quality measures and FDI inflows was found to significantly decrease the level of CO ₂ emissions	Bakhsh et al. (2021) study did not analyze the moderating role of institutional quality in the relationship between renewable and non-renewable energy consumption, economic growth, financial development, and carbon emissions, nor did it focus on the Sub-Saharan African region.

Khan and Rana (2021)	investigated the impact of trade, institutional quality, and their interactions on carbon dioxide emissions	The study employed the system generalized method of moments	The findings indicated that institutional reforms have a clear and undeniable positive impact on the environment	Khan and Rana (2021) study did not examine the moderating role of institutional quality in the relationship between renewable and non-renewable energy consumption, economic growth, financial development, and carbon emissions, nor did it focus on the Sub-Saharan African region
Khan and Rana (2021)	examined the cause-and-effect connection between economic growth, energy usage, openness to trade, development of the financial sector, foreign direct investment, government spending, institutional quality, and pollution emissions in 41 Asian economies from 1996 to 2015.	The study utilized the panel cointegration method and panel vector error correction models (VECM)	The results obtained from the analysis using the panel cointegration method and panel vector error correction models (VECM) confirmed the existence of a cointegration relationship among all the variables selected. Although economic development, energy consumption, trade openness, and foreign direct investment contribute to environmental degradation, financial development and improved economic institutions assist the selected countries in reducing their pollution emissions	Khan and Rana (2021) study did not examine the moderating role of institutional quality in the relationship between renewable and non-renewable energy consumption, economic growth, financial development, and carbon emissions, nor did it focus on the Sub-Saharan African region.

Source, Researcher (2024)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

The focus of this chapter is on the research paradigm, research design, target population, data collection, measurement of variables, data analysis and presentation, model specification, regression assumption and the ethical consideration.

3.2 Research Paradigm

The concept of a research philosophy or paradigm originates from the historical development of scientific inquiry. According to Bryman (2014), this phrase previously referred to a collection of theories that provided guidance on which topics to study, which research methodologies to employ, and how to assess the results. The selection of a paradigm by a researcher reflects their ontological and epistemological perspectives. According to Rubin and Rubin (2015), it serves as a perspective to see the world, analyzes the topic being studied, and offers guidance on who should carry out research and the scope of their investigations.

Ogula and Onsongo (2019) state that a research paradigm serves as a framework for considering the concept of truth, providing advice and requiring researchers to follow a specific methodology, describe data, and interpret outcomes. The study utilized the positivist hypothesis, which asserts that companies and other social entities have a reality similar to that of physical objects and natural events. The concept that the presence of reality remains unaltered by human perception highlights the importance of doing empirical investigation and inquiry in the development and progression of ideas (Walliman, 2017).

In addition, the positivist paradigm, which is commonly linked to quantitative, traditional, and objective research, is applicable to this research setting. This is especially true when working with pre-existing and carefully structured data (Scotland, 2012). Scotland asserts that the production of precise and significant data depends on procedures that can be observed and quantified. Epistemology, in this particular context, is primarily concerned with the identification and investigation of empirical facts and observable patterns. Scientists can potentially establish generalizations akin to rules by discerning causal relationships within the data (Gill & Johnson, 2002). The alignment of this statement with positivism is consistent with the ideas of neo-empirical research and positive accounting theory, both of which are firmly based on empiricism and objective positivism.

The aim of this study was to examine social phenomena by identifying rules, causal linkages, and patterns within different aspects of the social environment. The analysis focused on these specific elements, although it may not cover all aspects. Consequently, knowledge is primarily perceived as being objective, with the aim of faithfully reflecting reality. This paradigm is appropriate for this study due to its theoretical foundation, utilization of quantitative data for hypothesis testing, and the potential for generating generalizations based on the findings.

3.3 Research Design

Bloomfield and Fisher (2019) define a research design as “the blueprint or plan that will be used by researchers to answer a specific research question.” A research design is a conceptual framework for conducting research; it serves as the guide for collecting, measuring, and analyzing data (Kothari, 2004). The components of research design include strategies for conducting the study, tools for collecting the data, methods of interpreting the data, and ways for drawing inferences. This study was guided by both

the longitudinal and explanatory research design. According to Jöreskog, Olsson and Wallentin (2016) this design is ideal where the same measurement instruments are used on the same people at two or more occasions. One of the key benefit of a longitudinal design is its ability to track change and make causal statements of various types. Longitudinal designs allow the researcher to track change and monitor the responses of a system to a stimulus and how that response changes over time. Therefore, a longitudinal research design was suitable for this study because data was collected for each country over the period between 2000-2023. According to Creswell (2012), an explanatory research design is “a correlational design in which the researcher is interested in the extent to which two variables co-vary.” An explanatory research design is usually employed to deduce the cause-and-effect relationship between variables (Mohajan, 2020).

3.4 Target Population

According to Ngechu (2017), a population is a defined set of people, services, elements, events and groups or households being investigated, According to Alexander (2015), a target population is a group "about which conclusions are to be made." Therefore, the target population comprises a collection of elements upon which research findings were generalized. The study population consisted of all 49 countries in Sub-Saharan Africa. The study variables are renewable energy consumption, non-renewable energy consumption, economic growth, financial development, institutional quality and carbon emissions. The study period spanned from 2000-2023.

3.4.1 Inclusion and Exclusion Criterion

The inclusion and exclusion criterion was based on whether there was available published data over the study period of 2000 to 2023 and whether a country was a sovereign republic between the study period.

3.5 Data Collection

Byers (1995) defines data collection as "the process of gathering evidence to address research questions or test research hypotheses." Similarly, Arun et al. (2022) characterizes it as "the process of gathering, measuring, and analyzing accurate research data using standardized methods." For this study, secondary data was utilized, obtained through a structured data collection schedule. Scholars have contended that secondary data tends to be more reliable and impartial compared to primary data (Sekaran & Bougie, 2019; Vartanian, 2010). The data was sourced from the World bank data bank.

3.6 Measurement of Variables

This section outlines how the carbon emissions, renewable energy consumption, non-renewable energy consumption, economic growth, financial development, institutional quality and carbon emissions variables was operationalized.

3.6.1 Dependent Variable

3.6.1.1 Carbon emissions

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. The unit of measurement is kt (kiloton) (Boden, Marland & Andres, 2017). Carbon dioxide emissions are often calculated and reported as elemental carbon.

3.6.2 Independent Variables

3.6.2.1 Renewable energy consumption

Renewable energy consumption is typically measured in kilowatt-hours (kWh), which represents the amount of energy produced or consumed over a specific period. According to the International Energy Agency (IEA), renewable energy consumption

is quantified by summing the electricity generated from renewable sources, such as solar, wind, hydroelectric, and biomass, and converting it into kilowatt-hours (IEA, 2020).

3.6.2.2 Non-renewable energy consumption

Non-renewable energy consumption, much like renewable energy, can also be measured in kilowatt-hours (kWh), representing the amount of energy produced or consumed over a specific period. According to the International Energy Agency (IEA), non-renewable energy consumption is quantified by summing the electricity generated from fossil fuel sources, such as coal, natural gas, and petroleum, and converting it into kilowatt-hours (IEA, 2020).

3.6.2.3 Economic growth

Measuring economic growth is commonly done using Gross Domestic Product (GDP), a metric that represents the total value of all goods and services produced within a country's borders over a specific period. According to the World Bank, GDP growth is calculated by comparing the current period's GDP to the GDP of a previous period, usually on a quarterly or annual basis (World Bank, 2020)

3.6.2.4 Financial development

Empirical work done outlines various measure of financial development. These are: ratio of financial institutions' assets to GDP, ratio of liquid liabilities to GDP, and ratio of deposits to GDP. This study employed the ratio of financial institutions' assets to GDP (Adu, Marbuah & Mensah, 2013).

3.6.3 Moderator variable

3.6.3.1 Institutional quality

The study used Institutional Quality index developed by world governance indicators, i.e., Political stability, control of corruption, regulatory quality, the rule of law, voice and accountability, and government effectiveness (Easterly, 2002; Al-Marhubi, 2004; Méon and Weill, 2005; Bjørnskov, 2006; Kaufmann et al., 2009; Langbein and Knack, 2010).

3.6.4 Control variable

3.6.4.1 Population

The population of a given area is the number of people usually living in that country (Gu, Andreev & Dupre, 2021).

3.6.4.2 Industrialization

It is measured as manufacturing sector's net output market value of all final goods and services produced in the economy (Anchi, Aboubakary & Edoh, 2023).

3.6.4.3 Foreign direct investment

FDI is the measure of investment inflows (Pattayat, 2016).

Table 3. 1: Measurement of variables

Abbreviation	Name of the variable	Description and measurement	and	Source
CO ₂ Emissions	CO ₂	Overall amount of carbon dioxide emitted by a country in a specific year. It is often expressed in kilo tons.	World Data Set	Bank
Economic Growth	Economic Growth	Measured using GDP	World Data Set	Bank
Renewable Energy Consumption	REC	Kilowatt-Hours (kWh)	World Data Set	Bank
Non-renewable Energy Consumption	NREC	Kilowatt-Hours (kWh)	World Data Set	Bank
Institutional Quality	IQ	Governance index	World Data Set	Bank
Population	POP	the number of people usually living in that country	World Data Set	Bank
Industrialization	IND	Manufacturing sector's net output of all final goods and services produced in the economy	World Data Set	Bank
Foreign Direct Investment	FDI	measure of investment inflows by the ratio of GDP	World Data Set	Bank

Source, Author (2024)

3.7 Data Analysis and Presentation

The data obtained was examined using a variety of different methods of data analysis. This section provides a concise overview of each of these extremely important operations. To perform the analysis on all of the data, STATA version 16 was utilized, and Microsoft Excel was utilized to give output summaries. STATA is an important package since it provides extensive data manipulation capabilities as well as several statistical analysis techniques that are able to analyze data sets ranging in size from very small to extremely large (Baum, 2006). Pearson moment correlation coefficients was used to investigate the relationship between the dependent and independent variables,

multiple linear regressions and generalized method of moment (GMM) was used to test for direct effects, and Hayes Model 1 version 4.0 was used to investigate the effect of moderating variable which is institutional quality on the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions.

3.7.1 Descriptive Statistics

According to the definition provided by Stapor & Stapor, (2020) descriptive analysis is the process of converting raw data into a form that can be easily comprehended and interpreted. This is accomplished by rearranging, organizing, and manipulating the data in order to produce descriptive facts. Because each descriptive statistic condenses a big amount of data into a more manageable amount, they are of great assistance to researchers in simplifying large volumes of data in a manner that is both practical and approachable. The presentation of descriptive statistics can be done in either a numerical or graphical format. These are the two primary presentation methods. In this inquiry, the researcher made use of both of these methodologies. Approaches based on description and inferences was utilized for the analysis of quantitative data. A number of different measures of central tendency were utilized in the analysis of the data.

3.7.2 Inferential Statistics

Examples of inferential analysis include correlation analysis and regression analysis. In order to present the findings, the researcher used tables and figures. The statistical method known as correlation analysis investigates the degree of relationship that exists between two or more variables (Sutanapong & Louangrath, 2015). In statistical modeling, the analysis is the initial step in determining how the independent variables are connected to the dependent ones that are being modeled. A correlation matrix was created before beginning the process of doing multiple regression analyses. In order to

assist in the building of a multiple prediction model, the relationship that exists between the independent variables is studied. This helps to identify non-existence of relationships in situations when the correlation value is 0. The existence of an ideal negative or positive relationship is indicated when the correlation is equal to 1.0. In the interpretation of values, there is no relationship between 0 and 1, however in the interpretation of values, there is a perfect relationship between 0 and 1. In order to evaluate and estimate the impact of the independent variable on the dependent variable, the regression analysis that comes with the Panel data model was utilized. Panel data was applied in the analysis and quantification of relationships between variables, which was expressed as an equation capable of predicting generally the values of one variable given the values of other variables. This equation was derived from the panel data.

3.7.3 Conditions for moderation

According to Baron and Kenny (1986), a moderator is a variable that influences the strength and/or direction of the relationship between an independent variable and a dependent variable. The concept of moderation suggests that the association between two variables depends on the presence of a third variable, known as the moderator. This implies that statistical tests for moderation must be employed to assess whether the independent variable's effect on the dependent variable varies based on the moderator's influence. A moderator is considered enhancing when it strengthens the independent variable's impact on the dependent variable, buffering when it weakens the impact, and antagonistic when it reverses the effect (Aiken & West, 1991).

Moderation is established when three conditions are met. First, the contribution of the interaction term to the variance explained should be significantly greater than the variance explained without the interaction. Second, the coefficient of the interaction term must not be negative. Finally, both models—with and without the interaction

term—should demonstrate statistical significance (Hayes, 2012). To examine moderation effects, hierarchical moderated regression analysis is commonly applied, following a sequential process where additional variables are systematically introduced into the model. The change in the coefficient of determination (R^2) at each stage indicates the extent to which adding a new predictor influences the variance explained in the dependent variable (Little et al., 2012).

Hierarchical regression is preferred because it allows for a clear assessment of how introducing moderator variables, independent variables, and their interactions improves predictive accuracy. In this study, a four-step hierarchical regression approach was adopted to assess the moderating role of growth opportunity. Initially, control variables were entered into the model. Next, both control and independent variables were included to establish direct effects. In the third stage, the moderator variable was introduced alongside the control and independent variables. Finally, interaction terms were incorporated sequentially to test for moderation effects. In moderated regression analysis, the interaction effect is represented by a product term obtained by multiplying the independent variable with the moderator (Cohen et al., 2003; Jaccard & Turrisi, 2003; Saunders et al., 2009).

3.8 Model specification

Since the study's main objective was to investigate the moderation effect of institutional quality on the relationship energy consumption choices, economic growth and financial development on carbon emissions. The first model tested the effect of the control variables on carbon emissions, while the second regression examined the effect of energy consumption choices, economic growth, financial development on carbon emissions. The third regression analysis tested the effect of the moderator variable (institutional quality) on carbon emissions. The fourth to seventh models were used to

determine the interaction between the independent variables (energy consumption choices, economic growth and financial development) and moderator (institutional quality) on carbon emissions.

The study used panel data from 2000 to 2023. Hypotheses were tested using multiple regression analysis and generalized method of moment. The Hausman specification test were employed to determine the suitability of choice between fixed-effect regression and random-effect regression, as a basis of explaining the relationship between predictor variable and dependent variable. The study employed the multiple regression model (Baron & Kenny, 1986) to test the direct, and moderating effects. The hypotheses were tested using a series of multiple linear regression analysis. The model specifications and the regression equations for panel data analysis were applied as shown below.

First, to isolate the effect of the independent variables on the dependent variable, the study controlled for several variables as suggested by empirical literature.

$$EG_{it} = \beta_0 + \beta_1 POP_{1it} + \beta_2 IND_{2it} + \beta_3 FDI_{3it} + \varepsilon_{it}$$

Second, the study tested for the effect of the various sub-constructs of the independent variable on the dependent variable, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} \\ + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \beta_7 FND_{it} + \varepsilon_{it}$$

Third, the study tested moderating effect of institutional quality on the various sub-constructs of independent variables on the carbon emissions, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} \\ + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \beta_7 FND_{it} + \beta_8 IQ_{it} + \varepsilon_{it}$$

Fourth, the study tested the interaction between renewable energy consumption and institutional quality on the carbon emissions, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \\ \beta_7 FND_{it} + \beta_8 IQ_{it} + \beta_9 REN_{it} * IQ_{it} + \varepsilon_{it}$$

Fifth, the study tested the interaction between non-renewable energy consumption and institutional quality on the carbon emissions, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \\ \beta_7 FND_{it} + \beta_8 IQ_{it} + \beta_9 REN_{it} * IQ_{it} + \beta_{10} NRE_{it} * IQ_{it} + \varepsilon_{it}$$

Sixth, the study tested the interaction between economic growth and institutional quality on the carbon emissions, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \\ \beta_7 FND_{it} + \beta_8 IQ_{it} + \beta_9 REN_{it} * IQ_{it} + \beta_{10} NRE_{it} * IQ_{it} + \beta_{11} ECG_{it} * IQ_{it} + \varepsilon_{it}$$

Seventh, the study tested the interaction between financial development and institutional quality on the carbon emissions, while incorporating the control variables into the model as shown below:

$$CE_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} + \beta_5 NRE_{it} + \beta_6 ECG_{it} + \\ \beta_7 FND_{it} + \beta_8 IQ_{it} + \beta_9 REN_{it} * IQ_{it} + \beta_{10} NRE_{it} * IQ_{it} + \beta_{11} ECG_{it} * IQ_{it} + \\ \beta_{12} FND_{it} * IQ_{it} + \varepsilon_{it}$$

Where

CE_{it} is the Carbon emissions in time period " t " for the cross-sectional unit " i "

RE is the Renewable energy consumption in time period " t " for the cross-sectional unit " i "

NRE is the Solar energy consumption in time period " t " for the cross-sectional unit " i "

EG_{it} is the Economic Growth in period " t " for the cross-sectional unit " i "

FND_{it} is the Financial development in period " t " for the cross-sectional unit " i "

IQ_{it} is the Institutional quality in time period " t " for the cross-sectional unit " i "

FDI is the Foreign direct investment in time period " t " for the cross-sectional unit " i "

POP is the Population growth in time period " t " for the cross-sectional unit " i "

IND_{it} is the Industrialization in time period " t " for the cross-sectional unit " i "

FDI_{it} is the Foreign direct investment in time period " t " for the cross-sectional unit " i "

ε_{it} = error term

β_0 is the intercept.

β_1, \dots, β_n are the beta-coefficients

" i " is the cross-section units

" t " is the time period (2010 to 2023)

3.8.1 Generalized method of moment – Robust test

The Generalized Method of Moments (GMM) is an econometric estimation technique that provides a robust framework for addressing endogeneity, heteroskedasticity, and serial correlation in panel data models, including the fixed effects model. Developed by Hansen (1982), GMM improves on traditional estimation techniques such as Ordinary

Least Squares (OLS) and Fixed Effects (FE) regression by using instrumental variables (IVs) to obtain efficient and consistent estimates. In the context of fixed effects models, GMM is particularly useful in mitigating biases that arise from omitted variables, simultaneity, and measurement errors, making it a reliable approach for analyzing panel data.

Fixed effects models are commonly employed in panel data analysis to account for unobserved heterogeneity across individuals, firms, or countries that remains constant over time. While the fixed effects transformation effectively eliminates time-invariant unobserved heterogeneity, it does not address potential endogeneity issues that may arise due to reverse causality or omitted time-variant factors. When explanatory variables are endogenous, standard fixed effects estimation may lead to biased and inconsistent parameter estimates. To overcome these limitations, GMM provides an alternative approach by utilizing moment conditions based on instrumental variables, which help to correct for endogeneity and improve estimation accuracy.

In the context of fixed effects models, two primary GMM estimators are widely used: the difference GMM estimator, developed by Arellano and Bond (1991), and the system GMM estimator, introduced by Blundell and Bond (1998). The difference GMM estimator transforms the regression equation into first differences to eliminate fixed effects and then uses lagged values of endogenous variables as instruments. This approach assumes that past values of the explanatory variables are uncorrelated with the error term in subsequent periods, thereby mitigating simultaneity bias. However, difference GMM may suffer from weak instrumentation issues, particularly when the explanatory variables are highly persistent over time.

To address the limitations of difference GMM, the system GMM estimator was introduced as an improvement. System GMM combines the first-differenced equation with the level equation, using additional moment conditions to strengthen the instrument set. By incorporating both lagged differences and lagged levels as instruments, system GMM enhances estimation efficiency and reduces finite-sample biases. This makes it particularly suitable for panel data models with a large cross-section and a short time dimension ($N \gg T$), where traditional fixed effects estimators may be inefficient.

One of the key advantages of GMM as a robust test for fixed effects models is its ability to correct for autocorrelation and heteroskedasticity. Unlike conventional regression techniques, GMM provides robust standard errors that account for potential violations of classical regression assumptions. Additionally, the Hansen J-test for overidentifying restrictions ensures that the instruments used in the estimation are valid, further enhancing the reliability of the model.

3.9 Diagnostic Tests

The study conducted several diagnostic tests to explore problems inherent to regression analysis and determine whether certain assumptions appear reasonable (Fox 1991; Fox (2015) and Fox (2008)). Regression models have several assumptions that must hold before data analysis. These assumptions include Unit Root Test, autocorrelation, multicollinearity, homoscedasticity and model misspecification (Hayes, 2018).

3.9.1 Unit Root Test

The study used panel data and thus, there was need to determine whether the variables in question are stationary or non-stationary. Whenever there is a stationarity, a series of finite variance and uniform oscillations from the mean can be observed (Baltangi,

2005). Therefore, there was need to test whether the variables have a uniform mean and variance across time variation. It is possible to have deceptive inferences if the information that was collected was not stationery and regression models gained may be spurious or affected by uneven regression problems. Therefore, this study was conducted using numerous tests of unit root. These included: Levin- Lin Chu, Breitung and Im-Pesaran-Shin. Time series data consisted of observations which were considered to be random variables that were described by some stochastic processes. Time series is only possible where data is stationary. This means the data must have statistical properties (mean, variance and covariance) that never vary with time. Hence, it is important that the study first test a time series to see if it is stationary or not (Dwivedi and Subba, 2011). The hypothesis to be tested were:

Null hypothesis (H_o): Panel data contains unit root [non-stationary].

Alternative hypothesis (H_a): Panel data is stationary.

If the p-values is below the conventional significance levels of 0.05 then it implied that all variables are stationary and robust regression models was fitted without lags (at levels).

3.9.2 Multicollinearity

Multicollinearity indicates the presence of a linear relationship between two or more explanatory variables. Murray (2006), asserts that multicollinearity makes it hard to differentiate the individual effects of the explanatory variables and regression estimators may be biased in that they tend to have huge variances. Additionally, if there is a perfect linear relationship among the explanatory variables, the approximations for a regression model can-not be exceptionally calculated. The possible existence of multicollinearity is established based on the correlation matrix including all the

independent and control variables. Both Pearson and Spearman's rank correlation matrices were done to confirm if the correlation coefficients are less than 0.8, the limit or cut off correlation percentage commonly suggested by prior studies after which multicollinearity is likely to exist (Gujarati, 2003). The problem of Multicollinearity occurs when the relative movements of two or more independent variables match. In this, the standard OLS estimates become unable to distinguish between the variables. Given that many other independent variables in this study may have a prior suspect of multicollinearity, Variance Inflation Factors (VIF) tested after each standard OLS regression to examine the level of correlation between the variables.

To identify any possible problem of multicollinearity, two approaches were used; tolerance test and Variance Inflation Factor (V.I.F.). Under Tolerance and Variance Inflation Factor (VIF) multicollinearity is present if tolerance is less than 0.1 and the VIF value is higher than 10 (Gujarati, 2012 and Nor, Shanab, & Pearson (2008).

$$VIF = \frac{1}{1 - R^2}$$

Where:

R^2 : R squared

Tolerance: $1 / VIF$

The diagnostic test was conducted to find out whether the independent variables related to each other instead of being related to the criterion variable. However, for enhancement of regression validity, the multicollinearity test was performed as below:

Ho: data contains no multicollinearity

Ha: data contains multicollinearity

3.9.3 Autocorrelation

Brooks (2010), found that the fundamental assumptions of Linear Regression Model is that the covariance between the error terms over the time is equal to zero, or the error terms are not correlated with each other. If, however, the error terms are correlated it creates the problem of autocorrelation or serial correlation, which leads to making the standard error biased. Hence, the standard OLS estimators no longer remain the minimum variance ones. This follows that a diagnostic test was required to check for the presence of serial correlation after each standard OLS regression of the analysis. With the analysis of a long time series of 8 years, there may be a prior suspect of autocorrelation. The graphical method is commonly used as a first-hand method to judge the presence of autocorrelation. But to confirm the presence of autocorrelation a formal statistical test was required to apply. Tests such as Durbin-Watson, Breusch-Godfrey and Wooldridge are the simplest and commonly used tests in time series analysis in order to detect autocorrelation. Wooldridge statistic test was used in testing first-order correlation in this study. The basis for determining the violation of this assumption was seen from $\text{Prob} > F$. If the value is lower than 0.05 then there is a violation of this assumption.

3.9.4 Heteroskedasticity

The problem of heteroskedasticity occurs when the residuals of the regression are heteroskedastic. That is, the variance of residuals is not constant for all observations. In such case the standard OLS estimators no longer produce minimum variance. The standard error of the coefficients gives inaccurate estimates. In the presence of heteroskedasticity, the estimated parameters might remain consistent but inefficient. In order to test for heteroskedasticity the study performed Breusch Pagan/Cook-Weisberg (1979) test. The Lagrange Multiplier test that bases on the assumption that residuals are

normally distributed with K degree of freedom was used. If the test statistic have a p -value below an appropriate threshold ($p < 0.05$) then the null hypothesis of homoskedasticity is rejected and heteroskedasticity assumed (that is, if the significance level of f -statistics is not significant in 5% error level, homogeneity of variance is confirmed and heteroskedasticity of error terms is rejected.).

The null hypothesis stated that the variance of the disturbance terms is homoscedastic meaning that the variance of the error terms was constant. The hypothesis to be tested were:

H0: Error variance is homogeneous

H1: Error variance is not homogeneous

3.9.5 Specification Error Test

Model specification is a critical aspect of econometric analysis that ensures a regression model is correctly formulated. A well-specified model accurately captures the relationship between independent and dependent variables without omitting relevant variables, including unnecessary variables, or misspecifying the functional form (Gujarati & Porter, 2020). One of the most commonly used tests for detecting model specification errors is the Ramsey RESET (Regression Specification Error Test). This test helps identify whether the regression model has omitted variables or if the functional form is incorrectly specified. If a model is misspecified, the estimated coefficients may be biased and inefficient, leading to misleading conclusions in empirical research (Wooldridge, 2010).

The Ramsey RESET test evaluates whether the model is correctly specified. The hypotheses for the test are:

Null Hypothesis (H₀): The model has no omitted variables or specification errors.

Alternative Hypothesis (H_1): The model has omitted variables or incorrect functional form.

Rejecting the null hypothesis indicates that the model may suffer from specification errors, requiring modifications such as adding missing variables, transforming variables, or using nonlinear functional forms

3.9.6 Random and Fixed Effects

A panel data framework was used to test the hypotheses. Panel data, as noted by Hsiao (2014) has several distinct advantages: it provides more degrees of freedom, increases variations in the data and thereby reduces the chances of multicollinearity, and makes it possible to control for fixed effects, panel data has the strength of accepting more observations hence increases the degrees of freedom. In addition, it reduces the problem of collinearity of regressors and modeling flexibility of behavior differences within and between countries and/or groups or institutions (Hsiao 2007).

Panel data was analyzed using a fixed effect model and random effects model. Fixed effects model was used when controlling for omitted variables that differ between individuals but are constant over time. If some omitted variables might be constant over time but vary between individuals, and others might be fixed between individuals but vary over time, then random effects model was of help in taking the two types into account. The random effects model would be appropriate if data are representative of a sample rather than the entire population because the individual effect term can be a random outcome rather than a fixed parameter.

Lee & Thompson (2008), pointed out three test that can be run to compare the usefulness of the models; First, fixed effects was tested by the F test and the null hypothesis of all individual effects terms except one are zero was rejected at 0.1%

significance level. This suggested that the fixed effects model is better than the pooled OLS model. Second, random effects was examined by the Lagrange multiplier test and the null hypothesis cross-sectional variance components are zero are rejected at 0.1% significance level.

3.9.7 Hausman Test

Finally, Hausman test was conducted to decide whether the fixed effect or the random effect is the appropriate model to explain the relationship between variables. The null hypothesis is that the random effect model is more suitable. If the null hypothesis was rejected, then the fixed effect model was used (Greene 2008). The null hypothesis was that there is no significant correlation between the individual effects and the regressors. Null hypothesis was to be rejected if the probability obtained was to be less than 5%. Again, if the test value of Chi-square was to be higher than the critical value, the null hypothesis was to be rejected and the fixed effect was to be a better estimation method. The hypothesis to be tested were:

H₀: Random effect model is appropriate

H_a: Fixed effect model is appropriate

Decision criteria: Reject H₀ if the p-values obtained are less than the level of significance 0.05.

3.10 Ethical Considerations

The purpose of ethical considerations is to direct the study in ensuring that participants are protected in addition to building confidence in them. Ethical considerations focus on privacy of respondents and also the intended use of the data collected. This study posed few, if any, ethical considerations due to the following reasons.

First, the study used published data thus neither questionnaires nor respondents were required in data collection. Second, the data was publicly available on the KNBS, World Bank, IMF websites. However, the study observed the following ethical issues;

Data was collected in an objective approach as specified in data collecting schedules in order to ensure the results are objective. Furthermore, the study followed all the required procedures in carrying out such a study. This include getting approval from the University in order to proceed to the field and collect research data and also obtaining a license to conduct research in the area of interest.

The researcher referenced all of the sources of information after they were cited in the document. Additionally, consent was requested through a research permission from the national Commission for Science, Technology, and Innovation (NACOSTI).

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Overview

This chapter entails the findings of the research which are provided in five important sections; descriptive statistics, diagnostic tests, correlation analysis, hypothesis testing and discussion of findings.

4.2 Descriptive Statistics

The descriptive statistics in Table 4.1 present a snapshot of seven key variables over different observation counts (Obs) across various countries or regions. Carbon emissions have mean of 47,327.03 metric tons and standard deviation of 157,595.7, which suggests large differences in carbon emissions among countries. Sao Tome and Principe recorded the lowest carbon emission in Sub-Saharan Africa, while DRC emitted the highest, and the minimum value of 53.5 and maximum value of 865,283.2 illustrate that (Wang & Feng, 2022). The mean of foreign direct investment (FDI) is $-2.44e+08$ (approximately -244 million USD) and the standard deviation is $1.21e+09$ (1.21 billion USD). There is great variability in FDI inflows and outflows, the minimum value ($-3.51e+09$) and maximum value ($1.24e+10$) suggesting that some countries receive large investments such as Nigeria (US\$5.3 billion), South Africa (US\$4.4 billion), Angola (US\$2.2 billion), Liberia (US\$2 billion) and Ghana (US\$0.61 billion) (World Bank, 2022), while others experience large disinvestment such as Central Africa Republic, Eritrea, Burundi and Comoros, which may be due to economic or political instability (Okara, 2023). The population figures range very widely, from a low of 81,131 people to a high of 22,1907,294.4 people. The mean of industrialization is $6.72e+09$ (6.72 billion USD) with a large standard deviation of $2.49e+10$ (24.9 billion USD). Levels of industrial activity show significant differences, wide range from

3,996,971 to $2.36e+11$, which may be due to the developmental stage of various countries (Kuznets, 1973). The mean population is 40.9 million and the standard deviation is 142 million. The large standard deviation indicates that the sample covers both least populated countries such as Seychelles, Comoros, Sao Tome and Principe and highly populated countries such as Nigeria (15.4%) · Ethiopia (8.7%) · Egypt (7.7%) · DR Congo (7.1%) · Tanzania (4.5%) · South Africa (4.3%) · Kenya (3.7%), as is typical in global datasets (Zhang & Tan, 2016). Renewable and non-renewable energy consumption are nearly evenly distributed with mean values of 49.62% and 50.38%, respectively, signaling a balance between clean and fossil fuel energy use in the region. This range of 0.005% to nearly 100% demonstrates a regional move towards sustainable energy in some regions such as Ethiopia, Kenya, Tanzania, Uganda, Rwanda and South Africa, while other regions depend on non-renewable sources such as Nigeria, Angola, Ghana among others (Nguyen & Kakinaka, 2019). Economic growth shows a high mean ($6.09e+10$) but also considerable variability, reflecting diverse economic trajectories within Sub-Saharan Africa with countries such as Niger, Senegal, Libya, Rwanda, Cote d'Ivoire, Ethiopia, Benin, Djibouti, Tanzania, Togo and Uganda registering higher economic growth while countries such as Equatorial Guinea, Sudan, São Tomé and Príncipe registering lower economic growth. The average index score of financial development is 1.265, with large standard deviation of 3.51, minimum of -9.88 and maximum of 18.39. This implies large differences in financial sector development, with some countries such as South Sudan and Somalia having underdeveloped financial systems and others such as Kenya, Mali, Senegal, and South Africa with highly developed financial markets (Zhang, 2011). Institutional quality finally averages at -0.714 (std. dev. = 0.70) with values between -2.22 and 1.04. These figures indicate large variation in governance and institutional effectiveness, where

countries such as Mauritius, Botswana, South Africa, Cape Verde and Namibia are among the top scorers of institutional quality while Liberia, Congo Democratic and Somalia are the least performers (Karim et al., 2022).

Table 4. 1: Descriptive statistics

Variable	N	Mean	Sd	Min	max
Carbon Emissions	552	47327.03	157595.7	53.5	865283.2
Foreign Direct Investment	552	-2.44e+08	1.21e+09	-3.51e+09	1.24e+10
Population	552	2.06e+07	3.08e+07	81131	2.22e+08
Industrialization	552	6.72e+09	2.49e+10	3996971	2.36e+11
Renewable Energy Consumption	552	49.61874	34.32933	.0051146	99.97338
Non-renewable Energy Consumption	552	50.38126	34.32933	.0266168	99.99489
Economic Growth	552	6.08e+10	2.26e+11	5.77e+07	2.06e+12
Financial Development	552	1.265022	3.510553	-9.883455	18.39591
Institutional Quality	552	-.7145176	.7029199	-2.224527	1.044383

Source: Researcher 2024

4.3 Diagnostic tests

Before conducting the regression analysis, several diagnostic tests were performed to ensure the validity and reliability of the model. First, a unit root test was conducted to determine the stationarity of the data, preventing spurious regression results. Multicollinearity was examined to identify highly correlated independent variables that could distort coefficient estimates. The heteroscedasticity test checked for unequal variance in residuals, which could affect standard errors and inference. Autocorrelation was tested to detect serial correlation in residuals, ensuring model efficiency. Lastly, a specification error test was conducted to verify if the model was correctly specified and free from omitted variable bias. These diagnostic tests enhanced the robustness and accuracy of the regression model.

4.3.1 Unit Root Test

Unit root tests are fundamental in time series and panel data econometrics as they help determine whether a variable is stationary or exhibits a unit root (non-stationarity) (Gujarati & Porter, 2020). Stationarity is a critical assumption in regression models because non-stationary variables can lead to spurious regression results and unreliable inferences (Enders, 2020). To test for stationarity, three panel unit root tests were conducted: Harris-Tzavalis (HT), Levin-Lin-Chu (LLC), and Fisher-type unit root tests.

Null and Alternative Hypotheses

For all three-unit root tests, the hypotheses are as follows:

Null Hypothesis (H₀): The variable has a unit root (i.e., it is non-stationary).

Alternative Hypothesis (H_A): The variable does not have a unit root (i.e., it is stationary).

A p-value less than 0.05 suggests the null hypothesis should be rejected, indicating stationarity. Conversely, a p-value greater than 0.05 means the variable is non-stationary, requiring further transformations such as first differencing (Baltagi, 2021).

The test statistics for Carbon Emissions are HT = -52.1369, LLC = -16.1961, Fisher = -14.5988, all with p-values of 0.00. Since the p-values are statistically significant, the null hypothesis of a unit root is rejected, confirming that Carbon Emissions is stationary at level. This means that Carbon Emissions does not follow a random walk and can be used in regression analysis without differencing (Stock & Watson, 2020).

The results for FDI indicate HT = -61.0592, LLC = -17.5025, Fisher = -11.4016. While the HT and LLC tests have p-values of 0.00, the Fisher test has a p-value of 1.00, implying non-stationarity. The conflicting results suggest that FDI may be trend-

stationary or require transformation, such as first differencing, before inclusion in the regression model (Wooldridge, 2019).

Population exhibits strong negative test statistics (HT = -71.3322, LLC = -22.52, Fisher = -17.8317) with p-values of 0.00. These results indicate that Population is stationary at level, meaning that it does not require differencing for further analysis (Greene, 2018).

For Industrialization, the results (HT = -49.3451, LLC = -15.6078, Fisher = -14.9477) confirm stationarity at level since all p-values are 0.00. This suggests that industrialization trends are stable over time, making it a reliable predictor in econometric models (Dornbusch, Fischer, & Startz, 2021).

Both Renewable and Non-Renewable Energy exhibit identical results (HT = -51.1746, LLC = -10.1541, Fisher = -10.4308) with p-values of 0.00. This indicates that both energy consumption measures are stationary and do not exhibit a unit root problem (Hamilton, 2020).

The test results for Economic Growth (HT = -65.9098, LLC = -16.1162, Fisher = -15.0965) confirm stationarity, as all p-values are 0.00. This suggests that Economic Growth remains consistent over time, making it suitable for regression analysis (Maddala & Lahiri, 2021).

Financial Development also exhibits stationarity at level (HT = -63.8769, LLC = -12.7609, Fisher = -5.7478) with p-values of 0.00, implying that financial sector trends do not follow a unit root process (Stock & Watson, 2020).

Finally, Institutional Quality shows negative test statistics (HT = -60.5684, LLC = -9.5035, Fisher = -10.5478) with p-values of 0.00, confirming stationarity. This suggests

that Institutional Quality remains stable over time and is suitable for econometric modeling (Wooldridge, 2019).

The results indicate that all variables, except for FDI (Fisher test, $p = 1.00$), are stationary at level. This means that most variables do not require differencing, simplifying the regression analysis process. However, further tests such as first differencing or trend-stationarity checks may be needed for FDI to ensure model reliability. Ensuring stationarity in time series data is essential to avoid spurious regressions and obtain meaningful policy implications (Gujarati & Porter, 2020).

Table 4. 2: Results of Unit Root Test

	Harris-Tzavalis	Levin-Lin-Chu	Fisher-type unit-root test
Carbon Emissions	-52.1369	-16.1961	-14.5988
p value	0.00	0.00	0.00
Foreign Direct Investment	-61.0592	-17.5025	-11.4016
p value	0.00	0.00	1.00
Population	-71.3322	-22.52	-17.8317
p value	0.00	0.00	0.00
Industrialization	-49.3451	-15.6078	-14.9477
P value	0.00	0.00	0.00
Renewable Energy	-51.1746	-10.1541	-10.4308
p value	0.00	0.00	0.00
Non-renewable Energy	-51.1746	-10.1541	-10.4308
p value	0.00	0.00	0.00
Economic Growth	-65.9098	-16.1162	-15.0965
p value	0.00	0.00	0.00
Financial Development	-63.8769	-12.7609	-5.7478
p value	0.00	0.00	0.00
Institutional Quality	-60.5684	-9.5035	-10.5478
p value	0.00	0.00	0.00

Source: Researcher 2024

4.3.2 Multicollinearity

Multicollinearity is a statistical phenomenon in regression analysis where independent variables are highly correlated with each other, potentially distorting the estimated coefficients and leading to unreliable statistical inferences (Gujarati & Porter, 2020). When multicollinearity is present, it becomes difficult to isolate the individual effect of each predictor on the dependent variable, resulting in inflated standard errors and unstable coefficient estimates (Wooldridge, 2019). A common method for detecting multicollinearity is the Variance Inflation Factor (VIF), which measures how much the variance of a regression coefficient is inflated due to collinearity with other predictors. The reciprocal of VIF ($1/VIF$) provides insight into tolerance, where lower values indicate higher collinearity (Maddala & Lahiri, 2021). Generally, a VIF above 10 suggests severe multicollinearity, while a VIF between 5 and 10 indicates moderate multicollinearity (Gujarati & Porter, 2020). A VIF below 5 is considered acceptable.

Economic Growth (VIF = 2.78, $1/VIF = 0.3594$), Foreign Direct Investment (VIF = 2.43, $1/VIF = 0.4110$), and Industrialization (VIF = 2.33, $1/VIF = 0.4300$) exhibit moderate multicollinearity. While these values are below the critical threshold of 5, they suggest that these variables share some correlation. This is expected because FDI and industrialization are key drivers of economic growth, making them interdependent (Dornbusch, Fischer, & Startz, 2021). The lowest VIF values are observed for Population (VIF = 1.98, $1/VIF = 0.5041$), Institutional Quality (VIF = 1.46, $1/VIF = 0.6853$), and Financial Development (VIF = 1.06, $1/VIF = 0.9461$). These values indicate low multicollinearity, suggesting that these variables are relatively independent and will not cause estimation problems in the regression model (Greene, 2018). The Mean VIF is 3.94, which falls within the acceptable range, indicating that overall, the model does not suffer from severe multicollinearity.

Table 4. 3: Variance Inflation Factor test results

Variable	VIF	1/VIF
Non-renewable Energy Consumption	9.95	0.100466
Renewable Energy Consumption	9.56	0.104566
Economic Growth	2.78	0.359413
Foreign Direct Investment	2.43	0.411018
Industrialization	2.33	0.429985
Population	1.98	0.504076
Institutional Quality	1.46	0.685284
Financial Development	1.06	0.946083
Mean VIF	3.94	

Source: Researcher 2024

4.3.3 Autocorrelation Test

Autocorrelation, also known as serial correlation, refers to the correlation of a variable with its past values over time. In the context of panel data, where observations are collected across multiple entities over different time periods, autocorrelation arises when the error terms in one period are correlated with those in previous periods. The presence of autocorrelation violates the assumption of independence of residuals, which is crucial for obtaining unbiased and efficient estimators in regression analysis (Gujarati & Porter, 2020).

The Wooldridge test for autocorrelation is a widely used statistical test for detecting first-order autocorrelation in panel data models. Developed by Wooldridge (2002), this test is based on the assumption that if autocorrelation exists, then the residuals from the regression model will exhibit a systematic pattern over time rather than being randomly distributed. The test is particularly advantageous as it does not require strict assumptions about the distribution of errors and is applicable to both fixed and random effects models (Baltagi, 2021).

Null and Alternative Hypotheses

The Wooldridge test for autocorrelation in panel data is conducted under the following hypotheses:

Null Hypothesis (H0): There is no first-order autocorrelation in the panel data residuals. This implies that the errors are independently distributed across time, which is desirable for ensuring the validity of statistical inferences.

Alternative Hypothesis (H1): There is first-order autocorrelation in the panel data residuals, meaning that past errors significantly influence current errors, which could lead to inefficient parameter estimates.

The F-statistic measures the extent to which the residuals exhibit autocorrelation. A higher F-statistic would indicate stronger evidence against the null hypothesis, suggesting the presence of autocorrelation. However, in this case, the F-statistic is 0.097, which is very low, indicating weak evidence of autocorrelation.

The p-value of 0.7587 is greater than the conventional significance levels of 0.01, 0.05, or 0.10. Since the p-value is much higher than 0.05, we fail to reject the null hypothesis. This means that there is no significant evidence of first-order autocorrelation in the panel data residuals.

Table 4. 4: Wooldridge test results for autocorrelation

Wooldridge test for autocorrelation in panel data H0: no first order autocorrelation $F(1, 23) = 0.097$ Prob > F = 0.7587
--

Source: Researcher 2024

4.3.4 Test for Heteroskedasticity

Heteroscedasticity is a condition in regression analysis where the variance of the error terms is not constant across observations. In ordinary least squares (OLS) regression, one of the key assumptions is homoscedasticity, meaning that the residuals should have a constant variance. When this assumption is violated, the estimated standard errors become unreliable, leading to inefficient parameter estimates and invalid statistical inferences (Gujarati & Porter, 2020). Detecting heteroscedasticity is crucial for ensuring the accuracy of regression results, and one of the common tests for detecting it is the Breusch-Pagan test or the White test, both of which rely on the chi-square statistic.

The heteroscedasticity test evaluates whether the variance of residuals is constant across observations. The hypotheses for the test are:

Null Hypothesis (H₀): The residuals have constant variance (Homoscedasticity).

Alternative Hypothesis (H₁): The residuals have non-constant variance (Heteroscedasticity is present).

Rejecting the null hypothesis indicates the presence of heteroscedasticity, which requires corrective measures such as using robust standard errors or transforming the data.

Chi-square statistic ($\chi^2(1)=0.38$): The test statistic measures the strength of evidence against the null hypothesis. A lower value suggests weaker evidence of heteroscedasticity. p-value (Prob > $\chi^2 = 0.5399$): This represents the probability of observing the test statistic under the assumption that the null hypothesis is true. If the p-value is less than the 5 percent level significance level, we reject the null hypothesis and conclude that heteroscedasticity is present.

In this case, the p-value (0.5399) is much greater than the conventional significance level of 0.05. Therefore, we fail to reject the null hypothesis, implying that there is no significant evidence of heteroscedasticity in the regression model (Wooldridge, 2010). This means that the variance of residuals appears to be constant across different observations, satisfying one of the key assumptions of OLS regression.

Table 4. 5: Breusch-Pagan / Cook-Weisberg test results for Heteroscedasticity

Variables: Myresiduals	
chi2(1) =	0.38
Prob > chi2 =	0.5399

Source: Researcher, 2024

4.3.5 Specification Error Test

Model specification is a critical aspect of econometric analysis that ensures a regression model is correctly formulated. A well-specified model accurately captures the relationship between independent and dependent variables without omitting relevant variables, including unnecessary variables, or misspecifying the functional form (Gujarati & Porter, 2020). One of the most commonly used tests for detecting model specification errors is the Ramsey RESET (Regression Specification Error Test). This test helps identify whether the regression model has omitted variables or if the functional form is incorrectly specified. If a model is misspecified, the estimated coefficients may be biased and inefficient, leading to misleading conclusions in empirical research (Wooldridge, 2010).

The Ramsey RESET test evaluates whether the model is correctly specified. The hypotheses for the test are:

Null Hypothesis (H0): The model has no omitted variables or specification errors.

Alternative Hypothesis (H1): The model has omitted variables or incorrect functional form.

Rejecting the null hypothesis indicates that the model may suffer from specification errors, requiring modifications such as adding missing variables, transforming variables, or using nonlinear functional forms. F-statistic ($F(1, 23) = 0.097$): The F-statistic measures the strength of evidence against the null hypothesis. A low value suggests weaker evidence of model misspecification. P-value ($\text{Prob} > F = 0.7587$): This represents the probability of obtaining the test statistic under the null hypothesis. If the p-value is below the conventional significance level (e.g., 0.05 or 0.10), we reject the null hypothesis and conclude that the model is misspecified. In this case, the p-value (0.7587) is much greater than 0.05, indicating that we fail to reject the null hypothesis. This suggests that there is no significant evidence of model misspecification, meaning that the regression model used to estimate carbon emissions is likely correctly specified (Ramsey, 1969).

Table 4. 6: Ramsey RESET results (test using powers of the fitted values of Carbon Emissions)

Ho:	model has no omitted	Variables
	$F(1, 23) =$	0.097
	$\text{Prob} > F =$	0.7587

Source: Researcher 2024

4.3.6 Hausman Test

The Hausman test is conducted to determine whether a fixed effects (FE) or random effects (RE) model is more appropriate for panel data analysis (Hausman, 1978). The null hypothesis (H0) assumes that the difference in coefficients between the fixed and random effects models is not systematic, meaning that the RE model is efficient and consistent. The alternative

hypothesis (H1) suggests that the FE model is preferred because the RE estimates are inconsistent. In this case, the Hausman test statistic is $\chi^2(8) = 68.39$ with a p-value of 0.0000, which is highly significant. This result strongly rejects the null hypothesis, indicating that the fixed effects model is the appropriate choice for the analysis (Wooldridge, 2010).

Examining the coefficient differences (b - B), we observe some notable variations between the FE and RE estimates. For instance, population has a relatively large difference (0.0434) with a standard error of 0.00675, suggesting that its effect varies significantly between the models. Similarly, institutional quality has a notable coefficient difference of 0.0075, with a standard error of 0.0012, implying potential bias in the RE estimation. On the other hand, variables such as foreign direct investment (FDI) and non-renewable energy show minimal coefficient differences (-0.0003 and -0.0003, respectively), suggesting that their estimates are relatively stable across both models.

The coefficient estimates indicate that industrialization (0.896 in FE, 0.918 in RE) and economic growth (0.693 in FE, 0.681 in RE) positively influence the dependent variable, suggesting their crucial role in the model. Conversely, institutional quality (-0.030 in FE, -0.038 in RE) and population (-0.139 in FE, -0.182 in RE) exhibit negative effects, implying that weak institutions and high population growth might hinder economic performance. The results also highlight the importance of renewable energy (0.036 in FE, 0.046 in RE), suggesting its positive contribution to economic outcomes. The rejection of the RE model in favor of the FE model underscores the presence of individual-specific effects that must be accounted for to obtain consistent estimations (Baltagi, 2021).

Table 4. 7: Hausman test results

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	Fe	Re	Difference	S.E.
Foreign direct investment	-.0408146	-.0405364	-.0002782	.0022271
Population	-.1388009	-.182163	.0433621	.0067541
Industrialization	.8957821	.9176384	-.0218563	.0057872
Renewable Energy	.0361488	.0464436	-.0102948	.002358
Non-renewable energy	.0030065	.0033309	-.0003243	.0001032
Economic Growth	.6926169	.681296	.0113209	.0024147
Financial Development	.0430458	.0479574	-.0049116	.0018547
Institutional Quality	-.0302425	-.0377384	.0074959	.0011876

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$$\chi^2(8) = (b-B)'[(V_b-V_B)^{-1}](b-B)$$

$$= 68.39$$

$$\text{Prob}>\chi^2 = 0.0000$$

Source: Researcher 2024

4.4 Correlation Analysis

A correlation test is a statistical tool used to measure the strength and direction of the linear relationship between two variables (Gujarati & Porter, 2020). The correlation coefficient, denoted as r , ranges between -1 and 1. There is a moderate positive correlation between carbon emissions and foreign direct investment (FDI) ($r = 0.3417^*$). This suggests that as FDI increases, carbon emissions also tend to rise. This relationship could be attributed to foreign investors directing their capital towards industries that rely on fossil fuels, leading to higher emissions. Cole et al. (2006) highlight that multinational corporations may shift pollution-intensive activities to countries with less stringent environmental regulations, reinforcing this correlation.

The correlation between carbon emissions and population is weakly positive ($r = 0.1485^*$). This implies that as the population grows, carbon emissions also increase,

though the relationship is not strong. A growing population contributes to higher energy consumption, transportation use, and industrial activities, all of which result in increased emissions (Sadorsky, 2010). However, the relatively low correlation suggests that other factors, such as energy efficiency and technological advancements, might offset some of the population-induced emissions.

There is a strong positive correlation between carbon emissions and industrialization ($r = 0.6992^*$). This means that as industrial activities expand, carbon emissions increase significantly. Industrial processes heavily rely on fossil fuels, leading to higher emissions. This finding aligns with studies indicating that industrialization is a major driver of greenhouse gas emissions, particularly in developing economies that depend on coal, oil, and gas for energy production (Stern, 2011). A weak negative correlation is observed between carbon emissions and renewable energy ($r = -0.1720^*$). This indicates that as the share of renewable energy in total energy consumption increases, carbon emissions decrease. This is expected since renewable energy sources, such as solar and wind, do not emit carbon dioxide. This supports the argument that transitioning to renewable energy is crucial in reducing global carbon footprints (Panayotou, 1993). There is a weak positive correlation between carbon emissions and non-renewable energy use ($r = 0.2582^*$). This confirms that higher consumption of fossil fuels leads to greater emissions. The strong dependence on non-renewable energy sources, such as coal and oil, is a major contributor to global warming (Grossman & Krueger, 1995).

A strong positive correlation exists between carbon emissions and economic growth ($r = 0.6955^*$). This suggests that higher economic activity leads to increased emissions. The Environmental Kuznets Curve (EKC) hypothesis suggests that emissions initially rise with economic growth but eventually decline as countries adopt cleaner

technologies and environmental policies (Grossman & Krueger, 1995). However, in developing economies, rapid economic expansion is often associated with increased fossil fuel consumption, explaining the strong correlation. The correlation between carbon emissions and financial development is weakly positive ($r = 0.1625^*$). This suggests that an increase in financial sector activities might be associated with higher carbon emissions. Financial development can lead to increased industrial investments, potentially raising emissions (Shahbaz et al., 2013). However, the weak correlation indicates that financial markets may also support green investments, offsetting some negative environmental impacts. A negative correlation is observed between carbon emissions and institutional quality ($r = -0.1102^*$), indicating that better governance is associated with lower emissions. Strong institutions enforce environmental regulations, promote clean energy policies, and encourage sustainable development, leading to reduced emissions (Acemoglu & Robinson, 2012).

Table 4. 8: Correlation test results

Variables	CE	FDI	POP	IND	REW	NREW	EG	IQ
Carbon Emissions	1.0000							
Foreign Direct Investment	0.3417*	1.0000						
Population	0.1485*	-0.0792*	1.0000					
Industrialization	0.6992*	-0.1383*	0.3179*	1.0000				
Renewable Energy	-0.1720*	-0.0413	0.1136*	-0.1196*	1.0000			
Non-renewable Energy	0.2582*	0.0937*	-0.0801*	0.1817*	-0.6416*	1.0000		
Economic Growth	0.6955*	0.6675*	0.1760*	-0.0893*	-0.1070*	0.1736*	1.0000	
Financial Development	0.1625*	0.1269*	0.0890*	-0.0227	0.0168	-0.0395*	0.1490*	1.0000
Institutional Quality	-0.1102*	-0.0921*	-0.2502*	-0.0848*	-0.4185*	0.4185*	-0.1186*	-0.1187*

Source: Researcher (2024) ** $\rho < 0.05$, * $P < 0.1$

4.5 Results of the Regression Analysis

4.5.1 Testing the Effect of the Control Variables

Before investigating the effect of the independent variables on the dependent variable, the study examined the effect of the control variables, foreign direct investment, population and industrialization on carbon emissions. The results are as presented in

table 4.9. Fixed-effects regression is a statistical method used to analyze panel data by controlling for unobserved heterogeneity across groups, such as countries or years, that might influence the dependent variable. It removes time-invariant characteristics, ensuring that only within-group variations are analyzed (Wooldridge, 2019). This method is useful in assessing how independent variables impact a dependent variable over time while controlling for individual-specific characteristics. In this analysis, the fixed-effects regression examines the impact of control variables (foreign direct investment (FDI), population, and industrialization) on carbon emissions. The group variable is "year," meaning the model accounts for variations across different years.

Sigma_u (0.06514611) represents the standard deviation of the unobserved individual effects, indicating the variation in carbon emissions that remains unexplained by the model across different years. Sigma_e (0.60315933) is the standard deviation of the error term, showing the level of unexplained variation in carbon emissions within the model. Rho (0.01153121) indicates that only 1.15% of the total variance is due to unobserved individual effects, meaning that the majority of variation in carbon emissions is explained by the observed independent variables. This suggests that the model effectively captures most of the variability through the included predictors. The model provides three R-squared values, which indicate how well the independent variables explain variations in carbon emissions. The within R-squared value (0.6905) shows that 69.05% of the variation in carbon emissions within each year is explained by FDI, population, and industrialization. The between R-squared value (0.7515) suggests that 75.15% of the variation between different years is captured by the model, indicating a strong explanatory power across time. The overall R-squared value (0.6877) implies that 68.77% of the total variation in carbon emissions is accounted for by the independent variables. Additionally, the F-statistic (657.35) and its p-value

(0.0000) confirm the model's statistical significance. Since the p-value is below the 1% significance level, it indicates that at least one of the independent variables significantly influences carbon emissions (Gujarati & Porter, 2020).

The coefficient for FDI is 0.477968, which suggests a positive and significant relationship between FDI and carbon emissions. This means that a unit increase in FDI leads to a 0.477968 unit increase in carbon emissions, holding other factors constant. This finding supports the pollution haven hypothesis, which states that foreign investors often transfer pollution-intensive industries to developing economies with weaker environmental regulations (Cole et al., 2006). Additionally, the small standard error (0.0200599) indicates that the estimate is precise. The p-value (0.000) confirms that this relationship is statistically significant at the 1% level, meaning the effect of FDI on carbon emissions is highly reliable.

The coefficient for population is -0.0780829, indicating that an increase in population is associated with a slight decrease in carbon emissions. This result contradicts the expectation that a growing population leads to increased emissions due to higher energy consumption (Sadorsky, 2010). One possible explanation is that larger populations may drive policies promoting energy efficiency, sustainability, and cleaner energy consumption, which could offset the expected rise in emissions. The negative coefficient is statistically significant, as the p-value (0.000) confirms. Furthermore, the 95% confidence interval (-0.1207874 to -0.0353783) does not include zero, reinforcing the robustness of this finding.

Industrialization has the largest positive effect on carbon emissions, with a coefficient of 0.7949833. This suggests that a unit increase in industrialization leads to a 0.7949833 unit increase in carbon emissions, holding other factors constant. This result aligns with

past research indicating that industrial activities are a major contributor to greenhouse gas emissions, particularly in economies heavily reliant on fossil fuels and carbon-intensive production methods (Stern, 2011). The p-value (0.000) confirms that this relationship is statistically significant at the 5% level, making it a critical factor in understanding carbon emission trends.

Table 4. 9: Control variable test results

Fixed-effects (within) regression	Number of obs	= 552				
Group variable: year	Number of groups	= 24				
R-sq: within = 0.6905	Obs per group: min	= 22				
between = 0.7515	Avg	= 38.0				
overall = 0.6877	Max	= 38				
	F(3,884)	= 657.35				
corr(u_i, Xb) = -0.1050 (assumed)	Prob > F	= 0.0000				
Carbon Emissions	Coef.	Std. Err.	T	P>z	[95% Conf.	Interval]
Foreign direct investment	.477968	.0200599	23.83	0.000	.4385974	.5173385
Population	-.0780829	.0217586	-3.59	0.000	-.1207874	-.0353783
Industrialization	.7949833	.0202938	39.17	0.000	.7551537	.8348129
_cons	.0220697	.0199956	1.10	0.270	-.0171747	-.0613141
sigma_u	.06514611					
sigma_e	.60315933					
Rho	.01153121 (fraction of variance due to u_i)					

Source: Researcher 2024

4.5.2 Testing the Direct Effect

The regression model is used for the empirical statistics to analyze predictor variables, as shown in Table 4.10. In this analysis, carbon emissions serve as the dependent variable, while foreign direct investment (FDI), population, and industrialization are included as control variables. The independent variables examined in the model include renewable energy, non-renewable energy, economic growth, and financial development. The use of "year" as the group variable ensures that the model captures

variations across different years, allowing for a better understanding of how these factors influence carbon emissions over time.

The model demonstrates a strong explanatory power, as evidenced by the high R-squared values. The within R-squared value (0.9520) indicates that 95.20% of the variation in carbon emissions within each year is explained by the independent and control variables. The between R-squared value (0.9041) shows that 90.41% of the variation in carbon emissions across different years is accounted for by the model. Additionally, the overall R-squared value (0.9446) suggests that 94.46% of the total variation in carbon emissions is explained by the selected variables.

The F-statistic (1477.61) and the corresponding p-value (0.0000) confirm that the model is statistically significant. This indicates that at least one of the independent variables has a significant impact on carbon emissions. Such a high F-statistic value highlights the reliability of the model in explaining the relationship between the independent variables and carbon emissions. This finding supports previous research emphasizing the role of economic and energy-related factors in influencing environmental outcomes (Gujarati & Porter, 2020).

An analysis of the variance components provides further insight into the model's robustness. The σ_u value (0.09251278) represents the standard deviation of the unobserved individual effects related to each year. This suggests that while year-specific factors influence carbon emissions, their impact is relatively small. The σ_e value (0.23179517) represents the standard deviation of the error term, capturing unexplained variations in carbon emissions that are not accounted for by the included variables.

The rho value (0.13740476) indicates that 13.74% of the total variance in carbon emissions is due to unobserved individual effects. This suggests that the majority of the variation in carbon emissions is effectively explained by the observed variables included in the model. Overall, these results highlight the model's effectiveness in capturing the key factors influencing carbon emissions while acknowledging the presence of some unobserved variations.

Table 4. 10: Direct effect test results

Fixed-effects (within) regression	Number of obs =	552				
Group variable: Year	Number of groups =	24				
R-sq: within = 0.9520	Obs per group: min =	22				
between = 0.9041	Avg =	23.0				
overall = 0.9446	Max =	24				
	F(7, 521) =	1477.61				
corr(u_i, X) = -0.1335	Prob > F =	0.0000				
Carbon Emissions	Coef.	Std. Err.	t	P>z	[95% Conf.	Interval]
Foreign direct investment	-.0436657	.0124086	-3.52	0.000	-.0680428	-.0192886
Population	-.1148464	.0269021	-4.27	0.003	-.1676963	-.0619965
Industrialization	.8632002	.038679	22.32	0.000	.7872142	.9391862
Renewable Energy	.034178	.0190615	1.79	0.074	-.0032689	.0716249
Non-renewable energy	.0026524	.0009537	2.78	0.006	.0007789	.0045259
Economic Growth	.7026022	.0120275	58.42	0.000	.6789738	.7262306
Financial Development	.0440912	.010055	4.39	0.000	.0243379	.0638445
_cons	.0281733	.0107674	2.62	0.009	.0070206	.0493261
sigma_u	.09251278					
sigma_e	.23179517					
Rho	.13740476 (fraction of variance due to u_i)					

Source: Researcher 2024

The first hypothesis (H₀₁) stated that: there is no significant effect between renewable energy consumption and carbon emissions in Sub-Saharan Africa.

The results confirm that the effect of the renewable energy consumption on carbon emissions was positive and significant at 10 percent level of significant and insignificant at 5 percent level of significant ($\beta = 0.034178$, $\rho = 0.074$). Therefore, H₀₁ is accepted, and the conclusion is that renewable energy consumption does not have significant effect on carbon emissions. The coefficient for renewable energy is 0.034178, suggesting a positive relationship with carbon emissions, but the p-value (0.074) indicates that this effect is not statistically significant at the 5% level. This unexpected result could be due to the transitional phase of renewable energy adoption, where carbon-intensive infrastructure is still necessary for implementation (IEA, 2021). This finding contradicts with Ehigiamusoe & Dogan, (2022); Khan, Khan & Rehan, (2020).

The second hypothesis (H₀₂) stated that: there is no significant effect between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa.

The results confirm that the effect of the non-renewable energy consumption on carbon emissions was positive and significant ($\beta = 0.0026524$, $\rho = 0.006$). Therefore, H₀₁ is rejected, and the conclusion is that non-renewable energy consumption increases carbon emissions. The positive and significant coefficient non-renewable energy consumption indicates that that an increase in non-renewable energy consumption leads to a small but significant increase in carbon emissions. This finding is expected, as fossil fuel-based energy sources are a major contributor to emissions (BP, 2020). The p-value (0.006) confirms that this relationship is statistically significant. This finding aligns with Zhang et al., (2024); Banday & Aneja, (2020).

The third hypothesis (H₀₃) stated that: there is no significant effect between economic growth and carbon emissions in Sub-Saharan Africa.

The results confirm that the effect of the economic growth on carbon emissions was positive and significant ($\beta = 0.7026022$, $\rho = 0.000$). Therefore, H₀₁ is rejected, and the conclusion is that economic growth has the largest positive impact on carbon emissions, with a coefficient of 0.7026022. This means that a unit increase in economic growth results in a 0.7026 unit increase in emissions, holding other factors constant. This result aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that economic growth initially increases emissions before leading to reductions at higher income levels (Grossman & Krueger, 1995). This finding aligns with Narayan, Saboori & Soleymani, (2016); Schröder & Storm, (2020).

The fourth hypothesis (H₀₄) stated that: there is no significant effect between financial development and carbon emissions in Sub-Saharan Africa.

The results confirm that the effect of the financial development on carbon emissions was positive and significant ($\beta = 0.0440912$, $\rho = 0.000$). Therefore, H₀₁ is rejected, and the conclusion is that financial development has significant effect on carbon emissions. The coefficient for financial development is 0.0440912, indicating that higher financial development leads to an increase in carbon emissions. This suggests that financial expansion may encourage investments in industrial activities and energy consumption, leading to increased emissions. This finding aligns with Gök, (2020) and contradicts a study by Habiba & Xinbang, (2022).

4.5.3 Testing the effect of institutional quality on carbon emissions

The study's main objective was to examine whether institutional quality moderate the relationship between renewable energy consumption, non-renewable energy

consumption, economic growth and industrialization on carbon emissions. This is in accordance with Baron and Kenny (1986) who contend that the moderator must be significantly related to the outcome variable. To achieve this, the study regressed the outcome variable against the moderating variable while controlling for the independent variable. The regression results are presented in table 4.11 as shown below.

The model demonstrates strong explanatory power, as indicated by the high R-squared values. The within R-squared value (0.9527) shows that 95.27% of the variation in carbon emissions within each year is explained by the control, independent, and moderating variables. The between R-squared value (0.9005) suggests that 90.05% of the variation between different years is captured by the model, while the overall R-squared value (0.9455) indicates that 94.55% of the total variation in carbon emissions is accounted for by the included variables.

The F-statistic (1307.84) and its corresponding p-value (0.0000) confirm that the model is statistically significant. This means that at least one of the independent variables has a meaningful effect on carbon emissions. The strength of the model suggests that economic, energy-related, and institutional factors play a crucial role in determining carbon emissions over time. The σ_u value (0.0905) represents the standard deviation of unobserved individual effects related to each year, while the σ_e value (0.2305) captures unexplained variations in carbon emissions. The ρ value (0.1335) indicates that 13.35% of the total variance in carbon emissions is due to unobserved individual effects, confirming that most of the variation is effectively explained by the included variables.

Table 4. 11: Institutional quality on carbon emissions test results

Fixed-effects (within) regression	Number of obs	= 552				
Group variable: Year	Number of groups	= 24				
R-sq: within = 0.9527	Obs per group: min	= 22				
between = 0.9005	Avg	= 23.0				
overall = 0.9455	Max	= 24				
	F (8, 520)	= 1307.84				
corr(u_i, X) = -0.1312	Prob > F	= 0.0000				
Carbon Emissions	Coef.	Std. Err.	T	P>z	[95% Conf.	Interval]
Foreign direct investment	-.0408146	.0123908	-3.29	0.001	-.0651568	-.0164725
Population	-.1388009	.0283167	-4.90	0.000	-.19443	-.0831717
Industrialization	.8957821	.0404831	22.13	0.000	.8162515	.9753127
Renewable Energy	.0361488	.0189738	1.91	0.057	-.001126	.0734236
Non-renewable energy	.0030065	.0009584	3.14	0.002	.0011238	.0048893
Economic Growth	.6926169	.012571	55.10	0.000	.6679207	.7173131
Financial Development	.0430458	.0100088	4.30	0.000	.0233831	.0627085
Institutional Quality	-.0302425	.0117022	-2.58	0.010	-.0532319	-.0072531
_cons	.0410246	.0118074	3.47	0.001	.0178286	.0642207
sigma_u	.09048651					
sigma_e	.23054214					
Rho	.13348784 (fraction of variance due to u_i)					

Source: Researcher (2024)

According to table 4.11 institutional quality have a negative and significant effect on carbon emissions ($\beta = -.0302425$ and $p = 0.010$). Institutional quality ($\beta = -0.0302425$, $p = 0.010$) has a negative and statistically significant effect on carbon emissions. This indicates that stronger institutions help mitigate emissions by enforcing environmental regulations and promoting sustainable economic practices. These results agree with previous studies done by Haldar & Sethi, (2021); Salman, Long, Dauda & Mensah, (2019).

4.5.4 The moderating effect of institutional quality on the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions

Hypothesis H₀₅ sought to determine whether institutional quality moderates the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions. To establish the moderating effect the interaction terms were entered in a stepwise manner from model 4-model 7. The fixed effect results of model 7 were used to test the moderating effect. The summarized moderation results are reported in model 7 shown in table 4.13 and the hypotheses tested as follows:

Hypothesis (H5_a) stated that; *Institutional quality does not significantly moderate the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa.*

The regression results show that institutional quality significantly moderate the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa ($\beta = -.0075$ and $p = 0.009$); hence hypothesis H_{05_a} was rejected. The moderation results are further analyzed using a modgraph as shown below. Figure 4.1 below shows that carbon emissions is low for high renewable energy consumption and for high institutional quality. High institutional quality is associated with strong governance, well-enforced environmental regulations, and transparent policy frameworks, which collectively support the implementation of sustainable energy strategies (Acemoglu & Robinson, 2019). Governments with strong institutions are more likely to incentivize renewable energy investments through subsidies, tax benefits, and regulatory support while simultaneously imposing stricter emission controls on industries. Furthermore, well-functioning institutions enhance

accountability and reduce corruption, ensuring that environmental policies are effectively implemented and not undermined by vested interests (North, 1990).

Empirical evidence suggests that countries with high institutional quality experience greater success in decarbonizing their economies through the adoption of renewable energy. For instance, nations in Scandinavia, such as Sweden and Denmark, have significantly reduced their carbon emissions through a combination of strong institutions and aggressive renewable energy policies (OECD, 2021). In contrast, countries with weaker institutional frameworks may struggle to enforce environmental policies, leading to continued dependence on fossil fuels despite renewable energy investments.

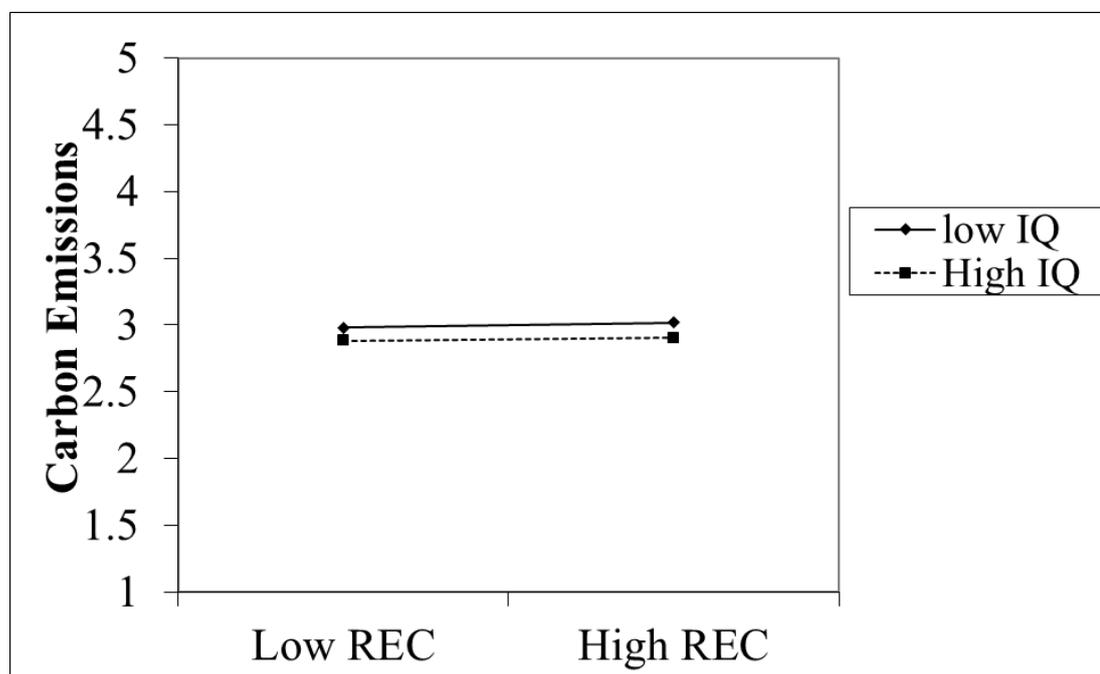


Figure 4. 1: Modgraph for renewable energy consumption, institutional quality and carbon emissions

Hypothesis (H5_b) stated that; *Institutional quality does not significantly moderate the relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa.*

The regression results show that institutional quality significantly negatively moderates the relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa ($\beta = -.0022$ and $\rho = 0.000$); hence hypothesis H05b was rejected. The moderation results are further analyzed using a modgraph as shown below. Figure 4.2 below shows that carbon emissions is low with low non-renewable energy consumption and high institutional quality. Institutional quality serves as a critical moderator in the relationship between non-renewable energy consumption and carbon emissions. High institutional quality is characterized by strong governance structures, effective regulatory enforcement, and transparent policymaking, all of which are essential for successfully reducing reliance on fossil fuels. Governments with strong institutions are more likely to implement policies that discourage non-renewable energy consumption, such as carbon taxes, emissions trading schemes, and subsidies for clean energy investments (Acemoglu & Robinson, 2019). Moreover, effective institutions enhance energy market efficiency by promoting competition and encouraging innovation in renewable energy technologies, making clean energy alternatives more accessible and cost-effective.

For example, European nations with high institutional quality, such as Germany and France, have successfully reduced their reliance on non-renewable energy by implementing ambitious climate policies and investing heavily in renewable energy (OECD, 2021). In contrast, countries with weak institutional frameworks often struggle to enforce environmental regulations, leading to continued dependence on fossil fuels and higher emissions. Therefore, the combination of reduced non-renewable energy

consumption and strong institutional governance plays a crucial role in achieving sustainable carbon emission reductions

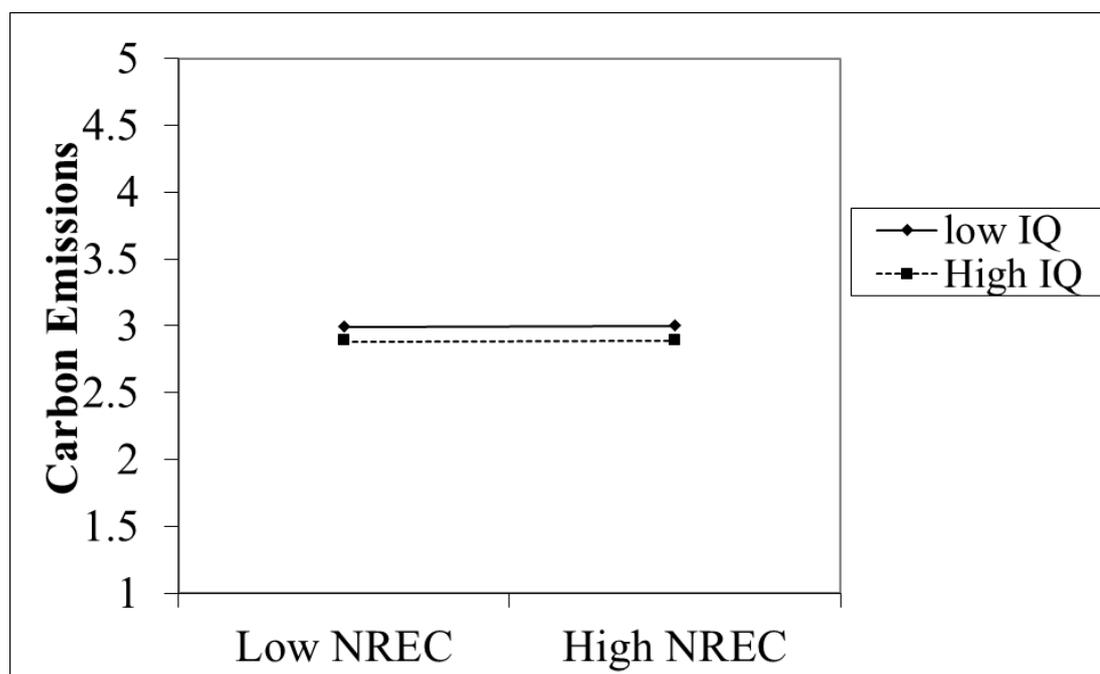


Figure 4. 2: Modgraph for non-renewable energy consumption, institutional quality and carbon emissions

Hypothesis (H5_c) stated that; Institutional quality does not significantly moderate the relationship between economic growth and carbon emissions in Sub-Saharan Africa.

Based on the regression results of model 7 ($\beta = -0.0378$ and $\rho = 0.05$) H05_c was rejected and the study concluded that institutional quality moderated the relationship between economic growth and carbon emissions in Sub-Saharan Africa. Therefore, hypothesis **H5_c** is rejected. Figure 4.3 below shows that carbon emissions is low with high economic growth and high institutional quality. Carbon emissions tend to be lower in economies with high economic growth when strong institutional quality is present. Economic growth, when driven by sustainable policies, leads to increased investments in clean energy technologies, energy efficiency, and advanced industrial processes that reduce carbon footprints (Grossman & Krueger, 1995). As economies expand, they

often transition from resource-intensive production to knowledge-based industries, which are less carbon-intensive. This phenomenon aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that while emissions may initially rise with economic growth, they eventually decline as countries adopt cleaner technologies and stronger environmental regulations (Stern, 2004).

High-quality institutions enforce environmental regulations, promote transparency, and create incentives for businesses to adopt green practices. Countries with strong institutional frameworks implement policies such as carbon pricing, emissions trading systems, and subsidies for renewable energy, ensuring that economic growth is decoupled from environmental degradation (Acemoglu & Robinson, 2019). Effective governance structures also support research and development (R&D) in sustainable technologies, which accelerates the adoption of low-carbon innovations. For example, Nordic countries, which have high economic growth and strong institutions, have successfully maintained low carbon footprints through proactive climate policies and investments in renewable energy (OECD, 2021). In contrast, economies with weak institutions often experience higher emissions despite economic expansion due to regulatory inefficiencies and lack of environmental accountability. The presence of corruption and weak enforcement mechanisms in such economies allows industries to bypass environmental laws, leading to continued reliance on fossil fuels and increased carbon emissions (Dutta & Das, 2020).

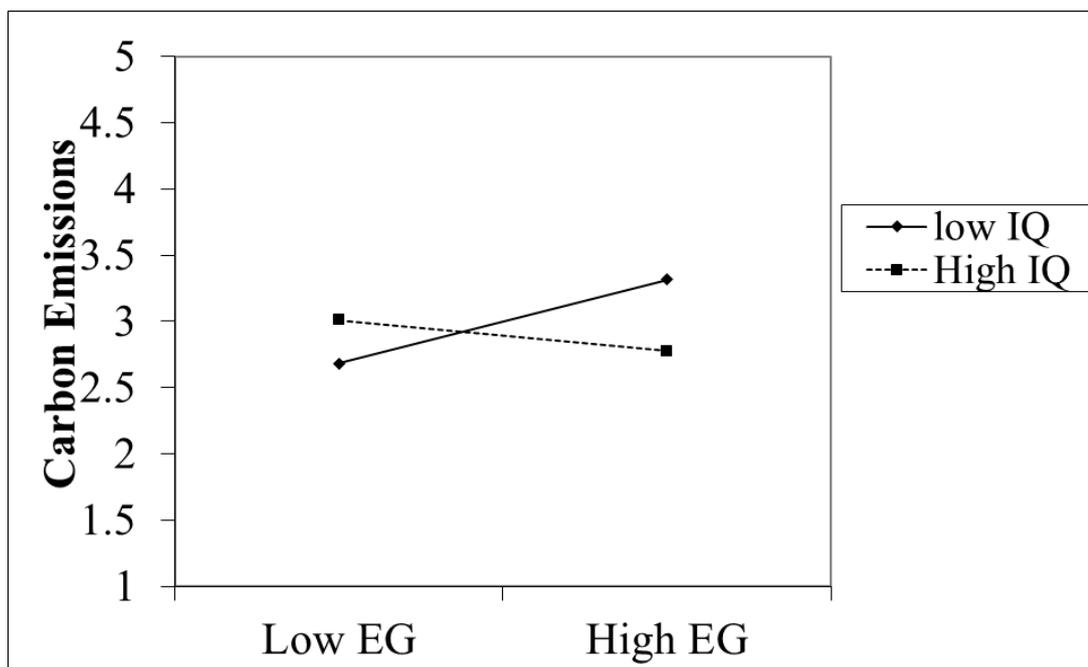


Figure 4. 3: Modgraph for economic growth, institutional quality and carbon emissions

Hypothesis (H5a) stated that; Institutional quality does not significantly moderate the relationship between financial development and carbon emissions in Sub-Saharan Africa.

The regression results presented in model 7 of table 4.13 ($\beta = -.0378$ and $\rho = 0.000$) indicated that institutional quality moderated the relationship financial development and carbon emissions in Sub-Saharan Africa. Consequently, H05d was rejected. Figure 4.4 below shows that carbon emissions is low for low financial development and high institutional quality. Carbon emissions tend to be lower in economies with low financial development, particularly when institutional quality is high. Financial development, which includes the expansion of credit markets, banking systems, and stock markets, often facilitates industrial growth, infrastructure expansion, and energy consumption, which can increase carbon emissions (Shahbaz et al., 2013). When financial markets are less developed, there is limited access to capital for high-carbon industries, reducing

large-scale investments in fossil fuel-based energy projects and heavy industrial production, thereby contributing to lower carbon emissions (Paramati et al., 2018).

Strong institutions ensure that financial resources, even when limited, are allocated toward environmentally sustainable projects rather than polluting industries. High institutional quality facilitates regulatory frameworks that encourage green financing, impose carbon taxes, and enforce stricter environmental policies, ensuring that economic activities remain environmentally sustainable (Acemoglu & Robinson, 2019). In economies with weak institutions, low financial development may still result in environmental degradation due to ineffective enforcement of environmental regulations and reliance on informal, high-carbon economic activities.

Countries with high institutional quality and limited financial development often experience lower emissions due to stringent environmental policies and controlled industrial expansion (Omri et al., 2015). For instance, economies with strong governance mechanisms prioritize investments in renewable energy and energy efficiency, even in the absence of highly developed financial markets. Countries with low financial development and strong institutions may also rely on alternative economic models that emphasize sustainability over rapid industrialization, leading to a reduced carbon footprint (Sadorsky, 2010). Thus, while financial development can contribute to economic growth, its impact on carbon emissions depends on institutional quality. High institutional quality ensures that financial resources, even in a constrained financial market, are directed toward sustainable development, mitigating the potential negative environmental effects of industrialization. This highlights the crucial role of governance in aligning economic policies with environmental sustainability.

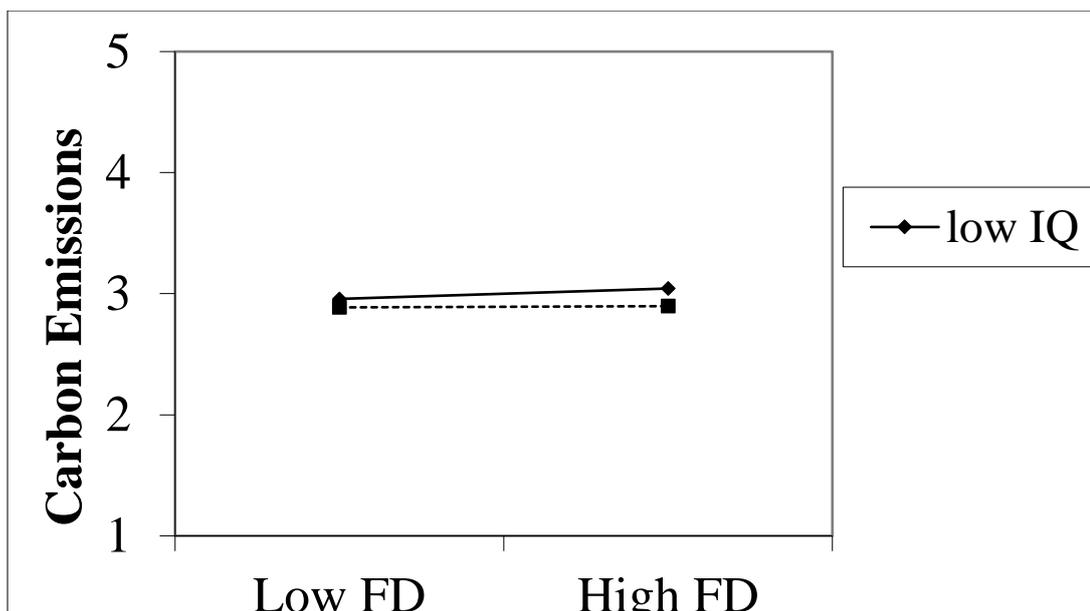


Figure 4. 4: Modgraph for financial development, institutional quality and carbon emissions

4.6 Robust test- Generalized method of moment model (Gmm)

The Generalized Method of Moments (GMM) model was employed in this study to ensure robustness and address potential endogeneity issues that may arise due to omitted variable bias, simultaneity, or measurement errors. The GMM estimation technique is particularly useful in panel data settings, as it allows for the control of unobserved heterogeneity and provides consistent estimates when the regressors are endogenous (Arellano & Bond, 1991). The results from the GMM model are compared with the fixed effects (FE) model to examine whether the findings remain consistent.

The coefficient for FDI is negative and statistically significant (-0.017 , $p < 0.05$), suggesting that an increase in FDI leads to a reduction in carbon emissions. This finding aligns with the pollution halo hypothesis, which suggests that foreign investors bring cleaner technologies and better environmental management practices (Shahbaz et al., 2020). The FE model also showed a negative coefficient for FDI, confirming the robustness of this relationship.

The coefficient for population is negative (-0.088, $p < 0.05$), implying that higher population growth is associated with lower carbon emissions. This finding contradicts traditional expectations, which typically link population growth to higher emissions due to increased energy demand. One possible explanation could be improved energy efficiency measures or the transition to greener energy sources in highly populated regions (Wang et al., 2021).

Industrialization is positively and significantly related to carbon emissions (0.794, $p < 0.05$). This suggests that as industrial activities expand, carbon emissions increase due to higher energy consumption and reliance on fossil fuels. This result is consistent with findings in the FE model, reinforcing the argument that industrialization remains a key driver of environmental degradation (Omri, 2017).

Both renewable energy (0.041, $p < 0.05$) and non-renewable energy consumption (0.062, $p < 0.05$) have positive and significant impacts on carbon emissions. The positive impact of renewable energy on emissions may indicate the presence of inefficiencies in renewable energy adoption, such as reliance on biofuels that still emit carbon (Apergis & Payne, 2012). However, non-renewable energy consumption is expectedly associated with higher emissions, confirming its role as a major pollutant.

Economic growth significantly increases carbon emissions (0.733, $p < 0.05$), supporting the Environmental Kuznets Curve (EKC) hypothesis, which states that emissions rise with economic growth until a certain threshold, after which they decline as economies shift to cleaner technologies (Grossman & Krueger, 1995). This result aligns with the FE model, indicating consistency in findings.

The coefficient for financial development is positive (0.031, $p < 0.05$), indicating that an expansion in financial markets leads to higher carbon emissions. This could be due to increased investment in energy-intensive industries (Sadorsky, 2010).

Institutional quality alone negatively influences carbon emissions (-0.023, $p < 0.05$), suggesting that stronger governance reduces emissions through stricter regulations and better policy enforcement. Additionally, all interaction terms involving institutional quality have negative and significant coefficients: These results suggest that institutional quality moderates the impact of economic activities on carbon emissions, reinforcing the role of governance in environmental sustainability (Farhani & Ozturk, 2015). The Arellano-Bond test for AR(1) ($p = 0.104$) and AR(2) ($p = 0.267$) confirms the absence of second-order autocorrelation, which is essential for GMM validity (Roodman, 2009). The Hansen test ($p = 0.104$) and Sargan test ($p = 0.699$) indicate that the instruments used in the model are valid, reinforcing the reliability of the GMM estimation.

The GMM results confirm the robustness of the fixed effects model while addressing endogeneity concerns. The findings highlight that industrialization, economic growth, and financial development drive carbon emissions, while institutional quality mitigates these effects. Policies should focus on strengthening governance and promoting efficient renewable energy adoption to balance economic growth with environmental sustainability.

Table 4. 12: Robust test- Generalized method of moment model (Gmm)

Carbon emissions	Gmm Model Coef.
Constant	.041(0.009) **
Foreign Direct investment	-0.017 (0.005) **
Population	-0.088(0.082) **
Industrialization	.794 (0.026) **
Renewable energy consumption	0.041 (0.013) **
Non-renewable energy consumption	0.062 (0.016) **
Economic growth	0.733 (0.012) **
Financial development	0.031 (0.002) **
Institutional Quality	-0.023(0.005) **
Renewable Energy* Institutional Quality	-0.108 (0.039) **
Non-renewable energy* Institutional Quality	-0.102 (0.038) **
Economic Growth* Institutional Quality	-0.773 (0.259) **
Financial Development* Institutional Quality	-0.037 (0.021) **
Post-estimation tests	
AR(1)	0.104
AR(2)	0.267
Sargan	0.699
Hansen	0.104
Observations	528
Groups	24
F	893.77
No. of instruments	10

Source: Researcher (2024); ** $\rho < 0.05$, * $P < 0.1$ standard errors in parentheses

4.7 Discussion of the results

The first objective was to determine whether renewable energy consumption influence carbon emissions in Sub-Saharan Africa.

The relationship between renewable energy consumption and carbon emissions is a critical area of study in environmental economics and energy policy. The results indicate that renewable energy consumption has a positive but statistically insignificant effect on carbon emissions at the 5% level ($\beta = 0.034178$, $p = 0.074$). The significance at the 10% level suggests a weak relationship, but it does not provide enough statistical

evidence to confirm a substantial impact. As a result, the null hypothesis (H01) is accepted, concluding that renewable energy consumption does not significantly affect carbon emissions.

The positive coefficient (0.034178) suggests that an increase in renewable energy consumption is associated with a slight increase in carbon emissions. This counterintuitive result may be explained by the transitional phase of renewable energy adoption, where carbon-intensive infrastructure is still required for development and integration into the energy system (International Energy Agency [IEA], 2021). The initial stages of renewable energy projects often involve fossil fuel-based manufacturing, transportation, and installation, which could temporarily increase carbon emissions. Additionally, energy mix disparities across regions may contribute to this finding, as some countries still rely on fossil fuels to complement intermittent renewable energy sources such as solar and wind (Zhang et al., 2022).

Contradictory findings have been reported in previous literature. Studies such as Ehigiamusoe and Dogan (2022) and Khan, Khan, and Rehan (2020) have found that renewable energy consumption significantly reduces carbon emissions. Ehigiamusoe and Dogan (2022) argue that the expansion of renewable energy reduces dependence on fossil fuels, leading to long-term carbon reductions. Similarly, Khan et al. (2020) emphasize that a higher share of renewables in the energy mix significantly curtails carbon emissions by replacing coal and oil-based energy production. The discrepancy between the current study's findings and these previous studies may be due to variations in data sources, regional energy policies, and the time frame of analysis.

Another possible explanation for the unexpected result is the issue of energy rebound effects, where efficiency improvements in energy use lead to increased consumption,

potentially offsetting emission reductions (Sorrell, 2009). Moreover, some renewable energy technologies, such as biomass, may still generate carbon emissions, albeit at a lower rate compared to fossil fuels (Cheng et al., 2021). This suggests that not all renewable energy sources are equally effective in reducing carbon emissions.

Despite the statistical insignificance at the 5% level, the positive relationship observed should not be dismissed outright. Policymakers should consider that the short-term impact of renewable energy transition might differ from the long-term effects. As renewable technology matures and reliance on carbon-intensive infrastructure diminishes, the expected negative relationship between renewable energy consumption and carbon emissions is likely to become more evident (Stern, 2022). Therefore, continued investment in clean energy and improved grid efficiency remains essential for achieving meaningful carbon reductions in the future

The second objective was to determine whether non-renewable energy consumption influence carbon emissions in Sub-Saharan Africa.

The results confirm that non-renewable energy consumption has a positive and significant effect on carbon emissions ($\beta = 0.0026524$, $p = 0.006$). The rejection of the null hypothesis (H_0) implies that increased reliance on non-renewable energy sources, such as coal, oil, and natural gas, directly contributes to rising carbon emissions. The coefficient of 0.0026524, though small, suggests that even marginal increases in fossil fuel consumption significantly elevate atmospheric carbon levels. The statistical significance of the relationship, as indicated by the p-value of 0.006, reinforces the robustness of this finding, confirming that the impact is not due to random variation but rather a genuine effect of non-renewable energy consumption on emissions.

The positive relationship between non-renewable energy consumption and carbon emissions is well-documented in previous studies. Zhang et al. (2024) provide empirical evidence that fossil fuel combustion remains the largest contributor to greenhouse gas emissions worldwide. Similarly, Banday and Aneja (2020) emphasize that economies highly dependent on non-renewable energy sources experience higher levels of environmental degradation due to the combustion of carbon-intensive fuels. These findings align with the current study, reaffirming the detrimental role of non-renewable energy in accelerating climate change.

One of the primary reasons for this strong link is the heavy reliance on fossil fuels in industrial activities, transportation, and electricity generation. According to BP (2020), over 80% of global energy consumption still comes from non-renewable sources, with coal and oil being the dominant contributors to carbon emissions. As a result, economies that fail to transition toward cleaner energy alternatives continue to experience worsening air pollution, global warming, and environmental instability (IEA, 2021).

The implications of these findings are crucial for policymakers and energy planners. The statistically significant impact of non-renewable energy consumption on emissions highlights the urgent need to accelerate the transition to renewable energy sources. Governments should consider implementing carbon pricing mechanisms, investing in cleaner technologies, and providing incentives for industries to adopt energy-efficient practices. Furthermore, integrating renewable energy sources, such as wind, solar, and hydropower, into national energy grids can help mitigate the harmful effects of fossil fuel dependency (Khan, Khan, & Rehan, 2020).

Despite these findings, it is essential to acknowledge that the energy transition process is complex. Developing economies, in particular, face structural challenges in shifting away from non-renewable energy due to infrastructure limitations and financial constraints. Zhang et al. (2024) argue that a balanced approach is necessary—one that ensures energy security while gradually reducing carbon intensity through technological innovations and policy interventions.

The third objective was to determine whether economic growth influence carbon emissions in Sub-Saharan Africa

Economic growth plays a crucial role in shaping environmental outcomes, particularly carbon emissions. The results of this study indicate that economic growth has a significant and positive impact on carbon emissions ($\beta = 0.7026022$, $\rho = 0.000$). The rejection of the null hypothesis (H_0) suggests that as economies expand, carbon emissions increase at a substantial rate. Specifically, a unit increase in economic growth results in a 0.7026-unit rise in carbon emissions, holding other variables constant. This relationship highlights the environmental trade-offs associated with economic development, as increased industrial activities, energy consumption, and transportation demands contribute to higher greenhouse gas emissions (Narayan, Saboori, & Soleymani, 2016).

The findings align with the Environmental Kuznets Curve (EKC) hypothesis, which posits that economic growth initially leads to environmental degradation but eventually reduces emissions as economies transition to cleaner technologies and stronger environmental regulations (Grossman & Krueger, 1995). In the early stages of economic development, industries rely heavily on fossil fuels and resource-intensive processes, leading to significant carbon emissions. However, as income levels rise,

governments and businesses invest in sustainable technologies, renewable energy, and emission-reducing policies, eventually leading to a decline in emissions (Schröder & Storm, 2020). This study's results support the first phase of the EKC hypothesis, where economic expansion is directly associated with increasing carbon emissions.

Several empirical studies support the positive relationship between economic growth and carbon emissions. For instance, Narayan et al. (2016) found that economic expansion in developing economies significantly increases carbon emissions due to high dependence on non-renewable energy sources and rapid industrialization. Similarly, Schröder and Storm (2020) emphasize that economic growth in emerging markets is often linked with increased energy consumption, deforestation, and higher carbon footprints. These studies align with the present findings, confirming that economic activities remain a key driver of emissions.

A possible explanation for this strong correlation is the energy-intensive nature of economic development. As countries experience economic growth, industrialization accelerates, leading to higher demand for electricity, transportation, and manufacturing, which are often powered by fossil fuels. Additionally, urbanization and increased consumption patterns contribute to greater carbon footprints (IEA, 2021). Despite global efforts to transition toward green economies, many countries still rely on carbon-intensive industries to sustain economic growth, thereby exacerbating environmental degradation.

The implications of these findings suggest the need for sustainable economic policies. Policymakers should focus on promoting green growth strategies that balance economic expansion with environmental sustainability. Investments in renewable energy, energy efficiency, and carbon capture technologies can help mitigate the adverse

environmental effects of economic growth. Furthermore, the implementation of carbon pricing mechanisms, stricter environmental regulations, and incentives for sustainable business practices can aid in reducing emissions while maintaining economic progress (OECD, 2022).

The fourth objective was to determine whether financial development influence carbon emissions in Sub-Saharan Africa.

The findings of this study indicate that financial development has a significant and positive impact on carbon emissions ($\beta = 0.0440912$, $\rho = 0.000$). The rejection of the null hypothesis (H_0) confirms that as financial markets expand, carbon emissions increase. Specifically, the coefficient of 0.0440912 suggests that financial development facilitates economic activities that lead to higher energy consumption and industrial production, ultimately contributing to increased carbon emissions. This relationship highlights the dual role of financial development—while it stimulates economic growth, it also intensifies environmental concerns (Gök, 2020).

One of the primary reasons financial development leads to higher carbon emissions is the increased availability of credit and investment in energy-intensive industries. When financial systems improve, businesses gain easier access to funding, allowing them to expand operations, adopt new technologies, and increase production capacity. However, in many developing and emerging economies, this expansion often relies on fossil fuels, leading to higher emissions (Sadorsky, 2010). Moreover, financial development fosters urbanization and infrastructure development, both of which contribute to higher energy consumption and carbon footprints. For instance, increased lending to the construction and transportation sectors often results in greater demand for non-renewable energy sources (Shahbaz et al., 2013).

Empirical studies support the positive relationship between financial development and carbon emissions. Gök (2020) found that financial deepening in emerging economies significantly contributes to increased energy consumption and carbon emissions due to rapid industrialization and urban expansion. Similarly, studies by Shahbaz, Nasreen, and Ozturk (2017) confirm that financial development can accelerate environmental degradation if not accompanied by sustainable investment policies. These findings align with the current study's results, emphasizing that financial expansion tends to increase emissions.

However, contrasting views exist in the literature. For instance, Habiba and Xinbang (2022) argue that financial development can also contribute to environmental sustainability by promoting investments in green technologies and renewable energy. In well-regulated financial markets, banks and investors may prioritize environmentally friendly projects, leading to a reduction in carbon emissions over time. Additionally, financial institutions can influence corporate sustainability by imposing environmental criteria for lending and investment decisions (Zhang, 2021). Therefore, while financial development has historically been linked to higher emissions, its impact largely depends on how financial resources are allocated.

The policy implications of these findings suggest the need for sustainable financial practices. Policymakers should encourage green finance initiatives, such as climate-related investment funds, green bonds, and incentives for businesses to adopt clean energy solutions. Additionally, regulatory frameworks should be strengthened to ensure that financial expansion aligns with environmental sustainability goals. Without proper policies, financial development may continue to drive carbon-intensive industrial activities, exacerbating climate change concerns (OECD, 2022).

The fifth objective was to determine whether institutional quality moderate the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions in Sub-Saharan Africa.

Moderating role of institutional quality on the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa.

The direct effect results indicate that renewable energy consumption has a positive but statistically insignificant relationship with carbon emissions in Sub-Saharan Africa (SSA). This finding suggests that increasing the consumption of renewable energy alone does not necessarily lead to a reduction in carbon emissions in the region. One possible explanation is that renewable energy infrastructure in SSA is still in its nascent stages and may not yet be developed enough to replace fossil fuels at a scale sufficient to reduce emissions significantly (Sarkodie & Adams, 2018). Additionally, many SSA countries still rely on hybrid energy systems where renewable energy sources, such as solar and wind, complement rather than fully substitute non-renewable sources like coal and natural gas. As a result, even as renewable energy consumption rises, fossil fuel consumption may not decline proportionally, leading to an insignificant effect on emissions.

Moreover, the inefficiencies in renewable energy technology and infrastructure could be contributing to this outcome. Many SSA countries face technical and financial barriers to fully utilizing renewable energy sources. Issues such as poor grid integration, lack of energy storage systems, and intermittent energy supply reduce the effectiveness of renewable energy in displacing high-carbon sources (Adom et al., 2021). Additionally, biomass, which constitutes a large portion of renewable energy use in

SSA, is often derived from traditional methods such as firewood and charcoal burning, which still contribute to carbon emissions despite being categorized as renewable energy (Acheampong et al., 2019).

However, the introduction of institutional quality as a moderating factor reversed the relationship between renewable energy consumption and carbon emissions, indicating antagonistic moderation. This implies that when strong institutions are in place, renewable energy consumption effectively reduces carbon emissions. Institutional quality plays a crucial role in ensuring that renewable energy policies are effectively implemented, resources are allocated efficiently, and environmental regulations are enforced (Omri & Daly, 2015). Countries with high institutional quality are more likely to have well-designed policies that encourage investment in clean energy technologies and phase out carbon-intensive energy sources.

In SSA, weak institutions often hinder the effective deployment of renewable energy projects, leading to inefficiencies and limited environmental benefits. Corruption, poor regulatory frameworks, and lack of policy enforcement can result in renewable energy projects being mismanaged or failing to reach their full potential in reducing emissions (Asongu & Odhiambo, 2020). However, in countries with strong governance structures, renewable energy adoption is more likely to align with emission reduction goals, as institutions enforce strict environmental standards and encourage technological advancements that improve the efficiency of renewable energy use.

Another possible reason for the antagonistic moderation effect is that institutional quality influences the energy mix. Strong institutions promote transparency, encourage foreign investment in clean energy projects, and facilitate research and development for improved renewable energy technologies (Paramati et al., 2018). This ensures that

renewable energy is not just an additional source of power but an effective replacement for fossil fuels, leading to a net reduction in emissions. Conversely, in regions with weak institutions, renewable energy projects may coexist with ongoing fossil fuel use rather than displacing it, rendering the effect of renewable energy consumption on emissions insignificant or even positive

Moderating role of institutional quality on the relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa.

The direct effect results indicate a positive and significant relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa (SSA). This outcome aligns with existing literature, as non-renewable energy sources, including coal, oil, and natural gas, are major contributors to greenhouse gas emissions (Acheampong et al., 2019). The combustion of these fossil fuels releases large amounts of carbon dioxide (CO₂) into the atmosphere, exacerbating environmental degradation and climate change. In SSA, many economies rely heavily on non-renewable energy sources due to the lack of sufficient renewable energy infrastructure, leading to an increase in emissions as energy demand grows (Adom et al., 2021).

However, the introduction of institutional quality as a moderating factor reversed the relationship between non-renewable energy consumption and carbon emissions, indicating an antagonistic moderation effect. This suggests that in countries with strong institutional frameworks, the impact of non-renewable energy consumption on carbon emissions is mitigated. Institutional quality plays a crucial role in shaping energy policies, enforcing environmental regulations, and promoting sustainable energy practices (Omri & Daly, 2015). In SSA, countries with better governance structures are more likely to implement policies that regulate fossil fuel consumption, encourage

energy efficiency, and promote cleaner production techniques, thereby reducing the emissions associated with non-renewable energy use.

One possible explanation for this antagonistic moderation is that strong institutions facilitate the adoption of cleaner technologies even within the non-renewable energy sector. Governments with high institutional quality are more likely to invest in emission-reducing technologies, such as carbon capture and storage (CCS) and cleaner fuel alternatives, to reduce the carbon footprint of fossil fuel consumption (Paramati et al., 2018). Additionally, well-functioning institutions enforce strict environmental regulations, ensuring that industries adhere to emission control standards. In contrast, weak institutions often fail to enforce such policies, allowing uncontrolled fossil fuel use that leads to higher carbon emissions.

Furthermore, institutional quality can influence energy efficiency practices. Countries with effective governance mechanisms encourage industrial and household sectors to adopt energy-saving technologies and efficient production processes. Regulatory policies, such as carbon taxes, subsidies for clean energy, and mandatory energy efficiency standards, can help lower emissions even when non-renewable energy sources remain part of the energy mix (Asongu & Odhiambo, 2020). In contrast, in regions with weak institutional oversight, fossil fuel use is often inefficient, leading to higher emissions per unit of energy consumed.

Another key factor is the role of institutions in promoting energy diversification. While non-renewable energy remains a significant source of power in SSA, strong institutions can facilitate a gradual transition toward a more balanced energy mix by integrating cleaner energy sources. For instance, governments with high institutional quality may encourage investment in natural gas over coal or crude oil, as natural gas emits

significantly less CO₂ per unit of energy produced (Sarkodie & Adams, 2018). By promoting policies that shift energy production toward less carbon-intensive sources, institutional quality helps counteract the negative environmental impact of fossil fuel consumption.

Moderating role of institutional quality on the relationship between economic growth and carbon emissions in Sub-Saharan Africa.

The results indicate a positive and significant relationship between economic growth and carbon emissions, aligning with the Environmental Kuznets Curve (EKC) theory, which suggests that as economies grow, carbon emissions initially increase before eventually decreasing as countries reach higher levels of development. This positive relationship between economic growth and carbon emissions is consistent with the notion that industrialization and increased energy demand lead to higher emissions due to greater reliance on non-renewable energy sources (Weimin et al., 2022).

However, the introduction of institutional quality as a moderating variable reversed this relationship, indicating an antagonistic moderation effect. Specifically, the study reveals that in countries with stronger institutional frameworks, the positive impact of economic growth on carbon emissions may be mitigated, or even reversed, leading to a reduction in emissions as economic growth continues. This suggests that strong institutions play a critical role in shaping the environmental outcomes of economic growth, transforming what would otherwise be a harmful relationship into a more sustainable one.

In countries with robust governance structures, institutional quality may help reduce the emissions associated with economic growth by implementing and enforcing environmental regulations, promoting energy efficiency, and encouraging the adoption

of cleaner technologies. This finding supports the idea that effective institutions may act as a catalyst for the adoption of green technologies, even in economies that heavily rely on non-renewable energy sources for industrial development (Omri & Daly, 2015). For example, governments with high institutional quality may invest in emission-reducing technologies, such as carbon capture and storage (CCS), and encourage the transition to cleaner fuels, which can significantly reduce the carbon footprint of fossil fuel consumption (Paramati et al., 2018).

Another mechanism through which institutional quality may reverse the impact of economic growth on carbon emissions is by promoting energy efficiency. Effective governance encourages industries and households to adopt energy-saving technologies and practices. Policies such as carbon taxes, subsidies for clean energy, and mandatory energy efficiency standards can help reduce emissions even when non-renewable energy sources remain part of the energy mix (Asongu & Odhiambo, 2020). In contrast, weak institutions often lack the enforcement capabilities to implement such policies, leading to inefficiency in fossil fuel use and, consequently, higher emissions.

Moreover, institutional quality may also facilitate energy diversification, helping to shift the energy mix toward cleaner alternatives. While non-renewable energy sources such as coal and oil still dominate in SSA, countries with strong institutions may encourage the transition toward less carbon-intensive sources like natural gas, which emits significantly less CO₂ per unit of energy produced (Sarkodie & Adams, 2018). By creating policies that incentivize cleaner energy alternatives, institutional quality helps reduce the environmental impact of fossil fuel consumption, allowing economic growth to occur without an equivalent rise in carbon emissions.

Moderating role of institutional quality on the relationship between financial development and carbon emissions in Sub-Saharan Africa.

The relationship between financial development and carbon emissions in Sub-Saharan Africa (SSA) is often positive because financial growth facilitates industrialization, increased energy consumption, and economic activities that contribute to carbon emissions. The direct effect results indicate a positive and significant relationship ($\beta = 0.0440912$, $\rho = 0.000$), suggesting that as financial development progresses, carbon emissions also rise. This is expected since a well-developed financial sector provides capital for investments in industries, infrastructure, and businesses that may rely on fossil fuels for production and expansion (Paramati et al., 2018). Access to credit, stock market growth, and increased foreign direct investment (FDI) enable businesses and households to consume more energy, thereby increasing carbon footprints (Shahbaz et al., 2016).

However, when institutional quality is introduced as a moderator, it reverses the relationship, leading to antagonistic moderation ($\beta = -0.0378$, $\rho = 0.000$). This suggests that in countries with strong institutions, financial development is associated with a reduction in carbon emissions rather than an increase. This reversal can be attributed to several key factors, including environmental regulations, green financing, and policy-driven sustainable investments.

First, high institutional quality enforces environmental regulations that mitigate the environmental impact of financial expansion. Governments with strong institutions ensure that financial resources are directed toward sustainable economic activities rather than carbon-intensive industries. Through stringent environmental policies, financial institutions are required to assess the environmental impact of the projects

they fund, thereby discouraging investments in high-emission sectors (Omri et al., 2015). This leads to a shift in financial resources toward cleaner technologies, reducing the carbon footprint of economic growth.

Second, institutional quality promotes green financing, which facilitates investments in renewable energy and low-carbon technologies. Countries with strong institutional frameworks establish policies that encourage banks and financial markets to prioritize green bonds, carbon credit trading, and sustainable lending practices. For example, financial institutions are more likely to finance renewable energy projects, energy-efficient infrastructure, and environmentally friendly innovations when institutional quality is high (Zhang et al., 2021). This shift in financial allocation results in a net reduction in carbon emissions, explaining the reversal of the relationship.

Moreover, financial development in the presence of strong institutions leads to improved corporate governance and environmental accountability. Firms operating in countries with high institutional quality are required to adhere to environmental, social, and governance (ESG) standards, which reduce emissions through sustainable business practices. Corporate accountability mechanisms ensure that businesses adopt energy-efficient production processes, invest in green supply chains, and comply with emission reduction targets (Acheampong et al., 2019). Without strong institutions, financial development often supports industries with lax environmental standards, leading to higher emissions.

Additionally, institutional quality enhances public awareness and climate change mitigation strategies. Governments with strong institutions invest in climate policies, public education, and international environmental agreements, ensuring that financial development aligns with sustainability goals (Acemoglu & Robinson, 2019). Public

pressure and advocacy groups further push financial institutions to support low-carbon projects, leading to emissions reduction

Table 4. 13: Summary Table for hierarchical regression model

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Carbon Emissions	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
CONSTANT	.022(0.020)	.028(0.011)**	.041(0.012)**	.042 (0.012)**	.059 (0.012)**	.112 (0.015)**	.107 (.014)**
Foreign direct investment	.478 (0.20)**	-.044(0.012)**	-.041(0.012)**	-.042(0.012)**	-.044 (0.012)**	-.049(0.012)**	-.052 (0.012)**
Population	-.078 (0.022)**	-.115(0.027)**	-.139 (0.028)**	-.140 (0.028)**	-.149 (0.028)**	-.156(0.027)**	-.149(0.027)**
Industrialization	.795 (0.020)**	.863 (0.039)**	.896(0.040)**	.891 (0.041)**	.932 (0.042)**	1.658(0.121)**	1.667(0.118)**
Renewable Energy		.034 (0.019)	.036 (0.019)*	.029 (0.022)	.020 (0.021)	.018(0.021)	.019(0.020)
Non-renewable energy		.003(0.001)**	.003 (0.001)**	.003 (0.001)**	.003(0.001)**	.003(0.001)**	.002 (0.001)**
Economic Growth		.703 (0.012)**	.693 (0.013)**	.693 (0.013)**	.684 (0.013)**	.324 (0.058)**	.317(0.056)**
Financial Development		.044 (0.010)**	.043(0.010)**	.043 (0.010)**	.043 (0.010)**	.038(0.010)**	.043(0.009)**
Institutional Quality			-.030 (0.012)**	-.027(0.013)**	-.035 (0.013)**	-.111(0.017)**	-.108(0.017)**
REW*IQ				.001 (.002)	-.008(0.003)**	-.007(0.003)**	-.008(0.003)**
NREW*IQ					-.002(0.001)**	-.002 (0.001)**	-.002(0.001)**
ED*IQ						-.425(0.066)**	-.437(0.065)**
FD*IQ							-.038 (0.008)**
sigma_u	.06514611	.09251278	.09048651	.09128055	.09119102	.09419864	.09441749
sigma_e	.60315993	.23179517	.23054214	.23065935	.22744651	.21916624	.21491744
Rho	.01153121	.13740476	.13348784	.13540294	.13848658	.15592719	.16177837
R ²	0.6877	0.9446	0.9455	0.9454	0.9468	0.9497	0.9514
ΔR ²	-	0.2569	0.0009	-0.0001	0.0014	0.0029	0.0017
F	657.35	1477.61	1307.84	1161.39	1076.57	1057.77	1010.14
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Noobs	552	552	552	552	552	552	552

**p<0.05; Standard error (Std. Err) in parentheses

Source: Researcher (2024)

Table 4. 14: Summary Results of Hypotheses Tests

Hypotheses	B	P<5%	Decision
H ₀₁ : Renewable energy consumption has no significant effect on carbon emissions in Sub-Saharan Africa	0.034	0.074	Accepted
H ₀₂ : Non-renewable energy consumption has no significant effect on carbon emissions in Sub-Saharan Africa	0.003	0.006	Rejected
H ₀₃ : Economic growth has no significant effect on carbon emissions in Sub-Saharan Africa	0.703	0.000	Rejected
H ₀₄ : Financial development has no significant effect on carbon emissions in Sub-Saharan Africa	0.044	0.000	Rejected
H _{05a} : Institutional quality does not moderate the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa	-0.008	0.009	Rejected
H _{05b} : Institutional quality does not moderate the relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa	-0.002	0.000	Rejected
H _{05c} : Institutional quality does not moderate the relationship between economic growth and carbon emissions in Sub-Saharan Africa	-0.437	0.000	Rejected
H _{05d} : Institutional quality does not moderate the relationship between financial development and carbon emissions in Sub-Saharan Africa	-0.038	0.000	Rejected

Source: Researcher (2024)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the findings, conclusions, recommendations, limitations and suggestions for further studies.

5.2 Summary of Findings of the Study

This study aimed to investigate moderating effect of institutional quality on the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, and financial development on carbon emissions in Sub-Saharan Africa. The independent variables consisted of renewable energy consumption, non-renewable energy consumption, economic growth, and financial development, the moderating variable was institutional quality and the dependent variable carbon emissions. The target population comprised all Sub-Saharan Africa States. The study period spanned from 2000 until 2023. The study's findings demonstrated that non-renewable energy consumption, economic growth, and financial development had a significant effect on carbon emissions while renewable energy consumption had an insignificant effect. Additionally, the study revealed that institutional quality had a moderating effect on the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development and carbon emissions in Sub-Saharan Africa.

5.2.1 Effect of renewable energy consumption on carbon emissions in Sub-Saharan Africa

The first objective of the study aimed to determine the influence of renewable energy consumption on carbon emissions in Sub-Saharan Africa. Findings revealed that renewable energy consumption had a positive but statistically insignificant effect on

carbon emissions at the 5% level ($\beta = 0.034178$, $p = 0.074$), indicating a weak relationship. As a result, the null hypothesis was accepted, concluding that renewable energy consumption does not significantly affect carbon emissions. The positive coefficient suggests a slight increase in emissions with renewable energy use, which may be attributed to the transitional phase of renewable energy adoption. Infrastructure development for renewable projects often relies on fossil fuels, contributing to emissions. Additionally, disparities in energy mix across regions, where fossil fuels complement intermittent renewables like solar and wind, may explain the findings.

Contradictory results in prior studies indicate that renewable energy consumption can reduce emissions by decreasing reliance on fossil fuels. Ehigiamusoe and Dogan (2022) and Khan et al. (2020) found a significant negative relationship between renewable energy use and emissions. However, differences in data sources, regional policies, and timeframe of analysis may account for these discrepancies. The energy rebound effect, where efficiency gains lead to increased consumption, could also offset potential emission reductions. Despite statistical insignificance at the 5% level, policymakers should consider long-term benefits, as advancements in renewable technology and reduced reliance on carbon-intensive infrastructure could eventually yield lower emissions.

5.2.2 Effect of non-renewable energy consumption on carbon emissions in Sub-Saharan Africa

The second objective examined the influence of non-renewable energy consumption on carbon emissions. Results indicated a positive and significant effect ($\beta = 0.0026524$, $\rho = 0.006$), leading to the rejection of the null hypothesis. Even marginal increases in fossil fuel consumption significantly elevate carbon levels. The relationship aligns with prior studies, such as Zhang et al. (2024) and Banday and Aneja (2020), which confirm

fossil fuel combustion as a major contributor to greenhouse gas emissions. Industrial reliance on non-renewable energy for transportation and electricity generation further exacerbates environmental degradation. The findings highlight the urgency for a transition to renewable energy. Policymakers should consider carbon pricing, cleaner technologies, and incentives for energy-efficient practices to reduce emissions. However, transitioning remains challenging due to infrastructure and financial constraints in developing economies.

5.2.3 Effect of economic growth on carbon emissions in Sub-Saharan Africa

The third objective assessed the impact of economic growth on carbon emissions. Findings confirmed a significant and positive effect ($\beta = 0.7026022$, $\rho = 0.000$), supporting the Environmental Kuznets Curve (EKC) hypothesis. Initially, economic expansion leads to environmental degradation due to industrial reliance on fossil fuels, but emissions may decline as economies invest in cleaner technologies. Studies by Narayan et al. (2016) and Schröder & Storm (2020) affirm this relationship. As industrialization increases, so does energy consumption and deforestation. Policymakers should focus on green growth strategies, renewable energy investments, and carbon capture technologies to mitigate emissions.

5.2.4 Effect of financial development on carbon emissions in Sub-Saharan Africa

The fourth objective explored financial development's impact on carbon emissions. Results showed a significant positive effect ($\beta = 0.0440912$, $\rho = 0.000$), indicating that financial expansion leads to higher emissions by facilitating industrial growth and energy consumption. While financial development can drive sustainability through green finance initiatives, current trends show it largely promotes carbon-intensive activities. Sustainable financial policies, such as green bonds and environmental regulations, are essential to align financial expansion with climate goals.

5.2.5 The moderating effect of institutional quality on the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, financial development on carbon emissions in Sub-Saharan Africa

The study aimed to assess whether institutional quality moderates the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, and financial development on carbon emissions. This aligns with Baron and Kenny's (1986) moderation framework, which states that a moderator must have a significant relationship with the outcome variable. To establish this effect, the study conducted a regression analysis where institutional quality was introduced as a moderating variable while controlling for the independent variables. The findings indicate that institutional quality has a negative and significant effect on carbon emissions ($\beta = -0.0302425$, $p = 0.010$), suggesting that stronger institutions can mitigate environmental degradation by enforcing environmental policies and fostering sustainable economic practices.

The negative coefficient (-0.0302425) implies that improving institutional quality leads to a reduction in carbon emissions. This can be attributed to the ability of strong institutions to implement and enforce environmental regulations, encourage cleaner energy alternatives, and ensure compliance with sustainable industrial and economic activities. Countries with robust institutions tend to impose stricter environmental policies, regulate industrial emissions, and promote the adoption of renewable energy sources, thereby reducing carbon footprints. These findings are consistent with prior studies by Haldar and Sethi (2021), as well as Salman, Long, Dauda, and Mensah (2019), who argue that institutional frameworks play a crucial role in shaping environmental policies and influencing carbon emissions.

5.2.5.1 The moderating effect of institutional quality on the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa

The regression analysis revealed that institutional quality significantly moderates the relationship between renewable energy consumption and carbon emissions in Sub-Saharan Africa. The results showed a negative and significant effect ($\beta = -0.0075$, $p = 0.009$), leading to the rejection of hypothesis H05a. A moderation graph (modgraph) further illustrated that carbon emissions are lower when both renewable energy consumption and institutional quality are high. This suggests that institutional strength plays a critical role in maximizing the environmental benefits of renewable energy adoption. High institutional quality is characterized by strong governance, well-enforced environmental regulations, and transparent policy frameworks. These factors collectively support the implementation of sustainable energy strategies (Acemoglu & Robinson, 2019). Governments with strong institutions are more likely to incentivize renewable energy investments through subsidies, tax benefits, and regulatory support while simultaneously imposing stricter emission controls on industries. Additionally, well-functioning institutions enhance accountability and reduce corruption, ensuring that environmental policies are effectively implemented and not undermined by vested interests (North, 1990).

Countries with high institutional quality experience greater success in decarbonizing their economies through the adoption of renewable energy. For instance, Scandinavian nations such as Sweden and Denmark have significantly reduced their carbon emissions through a combination of strong institutions and aggressive renewable energy policies (OECD, 2021). In contrast, countries with weaker institutional frameworks often struggle to enforce environmental policies effectively. This results in continued reliance

on fossil fuels, even when renewable energy investments are present, limiting the overall impact on carbon emission reduction.

5.2.5.2 The moderating effect of institutional quality on the relationship between non-renewable energy consumption on carbon emissions in Sub-Saharan Africa

The regression analysis demonstrated that institutional quality significantly and negatively moderates the relationship between non-renewable energy consumption and carbon emissions in Sub-Saharan Africa. The results ($\beta = -0.0022$, $p = 0.000$) led to the rejection of hypothesis H05b. A moderation graph (modgraph) further illustrated that carbon emissions are lower when non-renewable energy consumption is low and institutional quality is high. This finding underscores the importance of strong institutional governance in mitigating carbon emissions, even in regions where non-renewable energy remains a primary energy source.

Institutional quality plays a critical role in regulating non-renewable energy consumption and its environmental impact. Strong governance structures, effective regulatory enforcement, and transparent policymaking are essential for reducing reliance on fossil fuels. Governments with well-established institutions are more likely to implement policies that discourage non-renewable energy consumption, such as carbon taxes, emissions trading schemes, and subsidies for clean energy investments (Acemoglu & Robinson, 2019). Additionally, effective institutions enhance energy market efficiency by promoting competition and encouraging innovation in renewable energy technologies. This makes clean energy alternatives more accessible and cost-effective, further facilitating the transition toward sustainable energy sources.

Empirical evidence from developed nations supports these findings. European countries with strong institutional frameworks, such as Germany and France, have successfully

reduced their dependence on non-renewable energy through ambitious climate policies and substantial investments in renewable energy (OECD, 2021). These nations have implemented strict environmental regulations, incentivized clean energy development, and discouraged fossil fuel consumption, leading to significant reductions in carbon emissions. Conversely, countries with weaker institutional structures often struggle to enforce environmental regulations, leading to continued reliance on fossil fuels and higher emissions.

5.2.5.3 The moderating effect of institutional quality on the relationship between economic growth and carbon emissions in Sub-Saharan Africa

The regression results from model 7 ($\beta = -0.0378$, $p = 0.05$) confirmed that institutional quality significantly moderates the relationship between economic growth and carbon emissions in Sub-Saharan Africa. Consequently, hypothesis H05c was rejected. A moderation analysis further illustrated that carbon emissions tend to be lower in economies with high economic growth when strong institutional quality is present. This suggests that economic expansion, when accompanied by effective governance, supports sustainable development and emission reductions.

Economic growth, particularly when driven by sustainable policies, leads to increased investments in clean energy technologies, energy efficiency, and advanced industrial processes that lower carbon footprints (Grossman & Krueger, 1995). As economies develop, they tend to transition from resource-intensive industries to knowledge-based sectors, which are less carbon-intensive. This aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits that while emissions may initially increase with economic growth, they eventually decline as countries adopt cleaner technologies and stronger environmental regulations (Stern, 2004). Thus, the relationship between

economic growth and carbon emissions is not linear but depends on the quality of institutions governing environmental policies.

High institutional quality is essential in enforcing environmental regulations, ensuring transparency, and incentivizing businesses to adopt green practices. Countries with strong governance structures implement policies such as carbon pricing, emissions trading systems, and subsidies for renewable energy, ensuring that economic growth does not come at the cost of environmental degradation (Acemoglu & Robinson, 2019). Additionally, well-functioning institutions support research and development (R&D) in sustainable technologies, accelerating the transition to low-carbon economies. Nordic countries, such as Sweden and Norway, demonstrates the effectiveness of strong institutions in maintaining low carbon footprints despite high economic growth. These nations have successfully implemented proactive climate policies and invested heavily in renewable energy (OECD, 2021). Conversely, economies with weak institutions often experience increased emissions despite economic expansion due to regulatory inefficiencies and lack of environmental accountability. Corruption and weak enforcement mechanisms allow industries to bypass environmental laws, leading to continued reliance on fossil fuels and rising emissions (Dutta & Das, 2020). Strengthening institutional quality in Sub-Saharan Africa is therefore crucial in ensuring that economic growth contributes to sustainable environmental outcomes.

5.2.5.4 The moderating effect of institutional quality on the relationship between financial development and carbon emissions in Sub-Saharan Africa

The regression results from model 7 of Table 4.12 ($\beta = -0.0378$, $p = 0.000$) indicate that institutional quality significantly moderates the relationship between financial development and carbon emissions in Sub-Saharan Africa. As a result, hypothesis H05d was rejected. The findings suggest that carbon emissions tend to be lower in economies

with low financial development, particularly when institutional quality is high. This highlights the role of governance in ensuring that financial growth does not contribute to environmental degradation. Financial development, which includes the expansion of credit markets, banking systems, and stock markets, often facilitates industrial growth, infrastructure expansion, and energy consumption, potentially leading to higher carbon emissions (Shahbaz et al., 2013). In economies with underdeveloped financial markets, limited access to capital restricts investments in fossil fuel-based industries and heavy industrial production, thereby contributing to lower emissions (Paramati et al., 2018). However, the relationship between financial development and carbon emissions is influenced by the strength of institutions.

Strong institutions play a critical role in ensuring that financial resources, even when limited, are allocated toward environmentally sustainable projects rather than polluting industries. High institutional quality facilitates the implementation of green financing initiatives, the imposition of carbon taxes, and the enforcement of strict environmental regulations. These measures help ensure that financial development does not result in uncontrolled industrial pollution but instead supports sustainable economic activities (Acemoglu & Robinson, 2019). In contrast, in economies with weak institutions, even low financial development can still lead to environmental degradation due to ineffective enforcement of environmental laws and reliance on informal, high-carbon economic activities. Countries with strong governance mechanisms often prioritize investments in renewable energy and energy efficiency, even in the absence of highly developed financial markets. For instance, economies with robust institutions but low financial development may adopt alternative economic models that emphasize sustainability over rapid industrialization, leading to a reduced carbon footprint (Sadorsky, 2010). Ultimately, while financial development is crucial for economic growth, its

environmental impact depends on institutional quality. Strong institutions ensure that financial resources, even in constrained markets, are directed toward sustainable development, mitigating the negative environmental effects of industrialization.

5.3 Conclusions

The study examined the relationship between energy consumption, economic growth, financial development, and institutional quality on carbon emissions in Sub-Saharan Africa. The findings revealed several critical insights into how these factors interact to shape environmental outcomes in the region. Firstly, the study found that renewable energy consumption had a positive but statistically insignificant effect on carbon emissions. This suggests that while renewable energy adoption is increasing, its impact on reducing emissions is not yet significant. One possible explanation is the transitional phase of renewable energy infrastructure, which still relies on fossil fuels for development and implementation. Additionally, the intermittent nature of renewable sources, such as solar and wind, often necessitates a backup from fossil fuels, thereby limiting the expected reductions in emissions. Despite this, policymakers should not disregard the long-term potential of renewable energy. With technological advancements, improved energy storage systems, and more investment in clean energy infrastructure, renewable energy is likely to play a more substantial role in reducing emissions over time.

Secondly, the study confirmed that non-renewable energy consumption has a significant and positive effect on carbon emissions, consistent with existing literature. The reliance on fossil fuels for electricity generation, industrial production, and transportation has led to an increase in greenhouse gas emissions, exacerbating climate change. These findings underscore the urgent need for Sub-Saharan African countries to transition toward cleaner energy sources. Policymakers should consider strategies

such as carbon pricing, stricter environmental regulations, and investment in cleaner energy technologies to mitigate the negative environmental impacts of fossil fuel consumption. However, financial and infrastructural constraints present challenges in shifting to sustainable energy, requiring international cooperation and financial support.

Thirdly, economic growth was found to have a significant positive effect on carbon emissions, aligning with the Environmental Kuznets Curve (EKC) hypothesis. In the early stages of economic growth, industrialization and urbanization lead to increased energy consumption and environmental degradation. However, as economies develop, they often invest in cleaner technologies and stricter environmental regulations, potentially reducing emissions in the long run. Therefore, sustainable economic policies should focus on integrating green growth strategies, such as investment in renewable energy and carbon capture technologies, to ensure that economic expansion does not come at the cost of environmental sustainability.

Financial development also exhibited a significant positive effect on carbon emissions, suggesting that financial expansion tends to facilitate carbon-intensive industrial activities. While financial development can support sustainability through green finance initiatives, the current trend in Sub-Saharan Africa shows that it largely promotes investments in high-emission industries. This highlights the need for sustainable financial policies, such as green bonds, environmental credit regulations, and incentives for eco-friendly investments, to ensure that financial growth aligns with climate goals.

Lastly, institutional quality was found to play a crucial moderating role in mitigating carbon emissions. The study revealed that strong institutions significantly reduce emissions by enforcing environmental policies, promoting renewable energy adoption,

and regulating non-renewable energy consumption. Countries with high institutional quality tend to have more effective governance mechanisms that ensure compliance with environmental regulations, thereby mitigating the negative effects of economic and financial development on emissions. These findings emphasize the need for strengthening institutional frameworks in Sub-Saharan Africa to foster sustainable development and environmental protection. The study concluded that while economic growth, financial development, and non-renewable energy consumption contribute to higher carbon emissions, strong institutional quality can play a mitigating role in controlling environmental degradation.

5.4 Recommendations of the study

This section provides the theoretical, policy and managerial recommendations from the findings of the study.

5.4.1 Theoretical Implications

The findings of this study align with three key theories: the Environmental Kuznets Curve (EKC), Energy Transition Theory, and Institutional Theory. The Environmental Kuznets Curve (EKC) suggests that there is an inverted U-shaped relationship between economic growth and environmental degradation. At early stages of economic development, industrialization and financial expansion lead to increased carbon emissions due to reliance on fossil fuels and resource-intensive production processes. However, as economies grow and reach a certain level of income, they begin investing in cleaner technologies, stronger environmental regulations, and more sustainable energy sources, leading to a decline in emissions. The study's findings support this theory by demonstrating that economic growth and financial development significantly contribute to carbon emissions in SSA. However, the moderating effect of institutional quality suggests that well-functioning institutions can accelerate the downward slope

of the EKC by promoting sustainable policies and investment in clean energy solutions. In SSA, where institutional weaknesses persist, the full benefits of the EKC have yet to be realized, reinforcing the importance of strong governance in achieving environmental sustainability.

Energy Transition Theory explains the shift from high-carbon, non-renewable energy sources to low-carbon and renewable alternatives. According to this theory, energy systems evolve in response to economic, technological, and policy changes. The study found that renewable energy consumption had an insignificant impact on reducing carbon emissions in SSA, which suggests that the region is still in the early stages of energy transition. This finding aligns with the theory's argument that energy transition is often slow and requires institutional, technological, and financial support. The antagonistic effect observed when institutional quality was introduced as a moderator highlights the critical role of governance in enabling energy transitions. In SSA, weak institutions and policy instability may hinder the adoption and effectiveness of renewable energy initiatives. Strengthening regulatory frameworks, increasing incentives for renewable energy investment, and improving energy infrastructure are necessary to accelerate the transition towards a cleaner energy mix.

Institutional Theory emphasizes the role of formal and informal institutions in shaping economic and environmental outcomes. Institutions—such as governance structures, regulatory agencies, legal frameworks, and policies—determine how resources are managed, how industries operate, and how environmental policies are enforced. The study's findings align with this theory by demonstrating that institutional quality can alter the impact of key economic and energy-related variables on carbon emissions. Specifically, the reversal of effects when institutional quality was introduced as a moderator underscores the importance of strong institutions in mitigating

environmental degradation. In SSA, where corruption, weak regulatory enforcement, and political instability often undermine environmental policies, improving institutional frameworks is essential for ensuring that economic and financial growth contributes to sustainability rather than exacerbating carbon emissions.

5.4.2 Policy Implication

The findings of this study provide critical insights into the policy measures needed to mitigate carbon emissions in Sub-Saharan Africa (SSA). Given that non-renewable energy consumption, economic growth, and financial development significantly contribute to carbon emissions, while renewable energy consumption alone does not have a significant effect, policymakers may adopt targeted strategies to balance economic development and environmental sustainability. However, the introduction of institutional quality as a moderating variable revealed an antagonistic effect, reversing the impact of renewable and non-renewable energy consumption, economic growth, and financial development on carbon emissions. This suggests that strong institutions may play a pivotal role in ensuring that energy and financial policies align with environmental sustainability goals.

Firstly, policymakers may prioritize strengthening institutional quality through improved governance, regulatory frameworks, and transparency. The antagonistic effect observed in this study highlights that when institutional mechanisms are weak, investments in renewable energy may not effectively reduce carbon emissions. Governments may therefore enhance institutional structures that promote clean energy initiatives, enforce environmental regulations, and minimize inefficiencies in energy markets. Strengthening regulatory quality, reducing corruption, and ensuring political stability may create an environment where renewable energy investments can thrive and significantly contribute to lowering carbon emissions.

Secondly, given that non-renewable energy consumption remains a major contributor to carbon emissions, SSA countries may gradually transition towards low-carbon energy sources. However, rather than solely increasing renewable energy capacity, which was found to have an insignificant effect in the absence of strong institutions, policymakers may integrate renewable energy with institutional reforms. This may include implementing strict emission controls on fossil fuel consumption and providing financial incentives for industries to shift towards cleaner energy alternatives. Carbon taxation and emission trading systems may also be introduced to encourage businesses to reduce their carbon footprint while ensuring that institutional frameworks support their effective implementation.

Thirdly, financial development may be directed towards green investments. While financial development has been linked to increased carbon emissions, institutional quality may reverse this effect by ensuring that financial resources are allocated towards sustainable projects. Policymakers may encourage banks and financial institutions to develop green financing instruments such as green bonds, carbon credits, and climate-friendly investment portfolios. Governments may also establish environmental risk assessment guidelines for financial institutions to ensure that lending practices prioritize sustainability. By aligning financial sector development with environmental objectives, SSA countries may mitigate the adverse effects of economic growth on carbon emissions.

Moreover, since economic growth was found to exacerbate carbon emissions, policies may focus on fostering green economic growth. Governments may promote sustainable industrialization by implementing policies that encourage the adoption of cleaner production technologies. Investing in research and development (R&D) for energy-efficient innovations and supporting businesses that adopt sustainable practices may

help balance economic growth with environmental preservation. Additionally, integrating environmental policies into national development plans may ensure that economic expansion does not come at the cost of increased carbon emissions.

5.4.3 Managerial Implication

The findings of this study provide valuable insights for managers, business leaders, and practitioners in the energy, financial, and industrial sectors. The results indicate that non-renewable energy consumption, economic growth, and financial development significantly contribute to carbon emissions, while renewable energy consumption alone does not have a substantial impact on reducing emissions in Sub-Saharan Africa (SSA). However, the introduction of institutional quality as a moderating variable reversed these effects, suggesting that strong institutions may play a critical role in determining the environmental impact of energy and financial decisions. Therefore, practitioners may adopt strategic approaches that align with institutional frameworks to enhance sustainability.

Firstly, energy sector managers may integrate institutional factors into their decision-making processes when planning and implementing renewable energy projects. Given that renewable energy consumption was found to have an insignificant effect on carbon emissions without strong institutions, energy companies may work closely with policymakers to ensure regulatory support, policy stability, and transparent governance. This may include advocating for government incentives such as tax breaks, subsidies, and public-private partnerships to enhance the viability of renewable energy investments. Additionally, managers may ensure compliance with environmental regulations and industry standards to maximize the sustainability benefits of renewable energy initiatives.

Secondly, managers in industries that rely on non-renewable energy sources may implement energy efficiency measures and transition towards cleaner alternatives. Since non-renewable energy consumption significantly contributes to carbon emissions, businesses may adopt energy-saving technologies, improve operational efficiency, and explore low-carbon alternatives such as natural gas and hybrid energy solutions. Industrial practitioners may also conduct regular energy audits to identify inefficiencies and reduce energy waste, thereby lowering their carbon footprint and improving cost-effectiveness.

Financial sector practitioners may play a proactive role in promoting green finance solutions. The study's findings indicate that financial development contributes to carbon emissions unless strong institutions are in place to guide sustainable investments. Financial managers may develop and promote green financing instruments such as green bonds, sustainability-linked loans, and carbon credit markets to encourage investments in low-carbon projects. Additionally, financial institutions may integrate environmental, social, and governance (ESG) criteria into their risk assessment frameworks to ensure that loans and investments align with sustainability goals. This may help redirect financial resources towards environmentally responsible businesses and projects.

Business executives and corporate leaders may embed sustainability into their strategic planning. Given that economic growth was found to drive carbon emissions, companies may adopt sustainable business models that balance growth with environmental responsibility. This may include implementing circular economy principles, investing in cleaner production technologies, and integrating carbon reduction targets into corporate strategies. Managers may also engage in corporate social responsibility

(CSR) initiatives that support environmental conservation efforts, such as afforestation programs and community-based renewable energy projects.

Furthermore, practitioners in policy and governance roles may strengthen institutional quality by fostering transparency, accountability, and regulatory enforcement. Since institutional quality was found to reverse the negative impact of non-renewable energy consumption, economic growth, and financial development on carbon emissions, stakeholders may advocate for stronger environmental policies and effective governance structures. Collaboration between businesses, financial institutions, and government agencies may be essential in ensuring that economic and energy-related decisions contribute to long-term sustainability.

5.5 Limitations and Future Research

This study faced several limitations that should be acknowledged. One major limitation was the lack of comprehensive data for some Sub-Saharan African (SSA) countries, such as Somalia and South Sudan. The unavailability of reliable and consistent data for these nations may have affected the generalizability of the findings, as certain regional dynamics were not fully captured. Additionally, the study primarily focused on institutional quality as a moderating variable. However, other important moderators, such as corruption levels, political stability, and regulatory quality, were not considered. These factors can significantly influence the effectiveness of renewable energy policies and carbon emission reduction efforts, warranting further exploration in future research.

For future studies, researchers could expand the scope by including additional independent variables that influence carbon emissions, such as foreign direct investment (FDI), industrialization, and population growth. These factors have been shown to impact environmental sustainability and could provide a more comprehensive

understanding of carbon emissions in SSA. Moreover, future research could adopt a comparative approach by analyzing the relationship between energy consumption, economic growth, financial development, and carbon emissions in SSA relative to other regions, such as Europe, Asia, and America. A comparative study would help identify best practices and policy lessons that could be applied to SSA. Another recommendation is to consider greenhouse gas (GHG) emissions as the dependent variable instead of carbon emissions alone. Since GHG emissions encompass a broader range of pollutants, including methane and nitrous oxide, this approach would provide a more holistic perspective on environmental degradation. By incorporating diverse variables and expanding regional comparisons, future studies can offer deeper insights into sustainable energy transitions and climate policies in SSA.

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APPENDICES

Appendix I: Stata Output

```
. xtreg standardized_CE standardized_Foreign_direct_inv standardized_POP standardized_IND rewe
> nergy nrew standardized_EG standardized_FD standardized_IQ REWIQ , fe
```

```
Fixed-effects (within) regression      Number of obs   =      552
Group variable: year                   Number of groups =      24
```

```
R-sq:                                  Obs per group:
  within = 0.9527                       min =          22
  between = 0.9003                       avg =         23.0
  overall = 0.9454                       max =          24
```

```
corr(u_i, Xb) = -0.1320                  F(9,519)        =    1161.39
                                          Prob > F         =      0.0000
```

standardized_CE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
standardized_Foreign_dire~v	-.0416478	.0124563	-3.34	0.001	-.0661188	-.0171769
standardized_POP	-.140315	.0284167	-4.94	0.000	-.196141	-.0844891
standardized_IND	.8909412	.0411124	21.67	0.000	.810174	.9717085
rewenergy	.0290217	.0216348	1.34	0.180	-.0134808	.0715242
nrew	.0028375	.0009899	2.87	0.004	.0008927	.0047823
standardized_EG	.6934035	.0126294	54.90	0.000	.6685924	.7182146
standardized_FD	.0433499	.0100237	4.32	0.000	.0236579	.0630419
standardized_IQ	-.0266179	.0128427	-2.07	0.039	-.0518479	-.0013878
REWIQ	.0013718	.0019974	0.69	0.493	-.0025522	.0052958
_cons	.0422814	.0119543	3.54	0.000	.0187967	.0657662
sigma_u	.09128055					
sigma_e	.23065935					
rho	.13540294	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(23, 519) = 3.32      Prob > F = 0.0000
```

```
. xtreg standardized_CE standardized_Foreign_direct_inv standardized_POP standardized_IND rewe
> nergy nrew standardized_EG standardized_FD standardized_IQ REWIQ NREWIQ , fe
```

```
Fixed-effects (within) regression      Number of obs   =      552
Group variable: year                   Number of groups =      24
```

```
R-sq:                                  Obs per group:
  within = 0.9541                       min =          22
  between = 0.8899                       avg =         23.0
  overall = 0.9468                       max =          24
```

```
corr(u_i, Xb) = -0.1311                  F(10,518)       =    1076.57
                                          Prob > F         =      0.0000
```

standardized_CE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
standardized_Foreign_dire~v	-.0443597	.0123018	-3.61	0.000	-.0685272	-.0201922
standardized_POP	-.149072	.0281076	-5.30	0.000	-.2042909	-.0938532
standardized_IND	.9319438	.0418343	22.28	0.000	.849758	1.01413
rewenergy	.0200368	.0214531	0.93	0.351	-.022109	.0621826
nrew	.0030195	.0009772	3.09	0.002	.0010997	.0049394
standardized_EG	.6836752	.0126922	53.87	0.000	.6587406	.7086098
standardized_FD	.04277	.0098851	4.33	0.000	.0233501	.0621899
standardized_IQ	-.0348198	.0128312	-2.71	0.007	-.0600273	-.0096123
REWIQ	-.0077528	.0030266	-2.56	0.011	-.0136986	-.0018069
NREWIQ	-.0024214	.0006098	-3.97	0.000	-.0036195	-.0012234
_cons	.0586181	.0124852	4.70	0.000	.0340903	.0831458
sigma_u	.09119102					
sigma_e	.22744651					
rho	.13848658	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(23, 518) = 3.41      Prob > F = 0.0000
```

```
. xtreg standardized_CE standardized_Foreign_direct_inv standardized_POP standardized_IND rewe
> nergy nrew standardized_EG standardized_FD standardized_IQ REWIQ NREWIQ EGIQ , fe
```

```
Fixed-effects (within) regression      Number of obs   =      552
Group variable: year                  Number of groups =      24
```

```
R-sq:                                Obs per group:
  within = 0.9575                      min =      22
  between = 0.9041                     avg  =     23.0
  overall = 0.9497                      max  =      24
```

```
corr(u_i, Xb) = -0.1348                F(11,517)       =    1057.77
                                          Prob > F        =      0.0000
```

standardized_CE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
standardized_Foreign_dire~v	-.0487715	.011874	-4.11	0.000	-.0720987	-.0254443
standardized_POP	-.1560217	.0271061	-5.76	0.000	-.2092734	-.1027701
standardized_IND	1.658444	.1205651	13.76	0.000	1.421587	1.895302
rewnergy	.0182077	.0206741	0.88	0.379	-.0224078	.0588232
nrew	.0025249	.0009448	2.67	0.008	.0006687	.0043811
standardized_EG	.3241215	.0575496	5.63	0.000	.2110617	.4371812
standardized_FD	.0388565	.0095449	4.07	0.000	.0201049	.0576081
standardized_IQ	-.1108309	.0171523	-6.46	0.000	-.1445276	-.0771341
REWIQ	-.007248	.0029174	-2.48	0.013	-.0129795	-.0015165
NREWIQ	-.0021895	.0005887	-3.72	0.000	-.0033461	-.0010328
EGIQ	-.4248036	.0664402	-6.39	0.000	-.5553297	-.2942775
_cons	.1124915	.0146878	7.66	0.000	.0836363	.1413467
sigma_u	.09419864					
sigma_e	.21916624					
rho	.15592719	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(23, 517) = 3.89                Prob > F = 0.0000
```

```
. xtreg standardized_CE standardized_Foreign_direct_inv standardized_POP standardized_IND rewe
> nergy nrew standardized_EG standardized_FD standardized_IQ REWIQ NREWIQ EGIQ FDIQ , fe
```

```
Fixed-effects (within) regression      Number of obs   =      552
Group variable: year                  Number of groups =      24
```

```
R-sq:                                Obs per group:
  within = 0.9592                      min =      22
  between = 0.9046                     avg  =     23.0
  overall = 0.9514                      max  =      24
```

```
corr(u_i, Xb) = -0.1349                F(12,516)       =    1010.14
                                          Prob > F        =      0.0000
```

standardized_CE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
standardized_Foreign_dire~v	-.0517963	.0116619	-4.44	0.000	-.0747069	-.0288856
standardized_POP	-.1493457	.0266193	-5.61	0.000	-.2016412	-.0970501
standardized_IND	1.666929	.1182419	14.10	0.000	1.434634	1.899223
rewnergy	.0190269	.0202741	0.94	0.348	-.020803	.0588567
nrew	.0024901	.0009265	2.69	0.007	.0006699	.0043104
standardized_EG	.3165939	.0564571	5.61	0.000	.2056799	.427508
standardized_FD	.0429524	.0094012	4.57	0.000	.0244831	.0614217
standardized_IQ	-.1078496	.016832	-6.41	0.000	-.1409173	-.074782
REWIQ	-.0075093	.0028614	-2.62	0.009	-.0131308	-.0018879
NREWIQ	-.0021549	.0005774	-3.73	0.000	-.0032892	-.0010205
EGIQ	-.4327176	.0651744	-6.64	0.000	-.5607574	-.3046777
FDIQ	-.0378018	.0081255	-4.65	0.000	-.0537649	-.0218388
_cons	.1069144	.0144529	7.40	0.000	.0785206	.1353082
sigma_u	.09441749					
sigma_e	.21491744					
rho	.16177837	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(23, 516) = 4.06                Prob > F = 0.0000
```

Appendix II: Data Collection Schedule

Variable	1	2	3	4	5	6
	Renewable energy consumption	Non-renewable energy consumption	Economic growth	Financial development	Institutional quality	Carbon emissions
Years						
2001						
2002						
2003						
2004						
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
2016						
2017						
2018						
2019						
2020						
2021						
2022						
2023						

Appendix III: Introduction Letter



**MOI UNIVERSITY
POSTGRADUATE OFFICE
SCHOOL OF BUSINESS AND ECONOMICS**

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Kenya

RE: MU/SBE/PGR/ACD/21B

DATE: 15th May, 2024

TO WHOM IT MAY CONCERN:

RE: PETER KINUTHIA MWAI – PHD/ECON/5389/23

The above named is a bonafide student of Moi University, School of Business & Economics. He is pursuing Doctor of Philosophy in Economics Degree.

Mr. Kinuthia successfully completed coursework and has defended his proposal at both Departmental and School Levels. He is proceeding to the field to collect data for his research titled: ***“Energy Consumption Choices, Economic Growth, Financial Development, Institutional Quality and Carbon Emissions in Sub-Saharan Africa”***.

Any assistance accorded to him will be highly appreciated.

Yours faithfully,

SCHOOL OF BUSINESS &
ECONOMICS
MOI UNIVERSITY
P. O. Box 3900 ELDORET 30100

PROF. RONALD BONUKE
ASSOCIATE DEAN AND CHAIR-POSTGRADUATE STUDIES

/pn



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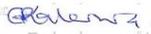
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CERM-ESA Project Leader Date: 16/06/2025