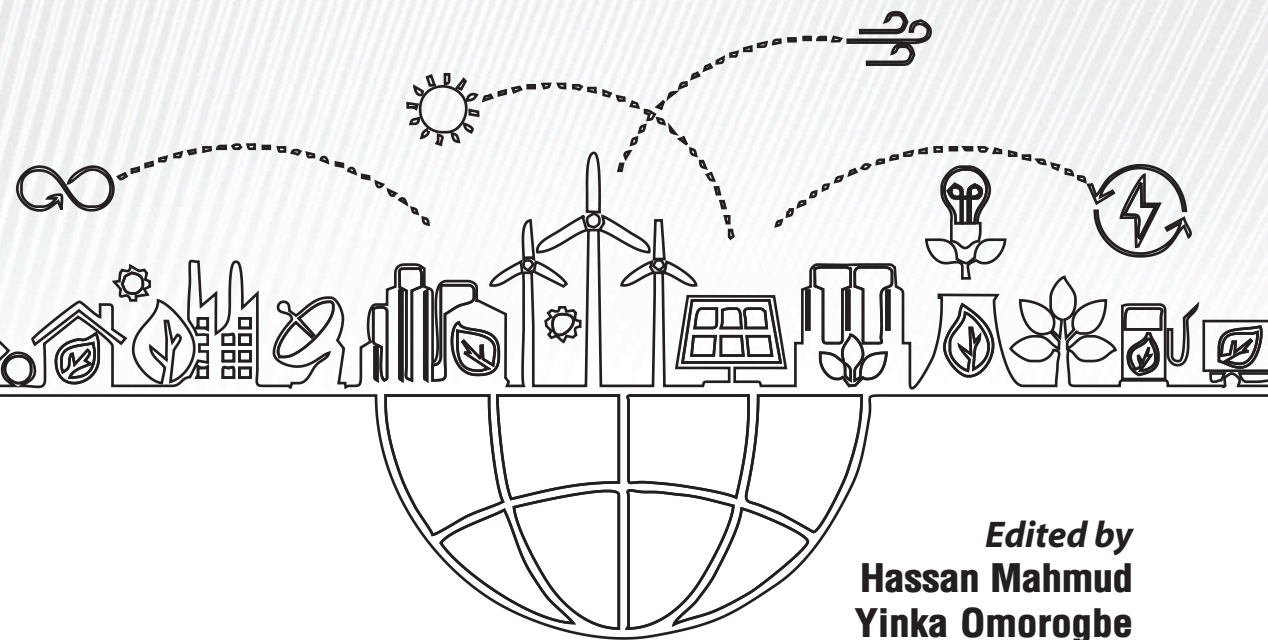


NAEE/IAEE 2024 Conference Proceedings

The Energy, Economy and Environment Nexus:

Imperative for Good Governance and
Sustainable Development



Edited by
Hassan Mahmud
Yinka Omorogbe
Wunmi Iledare
Adeola Adenikinju
Ben Obi
Obindah Gershon

About NAEE

The Nigerian Association for Energy Economics (NAEE) is the Nigerian affiliate of the International Association for Energy Economics (IAEE) with a presence in over 120 countries all over the world.

The NAEE is however the first affiliate of the International Association for Energy Economics (IAEE) in Africa and the largest Energy Economics Association in Nigeria.

The NAEE was officially inaugurated in Nigeria in December 2006 at the Nigerian National Petroleum Corporation (NNPC) Towers, Abuja. It organized its inaugural international conference on April 28 and 29, 2008 at Transcorp Hilton Hotel, Abuja. The Association is a nationwide non-profit organization of business, academic and other professionals that advances the understanding and application of economics across all facets of energy development and use, including theory, Business, Public policy, and Environmental consideration.

To this end, the Association

- * Provides a forum for the exchange of ideas, advancement and professional experience in Energy Economics.
- * Promotes the development and education of Energy Professionals.
- * Fosters and improves understanding of energy economics and energy related issues by all interested parties.
- * Provides a forum for contribution to national discourse on energy policy issues in Nigeria and Africa.

Activities of the NAEE

The NAEE seeks to achieve its objectives through the following activities:

- * Publication of Professional Journal, Books, Newsletters and Press release.
- * Organizing Seminars, Conferences, Workshops, Public Lectures and other similar fora.
- * Meetings and such other activities that will promote the objectives of the Association.



www.naee.org.ng

Themes of Past Conference Proceedings

- 2010 – Energy, Environment and Economic Growth
- 2011 – Green Energy and Energy Security: Options for Africa
- 2012 – Energy Technology and Infrastructure for Development
- 2013 – Energy Resource Management in a Federal System
- 2014 – Energy Access and Economic Development: Politics, Institutional Framework and Strategic Options
- 2015 – Future Energy Policy Options: Assessment, Formulation and Implementation
- 2016 – Energizing Emerging Economics: The Role of Natural Gas and Renewable Energy
- 2017 – Energy, Economy and the Environment: The Interplay of Technology, Economics and Public Policy
- 2018 – New Era in Global Energy Landscape: Implications for an Emerging Economy
- 2019 – Energy Efficiency and Access Imperatives for Sustainable Development in Emerging Economics
- 2020 – Energy and Petroleum in a Post COVID World
- 2021 – Strategic Responses of Energy Sector to COVID-19: Impacts on African Economies
- 2022 – Energy Transition and Climate Change Policy Pathway for Sustainable Development in Africa
- 2023 – Energy Evolution, Transition and Reform: Prospects for African Economies

2023- 2025 Council Members

President

Dr. Hassan Mahmud
Nigerian Association for Energy Economics (NAEE)
Abuja.

Immediate Past President

Prof. Yinka Omorogbe SAN
CEO, EtinPower Limited, Benin City.

Vice President (Conferences & Publications)

Prof. Ben Obi
Department of Economics, University of Abuja.

Vice President (Membership & Liaison)

Mrs. Folashade Oje
Federal Ministry of Health
Abuja.

Treasurer

Dr. Mrs. Margaret Hilili
Central Bank of Nigeria (CBN),
Abuja.

Secretary

Mr. Ere Iyalla
Petroleum Technology Development Fund (PTDF)
Abuja.

Assistant Secretary

Mr. Simeon Abiri
Nigerian Upstream Petroleum
Regulatory Commission (NUPRC), Abuja.

Public Relation Officer (PRO)

Mr Feso Bright
NNPC Upstream Investment Management
Services (NUIMS)
Abuja.

Auditor

Mrs. Amina Danmadami
Nigerian Midstream & Downstream
Petroleum Regulatory Authority (NMDPRA)

Legal Adviser

Dr. Terhemen Andzenge
Research Fellow, University of Cape Town,
South Africa

Editor

Dr. Obindah Gershon
Covenant University, Canaanland Ota.

Student Representative

Ms. Rachel Fagboyo
Centre for Petroleum Energy Economics & Law
University of Ibadan.

Ex-officio Members

Prof. Uche Nwogwugwu
Nnamdi Azikwe University, Awka

Mrs. Priscillia Ekpe
Nigerian Midstream & Downstream Petroleum
Regulatory Authority, Abuja.

Dr. Oge Funlola Modie
Former SSA to the President on
Strategic Communications, The Presidency
Aso Villa, Abuja.

Council Advisers

Prof. Akin Iwayemi
CPEEL, University of Ibadan.

Prof. Adeola Adenikinju
President, Nigerian Economic Society

Prof. Wumi Iledare
Executive Director,
Emmanuel Egboah Foundation,
Abuja, Nigeria.

Mr. Jide Adebulehin
Petroleum Technology Development Fund (PTDF)
Abuja.



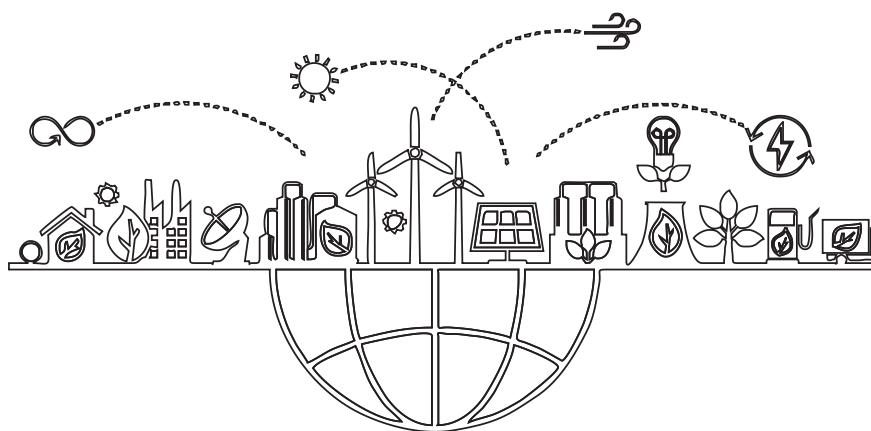
The Energy, Economy and Environment Nexus:

Imperative for Good Governance and
Sustainable Development



The Energy, Economy and Environment Nexus:

Imperative for Good Governance and
Sustainable Development



Edited by
Hassan Mahmud
Yinka Omorogbe
‘Wunmi Iledare
Adeola Adenikinju
Ben Obi
Obindah Gershon

NAEE/IAEE 2024 Conference Proceedings

**The Energy,
Economy and
Environment Nexus:**
**Imperative for Good Governance and
Sustainable Development**

Published in Nigeria by



www.naee.org.ng

The Nigerian Association for Energy Economics
c/o Department of Economics
University of Ibadan,
Ibadan, Nigeria

First Published 2024

Copyright © NAEE

ISBN: 978-978-62722-0-7 (Print)
978-978-62722-3-8 (Online)

All rights reserved

This book may not be reproduced, stored in a retrieval system or transmitted, in any form or by any means: electronic, photocopying, or otherwise, except for brief quotations in reviews, without the prior written consent of the copyright owners.

Printed by
Artsmostfare Prints
Tel: +234 8028618360

Contents

Keynote Speech for the 17th NAEE/IAEE Annual International Conference, Delivered by Prof. Anthony O. Adegbulugbe, FNAEE, FNES, Chairman/CEO, Green Energy International Limited, Abuja, Nigeria on Monday 21" October 2024 at NICON Luxury Conference Centre, Abuja viii

Welcome Address by Dr. Hassan Mahmud, PhD, FCIB, FNSA, CBE President, Nigerian Association for Energy Economics at the 17th NAEE/IAEE Annual International Conference NICON Luxury Hotel 20th – 22nd October, 2024 Abuja – Nigeria..... xxiii

List of Contributors..... xxvii

CONCURRENT SESSIONS

PART 1 CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Chapter 1 The Role of Good Governance in Addressing Climate Change Towards Sustainable Development: Evidence for Selected Sub-saharan Countries
Abikoye Michael Oluwafemi, Dogo Bishara Saidu and Badiru Francisca Isibhakhomen 5

PART 2 ENERGY, ENVIRONMENT AND GOOD GOVERNANCE FOR SUSTAINABLE DEVELOPMENT

Chapter 2 Energy and Good Governance on Economic Growth in Sub-Saharan Africa
Paul Alaje 33

PART 3	CLIMATE CHANGE, POVERTY AND GOOD GOVERNANCE	
Chapter 3	Assessing the Nexus Among Electricity Infrastructure, Foreign Direct Investment and Economic Growth in SSA <i>Mahmud Imam Hassan</i>	65
PART 4	CLIMATE CHANGE, GOOD GOVERNANCE AND TECHNOLOGY	
Chapter 4	Understanding the Nexus Between Climate Change, Resilience, and Economic Prosperity in Nigeria <i>Yusuf, Umar, Abikoye, Michael O. and Dogo, Bishara S.</i>	83
PART 5	SOCIO-ECONOMIC ASPECTS FOR ENERGY AND ENVIRONMENT	
Chapter 5	An Analysis of the Economic Determinants of Cooking Energy Choice in Delta State, Nigeria <i>Iruoghene Emohefe Odenu, Shuaibu Mohammed, Magaji, Musa Adewumi and Ifeanyi Polycarp Maduechesi</i>	109
Chapter 6	The Role of Remittances in Addressing Adoption of Renewable Energy: Evidence for Nigeria <i>Dogo, Bishara Saidu, Abikoye, Michael Oluwafemi and Umar, Yusuf</i>	141
PART 6	TECHNOLOGICAL SOLUTIONS TO ENHANCE THE GREEN ECONOMY	
Chapter 7	Transitioning to Low Carbon on - Road Transport Industry in Nigeria: Challenges and Prospects <i>Mobolaji, D and Isola, W.A.</i>	165

PART 7	INNOVATIONS FOR A LOW-CARBON FUTURE	
Chapter 8	Innovative and Sustainable Financing: Options for the Development of A Green Economy <i>Mercy Sunsuwa, Mercy Ewea Egwakhide and Maryam Okikiola Sekoni</i>	181
Chapter 9	Utilization of Natural Gas for Sustainable Economic Growth: A Case Study of Nasarawa State <i>Ahmed Adamu, Abdullahi Muhammad Etokonz, Ikechukwu Okafor, Musa Umar Kolo and Khaleel Jakada</i>	201
Chapter 10	Nigeria's Energy Dilemma: Balancing Industrialization and Environmental Sustainability in a Changing Global Energy Landscape <i>Yaknan Haruna Mamdam and Nanven Haruna Mamdam</i>	215
PART 8	ECONOMIC TRANSITION	
Chapter 11	Examining the Relationship Between Renewable Energy Adoption, Population Dynamics, and Economic Growth in Africa <i>Ichedi Winifred, Kings Timipre and Mahmud Alamin</i>	233
Chapter 12	Assessing the Global Energy Transition: Balancing Fossil Fuel Demand with Renewable Integration and Energy Mix Strategy in Africa <i>Ahmed Adamu, Abdulmalik Ajibade and Aisha Omotolani Adebayo</i>	261

PART 9	OTHERS	
Chapter 13	Impact of the Geopolitical Dynamics of Energy System Transformation on Nigeria <i>Victory K. Obasi and Fatima Isa Bima</i>	281
Chapter 14	Asymmetric Impact of Oil Price Changes on Import Demand in Nigeria <i>Gbenga Peter Sanusi, Adeola Adenikinju, L. Oladele. Oderinde, Isaiah O. Oluriola and Festus Osagu</i>	311
INDEX		335

**Keynote Speech for the 17th NAEE/IAEE Annual
International Conference, Delivered by
Prof. Anthony O. Adegbulugbe, FNAEE, FNES,
Chairman/CEO, Green Energy International Limited,
Abuja, Nigeria
on Monday 21st October 2024 at NICON Luxury
Conference Centre, Abuja.**

Your Excellency,

Bola Ahmed Tinubu, GCFR, President and Commander-in-Chief of
the Armed Forces, Federal Republic of Nigeria,

The Chairman, Hon. Heineken Lokpobiri, Hon. Minister of State,
Petroleum Resources,

Other Ministers present,

The IAEE President, Prof Anne Neumann,

The NAEE President, Dr. Hassan Mahmud,

Distinguished Guests,

Past Presidents and Fellows of the NAEE

Members of the NAEE

Gentlemen of the Press

Ladies and gentlemen

It is with great honour that I stand before you today at the 17th Annual International Conference of the Nigerian Association for Energy Economics (NAEE) and the International Association for Energy Economics (IAEE). The theme for the 2024 conference, The Energy, Economy, and Environment Nexus: Imperative for Good Governance and Sustainable Development, could not be timelier as it addresses the current pressing challenges and opportunities.

Let me start by expressing my admiration and congratulations to the NAEE for sustaining the annual conference since 2007. I am proud of your accomplishments and progress over the years, building a

vibrant association of energy economists across the various energy professionals, engineers, economists, lawyers and others.

I salute the President of the NAEF, Dr Hassan Mahmud, and past Presidents, Professors Akin Iwayemi, Adeola Adenikinju, Wumi Iledare and Yinka Omorogbe, SAN, and their teams, for keeping the light blazing.

Your conference's theme is timely and apt as the world faces the trilemma of energy security, availability and sustainability. Many countries, especially in Africa and Asia, struggle to grow their economies, provide hope for their people, and break energy and economic poverty limitations. Nevertheless, all around them, the consequences of the Advanced Economies' choices in energy use continue to be evident in global warming and the effects of climate change that have defied geographical locations.

Distinguished Ladies and Gentlemen, as we gather here today, the interconnectedness between energy systems, economic growth, and environmental sustainability becomes increasingly evident. I hope our discussions during the conference will stimulate intellectual exchange and provide actionable insights to shape policy and drive the sustainable development goals we all aspire to achieve.

Nigeria, Africa, and indeed the world face a critical juncture, Energy systems are evolving remarkably, shifting from fossil fuel dominance to renewable sources, and this transition fundamentally reshapes economies and the environment. In this transformation, we are tasked with an essential question: How do we harness the energy-economy-environment nexus to foster good governance and achieve sustainable development?

To explore this, we must first acknowledge the complexity of the nexus. The energy sector fuels economies, creates jobs, and drives industrialisation but also contributes to environmental degradation if not properly managed. On the other hand, environmental preservation is essential to long-term economic stability but requires carefully planned energy policies. This balancing act necessitates robust governance frameworks that ensure transparency, accountability, and effective

resource management. Energy is the backbone of economic development. In Africa, energy access is critical to unlocking the potential for industrialisation, innovation, and improved livelihoods. However, many across the continent, including Nigeria, remain energy-poor. According to the 2022 Energy Access Report from the World Bank, Nigeria has one of the most significant energy deficits in the world. Also, as of 2021, 85 million individuals-more than 4 out of 10 Nigerians, do not have access to power from the national grid.

A Brief Overview of the Literature

The empirical literature is unanimous on the importance of energy to human development. Chien et al. (2023), and Luan et al. (2023) argue that energy is a fundamental element for sustaining human survival and development. Thus, excessive energy poverty may hinder sustainable human development. Energy poverty stifles economic growth, education, healthcare, and gender equity.

Similarly, studies like Pachauri et al. (2004), Sesan et al. (2013), and Belaïd (2022) identified energy poverty as one of the critical developmental challenges faced by developing and emerging economies.

The nexus of energy generation and consumption, economic growth and environmental degradation revolves around three significant hypotheses: the growth hypothesis, conservation hypothesis and feedback hypothesis. The growth hypothesis studies claimed that economic growth depends on energy consumption (Adams et al., 2018; Zafar et al., 2019). The conservation hypothesis was the opposite: economic growth fuels energy consumption (see Destek & Aslan, 2017). However, a feedback hypothesis is upheld where a two-way causality exists among these three variables (i.e., energy, economy and environment) (Aydin, 2019; Tugcu et al., 2012).

In Africa, some research has been conducted to ascertain the extent, causality and implications of energy consumption. One such example is the work of Acheampong (2018), who found that a

positive shock to GDP increases energy consumption and carbon emissions in the short run but also increases stability in the long run. This finding corroborates with Paramati et al. (2018), who noted that industrialization enhances energy saving for most African countries. On the contrary, Awodumi and Adewuyi (2020) discovered that CO₂ emissions across African economies remained highly unstable, with Algeria being the leading carbon emitter due to the dominance of non-renewable energy consumption.

Therefore, energy consumption apparently promotes economic growth but contributes to higher carbon emissions. This raises some pertinent questions: To what extent do production and consumption of energy resources contribute to economic growth and carbon emissions in African economies? Should policy focus more on growth than reducing carbon emissions arising from energy resource consumption? These are policy-relevant questions.

Regarding the nexus between energy and good governance, pioneering studies have shown that the empirical side of the nexus aligns with economic theories. Fredriksson et al. (2004) analysed 12 OECD countries. They concluded that corruption reduces the effects of energy policy: increasing corruption leads to increased energy intensity and, implicitly, a decrease in energy efficiency. Stern (2012) discovered that the decline in corruption directly leads to increased energy efficiency. Further, Nicolli and Vona (2015) concluded that increased corruption indirectly affects renewable energy policy through its impact on the regulation of the energy products market.

Relevance for Africa

The African continent is energy-poor, the poorest in the world. About 600 million Africans lack access to electricity, while over 900 million rely on traditional biomass fuels, such as wood and charcoal, for cooking and heating. These fuels lead to deforestation and indoor air pollution, contributing to an estimated 600,000 premature deaths annually (WHO, 2022). Limited access to electricity hampers

economic development, educational opportunities, and healthcare services, further perpetuating poverty and inequality.

Moreover, an estimated three billion people worldwide still lack access to clean energy technologies for cooking (IEA, 2022). In the IEA's most recent Global Energy Outlook report, global energy demand will increase by around 33% by 2050. This implies that energy, and sustainable energy for that matter, will remain central to our daily lives, the lifeblood that enables us all to function and prosper.

There is no doubt that the world needs more energy, but this need must be met ever more efficiently and sustainably, considering the challenges posed by climate change to our future. However, Africa needs even more energy. Its population is set to increase from 1.4 billion people today to around 2.5 billion by 2050. Its economic output is expected to triple, and energy demand will increase by 82%. It would increase even more, by 150%, if its GDP per capita doubled to 5,000 dollars in 2050 (World Bank, 2021).

At the same time, Africa suffers significantly from the effects of climate change despite being the least responsible for it. Africa's cumulative Greenhouse gas (GHG) emissions are very low, and even today, Africa accounts for only 3 to 4% of the world's total GHG emissions despite being home to 17% of the world's population.

Distinguished Ladies and gentlemen, given the evident developmental challenges confronting the African continent, it is clear that the narrative that Africa should abandon the development of its natural resource base for environmental protection is misguided. A wealthier Africa would be better positioned to contribute to climate change mitigation and adaptation efforts while addressing its energy security and socioeconomic development needs.

By leveraging the continent's abundant natural resources, African nations can bolster their economies, lift millions out of poverty, and create the necessary infrastructure to facilitate the adoption of renewable energy technologies in the future. However, harnessing the potential of natural resources in Africa is not without challenges.

One of the primary obstacles is the lack of infrastructure capacity to transport and distribute natural gas, for example. Constructing pipelines, liquefaction plants, and other infrastructure requires significant investments and long-term planning. My company, Green Energy International Limited, is already leading the way here in Nigeria by constructing the first indigenous terminal in Rivers State.

As Africa's largest economy, Nigeria's wide range of livelihoods, agricultural practices, and commodities are threatened by climate change. Rising sea levels increase vulnerability to flooding and waterborne disease. Additionally, drought and increasing flooding hinder agricultural production and fishing, reducing food security and negatively impacting health and nutrition in our dear nation. Drought, reduced rainfall and rising air temperatures inhibit the country's hydropower systems. The energy sector, deforestation, and land-use change are the most significant contributors to Nigeria's greenhouse gas (GHG) emissions (USAID report, 2023).

About 70% of Nigeria's primary energy supply is derived from biomass. Poor on-grid power supply, which rarely exceeds 5 gigawatts, forces Africa's largest economy to rely on more than 14 gigawatts of inefficient petrol and diesel backup generators across the country, contributing to around 30% of the fine particulate matter emissions from the continent (USAID report, 2023). According to the United Nations, Nigeria has the highest rate of deforestation worldwide, losing about 3.7% of its forest yearly.

All hands must be on deck to address the existential challenges of climate change. As responsible citizens of the globe, we must recognise that there is no 'Plan B' in addressing climate change. Today, it is more important than ever to drive forward the global energy transition in the interest of climate change mitigation, energy security, and economic diversification and development.

We are already witnessing the global energy landscape changing dramatically, as seen in the succeeding United Nations-organized Conference of Parties. Countries and regions have developed energy

transition plans. However, it is important to stress that energy transition in developing countries, including Africa, must involve **transitioning out of poverty, transitioning towards growth, transitioning towards development, and transitioning sustainably.**

Global investment in renewable energy reached a record high in 2022-at USD 0.5 trillion, but this represented less than 40% of the average investment needed each year between 2021 and 2030, according to World Bank statistics, to meet the sustainable development goals and limit global warming to 1.5°C. More striking than the absolute numbers is that sub-Saharan Africa received less than 1.5% of the global investment in renewable energy.

The disparity in renewable energy financing received by developed versus developing countries has increased significantly over the past six years. For this reason, we must be creative and develop new approaches to ensure that no one is left behind regarding sustainable and affordable energy for all by 2030 and beyond.

Distinguished ladies and gentlemen, African governments must prepare energy transition plans considering the reality of green growth. These plans are critical policy and investment tools to deliver affordable, reliable, and clean energy while expanding energy services for all. Many African countries have demonstrated a willingness to be leaders and equal partners in the energy transition, with countries like Kenya, Nigeria, Ghana, and others developing world-class whole-economy transition plans (ETPs).

These ETPs are very important, and I may use the example of the Nigeria ETP, which Former President Buhari launched at COP26. The ETP in Nigeria is backed by law. The ETP covers all sectors of the economy, including the power sector, transport, housing, agriculture and forestry, and clean cooking. The ETP gives a price tag of USD 1.9 Trillion for Nigeria to reach net zero by 2060, of which USD 410 billion will be above business-as-usual spending. These figures are definitely beyond Nigeria's ability alone. The Advanced Economies must come to her aid.

The Pathway Forward

While energy drives economic growth, we must not ignore its profound environmental impact. Carbon emissions from energy production and industrial activities have escalated the climate crisis, leading to more frequent natural disasters, rising sea levels, and extreme weather conditions that disproportionately affect the poorest populations. We have a collective responsibility to act. Africa, while contributing the least to global carbon emissions, remains one of the most vulnerable regions to climate change impacts. This paradox compels us to think critically about our development pathways.

Meanwhile, renewable energy offers a beacon of hope. The International Renewable Energy Agency (IRENA) estimates that 90 per cent of the world's electricity will come from renewable energy by 2050. This is an opportunity we must seize. In Africa, it is likewise projected that 76% of the continent's energy could come from renewable sources by 2040. If harnessed efficiently, Africa is endowed with abundant solar, wind, and hydropower resources that can power our industries, rural areas, and fast-growing cities. The energy transition presents a path to prosperity for millions of Nigerians and Africans, but only if we prioritise infrastructure, innovation, and research investments to ensure the transition is inclusive and equitable. Africa needs help to achieve the energy finance and advanced technology needed to achieve this.

Sustainable development demands that we embrace renewable energy solutions that reduce our carbon footprint. Adopting solar energy, wind farms, and energy-efficient technologies is no longer a choice but a necessity. Moreover, Africa's vast forests, wetlands, and ecosystems must be protected as carbon sinks, vital for mitigating climate change. However, achieving this will require more than just good intentions. We must build the institutional capacity to monitor and enforce environmental regulations, ensuring that our natural resources are preserved for future generations. Robust governance

frameworks that integrate environmental sustainability into economic planning will be essential.

Good governance lies at the heart of this nexus. The glue holds the energy, economy, and environment together in harmony. Without sound governance, policy fragmentation occurs, leading to inefficiencies, corruption, and, ultimately, failure to achieve sustainable development. Governance in the energy sector requires a multi-stakeholder approach. Governments must lead with clear, long-term strategies but cannot act alone. Private sector investments, international cooperation, and the involvement of local communities are crucial. Public-private partnerships (PPPs) should be encouraged to accelerate energy infrastructure projects, and innovative financing mechanisms should be explored to support renewable energy adoption.

Furthermore, transparency and accountability are non-negotiable. Citizens must be informed and involved in decision-making, particularly regarding resource allocation, environmental management, and policy implementation. Open dialogue and inclusive governance foster trust and drive the effective execution of policies that benefit the economy, the environment, and society.

The energy transition is a global challenge; no single nation can solve it alone. International cooperation is essential, particularly for African nations. Technology transfer, capacity building, and financing are areas where partnerships with the international community can support Africa's energy transition and climate resilience efforts.

We must also recognise that Africa's energy and environmental issues are not isolated. Africa must be a key player as global energy systems move toward renewable dominance. This means engaging with international bodies, leveraging global best practices, and ensuring that Africa's voice is heard in global forums, from the United Nations Climate Change Conference (COP) to the International Energy Agency (IEA).

In conclusion, the nexus between energy, the economy, and the environment is the cornerstone of sustainable development. We

need bold leadership, sound governance, and an unwavering commitment to sustainability to harness this nexus. As we deliberate in this conference over the coming days, let us focus on actionable strategies to address Africa's energy challenges, promote economic growth, and protect our environment.

What we do today will determine the legacy we leave for future generations. As I said before, sustainable consumption is not necessarily about consuming less. It is about consuming better-in an intelligent and environmentally sustainable way.

Thank you.

Welcome Address
by
Dr. Hassan Mahmud, PhD, FCIB, FNSA, CBE
President, Nigerian Association for Energy Economics
at the
17th NAEE/IAEE Annual International Conference
NICON Luxury Hotel
20th – 22nd October, 2024
Abuja - Nigeria

Your Excellency,
Bola Ahmed Tinubu, GCFR, President and Commander-in-Chief of
the Armed Forces, Federal Republic of Nigeria,
The Chairman,
Other Ministers present,
The IAEE President,
Distinguished Guests,
Past Presidents and Fellows of the NAEE
Members of the NAEE
Gentlemen of the Press
Ladies and gentlemen

It is my distinguished honour and great pleasure to welcome you all
to the 17th Annual International Conference of the Nigerian Association
for Energy Economics (NAEE), in collaboration with the International
Association for Energy Economics (IAEE), USA.

The Nigerian Association for Energy Economics (NAEE) is the
Nigerian Affiliate of the International Association for Energy
Economics (IAEE) – which has presence in over 120 countries around
the world. The Nigerian affiliate was officially inaugurated in December
2006 at the Nigerian National Petroleum Corporation (NNPC) Towers,
Abuja with our pioneering President- Professor Akin Iwayemi.

The Association is a non-profit organisation of corporate, private and public Institutions, academics, policy analyst and policy makers, professionals, researchers, students, that explore, advance and advocate the understanding and application of economics across all facets of energy sources, development, distribution, consumption and management, including theory, technology, engineering, legal framework, regulation, risks, geo-politics, energy mix and transition, environment and climate issues, as well as, the governance of the energy solution ecosystem.

The Association provides a veritable platform for the gathering of these experts and professionals, for the exchange of ideas, experiences, challenges and solutions to how we can harness the potentials and opportunities, along the entire energy value-chain, for the development of our economies and its people, albeit, in a sustainable and efficient manner.

This year's conference is, themed “*The Energy, Economy, and Environment Nexus: Imperative for Good Governance and Sustainable Development*,” - centering on exploring the effective linkage of these three key corridors (Energy, Economy and Environment), through good governance (rule of law, transparency and accountability), to maximize the benefits of our energy potentials for our economic development and industrialization.

We must admit, particularly for developing and emerging economies, that a key factors that determines our ability to transform our abundant energy potentials (both fossil fuel and renewables) to economic growth and development, and improved standard of living our citizens, is our governance structure and institutional arrangements. Abundant evidences in the literature have established that weak institutions and poor governance have led to the inability of some countries to transform their abundant human capital and natural resources endowment, to positive economic and social outcomes, including industrialization and political stability – the Resource- Curse Syndrome.

In the of the direction of evolving good governance in energy development and uses in Nigeria, a major achievement was recorded in the establishment of a robust and country- specific legal instrument to facilitate the transition and transformation.

The Petroleum Industry Act (PIA) of 2022 marks a significant milestone in addressing some major structural, institutional and bureaucratic deficiencies in the energy sector. It prioritised the reforms to Nigeria's energy sector, streamlining the regulatory framework, encouraging investment, and improving transparency. These reforms come at a critical time, as Nigeria seeks to diversify its energy mix, moving away from the heavy reliance on oil and gas to incorporate renewables energy sources, including solar, wind, and hydroelectric. The PIA is meant to foster a more competitive and dynamic energy market, positioning Nigeria as a regional leader in energy development with particular emphasis on creating more local content and boosting indigenous capacity within the energy sector. Recognising the need to harness the capabilities of indigenous professionals and firms towards ensuring that our energy sector remains globally competitive while fostering economic emancipation and poverty-reducing growth.

However, regardless of the innovative and comprehensive pillars of the PIA, evolving a matching institutional and political arrangements to facilitate the implementation of the legal instrument to fast-track the transition from Nigeria energy sector potentials to inclusive and sustainable economic growth and development has remained, rather elusive.

At this conference, we would therefore delve into some of these teething governance issues and institutional structures, as well as other relevant and related technical issues on the Energy, Economy and Environment nexus. We have a huge line-up of researchers, policy makers and professionals, in diverse fields, to facilitate discussions in these areas during the plenary and concurrent sessions. We also have a dedicated roundtable session tomorrow to mark the World Energy Day, where discussions would center on climate and

environmental implications of our energy production and consumption processes, as well as other macroeconomic consequences.

Let me once again, welcome, particularly, the Honourable Minister of Mines (Solid Minerals) – Dr. Dele Alake and other distinguished guests, including our plenary keynote speaker, IAEE President, past NAEE Presidents, past and current council members, our esteem facilitators, session chairs, paper presenters, participants and university students, our sponsors and financiers, friends and partners, invited media houses and personnel, ladies and gentlemen.

We sincerely appreciate your presence and wish you a very fruitful and impactful time at our 2024 annual international conference. The proceedings of this conference, like the previous ones, would be shared for public consumption and adoption by policy makers and practitioners.

On this note, I therefore, most respectfully, welcome you All to the 17th NAEE/IAEE Annual International Conference 2024, holding here in the beautiful city of Abuja, Nigeria.

Thank you sincerely, very much for your kind attention.

Dr. Hassan Mahmud

President,

Nigerian Association for Energy Economics

List of Contributors

Abdullahi Muhammad Etokonza is of the Department of Economics, Nile University of Nigeria, Abuja.

Abdulmalik Ajibade is of the Department of Economics, Nile University of Nigeria, Abuja.

Abikoye, Michael Oluwafemi is of the Department of Economics, Nile University of Nigeria, Abuja and Research Department, Central Bank of Nigeria.

Adeola Adenikinju is a Professor of Economics, University of Ibadan, Ibadan, Nigeria and the President of the Nigerian Economic Society.

Ahmed Adamu is of the Department of Economics, Nile University of Nigeria, Abuja.

Aisha Omotolani Adebayo is of the Department of Economics, Nile University of Nigeria, Abuja.

Badiru Francisca Isibhakhomen is of the Department of Economics, Nile University of Nigeria, Abuja.

Dogo, Bishara Saidu is of the Department of Economics, Nile University of Nigeria, Abuja and Research Department, Central Bank of Nigeria.

Fatima ISA Bima is of the Department of Economics, Nile University of Nigeria, Abuja.

Festus Osagu is of the Research Department, Central Bank of Nigeria

Gbenga Peter Sanusi is of the Department of Economics, Anchor University, Lagos, Nigeria.

Isaiah O. Oluriola is of the Department of Economics, Anchor University, Lagos, Nigeria.

Ichedi Winifred is of the Department of Economics, Nile University of Nigeria, Abuja.

Ifeanyi Polycarp Maduechesi (PhD) is of the Department of Economics, University of Abuja, FCT, Nigeria.

Ikechukwu Okafor is of the Department of Economics, Nile University of Nigeria, Abuja.

Iruoghene Emohefe Odeni, (PhD) is of the Department of Economics, University of Abuja, FCT, Nigeria.

Isola, W.A. (PhD) is of the Department of Economics, University of Lagos, Akoka, Yaba, Nigeria.

Khaleel Jakada is of the Department of Economics, Nile University of Nigeria, Abuja.

Kings Timipre is of the Department of Economics, Nile University of Nigeria, Abuja.

L. Oladele Oderinde is of the Department of Economics, Anchor University, Lagos, Nigeria.

Magaji Sule (PhD) is a Professor in the Department of Economics, University of Abuja, FCT, Nigeria.

Mahmud Alamin is of the Department of Economics, Nile University of Nigeria, Abuja.

Mahmud Imam Hassan is of the Department of Economics, Baze University, Abuja.

Maryam Okikiola Sekoni is of the Nile University of Nigeria, Abuja.

Mercy Ewea Egwakhide is of the Nile University of Nigeria, Abuja.

Mercy Sunsuwa is of the Nile University of Nigeria, Abuja.

Mobolaji, D. Akinbomi is of the Department of Economics, University of Lagos, Akoka, Yaba, Nigeria.

Musa Adewumi Sulaimon (PhD) is of the Department of Economics, University of Abuja, FCT, Nigeria.

Musa Umar Kolo is of the Department of Economics, Nile University of Nigeria, Abuja.

Nanven Haruna Mamdam is the Research Consultant.

Paul Alaje is a student of the Nile University of Nigeria, Abuja.

Shuaibu Mohammed (PhD) is of the Department of Economics, University of Abuja, FCT, Nigeria.

Umar, Yusuf is of the Department of Economics, Nile University of Nigeria, Abuja and Research Department, Central Bank of Nigeria.

Victory K. Obasi is of the Department of Economics, Nile University of Nigeria, Abuja.

Yaknan Haruna Mamdam is of the Federal Ministry of Water Resources.

www.naee.org.ng

CONCURRENT SESSIONS



PART 1



Climate Change and Sustainable Development





The Role of Good Governance in Addressing Climate Change Towards Sustainable Development: Evidence for Selected Sub-saharan Countries

Abikoye Michael Oluwafemi, Dogo Bishara Saidu
and Badiru Francisca Isibhakhomen

Abstract

This study employs Panel Data fixed effects model to analyze the role of governance in addressing climate change in selected Sub-Saharan countries, revealing significant findings. The findings indicate that Government effectiveness and energy consumption increases climate vulnerability, likely due to inefficiencies and unsustainable energy practices. In contrast, environmental sustainability and GDP per capita reduce vulnerability. Validation tests support the model's validity, with Kenya showing a higher baseline vulnerability, while Nigeria and South Africa have lower levels. Policy recommendations include enhancing government effectiveness through improved institutional quality and transparency, promoting environmental sustainability, transitioning to cleaner

energy sources, and implementing economic policies to boost GDP per capita. These strategies should be tailored to each country's specific context to effectively mitigate climate vulnerability in Sub-Saharan Africa.

Keywords: Climate Change, Vulnerability, Government Effectiveness, Panel Data

JEL Classification: C33, Q54, Q58

1.1 Introduction

Climate change is a critical global concern with wide-ranging implications beyond the environment, necessitating immediate attention. It poses a significant threat to sustainable development, particularly in Sub-Saharan Africa where the impacts are often disproportionately severe (Adekunle, 2020). Various governmental, intergovernmental, and other institutional governance efforts have been proffered with the aim of addressing its impacts (Asongu & Odhiambo, 2020). Effective governance plays a crucial role in combating this crisis, and its significance cannot be underestimated (Leal Filho, 2010; Bhuiyan, 2015; Le et al., 2016; Asongu & Odhiambo, 2020). Governance refers to the process of making and enforcing decisions within an organisation or community. It includes decision-making, rule-making, and enforcement procedures that govern the operation of an organisation or society. Effective governance is necessary for preserving order, attaining goals, and meeting the requirements of the community or members of the organisation.

Furthermore, successful governance promotes transparency, creates trust among stakeholders, and adjusts to changing circumstances, ensuring that the organisation or society stays responsive and resilient in meeting its goals.

In terms of climate change, governance therefore, encompasses the policies, regulations, and actions by governments, international

bodies, businesses, and civil society to reduce emissions, adapt to impacts, and enhance resilience. Good governance, defined as the effective management of a country's economic, political, and social affairs, is widely recognized as a critical enabler of sustainable development (Siddique & Ghosh, 2015). It can therefore be noted that good governance is indispensable in combating climate change, guiding pathways toward sustainability through informed collaboration. The intersection of governance and climate action, particularly within climate change governance (CCG), has garnered significant scholarly interest, as it has become increasingly crucial to recognise and understand governance's pivotal role in informing policy formulation, risk mitigation, innovation, social equity promotion, and long-term sustainability assurance (see Meadowcroft, 2009; Bernauer, & Schaffer, 2010; Le et al., 2016).

Studies have examined the relationship between good governance and environmental sustainability in the African context (Adekunle, 2020; Karimi (2021)). These studies suggest that improving governance standards, including political, economic, and institutional frameworks, can have a positive impact on environmental outcomes such as emissions reductions. For example, Shefiu et al., (2019) opines that good governance is crucial for ensuring stable political and economic environments, sustainable development of resources, improved infrastructure and access to basic services, and the protection of human rights. However, the specific mechanisms and the contextual factors that mediate this relationship remain underexplored, particularly in the realm of climate change. As it has been noted by Kweyu et al. (2023) that climate change governance in Sub-Saharan Africa faces several challenges, including limited institutional capacity, lack of financing, inadequate policy frameworks, and weak enforcement mechanisms. Intergovernmental organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the International Renewable Energy Agency (IRENA) play a vital role in providing guidance and technical support to African countries in their efforts to address climate change (Filho, 2010; Adams &

Asante, 2020). Additionally, national governments in Sub-Saharan Africa have enacted various policies and strategies to combat climate change, such as the adoption of renewable energy targets, emissions reduction goals, and adaptation plans (Kweyu et al., 2023). While these efforts are commendable, more coordinated and effective governance is needed to ensure the successful implementation of these initiatives and drive sustainable development in the region.

The adoption of the AU Agenda 2063, a shared framework for inclusive growth and sustainable development for Africa, has also provided a platform for enhanced climate change governance in the region. However, the realization of this agenda requires strengthening the capacity of African institutions and improving the coordination of climate-related policies and programs across different levels of government.

To address the climate change challenges in Sub-Saharan Africa, good governance must be at the forefront of the agenda. This includes enhancing transparency, accountability, and inclusivity in decision-making processes, as well as strengthening the capacity of institutions to implement and enforce climate-related policies and regulations. This study therefore examines the effectiveness of governance in addressing climate change in Sub-Saharan Africa, highlighting its pivotal role in developing sustainable solutions. It is expected that as sustainable solutions develop through the instrumentality of good and effective governance, emissions will reduce thereby ultimately leading to the reduction of the vulnerability faced by countries and the earth at large as a result of climate change related disastrous events.

Following the introduction, Section 2 presents the literature review in the study area, Section 3 focuses on the data and methodology utilised in the study. Section 4 discusses the results and findings of the study while Section 5 concludes the study with some recommendations.

1.2 Literature Review

1.2.1 Conceptual Clarification: Good Governance, Climate Change and Sustainable Development

World Bank (1992) defines good governance as an essential complement to sound economic policies which is central to creating and sustaining an environment that fosters strong and equitable development. The need for good governance was emphasized and identified as the existence of transparent processes, including a bureaucracy performed with professional ethos, a government that takes responsibility for its actions, and a strong civil society engaged in public affairs acting under the rule of law.

United Nations (1992) describes climate change as long-term shifts in temperatures and weather patterns. These shifts may be natural, but since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels (like coal, oil and gas), which produces heat-trapping gases.

Sustainable development is an approach to growth and human development that aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. The aim is to have a society where living conditions and resources meet human needs without undermining planetary integrity (Wikipedia, 1983).

1.2.2 Theoretical Framework

To Pollution Havens Hypothesis, investors tend to shift their investments to countries with lenient regulations (Gyamfi, Bein et al., 2021; Shahbaz et al., 2015). Also, economic factors alongside environmental, governance and institutional have been observed to influence FDI by extension sustainable development (Chipalkatti et al., 2021; Dornean et al., 2021; Nguyen, 2017). The EKC is named after Kuznets (1955), who postulated that as economic growth advances, income disparity initially rises and later falls. According

to Kuznets (1955), there is an inverted-U-shaped relationship between various toxins and per capita income, meaning that as wealth rises, environmental burden increases until a certain point before declining.

Degradation and pollution increase during the early stages of economic development, but after reaching a certain income per capita threshold—which will vary depending on a variety of indicators—the trend reverses, and at high income levels, economic growth results in improved environmental conditions. This implies that the relationship between income per capita and the environmental effect indicator is an inverted U-shaped one. Furthermore, the anticipated impacts of climate change are expected to further strain livelihoods and the country's economy (Andersson et al., 2020; Climate Risk Profile, 2021; Federal Government Nigeria, 2020).

Again, from theoretical perspective, most of these studies mainly focus on testing the validity of the Environmental Kuznets Curve (EKC) (Olusanya 2012; Bozkurt & Akan 2014; Adekunle, 2021), and do not consider investigating the individual effect of climate change and environmental degradation in the same framework on real sectors (agriculture and industrial sectors). Institutions as one of the determinants of economic growth was first discuss by North (1990) and since then there are several supporting literatures to its effectiveness. Kormendi and Meguira (1985), Tullock (1987) reveal that nations with high level of civil liberties "strong institutions" experience economic performance. Organization of Economic Cooperation and Development (2001) reveal that governance performances influences country's economic performance.

1.2.3 Empirical literature

The intersection of good governance, climate change mitigation, and sustainable development is critical, particularly for Sub-Saharan African countries, which face unique environmental and socio-economic challenges. This literature review examines how good governance can contribute to effective climate change mitigation

and adaptation, promoting sustainable development in selected Sub-Saharan countries. It draws on diverse studies that explore the roles of governance in environmental policy, sustainable development, and climate change resilience.

Karimi (2021) emphasized that good governance is essential for effective climate change mitigation and adaptation in Africa. The study argued that embedding elements of good governance into climate change policies can address governance challenges and enhance the effectiveness of these policies. This perspective aligns with the broader view that good governance facilitates the implementation of climate strategies, ensuring transparency, accountability, and public participation.

Similarly, Le et al. (2016) found that good governance positively affects environmental performance while reducing vulnerability to climate change. The global panel data analysis included 122 countries from 2000 to 2012 and showed the importance of good governance in achieving environmental sustainability. This suggested that Sub-Saharan African countries can benefit from strengthening governance frameworks to improve climate resilience and environmental outcomes.

Omri and Mabrouk (2020) discussed the role of good governance in balancing the economic, environmental, and social components of sustainable development. The study focused on 20 Middle East and North Africa (MENA) economies, highlighted the importance of economic, political, and institutional governance in achieving sustainable development. Although the study was not specific to Sub-Saharan Africa, the findings suggested that good governance is a critical factor in achieving a balanced approach to development that includes effective climate action.

Bhuiyan (2015) focused on Bangladesh but provided valuable insights into the role of good governance in climate change adaptation. The study found that inadequate governance can hinder adaptation efforts, a lesson that is applicable to Sub-Saharan Africa, where similar governance challenges exist. Improving governance can

enhance adaptation preparedness, making countries more resilient to climate impacts.

Auriacombe and Vyas-Doorgapersad (2019) critiqued the World Bank's approach to governance reforms, which are often imposed on recipient countries without clear timelines or support mechanisms. This leads to fragmented implementation of governance reforms, diluting their effectiveness. For Sub-Saharan African countries, this implies the need for tailored, well-supported governance reforms that can sustainably integrate climate change mitigation and adaptation.

Filho (2010) outlined the concept of Climate Change Governance (CCG), providing examples of good practices. The paper highlighted the need for comprehensive action to put CCG principles into practice, a relevant point for Sub-Saharan Africa where governance structures may be weak or underdeveloped. Effective CCG can provide a framework for integrating climate policies into broader governance systems.

Meadowcroft (2009) explored the role of national governments in climate change governance. The paper found that national governments play a crucial role in establishing institutions, policies, and measures to promote climate mitigation and adaptation. This is particularly pertinent for Sub-Saharan African countries, where strong governmental leadership is necessary to drive climate policy and encourage climate-smart development.

Swat et al. (2003) discussed the scientific linkages between climate change and sustainable development, emphasizing the need for integrated policy development. They highlighted the opportunities for creating policies that address both climate and development goals simultaneously. This integrated approach is vital for Sub-Saharan Africa, where development needs are urgent, and climate impacts are severe.

Lundström and Carlsson (2000) investigated the effect of political and economic freedom on CO₂ emissions, finding that political freedom does not significantly affect emissions in either high- or

low-income countries. While the study suggests that political freedom alone is insufficient to drive climate action, it identified the need for comprehensive governance that includes economic and institutional dimensions.

The literature emphasised the critical role of good governance in addressing climate change and promoting sustainable development in Sub-Saharan Africa. Effective governance can enhance the implementation of climate policies, improve environmental performance, and increase resilience to climate impacts. However, governance reforms must be tailored, well-supported, and integrated into broader development strategies to be effective. Sub-Saharan African countries can benefit from adopting comprehensive governance frameworks that balance economic, environmental, and social goals, thereby achieving sustainable development in the face of climate challenges.

While numerous studies examine the role of governance in climate change mitigation and adaptation globally or in other regions, such as those by Karimi (2021), Omri & Mabrouk (2020), and Le et al. (2016), there is a distinct lack of focused empirical analysis on Sub-Saharan Africa using robust econometric models like the Panel Data fixed effects model. This study fills this gap by specifically employing a Panel Data fixed effects model to analyse governance in selected Sub-Saharan countries. This approach provides an understanding of the unique governance and climate dynamics within the region.

The impact of government effectiveness and energy consumption on climate vulnerability has not been thoroughly explored in the context of Sub-Saharan Africa. While existing literature discussed the general impacts of governance on climate vulnerability, as seen in the works of Bhuiyan (2015) and Meadowcroft (2009), the specific mechanisms by which inefficiencies and unsustainable energy practices increase climate vulnerability have been less examined. This study will investigate if government effectiveness and energy consumption can impact climate vulnerability. This specific enquiry

would provide insights into how governance quality and energy policy impact climate resilience in Sub-Saharan Africa.

Furthermore, though the general benefits of good governance on environmental performance were discussed in studies like those by Le et al. (2016), the specific roles of environmental sustainability and GDP per capita in reducing climate vulnerability in Sub-Saharan Africa were not exhausted. This study would address this gap by revealing the relationship between environmental sustainability and GDP per capita on climate vulnerability.

Previous studies, including those by Auriacombe & Vyas-Doorgapersad (2019) and Filho (2010), provided broad recommendations without specific country-level analysis or tailored strategies. The need for tailored governance and policy recommendations for individual countries within Sub-Saharan Africa remains underexplored. This study would address this gap by providing detailed, country-specific findings. This would allow for more precise and effective policy recommendations, such as enhancing government effectiveness, promoting sustainability, transitioning to cleaner energy sources, and boosting GDP per capita, tailored to each country's context.

This paper contributes to the need for rigorous model validation to ensure the reliability of findings by performing validation tests to support the model's validity. This methodological rigor would strengthen the credibility of the conclusions and policy recommendations, ensuring that the findings are reliable and actionable. The study would address several key gaps in the existing literature on good governance and climate change in Sub-Saharan Africa. By employing a Panel Data fixed effects model, focusing on specific impacts such as government effectiveness and energy consumption, emphasizing the roles of environmental sustainability and GDP per capita, providing country-specific findings and recommendations.

1.3 Methodology

The study utilizes secondary data to examine key variables, with dependent variable measured by Vulnerability to climate change (VUL) and key independent variable as governance assessed through Government Effectiveness (GEFF). Relevant control variables include CO2 emissions (kg per 2015 US\$ of GDP) (ENV, GDP per capita (current US\$) (GDPC), and Energy intensity level of primary energy (MJ/\$2017 PPP GDP) (ENG) across selected Sub-Saharan African countries such as Nigeria, Cote d'Ivoire, Ghana, Kenya, South Africa. Employing the panel data which has advantages over cross-sectional or time series data as it allows for more observations by pooling the time series data across countries and results in higher power. Data on vulnerability and government effectiveness were drawn from World Governance Indicators while data on CO2 emissions, energy use, GDP per capita, were drawn from World Development Indicators for the respective countries.

1.3.1 Fixed Effects Model

The general framework of the fixed effects panel data analysis is a regression model of the form.

$$Y_{it} = \alpha_i + \beta_2 X_{2it} + \dots + \beta_k X_{kit} + \mu_{it} \quad \text{.....Eqn 1.1a}$$

The equation (1.1a) could be compactly written in matrix form as

$$Y_{it} = \alpha_i + X'_{it} \beta'_{it} + \mu_{it} \quad \text{.....Eqn 1.1b}$$

for $i = 1, 2, \dots, n$ and $t = 1, 2, \dots, T$,

where γ_{it} is the response for unit i at time t , α_i is the individual-specific intercept, vector X'_{it} contains k regressors for unit i at time t , vector β contains k regression coefficients to be estimated and μ_{it} is the error component for unit i at time t .

This model is suitable for explanatory variables that vary among subjects but is constant over time for a given subjects (time-invariant). The model examines group differences in intercept, assuming the same slope and constant variance across entities or subjects. Since a group (individual specific) effect is time invariant and considers a part of the intercept, the unobserved effects (α_i) is allowed to be correlated to other regressors.

1. 3.2 Model Estimation:

There are several methods of estimating linear panel regression models, namely, pooled estimators; fixed effects model an estimator which includes Least Squares Dummy Variable (LSDV), within-group regression and the First Differences (FD) methods; random effect model.

In the pooled estimator, we neglect the cross-section and time series nature of the data and pool all observation together and estimate a 'grand' regression using Ordinary Least Square (OLS).

$$Y_{it} = \beta_2 X_{2it} + \dots + \beta_k X_{kit} + \mu_{it} \quad \text{.....Eqn 1.2}$$

Applying OLS, this equation gives the pooled OLS estimator

$$pols = \sum_{i=1}^N \sum_{t=1}^1 (X^1 X)^{-1} \sum_{i=1}^N \sum_{t=1}^L (X^1 Y) \quad \text{.....Eqn 1.3}$$

The pooled OLS assumes that the intercept and slope coefficients are constant across time and individuals (Oyeniyi, 2012).

In the least square dummy variable (LSDV), we pool all observations together, but allow each cross-section unit to have its own (intercept) dummy variable. Symbolically, equation (1.1a) can be restated capturing the dummy variables as:

$$Y_{it} = \alpha_1 + \alpha_2 D_{2i} + \dots + \alpha_k D_{ki} + \beta_2 X_{2it} + \dots + \beta_k X_{kit} + \mu_{it} \quad \text{.....Eqn 1.4}$$

where α_1 is intercept for VUL which is the benchmark and $\alpha_2, \alpha_3, \alpha_4$, and α_5 are the differential intercepts for GEFF, ENV, ENG, and GDPC respectively. In this case, all the heterogeneity is subsumed in the intercept values and the estimated intercepts for each subject or crop in this case represent the subject-specific characteristics. The parameters α_i , for $i = 1, 2, 3, \dots, N$ and β can be estimated by OLS. The implied estimator for β is referred to as the Least Square Dummy Variable (LSDV) estimator (Park, 2011).

1.3.3 Hypotheses

To assess the validity of the fixed effects method, there is the need to apply tests to determine whether fixed effects (differences in the intercepts for each variable) should be included in the model. To do this, the equation must be tested under the pooled ordinary least square model and then the Breusch-Pagan test applied to identify the acceptance or rejection of the null hypothesis which states that the pooled ordinary least square is appropriate than the fixed effective model or random effective model.

Upon rejecting the null hypothesis based on the p-value being significant at 5 per cent, Hausman test is further needed to choose between the fixed effective model or random effective model. For this, the null hypothesis states that random effective model is more appropriate than the fixed effective model. A rejection of the null hypothesis leads to the application of the fixed effective model, of which the least square dummy variable method of the three types of fixed effective model is adopted in this study due to its advantage of explicitly estimating individual intercepts for each cross-sectional unit, providing clear and interpretable fixed effects for each entity in the model as required in this study.

1.4 Results and Estimation

The fixed effects model was applied to the data collected for this study and necessary hypotheses tests were carried out, the following results were obtained.

Table 1.1: Summary Statistics of Variables

	VUL	GEFF	ENV	ENG	GDPC
Mean	0.477966	-0.498982	0.459098	5.637263	2534.723
Median	0.496477	-0.539629	0.246820	5.530000	1900.398
Maximum	0.537319	0.607831	1.495026	9.010000	8737.041
Minimum	0.384811	-1.349594	0.173774	2.630000	297.0470
Std. Dev.	0.047240	0.531186	0.435337	1.745653	2106.874
Skewness	-1.009767	0.256169	1.489391	0.005907	1.457241
Kurtosis	2.614529	1.990272	3.329917	2.046553	3.914707
Jarque-Bera	16.73230	5.074746	35.55370	3.598918	36.93478
Probability	0.000233	0.079074	0.000000	0.165388	0.000000
Sum	45.40681	-47.40330	43.61436	535.5400	240798.7
Sum Sq. Dev.	0.209770	26.52288	17.81472	286.4467	4.17E+08
Observations	95	95	95	95	95

Source: Author’s data analysis using EViews 12

The table presents a range of descriptive statistics for five variables VUL (Vulnerability), GEFF (Government Effectiveness), ENV (Environmental Sustainability), ENG (Energy Consumption), and GDPC (GDP per Capita) of the selected Sub-Saharan countries. Each variable's mean provides a central tendency measure, while the median indicates the middle value, offering insight into the distribution's symmetry. For instance, VUL has a mean of 0.477966 and a median of 0.496477, suggesting a slight left skew confirmed by its negative skewness (-1.009767). In contrast, GEFF's mean (-0.498982) and

median (-0.539629) are close, indicating a relatively symmetrical distribution with slight positive skew (0.256169). The ENV variable, with a mean of 0.459098 and a median of 0.24682, is highly right-skewed (skewness of 1.489391), indicating that most countries have lower environmental sustainability scores with a few high values pulling the mean up.

Standard deviation (Std. Dev.) measures the dispersion around the mean, with higher values indicating greater variability within the dataset. GDPC, with a Std. Dev. of 2106.874, shows significant variability in GDP per capita across different observations, implying a wide economic disparity. VUL, in contrast, has a much lower Std. Dev. (0.04724), suggesting that vulnerability scores are relatively consistent among the observations. Skewness and kurtosis further describe the data's shape; positive skewness indicates a tail on the right, while negative skewness indicates a tail on the left. Kurtosis values higher than 3 indicate a sharper peak (leptokurtic), while values less than 3 indicate a flatter distribution (platykurtic). VUL and GDPC exhibit leptokurtic distributions, implying more data around the mean and sharper peaks.

The Jarque-Bera test results and their associated probabilities assess the normality of the data. VUL and ENV show significant p-values (0.000233 and 0, respectively), indicating strong evidence against normality, which is corroborated by their high skewness and kurtosis values. GEFF and ENG, with higher p-values (0.079074 and 0.165388), do not reject the null hypothesis of normality as strongly, suggesting these distributions are closer to normal. GDPC's extreme values (maximum 8737.041 and minimum 297.047) and positive skewness (1.457241) result in a non-normal distribution, highlighted by a Jarque-Bera probability of 0.

Table 1.2: Cross-Section Dependency Test

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	11.84825	10	0.2953
Pesaran scaled LM	0.413282		0.6794
Bias-corrected scaled LM	0.274393		0.7838
Pesaran CD	0.590645		0.5548

Source: Author’s data analysis using EViews 12

The Residual Cross-Section Dependence Test is used to determine whether there is cross-sectional dependence, or correlation, among the residuals of a panel data model. The null hypothesis for this test posits that there is no cross-sectional dependence in the residuals. In this specific case, the data includes 19 periods and 5 cross-sections, leading to a total of 95 panel observations. The cross-section effects were removed during the estimation process to isolate the residuals.

The results of four different statistical tests are provided: the Breusch-Pagan LM test, the Pesaran scaled LM test, the Bias-corrected scaled LM test, and the Pesaran CD test. The Breusch-Pagan LM test yields a statistic of 11.84825 with a probability value (p-value) of 0.2953, the Pesaran scaled LM test yields a statistic of 0.413282 with a p-value of 0.6794, the Bias-corrected scaled LM test yields a statistic of 0.274393 with a p-value of 0.7838, and the Pesaran CD test yields a statistic of 0.590645 with a p-value of 0.5548. Since all p-values are higher than the conventional significance level (typically 0.05), we fail to reject the null hypothesis in each case, indicating no significant cross-sectional dependence in the residuals.

Table 1.3: Panel Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.495858	0.004323	114.7067	0
GEFF	0.036129	0.006079	5.943471	0
ENV	-0.15061	0.013441	-11.2048	0
ENG	0.014165	0.001471	9.629276	0
GDPG	-4.17E-06	1.44E-06	-2.89911	0.0047
R-squared	0.944156	Mean dependent var		0.477966
Adjusted R-squared	0.941674	S.D. dependent var		0.04724
S.E. of regression	0.011409	Akaike info criterion		-6.05768
Sum squared resid	0.011714	Schwarz criterion		-5.92327
Log likelihood	292.7398	Hannan-Quinn criter.		-6.00337
F-statistic	380.4101	Durbin-Watson stat		0.437901
Prob(F-statistic)	0			

Source: Author’s data analysis using EViews 12

The panel least squares regression analysis was conducted on the dependent variable VUL, using data from 2002 to 2020, spanning 19 periods and including 5 cross-sections, resulting in a total of 95 balanced observations. The regression model incorporates four independent variables: GEFF, ENV, ENG, and GDPG. The constant term (C) has a coefficient of 0.495858, indicating its significant positive effect on VUL with a t-statistic of 114.7067. GEFF (government efficiency) shows a positive coefficient of 0.036129, significant at the 1% level (t-statistic 5.943471). Conversely, ENV (environmental variable) has a negative coefficient of -0.150607, highly significant with a t-statistic of -11.20482. ENG (energy consumption) positively influences VUL with a coefficient of 0.014165 and a t-statistic of 9.629276. The GDPG (gross domestic product per capita) has a negative but smaller effect, with a coefficient of -4.17E-06 and a t-statistic of -2.899114, significant at the 1% level. The model explains a high proportion of the variance in VUL, with an R-squared of 0.944156 and an adjusted R-squared of 0.941674. The standard error of the regression is 0.011409, indicating good model fit, while

the Akaike information criterion, Schwarz criterion, and Hannan-Quinn criterion values suggest the model's robustness. The F-statistic of 380.4101 and its associated probability of 0 indicate the overall model is highly significant, although the Durbin-Watson statistic of 0.437901 suggests potential autocorrelation issues. To ensure the appropriateness of using the pooled ordinary least squares model over the fixed effects or random effects models, the Breusch-Pagan test must be applied. This test evaluates the null hypothesis that the simpler pooled OLS model is appropriate, and its rejection would suggest that either the fixed effects or random effects models are more suitable.

Table 1.4: Breusch-Pagan Test

	Cross-section	Time	Both
Breusch-Pagan	135.4224 0	1.461493 0.2267	136.8839 0
Honda	11.63711 0	-1.20892 -0.8867	7.373845 0
King-Wu	11.63711 0	-1.20892 -0.8867	10.01068 0
Standardized Honda	24.46885 0	-1.07402 -0.8586	6.043122 0
Standardized King-Wu	24.46885 0	-1.07402 -0.8586	13.22622 0
Gourieroux, et al.	--	--	135.4224 0

Source: Author’s data analysis using EViews 12

The Lagrange Multiplier (LM) tests for random effects are statistical procedures used to determine the presence of random effects in panel data models. The null hypothesis in these tests is that there are no random effects (i.e., the variances of the random effects are zero), while the alternative hypotheses vary: the Breusch-Pagan test

uses a two-sided alternative, whereas the other tests (Honda, King-Wu, Standardized Honda, and Standardized King-Wu) use one-sided alternatives. The results are presented for cross-sectional, time, and both dimensions. The Breusch-Pagan test shows significant results for cross-section (135.4224) and both dimensions (136.8839), suggesting strong evidence of random effects, but not for time (1.461493). The Honda, King-Wu, and their standardized versions yield significant positive values for cross-section, indicating the presence of random effects, while negative values for the time dimension suggest no random effects there. The Gouriéroux, et al. test also supports the presence of random effects in the combined model with a significant statistic (135.4224). The p-values (all 0 for significant tests) indicate that the null hypothesis of no random effects is rejected in favor of the alternative hypothesis in these cases.

Table 1.5: Hausman Test

Test Summary		Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random		69.23401	4	0
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
GEFF	0.024695	0.036129	0.000041	0.0754
ENV	-0.12108	-0.15061	0.000832	0.3058
ENG	0.012516	0.014165	0.000003	0.3723
GDPC	-4E-06	-4E-06	0	0.5172
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.484685	0.013021	37.22329	0
GEFF	0.024695	0.007923	3.11675	0.0025
ENV	-0.12108	0.030599	-3.95689	0.0002
ENG	0.012516	0.002161	5.792512	0
GDPC	-3.70E-06	1.32E-06	-2.80377	0.0062
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.969062	Mean dependent var		0.477966
Adjusted R-squared	0.966185	S.D. dependent var		0.04724
S.E. of regression	0.008687	Akaike info criterion		-6.56406
Sum squared resid	0.00649	Schwarz criterion		-6.32211
Log likelihood	320.7926	Hannan-Quinn criter.		-6.46629
F-statistic	336.7242	Durbin-Watson stat		0.617923
Prob(F-statistic)	0			

Source: Author’s data analysis using EViews 12

The Correlated Random Effects - Hausman Test is utilized to determine whether the preferred model for panel data analysis should be the fixed effects model or the random effects model. The test hinges on whether the unique errors (cross-section random effects) are correlated with the regressors; the null hypothesis suggests no correlation, implying that the random effects model is appropriate. In this case, the Chi-Sq. Statistic of 69.234009 with 4 degrees of freedom and a p-value of 0 indicates that the null hypothesis is rejected, favoring the fixed effects model. The test summary shows that variables like GEFF, ENV, ENG, and GDPC exhibit differences in their coefficients

between the fixed and random effects models, with GEFf having a notable p-value of 0.0754, indicating some statistical significance in the difference. The fixed effects model results, provided in the test equation summary, reveal significant coefficients for all variables, demonstrating their impact on the dependent variable VUL (vulnerability). The model explains 96.91% of the variance ($R\text{-squared} = 0.969062$) with high significance ($\text{Prob(F-statistic)} = 0$), confirming the robustness of the fixed effects approach for this panel data set.

Table 1.6: Fixed Effective Model (Least Square Dummy Variable) Estimation Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.484685	0.013021	37.22329	0
GEFF	0.024695	0.007923	3.11675	0.0025
ENV	-0.12108	0.030599	-3.95689	0.0002
ENG	0.012516	0.002161	5.792512	0
GDPC	-3.70E-06	1.32E-06	-2.80377	0.0062
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.969062	Mean dependent var	0.477966	
Adjusted R-squared	0.966185	S.D. dependent var	0.04724	
S.E. of regression	0.008687	Akaike info criterion	-6.56406	
Sum squared resid	0.00649	Schwarz criterion	-6.32211	
Log likelihood	320.7926	Hannan-Quinn criter.	-6.46629	
F-statistic	336.7242	Durbin-Watson stat	0.617923	
Prob(F-statistic)	0			

Source: Author’s data analysis using EViews 12

The panel least squares regression analysis examines the dependent variable VUL across a sample period from 2002 to 2020, including 19 periods and 5 cross-sections, resulting in a balanced panel of 95 observations. The model incorporates fixed effects for each cross-section, as indicated by the cross-section dummy variables. The

estimated coefficients for the independent variables are as follows: GEFF (government effectiveness) positively impacts VUL with a coefficient of 0.024695 ($t=3.11675$, $p=0.0025$); ENV (environmental factor) negatively impacts VUL with a coefficient of -0.121077 ($t=-3.956893$, $p=0.0002$); ENG (energy use) has a positive effect with a coefficient of 0.012516 ($t=5.792512$, $p=0.0000$); and GDPC (GDP per capita) negatively affects VUL with a very small coefficient of -3.70E-06 ($t=-2.803773$, $p=0.0062$). The intercept (C) is 0.484685, highly significant ($t=37.22329$, $p=0.0000$). The model explains a substantial portion of the variance in VUL, with an R-squared of 0.969062 and an adjusted R-squared of 0.966185, indicating a strong fit. The standard error of the regression is 0.008687, and the F-statistic of 336.7242 ($p=0.0000$) confirms the overall significance of the model. However, the Durbin-Watson statistic of 0.617923 suggests potential autocorrelation in the residuals.

Table 1.7: Individual Country Intercept

VAR01	Effect
_CIV	0.00482
_GHN	-0.0015
_KNY	0.017709
_NIG	-0.00703
_SA	-0.014

Source: Author’s data analysis using EViews 12

The VAR01 effect represents the fixed effects for each of the five cross-sections (countries) included in the panel least squares regression analysis, indicating the individual country's unique impact on the dependent variable VUL, after accounting for the overall model. Côte d'Ivoire has a positive fixed effect of 0.00482, suggesting that, all else equal, the baseline level of VUL is slightly higher in Côte d'Ivoire compared to the reference category. Ghana, on the other hand, has a negative fixed effect of -0.0015, indicating a slight

decrease in the baseline level of VUL. Kenya shows a substantial positive fixed effect of 0.017709, suggesting a significantly higher baseline level of VUL relative to the reference. Conversely, Nigeria and South Africa both exhibit negative fixed effects, -0.00703 and -0.014 respectively, implying that these countries have lower baseline levels of VUL compared to the reference. These fixed effects capture the unique country-specific factors influencing VUL that are not explained by the other independent variables in the model.

1.5 Conclusion and Policy Recommendations

The fixed effects model applied to this study reveals several significant findings regarding the determinants of vulnerability (VUL) in selected Sub-Saharan countries. The analysis indicates that government effectiveness (GEFF) and energy consumption (ENG) positively impact vulnerability, while environmental sustainability (ENV) and GDP per capita (GDPC) have negative effects. Specifically, improved government effectiveness and higher energy consumption correlate with increased vulnerability, possibly due to inefficiencies or unsustainable practices in energy use. Conversely, better environmental sustainability and higher economic performance (as indicated by GDP per capita) are associated with reduced vulnerability. The high R-squared value (0.969062) suggests that the model explains a substantial portion of the variance in vulnerability, demonstrating its robustness. However, the Durbin-Watson statistic indicates potential autocorrelation issues that need to be addressed in future research to ensure the reliability of the results.

The Residual Cross-Section Dependence Test and the Breusch-Pagan test results indicate no significant cross-sectional dependence in the residuals, supporting the model's validity. The Hausman test favors the fixed effects model over the random effects model, further validating the choice of the fixed effects approach. The country-specific intercepts reveal that Kenya has a significantly higher baseline level of vulnerability, while Nigeria and South Africa have lower

baseline levels compared to the reference category. These findings underscore the importance of considering country-specific factors when developing policies to mitigate vulnerability. Overall, the study highlights the critical roles of government effectiveness, environmental sustainability, energy consumption, and economic performance in influencing vulnerability in Sub-Saharan Africa.

Policy Recommendations

Based on the study's findings, several policy recommendations can be made to reduce vulnerability in Sub-Saharan countries. Firstly, enhancing government effectiveness is crucial. Governments should focus on improving institutional quality, transparency, and efficiency to better manage resources and implement policies that reduce vulnerability. This could involve strengthening public administration, enhancing regulatory frameworks, and combating corruption to ensure that government actions effectively address the needs of vulnerable populations.

Secondly, promoting environmental sustainability is essential for reducing vulnerability. Policymakers should implement and enforce environmental regulations that encourage sustainable practices and reduce ecological degradation. Initiatives could include reforestation projects, sustainable agricultural practices, and investment in renewable energy sources. Additionally, addressing energy consumption patterns is important; transitioning to cleaner and more efficient energy sources can mitigate the negative impact of high energy consumption on vulnerability. Finally, economic policies aimed at boosting GDP per capita, such as fostering economic diversification, supporting small and medium enterprises (SMEs), and improving education and healthcare, can enhance economic resilience and reduce vulnerability. Tailoring these policies to the specific needs and contexts of individual countries, as highlighted by the country-specific effects, will be key to their success.

References

- Adams, S., & Asante, W. (2019). Politics of renewable energy in Africa: Nature, prospects, and challenges. *Innovation in Global Green Technologies*.
- Adekunle, I. A. (2021). On the search for environmental sustainability in Africa: the role of governance. *Environmental Science and Pollution Research*, 28(12), 14607-14620.
- Asongu, S. A., & Odhiambo, N. M. (2021). Enhancing governance for environmental sustainability in sub-Saharan Africa. *Energy Exploration & Exploitation*, 39(1), 444-463.
- Auriacombe, C., & Vyas-Doorgapersad, S. (2019). Critical considerations for the role of governments in the interface between good governance and sustainable development in developing countries. *International journal of eBusiness and eGovernment Studies*, 11(1), 1-15.
- Bernauer, T., & Schaffer, L. M. (2010). Climate change governance. CIS Working Paper, 60. <http://dx.doi.org/10.2139/ssrn.1661190>
- Bhuiyan, S. (2015). Adapting to climate change in Bangladesh: good governance barriers. *South Asia Research*, 35(3), 349-367.
- Bhuiyan, S. (2015). Adapting to climate change in Bangladesh: good governance barriers. *South Asia Research*, 35(3), 349-367.
- Carlsson, F., & Lundström, S. (2001). Political and economic freedom and the environment: the case of CO2 emissions. Department of Economics, Goteborg University, Goteborg.
- Chipalkatti, N., Le, Q. V., & Rishi, M. (2021). Sustainability and society: Do environmental, social, and governance factors matter for foreign direct investment? *Energies*, 14(19), 6039.
- Dornean, A., Chiriac, I., & Rusu, V. D. (2021). Linking FDI and Sustainable Environment in EU countries. *Sustainability*, 14(1), 196.
- Gyamfi, B. A., Adebayo, T. S., Bekun, F. V., Agyekum, E. B., Kumar, N. M., Alhelou, H. H., & Al-Hinai, A. (2021). Beyond environmental Kuznets curve and policy implications to promote sustainable development in Mediterranean. *Energy Reports*, 7, 6119–6129.
- IBRD. (1992). Governance and Development: The International bank for Reconstruction and Development. World Bank Group.
- Karimi, S., (2020) Role of Good Governance in Combating Climate Change in Africa: *Journal of cmsd Volume 7(3)*, 142-146
- Kweyu, R. M., Asokan, S. M., Ndesanjo, R. B., Obando, J. A., & Tumbo, M. H. (2023). Climate governance in Eastern Africa: The challenges and

- prospects of climate change adaptation policies. *State Politics and Public Policy in Eastern Africa: A Comparative Perspective*, 347-369.
- Le, H. T., Chang, Y., & Park, D. (2016). Governance, vulnerability to climate change, and green growth: International evidence. *Asian Development Bank Economics Working Paper Series*, (500).
- Leal Filho, W. (2010). Climate change and governance: state of affairs and actions needed. *International Journal of Global Warming*, 2(2), 128-136.
- Meadowcroft, J. (2009). Climate change governance. World Bank Policy Research Working Paper, 4941.
- Nguyen, Q. T. K. (2017). Multinationality and performance literature: A critical review and future research agenda. *Management International Review*, 57(3), 311–347
- Omri, A., & Mabrouk, N. B. (2020). Good governance for sustainable development goals: Getting ahead of the pack or falling behind?. *Environmental Impact Assessment Review*, 83, 106388.
- Oyeniya, T. A. (2012). Fundamental Principles of Econometrics, Cedar publishers (Nig.) Ltd, 349-359.
- Park, H. M. (2011): Practical Guides to Panel Data Modeling: A Step-by-Step Analysis using Stata. A training manual available online at <http://www.iuj.ac.jp/faculty/kucc625>, 1-35.
- Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2015). Does foreign direct investment impede environmental quality in high-middle-, and low-income countries? *Energy Economics*, 51, 275–287
- Shefiu, R., Peluola, S. B., & Adebayo, M. S. (2019). Good Governance as the 'Pivot' for Sustainable Development in Nigeria. Available at SSRN 3504155.
- Siddique, M. A. B., & Ghosh, R. N. (2015). Conclusion: Good Governance and Sustainable Development. In *Corruption, Good Governance and Economic Development: Contemporary Analysis and Case Studies* (pp. 259-264).
- Swart, R., Robinson, J., & Cohen, S. (2003). Climate change and sustainable development: expanding the options. *Climate policy*, 3(sup1), S19-S40.
- United nations (1992) Climate Action. Available Online. <https://www.un.org/en/climatechange/what-is-climate-change>
- Wikipedia (1983) Sustainable development. Available online. https://en.wikipedia.org/wiki/Sustainable_development

PART 2



Energy, Environment and Good Governance for Sustainable Development



2



Energy and Good Governance on Economic Growth in Sub-Saharan Africa

Paul Alaje

Abstract

The sub-Saharan Africa's economies have been under various outlooks and academic studies considering the concentration of the highest poor population of the world in this region. This has been associated with poor governance, low energy access and poor power sector. This situation coupled with the Paris Agreement to limit carbon emission to 1.5^o C which is below 2.0^oC and above the industrial level. The region in conformity and alignment with the Paris Agreement is faced with the responsibility of developing the energy sector sustainably by avoiding sources that increase carbon emission in its development approach. This study investigated The Impact of Energy and Good Governance on Sustainable Growth in sub-Saharan Africa Using Nigeria, Kenya and South Africa as a Case Study.

The study used secondary Panel Data from 1999 to 2023 fiscal year of the three countries and employed a regression model, F-test and R^2 coefficient of determination to ascertain the impact of energy and good governance on sustainable growth in the region. The result revealed that the independent variables; Access to clean energy, Access to Electricity Per Capita, Political Stability (including the absence of violence and terrorism), Population, Labour and renewable energy, CO_2 emission jointly impact Sub-Saharan Africa's economy positively with an R^2 result of 94.93% approximately. In other words, this indicates that for every rise in Energy and Good Governance, the region's economy will rise by 94.93%. The P-value result of 0.0000 indicates that it is significant. The regression result of individual variables shows that access to clean energy impacts the economy negatively when developed alone without considerable development of the public sector and the power sector. More so, for access to electricity, the result revealed that holding other variables constant, a rise in access to electricity will result in a consequential rise in the economies of the countries in sub-Saharan Africa. Population and Labour have impact economic growth positively with a coefficient 3542559 and $2.25E+12$. A coefficient of $-1.91E+12$ of renewable energy shows that renewable energy negatively impact economic growth. Lastly, CO_2 and political stability results revealed a positive relationship between the two independent variables and growth of the economies in the region with a coefficient result of $2.81E+13$ and $-7.31E+12$ respectively, however not statistically significant with p-values of 0.0000 and 0.0000 respectively. The study recommends that the government, private sector and stakeholders in energy sector within the sub-Saharan region must urgently prioritise joint investment in clean energy, electricity, political stability and CO_2 emission reduction because it will boost the economies in the region.

Keywords: Energy, Good Governance, government,
Sub-Saharan Africa

2.1 Introduction

Energy is a key component that propels economic growth, especially in Sub-Saharan Africa (SSA). Nonetheless, the area confronts several obstacles in efficiently utilizing its energy reserves to foster enduring economic expansion. Even though the region has an abundance of energy resources, governance mechanisms must be effective in maximizing these resources' potential and guaranteeing fair access to energy services in order to support sustainable economic growth in Sub-Saharan Africa (SSA).

According to International Energy Agency (IEA) (2014), energy may play a bigger role in driving inclusive economic and social growth. It is now generally acknowledged that SSA nations must have a dependable and effective energy supply in order to achieve sustainable economic growth and alleviate poverty (Turkson and Wohlgemuth, 2001). It is crucial to note that although SSA has an abundance of energy resources, its supply of energy is extremely inadequate. Thus, it becomes imperative to provide broadly accessible, affordable, and reliable energy to support the development of an area that has 13% of the world's population but just 4% of its energy consumption (IEA, 2014). Approximately two-thirds of the world's population or over 620 million people lack access to electricity. More than 60% of people still rely on biomass as their primary energy source, which includes crop leftovers, firewood, and charcoal, even in this highly developed era. When we take into account that, in the early 2000s, the typical African's energy consumption was less than that of an average British person in England over a century ago, the situation becomes even more dire (Davidson and Sokona, 2002).

Due to the region's inadequate energy infrastructure, Sub-Saharan Africa has become the focus of attention for the global energy poverty crisis, according to the IEA (IEA, 2014). It is important to note, nevertheless, that things are improving. For instance, energy consumption has increased by more than 45% in the past ten years (since 2000), and almost 145 million more people now have access

to power. Overall, the SSA's rate of power availability increased from 23% in 2000 to 32% in 2012. Is the region's economy growing more favourably as a result of the sharp expansion of the energy infrastructure? The paper aims to answer this important question.

There is disagreement regarding the relationship between energy and growth, despite the fact that numerous studies have been done in this regard (see, for instance, Soytaş and Sari, 2007; Menyah and Wolde-Ru-fael, 2010; Eggoh et al., 2011; Shahbaz et al., 2013; Omri and Ka-houli, 2014). The various political, economic, and sociocultural elements that exist in the various nations and regions of the world have been suggested as the cause of the disparate results (Squalli, 2007; Ozturk, 2010; Karanfil and Li., 2015).

As a result, a number of recent studies have looked at a few of these factors, such as the cost of energy (Asafu-Adjaye, 2000; Odhiambo, 2010), net energy imports and exports (Eggoh et al., 2011), the degree of financial development (Shahbaz et al., 2013; Tang and Tan, 2014), developments on a national and international scale (Belke et al., 2010), tourism (Tang and Abosedra, 2014), urbanisation (Karanfil and Li, 2015), and information and communications technology (Technology and applications). None of these, meantime, have taken into account the governance framework that guides the formulation of energy policy decisions. Put another way, to our knowledge, no study has examined how characteristics such as governance, regulatory regime, kind of regime, or other factors affect or mitigate the energy-growth relationship. This work aims to close this gap. We do this experimentally by analysing the impact of political system democratisation on the energy-growth link in SSA nations with comparable socioeconomic and cultural conditions. The regression estimations' bias is lessened by the comparable features.

According to the IEA (2014) research, the establishment of efficient governance frameworks is a crucial prerequisite for African nations to achieve their development goals. According to the research, insufficient regulatory and legal frameworks, corruption, and a lack

of accountability and transparency are all results of ineffective institutions. Deepening democratic systems is one important element that has been shown to reduce these failures. It is noteworthy that numerous nations in the area have attempted, with differing degrees of success, political system reforms during the past forty years. This is consistent with the ecological ideas, which as addressed in the works of Aristotle and Montesquieu, demonstrate a relationship between the physical location, the personalities of the population, and their governments. So, the query is: What impact are political or governmental reforms having on the link between energy and growth? There isn't much study done in this field.

Consequently, by investigating how democratisation is affecting the energy-growth link, the study adds to the body of literature. This research is crucial because a nation's changing political and socioeconomic landscape affects how energy is provided and consumed (Moss, 2014). The literature review is presented in the following sections, which are followed by a discussion of the methodology, the data, an analysis of the findings, and recommendations for policy.

2.2 Literature Review

Numerous studies have been conducted to identify the type of relationship that exists between energy and the growth of the economy. While some of the studies in this field are panel studies, others are country-specific investigations. The outcomes though have been equivocal. A number of the research support the "growth hypothesis," which holds that economic expansion is a result of energy use. The "conservation hypothesis," which holds that rising economic growth leads to rising energy consumption, is supported by several additional studies. The feedback hypothesis is another type of hypothesis that arises when there is a two-way causal relationship between economic growth and energy use. The last category, known as the "neutrality hypothesis," arises when there is no causal relationship between energy use and economic growth.

The purpose of this paper is to support one of these claims and add to the body of material already in existence (Ayobami et al, 2018).

2.2.1 Energy Sector Governance

Corruption, inefficiency, and a lack of transparency are just a few of the governance problems that have beset the energy industry in several SSA nations. Inadequate governance structures frequently lead to resource mismanagement, regulatory lapses, and impeded investment in energy infrastructure. Transparency, accountability, and strong regulatory frameworks are hallmarks of good governance, and they are essential to guaranteeing the economical use of energy resources and creating an atmosphere that is favourable to sustained economic growth.

2.2.2 The Nexus Between Energy, Governance, and Economic Growth

According to (Ayobami et al., 2018), the literature currently in publication indicates that the relationship between energy, governance, and economic growth is intricate and multifaceted. Increased investment, better infrastructure, and better service delivery are all possible outcomes of good governance in the energy industry, which can also boost economic growth and enhance energy access. On the other hand, bad governance can worsen energy poverty, impair the functioning of the energy sector, and impede economic growth. Corruption, unstable political environments, and ineffective regulations frequently result in inefficient use of resources and delivery of energy, which limits the potential for overall economic growth.

2.2.3 The Physical Theory of Production

One of the most important ideas in production economics is reproducibility. While some production inputs cannot be produced again, others can be produced economically within the system of

economic production at a cost. While intermediate inputs are those created during the production period under consideration and are completely used up in production, primary factors of production are those that exist at the beginning of the period under consideration and are not directly used up in production (though they can be degraded and added to). These definitions are obviously somewhat ambiguous. The main components of production, according to mainstream economics, are land, labour, and capital; items like fuel and materials are considered intermediate inputs. In the end, the prices paid for each distinct input are viewed as payments made to the principal input owners for the services rendered, either directly or through the production of intermediate inputs (Stern, 1999).

2.2.4 The Mainstream Theory of Growth

Although there is nothing intrinsic to economics that limits the potential role of resources in the economy, conventional production and growth theory has an ingrained bias to minimise the importance of resources in the economy. The 1956 study of Solow, who won the Nobel Prize, provides the fundamental theory of economic growth and makes no mention of resources. Later, non-renewable resources, renewable resources, and certain waste absorption services were included to this model (for surveys see Kamien and Schwartz, 1982; Toman et al., 1994). However, these extended models are not used in conventional macro-economic applications; rather, they are exclusively utilised in discussions concerning environmental sustainability.

Few studies as indicated in the empirical review showed the relationship between energy and sustainable economic growth. Pao and Fu (2013), used annual data covering 31 years (1980-2010) to investigate the relationship between various energy sources and economic growth in Brazil. The findings demonstrated that renewable energy has a causal relationship and a favourable impact on economic growth. The authors recommended that further

incentives be used by policy makers to promote the usage of renewable energy sources in Brazil. Similarly, Leitaó (2014) examined the connection between globalisation, carbon emissions, economic growth, and renewable energy in Portugal. The author used a number of econometric tests, such as the Granger causality tests, the generalised technique of moments, and ordinary least squares, to achieve this goal. Globalisation, renewable energy sources, and carbon emissions have all been shown to favourably impact economic growth. Furthermore, the growth hypothesis was validated.

Thombs (2017) examined the connection between economic growth and renewable energy using a panel of 129 nations. Various results were found for nations belonging to distinct income brackets. The usage of renewable energy is found to have a negative impact on carbon emissions most significantly in low-income countries, but not much in high-income countries. Armeanu et al. (2017) found that their analysis of 28 EU member states between 2003 and 2014 supported the growth theory in both the short and long terms. When renewable energy was broken down into its various forms, the same results were found.

Kocak and Sarkgunesi (2017) investigated the relationship between economic growth and renewable energy in nine Balkan and Black Sea nations. For each of the several nations, various outcomes were found. With the exception of one nation that sided with the neutrality hypothesis, the majority of the countries endorsed the growth hypothesis while the remaining nations supported the feedback hypothesis. However, Kahia et al. (2017) investigated the connection between the disaggregated energy consumption and economic growth for a panel of 11 net oil-importing Middle Eastern and North African (MENA) nations. They employed annual data from 1980 to 2012. In the long and short runs, the feedback hypothesis was verified for both forms of energy. In a similar vein, the findings of Lin and Moubarak (2014) for China provided support for the feedback. Apergis and Payne (2011), Sebri and Salha (2013), Cho et al.

(2015), Amri (2017), Ben Jebli et al. (2015), and Troster et al. (2018) are among the other studies that back up the feedback theory.

The focus of study has recently changed to determine if using renewable energy affects greenhouse gas emissions, particularly CO₂ emissions. Silva et al. (2012) examined the relationship between economic growth and carbon emissions in a panel of four nations and the growing proportion of renewable energy sources in power generation. It's interesting to note that the scientists discovered a negative correlation between economic growth and carbon emissions and an increase in the proportion of renewable energy. They advocated for the implementation of complementing policies for renewable energy, like demand management and energy saving measures.

According to Abolhosseini et al. (2014), there is a positive correlation between economic growth and carbon emissions within the EU-15. Reducing carbon emissions was more successfully accomplished through government support systems. The writers emphasised that having a cleaner environment did not require economic growth. Therefore, even in the absence of significant economic growth, developing nations could reach cleaner ecosystems.

Farhani (2015) found that, for a group of 12 MENA countries, there was only a unidirectional causal relationship from renewable energy consumption to carbon emissions in the short run. There was no other causal relationship between renewable energy consumption, economic growth, and carbon emissions. Eventually, nevertheless, the author found that usage of renewable energy was the result of unidirectional causality between economic growth and carbon emissions. Boontome et al. (2017) conducted research on Thailand to discover the causal relationship between different forms of energy use, CO₂ emissions, and economic growth. The authors verified the presence of co-integration and causation flows from non-renewable energy use to CO₂ emissions using annual data spanning from 1971 to 2013. It was suggested by them that Thailand should utilise more renewable energy. Brini et al. (2017) were able to look into the

relationship between the price of non-renewable energy (oil price), economic growth, and the consumption of renewable energy using data from Tunisia. Using annual data from 1980 to 2011, the authors applied the ARDL model and discovered a positive correlation between the price of oil and the use of renewable energy. It was also shown that there is a one-way relationship between the price of non-renewable energy and the amount of renewable energy consumed. In the context of governance, a number of SSA case studies offer empirical insights into how energy affects sustainable economic growth. Strong governance framework nations like Ghana and Rwanda have made great progress in increasing energy access, encouraging the use of renewable energy sources, and supporting inclusive economic growth. With an emphasis on the function of good governance, this research seeks to investigate the relationship between energy availability, utilisation, and sustainable economic growth in SSA.

2.3 Research Method

2.3.1 Nature and Sources of Data

This study used secondary annual panel data spanning from 2000 to 2024. The model employed for the purpose of this study relied on annual data from selected country across the sub-Saharan Africa using Nigeria, Kenya and South Africa as a case study. The data includes; political stability, CO2 emissions, Access to clean energy, GDP, Electric Power consumption per capital gotten from Central Bank of the various countries respectively and World Bank Indicator Data respective.

2.3.2 Model Specification

In order to assess the relationship existing between the independent variables and the dependent variables, it is of importance to specify the model. Model specification involves the identification of the

endogenous and exogenous variables that will be included in the model during the analysis. Thus, in order to specify a model, this study will mathematically express the chosen model;

$$RGDPG_t = \alpha_0 + \beta_1 ELECTC_t + \beta_2 POL_t + \beta_3 ACC - C_t + \beta_4 CO_2 t + \mu t$$

Where RGDP = Real Gross Domestic Product (GDP) Growth, **ELECTC**= is for Electricity Consumption per capita, Good governance proxy by Political stability = POL, ACC-C = Access to Clean Energy, CO₂ = Carbon Emission and Lastly α , β = Intercept, Coefficients, μ = Error Term it depicts the discrepancies of a variable observed value from its real value and it is also known as the residual value, and t proxied time.

2.3.3 The Coefficient of Determination (R^2)

One important metric to evaluate the goodness of fit of our regression model is the coefficient of determination (R^2). According to Shaun (2023), the coefficient of determination ranges from 0 and 100% and it evaluates the degree to which a statistical model defines the outcome.

A higher R^2 value indicates that the model is of good quality to the data, also revealing that energy consumption plays a significant role in shaping sustainable economic growth outcomes of the examined countries. R-squared is a statistical measure of how close the data are to the fitted regression line.

$$R^2 = \text{Explained variation} / \text{Total variation}$$

Hence, R^2 less than 50% indicates that the independent variables can only explain a little proportion of the dependent variable and above 50% indicates most variations can be explained by this model.

2.3.4 The F-test

The F-Statistics here, examine the null hypothesis to ascertain the overall significance of the variables. That is, to evaluate whether the coefficient of independent variables in the regression model aggregately are not statistically different from zero. The null hypothesis is given as $H_0: \beta_0 = \beta_1 = \beta_2 = \dots = \beta_n = 0$, against $H_1: \beta_0 = \beta_1 = \beta_2 = \dots = \beta_n \neq 0$.

2.4 Results

Table 2.1: Descriptive Statistics Result

Statistics	Access to Clean Energy	Access to Electricity	Co2 Emission	Political Stability	GDP	Population	Labour	Renewable Energy
Mean	21.72732	46.10985	2.104506	-1.274991	2.64E+13	48410521	63.85869	57.09227
Median	5.600000	48.98446	0.450979	-1.374036	5.57E+12	34618175	60.24300	77.88000
Maximum	88.40000	90.00000	8.446650	0.215347	2.02E+14	1.18E+08	74.41000	88.68000
Minimum	0.500000	4.807798	0.025112	-2.699193	9.07E+11	15446878	54.17000	7.720000
Std. Dev.	30.33898	28.36853	3.119847	0.733848	4.58E+13	30106622	7.020393	33.62263
Skewness	1.251172	0.015839	1.176570	0.466530	2.210064	0.893510	0.579140	-0.672133
Kurtosis	2.861564	1.586345	2.460252	2.034569	7.079893	2.366807	1.554899	1.516506
Jarque-Bera	25.38528	8.330934	24.28581	7.210630	110.0568	10.78312	10.71853	11.02146
Prob.	0.000003	0.015522	0.000005	0.027179	0.000000	0.004555	0.004704	0.004043
Sum	2107.550	4610.985	210.4506	-122.3991	1.92E+15	3.49E+09	4789.402	3768.090
Sum Sq. Dev.	88363.57	79672.56	963.6112	51.16067	1.51E+29	6.44E+16	3647.158	73481.29
Obs.	97	100	100	96	73	72	75	66

Source: Authors Survey (2023)

The descriptive statistics is revealed the characteristics of the variables in the OLS regression model. It provides measures of location and dispersion together with a descriptive explanation of the data distribution used in this model. Table 2.1 contains the result of descriptive statistics; Access to Clean Energy, Access to Electricity, Co2, Political Stability, GDP, Population, renewable energy and Labour. Their mean values are; 21.72732, 46.10985, 2.104506, -1.274991, 2.64E+13, 48410521 57.09227 63.85869 respectively. Considering the mean value falling in between the maximum and minimum values, the mean as well as the median values are consistent for all the variables in the model. Skewness result shows

how symmetric the panel data is. In other words, whether it is symmetrically positive or symmetrically negative or central within its mean. All of the relevant variables are positively skewed, according to the skewness values, with the exception of the GDP growth rate, which is negatively skewed. This suggests that the tail of the distributions tends to the lower value for the GDP growth rate and to higher values for all the variables.

The kurtosis however measures kind of distribution of the variables which can either be peak-topped (i.e. leptokurtic, $K > 3$), flat-topped (i.e. platykurtic, $K < 3$) or normal (i.e. mesokurtic, $K = 3$). The result showed that all variables are flat-topped with their $K < 3$, except for GDP whose Kurtosis value is above 3, hence peak-topped.. The Jarque-Bera (JB) statistic is used to test for the normality of a distribution. The null hypothesis of normality is rejected if its p-value > 0.05 and if otherwise, it is accepted. Thus, all the variables under consideration are not normally distributed with their p-values less than 0.05.

Table 2.2: Unit Root Test Result (Constant)

Variables	PP-Fishers		ADF Test		Im. Pesaran and Shin W-stat	
	Statistics	Prob	Statistics	Prob	Statistics	Prob
D(Political Stability)	573.481	0.0000	49.1425	0.0000	-6.70166	0.0000
D (CO2 Emissions Metric Tons per Capita)	69.4656	0.0000	31.6733	0.0001	-4.28705	0.0000
D(Access to Electricity of POP)	316.323	0.0000	36.9473	0.0000	-5.02493	0.0000
D (Access to Clean Fuels and Techn,2)	797.147	0.0000	37.6066	0.0000	-3.52943	0.0002
(GDP)	27.7776	0.0001	16.6205	0.0108	-2.32959	0.0099
D(Population,2)	39.6851	0.0000	31.7183	0.0000	-4.57748	0.0000
Renewable Energy	111.645	0.0000	31.6586	0.0000	-4.75205	0.0000
D(Labour, 2)	449.368	0.0000	43.6214	0.0000	6.35112	0.0000
Variables	Levin, Lin & Chu t*					
Political Stability	-5.16251	0.0000				
D(CO2 Emissions Metric Tons per)	-3.91226	0.0000				
D(Access to Electricity of POP)	3.74210	0.0001				
D(Access to Clean Fuels and Techn ,2)	107.613	1.0000				
D(GDP Growth Annually GDPM)	-1.61990	0.0526				
D(RENEW,2)	2.43224	0.0075				
D(Labour, 2)	-4.63273	0.0000				

Source: Author’s Computation (2024)

The unit root test is applied to examine the stationarity of the panel data prior to the performance of data analysis to answer the objective of this research. This is because the use of data that are not stationary can result to spurious regression results and hence, to prevent it, a unit root test is conducted on all variables. In other to assess the stationarity of the panel data, Augmented Dickey Fuller (ADF), PP-Fisher, Im. Pesaran and Shin W-stat , Levin, Lin & Chu t* and Breitung t-stat were used for this analysis. The result of the stationarity revealed that most of the variables; GDP, political stability (absence of violence and Terrorism), Co2 emission, population, labour and renewable are all stationary as their result is less than

the significant value of 0.05. D(GDP) has a significant level of 0.05 approximately 0.05 and hence, still significant for Levin, Lin & Chut.

Table 2.3: Summary of Regression Result

Dependent Variable: GDP Growth Annual
Cross-sections included: 4
Total panel (unbalanced) observations: 96

Variables	Coefficient	Standard Error	T-Statistics	Probability
Co2_Emissions Metric Tons Per Capita	2.81E+13	3.48E+12	8.069059	0.0000
Access to Electricity (%) of Population.	6.66E+10	1.42E+11	0.470032	0.6401
Access to Clean Fuels and Technology	-1.02E+12	2.15E+11	-4.763362	0.0000
Population	3542559.	189327.8	18.71124	0.0000
Labour	2.25E+12	9.61E+11	2.343953	0.0226
Political_stability and Absence of Terrorism	-7.31E+12	1.35E+12	-5.405799	0.0000
Renewable Energy	-1.91E+12	1.67E+11	-11.48102	0.0000
C	-1.82E+14	5.90E+13	-3.085181	0.0031
R ² = 0.949397 Adjusted R ² = 0.943182	F-Stat = 152.7722 Durbin-Watson Stat = 2.041146	Prob. (F-Statistics) = 0.000000		

Source: Authors Survey (2023)

1. **Co2 Emission:** The coefficient of Co2 Emission showed that when other independent variables are held constant, a change in GDP by 2.81E+13 which is 28,100,000,000,000 can be associated to increase in metric tons per capita of CO₂ Emitted. However, considering the T-statistics of 8.069059 and significant P value of 0.0000, hence the result is significant. This is because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. In other words, Co2 Emission cannot increase the growth rate in sub-Saharan Africa.
2. **Access to Electricity:** On the other hand, the coefficient of access to electricity reveals that holding other independent variables constant, a rise in GDP by 6.66E+10 which can be

translated to 66,600,000,000 change in GDP can be associated to rise in access to electricity. Additionally, with consideration on the T-statistics of 0.470032 and significant P value of 0.6401, the result is not significant. Since, the absolute value of T-statistics is less than 2.00 and significant level is greater than 5%. In other words, Access to electricity increases the GDP in sub-Saharan Africa but not statistically significant.

3. **Access to Clean Energy:** The coefficient of access to clean energy reveals that holding other independent variables constant, rise in access to clean energy leads to consequential fall in GDP by $-1.02\text{E}+12$ which is translated to -10,200,000,000. However, considering the T-statistics and significant level, the result is significant. This is because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. However, this can be so because current records of clean energy are but a few compared to the contribution of fossil fuel in the economy currently. Hence, with this supporting evidence, access to clean energy though revealed a negative impact on gross domestic product in sub-Saharan Africa. This could be a call for more investment in clean energy since the result can be associated to the rising nature of the sector with small contribution of the sector to the overall energy use in Sub-Saharan Africa.
4. **Population:** The coefficient of political stability of 3542559 revealed that holding other independent variables constant, increase in population will result to a 3542559 increase in GDP of sub-Saharan Africa; a case study of Nigeria, South Africa and Kenya. The T-statistics of 18.71124 and significant P value of 0.0000 indicates that the result is not significant. This is because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. In other words, Population can significantly increase the economic growth rate in sub-Saharan Africa.

5. **Labour:** The coefficient of labour of $2.25E+12$ revealed that holding other independent variables constant, labour will result to a $2.25E+12$ in other word, 2,250,000,000,000 increase in economic growth rate of sub-Saharan Africa; a case study of Nigeria, South Africa and Kenya. The T-statistics of 18.71124 and significant P value of 0.0000 indicates that the result is significant. This is because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. In other words, labour can significantly increase the growth rate in sub-Saharan Africa.
6. **Political Stability:** The coefficient of political stability of $-7.31E+12$ revealed that holding other independent variables constant, political stability including absence of terrorism and violence will result to a $-7.31E+12$ decrease in economic growth rate of sub-Saharan Africa; a case study of Nigeria, South Africa and Kenya. The T-statistics of 5.405799 and significant P value of 0.0000 indicates that the result is significant. This is because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. In other words, political stability can significantly decrease the growth rate in sub-Saharan Africa. However, the data on political stability revealed the rate at which political stability and absence of terrorism exist in the region. Hence, the result shows that political instability and the rate of terrorism existence in the region as most of the result shows negative rather than positive. In other words, where terrorism and instability exist, economic growth (GDP) falls.
7. **Renewable Energy:** The coefficient of Political Stability of $-1.91E+12$ revealed that holding other independent variables constant, political stability including absence of terrorism and violence will result to a $-1.91E+12$ increase in economic growth rate 2of sub-Saharan Africa; a case study of Nigeria, South Africa and Kenya. The T-statistics of -11.48102 and significant P value of 0.0000 indicates that the result is not significant. This is

because the absolute value of T-statistics is greater than 2.00 and significant level is less than 5%. In other words, renewable energy leads to significantly decrease in the economic growth rate of sub-Saharan Africa. However, this result can be largely associated to small contribution of the sector to the economic growth. Hence, indicating that the current impact on economic growth of the region is still negative rather positive.

- 8. **Constant (C):** Constant of the regression indicates -1.82E+14 and this is indicating that para-adventure if all exogenous variables are zero, the expected value of the dependent variable of the regression GDPG (i.e) Gross Domestic Product Growth Rate of the sub-Saharan Africa is -1.82E+14. The t-statistic of -3.085181 and P-value of 0.0031 indicates that the constant is statistically significant at the 5% level and the T-statistics in absolute term is greater than 2.00 also support the evidence provided by the P-value.

Table 2.4: Result For F-test
Dependent Variable: GDPGt

Probability(F-Statistics)	Decision Rule	Conclusion
0.000000	Less than 0.05	Jointly Significant

The result shows F-statistics probability less than 0.000000 which is less than 0.05 critical value, hence the null hypothesis is rejected that the independent variables does not jointly influence the dependent variables. In other words, the independent variables jointly influence the dependent variables and it therefore can be concluded that the overall variable is statistically significant.

The value of R-squared for the model also **0.949397** indicating that the independent variables will jointly influence the dependent variable by 94.94%. In essence, 94.94% growth rate of sub-Saharan Africa, a case study of Nigeria, Kenya and South Africa can be jointly

explained by access to clean energy, access to electricity per capita, population, labour, political stability (including absence of violence and terrorism), renewable energy and Co2 emission in the region.

The Adjusted R-squared indicates the possibility of over-estimation of r-squared regarding the model success. The result of Adjusted R² **of 0.943182** showing that the Adjusted R² is not far from the value R². Hence, the success of the model is not over-estimated.

2.4.1 Autocorrelation

The Durbin-Watson test result revealed that there is autocorrelation since the assumption says a Durbin Watson result between 1.5 to 2.0 no autocorrelation. The result of the Durbin Watson test shows 0.782660 hence, autocorrelation exist but was adjust using HAC.

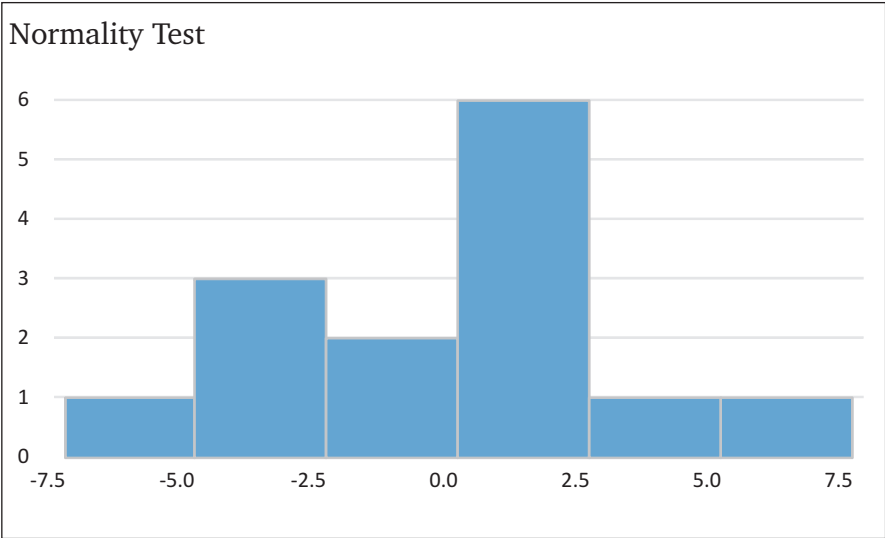


Figure 2.1: Normality Test

Series: Standardized
Residuals
Sample 2001 2012
Observations 14

Mean	-1.21e-15
Median	0.531042
Maximum	6.797022
Minimum	-6.944054
Std. Dev.	3.555151
Skewness	-0.048819
Kurtosis	2.881313

Jarque-Bera	0.013778
Probability	0.993135

2.5 Conclusion and Recommendation

All availability of Energy and good governance in the Sub-Saharan Africa economy impact the economy positively and significantly. It then revealed that a rise in the development of both the public sector, environment, human capital and energy in the sub-Saharan Africa will witness a rise in growth. In fact, according to the data, 94.94% of the change in economic growth proxy by GDP can be associated to an increase in development of public sector, environment, energy and human capital and this connote a sustainable development.

The result independently also revealed impact of isolated development of one the sectors rather than joint development. The result revealed that access to clean energy development may not yield considerable growth unless combined with a developing public sector and power sector as the result shows a negative coefficient of -16.3% that is significant. Moreover, it also revealed that the sector is still in its growth or rather the early phase. Due to this as recorded by data from World Development Indicator (WDI),

its impact on economic growth currently may reveal a negative impact since it contains a smaller proportion of the energy access in the region. Hence, there is need for more investment in the sector in order to promote tangible contribution of the sector. On the other hand, development of Power sector indicates a positive growth on the economy of the region with a positive coefficient indicating that power sector can pull the economic growth positively since it impacts both household and private. Hence, driving production in the region which substantially lead to economic growth and increase in productivity. On the other hand, public sector is the sector that manage policies creation that affect both the household and private sectors. However, the result shows that political stability and absence of terrorism negatively impact economic growth. However, this is because the data released indicated negative and little score of stability for the economies examined. Hence, it therefore indicates that political stability in the region still require more attention. This also revealed that situations where political stability is not yet completely guaranteed, economic growth of that region, contribution of public sector of that region to economic growth will result be negative in the region. More so, development of human capital (labour and population) indicates a positive impact on economic growth and hence, it therefore means a conscious investment on human capital leads to economic growth. As mentioned earlier, a rise in these sectors will jointly impact economic growth positively and significantly. In essence, the region should prioritize the development of these examined sectors.

References

- Abolhosseini, S., Heshmati, A., Altmann, J. (2014), The Effect of Renewable Energy Development on Carbon Emissions Reduction: An Empirical Analysis for the EU-15 Countries. IZA Discussion Paper No. 7989, Forschungsinstitut zur Zukunft der Arbeit/Institute for the Study of Labor.

- Alege, Philip/Jolaade, Ayobami et. al. (2018). Is there cointegration between renewable energy and economic growth in selected sub-saharan African countries?. In: *International Journal of Energy Economics and Policy* 8 (4), S. 219 - 226.
- Amri, F. (2017), Intercourse across economic growth, trade and renewable energy consumption in developing and developed countries. *Renewable and Sustainable Energy Reviews*, 69, 527-534.
- Apergis, N., Payne, J.E. (2011), On the causal dynamics between renewable and non-renewable energy consumption and economic growth in developed and developing countries. *Energy Systems*, 2(3-4), 299-312.
- Armeanu, D.S., Vintila, G., Gherghina, S.C. (2017), Does renewable energy drive sustainable economic growth? Multivariate panel data evidence for EU-28 countries. *Energies*, 10, 1-21.
- Asafu-Adjaye, J., 2000. The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Econ.* 22, 615–625.
- Belke, A., Dreger, C., de Haan, F., 2010. Energy consumption and economic growth-new insights into the cointegration relationship. *Ruhr Economic Papers* No. 190, pp. 1-22.
- Ben Jebli, M., Ben Youssef, S., Ozturk, I. (2015), The role of renewable energy consumption and trade: environmental kuznets curve analysis for sub-saharan Africa countries. *African Development Review*, 27(3), 288-300.
- Boontome, P., Therdyothin, A., Chontanawat, J. (2017), Investigating the Causal Relationship between Non-Renewable and Renewable Energy Consumption, CO2 Emissions and Economic Growth in Thailand. *International Conference on Alternative Energy in Developing Countries and Emerging Economies*. Bangkok, Thailand: *Energy Procedia*. p925-930.
- Brini, R., Amara, M., Jemmali, H. (2017), Renewable energy consumption, international trade, oil price and economic growth inter-linkages: The case of Tunisia. *Renewable and Sustainable Energy Reviews*, 76, 620-627.
- Davidson, O., Sokona, Y., 2002. A new sustainable energy path for African development: think bigger act faster. *Energy and Development*

- Research Centre, Cape Town, and the Environmental Development Action in the Third World, Senegal.
- Eggoh, J.C., Bangake, C., Rault, C., 2011. Energy consumption and economic growth revisited in African countries. *Energy Policy* 39, 7408–7421.
- International Energy Agency, 2014. *Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa*.
(http://www.iea.org/publications/freepublications/publication/weo2014_africaenergyoutlook.pdf) (accessed 20.07.15).
- Farhani, S. (2015), *Renewable Energy Consumption, Economic Growth and CO2 Emissions: Evidence from Selected MENA Countries*. IPAG Working Paper 612, IPAG Business School.
- Kahia, M., Aissa, M.S., Lanouar, C. (2017), *Renewable and non-renewable energy Use – Economic growth nexus: The case of MENA net oil importing countries*. *Renewable and Sustainable Energy Reviews*, 71, 127-140.
- Kamien M. I. and Schwartz, N. L. (1982) *The role of common property resources in optimal planning models with exhaustible resources*, in V.K. Smith and J. V. Krutilla (eds.), *Explorations in Natural Resource Economics*, Johns Hopkins University Press, Baltimore.
- Karanfil, F., Li, Y., 2015. Electricity consumption and economic growth: exploring panel-specific differences. *Energy Policy* 82, 264–277.
- Kocak, E., Sarkgunesi, A. (2017), *The renewable energy and economic growth nexus in black sea and balkan countries*. *Energy Policy*, 100, 51-57.
- Leitao, N.C. (2014), *Economic growth, carbon dioxide emissions, renewable energy and globalization*. *International Journal of Energy Economics and Policy*, 4(3), 391-399.
- Lin, B., Moubarak, M. (2014), *Renewable energy consumption – economic growth nexus for China*. *Renewable and Sustainable Energy Reviews*, 40, 111-117.
- Menyah, K., Wolde-Rufael, Y., 2010. Energy consumption, pollutant emissions and economic growth in South Africa. *Energ. Econ.* 32 (6), 1374–1382.
- Moss, T., 2014. Socio-technical change and the politics of urban infrastructure: Managing energy in Berlin between dictatorship and democracy. *Urban Stud.* 51 (7), 1353–1377.

- Odhiambo, N.M., 2010. Energy consumption, prices and economic growth in three SSA countries: a comparative study. *Energ. Policy* 38 (5), 2463–2469.
- Omri, A., Kahouli, B., 2014. Causal relationships between energy consumption, foreign direct investment and economic growth: Fresh evidence from dynamic simultaneous-equations models. *Energy Policy* 67, 913–922.
- Pao, H.T., Fu, H.C. (2013), Renewable energy, non-renewable energy and economic growth in Brazil. *Renewable and Sustainable Energy Reviews*, 25, 381–392.
- Sebri, M., Salha, O.B. (2013), On the Causal Dynamics between Economic Growth, Renewable Energy Consumption, CO₂ Emissions and Trade Openness: Fresh Evidence from BRICS Countries. Munich Personal RePEc Archive.
- Shahbaz, M., Khan, S., Tahir, M.I., 2013. The dynamic links between energy consumption, economic growth, financial development and trade in China: Fresh evidence from multivariate framework analysis. *Energy Econ.* 40, 8–21.
- Silva, S., Soares, I., Pinho, C. (2012), The impact of renewable energy sources on economic growth and CO₂ emissions-A SVAR approach. *European Research Studies*, 15 Special Issue, 133–144.
- Soytas, U., Sari, R., 2007. The relationship between energy and production: evidence from Turkish manufacturing industry. *Energy Econ.* 29 (6), 1151–1165.
- Squalli, J., 2007. Electricity consumption and economic growth: bounds and causality analyses of OPEC Members. *Energy Econ.* 29 (6), 1192–1205.
- Stern D. I. (1999) Is energy cost an accurate indicator of natural resource quality?, *Ecological Economics* 31: 381–394.
- Tang, C.F., Abosedra, S., 2014. The impacts of tourism, energy consumption and political instability on economic growth in the MENA countries. *Energy Policy* 68, 458–464.
- Thombs, R.P. (2017), The paradoxical relationship between renewable energy and economic growth: A cross-national panel study, 1990–2013. *Journal of World-Systems Research*, 23(2), 540–564.

- Toman M. A., J. Pezzey and J. Krautkraemer (1994) Neoclassical economic growth theory and sustainability, in D. Bromley (ed.), *Handbook of Environmental Economics*, Blackwell, Oxford.
- Troster, V., Shahbaz, M., Uddin, G.S. (2018), Renewable Energy, Oil Prices, and Economic Activity: A Granger-Causality in Quantiles Analysis. Munich Personal RePEc Archive.
- Turkson, J., Wohlgemuth, N., 2001. Power sector reform and distributed generation in sub-Saharan Africa. *Energy Policy* 29, 135–145.

Appendix

DependentVariable:GDP_GROWTH__ANNUAL____NY_GDP_MKTP_KD
ZG

Method:Panel LeastSquares

Date:05/12/24 Time:15:05

Sample:1999 2023

Periods included:25

Cross-sections included:4

Total panel (unbalanced) observations:95

Variable	Coefficient	Std. Error	t-Statistics	Prob.
ACCESS_TO_CLEAN_FUELS_AND_TE...	-0.162503	0.067866	-2.394480	0.0187
ACCESS_TO_ELECTRICITY____OF_PO...	0.082295	0.031209	2.636918	0.0099
CO2_EMISSIONS__METRIC_TONS_PER...	0.415238	0.612717	0.677699	0.4997
POLITICAL_STABILITY_AND_ABSENCE_...	2.133602	1.432664	1.489255	0.1399
C	4.885354	2.700372	1.809141	0.0738
R-squared	0.107898	Mean dependent var	3.214737	
Adjusted R-squared	0.068249	S.D. dependent var	5.109253	
S.E. of regression	4.931820	Akaike info criterion	6.080489	
Sum squared resid	2189.057	Schwarz criterion	6.214904	
Log likelihood	-283.8232	Hannan-Quinn criter.	6.134803	
F-statistic	2.721339	Durbin-Watson stat	2.041146	
Prob(F-statistic)	0.034372			

DependentVariable:GDP_GROWTH__ANNUAL____NY_GDP_MKTP_KD
ZG

Method:Panel LeastSquares

Date:05/12/24 Time:15:49

Sample:1999 2023

Periods included:25

Cross-sections included:4

Total panel (unbalanced) observations:95

Variable	Coefficient	Std. Error	t-Statistics	Prob.
ACCESS_TO_CLEAN_FUELS_AND_TE...	-0.127465	0.108991	-1.169506	0.2466
ACCESS_TO_ELECTRICITY____OF_PO...	0.051403	0.076866	0.668735	0.5061
CO2_EMISSIONS__METRIC_TONS_PER...	0.350564	2.395165	0.146363	0.8841
POLITICAL_STABILITY_AND_ABSENCE_...	2.596618	3.927960	0.661060	0.5110
C	6.259783	10.33289	0.605812	0.5468

Effects Specification

Cross-section fixed (dummy variables)

Period fixed (dummy variables)

R-squared	0.374956	Mean dependent var	3.214737
Adjusted R-squared	0.067395	S.D. dependent var	5.109253
S.E. of regression	4.934081	Akaike info criterion	6.293152
Sum squared resid	1533.744	Schwarz criterion	7.153405
Log likelihood	-266.9247	Hannan-Quinn criter.	6.640759
F-statistic	1.219127	Durbin-Watson stat	2.043853
Prob(F-statistic)	0.249178		

Stability Test

	ACCESS_T...	ACCESS_T...	CO2_EMIS...	POLITICAL_...	GDP_GRO...
Mean	21,72732	46,10985	2,104506	-1,274991	3,194352
Median	5,600000	48,98446	0,450979	-1,374036	3,784675
Maximum	88,40000	90,00000	8,446650	0,215347	15,32916
Minimum	0,500000	4,807798	0,025112	-2,699193	-36,39198
Std. Dev.	30,33898	28,36853	3,119847	0,733848	4,988965
Skewness	1,251172	0,015839	1,176570	0,466530	-4,995654
Kurtosis	2,861564	1,586345	2,460252	2,034569	41,16458
Jarque-Bera	25,38528	8,330934	24,28581	7,210630	6484,840
Probability	0,000003	0,015522	0,000005	0,027179	0,000000
Sum	2107,550	4610,985	210,4506	-122,3991	319,4352
Sum Sq. Dev.	88363,57	79672,56	963,6112	51,16067	2464,087
Observations	97	100	100	96	100

Unit Root

Panel unitroottest Summary

Series: D (POLIT_{it})

Date: 05/12/24 Time: 16:47

Sample: 1999 2023

Exogenous variables: Individual effects, individual linear trends

User-specified lags: 1

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unitroot (assumes common unitroot process)				
Levin, Lin & Chu t*	-5,16251	0,0000	4	84
Breitung t-stat	-5,00099	0,0000	4	80
Null: Unitroot (assumes individual unitroot process)				
Im, Pesaran and Shin W-stat	-6,70166	0,0000	4	84
ADF - Fisher Chi-square	49,1425	0,0000	4	84
PP - Fisher Chi-square	573,481	0,0000	4	88

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Panel unitroottest Summary

Series: D(GDP_GROWTH__ANNUAL____NY_GDP_M)

Date: 05/12/24 Time: 16:53

Sample: 1999 2023

Exogenous variables: Individual effects, individual linear trends

User-specified lags: 1

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unitroot (assumes common unitroot process)				
Levin, Lin & Chu t*	-5.68444	0.0000	4	88
Breitung t-stat	-5.20115	0.0000	4	84
Null: Unitroot (assumes individual unitroot process)				
Im, Pesaran and Shin W-stat	-6.22355	0.0000	4	88
ADF - Fisher Chi-square	46.0386	0.0000	4	88
PP - Fisher Chi-square	736.276	0.0000	4	92

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Panel unitroottest Summary

Series: D(CO2_EMISSIONS__METRIC_TONS_PER_)

Date: 05/12/24 Time: 16:54

Sample: 1999 2023

Exogenous variables: Individual effects, individual linear trends

User-specified lags: 1

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unitroot (assumes common unitroot process)				
Levin, Lin & Chu t*	-3.91226	0.0000	4	88
Breitung t-stat	-5.13792	0.0000	4	84
Null: Unitroot (assumes individual unitroot process)				
Im, Pesaran and Shin W-stat	-4.28705	0.0000	4	88
ADF - Fisher Chi-square	31.6733	0.0001	4	88
PP - Fisher Chi-square	69.4656	0.0000	4	92

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Panel unitroottest Summary

Series: D (ACCESS_TO_ELECTRICITY____OF_POP)

Date: 05/12/24 Time: 16:58

Sample: 1999 2023

Exogenous variables: Individual effects, individual linear trends

Userspecified lags: 1

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross- sections	Obs
Null: Unitroot (assumes common unitroot process)				
Levin, Lin & Chu t*	-3.74210	0.0001	4	88
Breitung t-stat	-4.08562	0.0000	4	84
Null: Unitroot (assumes individual unitroot process)				
Im, Pesaran and Shin W-stat	-5.02493	0.0000	4	88
ADF - Fisher Chi-square	36.9473	0.0000	4	88
PP - Fisher Chi-square	316.323	0.0000	4	92

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Panel unitroottest Summary

Series: D (ACCESS_TO_CLEAN_FUELS_AND_TECHN,2)

Date: 05/12/24 Time: 17:01

Sample: 1999 2023

Exogenous variables: Individual effects, individual linear trends

Userspecified lags: 1

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross- sections	Obs
Null: Unitroot (assumes common unitroot process)				
Levin, Lin & Chu t*	107.613	1.0000	4	81
Breitung t-stat	1.56090	0.9407	4	77
Null: Unitroot (assumes individual unitroot process)				
Im, Pesaran and Shin W-stat	-3.52943	0.0002	4	81
ADF - Fisher Chi-square	37.6066	0.0000	4	81
PP - Fisher Chi-square	797.147	0.0000	4	85

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

www.naee.org.ng

PART 3



Climate Change, Poverty and Good Governance





Assessing the Nexus Among Electricity Infrastructure, Foreign Direct Investment and Economic Growth in SSA

Mahmud Imam Hassan

Abstract

This study analysed the dynamic relationship among electricity infrastructure, foreign direct investment, and economic growth in Sub-Sahara Africa. The study assessed the extent of impacts among electricity infrastructure, foreign direct investment, and economic growth using the Generalised Method of Moments. The study utilises data from 44 Sub-Saharan African countries spanning 2017 to 2022. Findings from the study showed a negative but significant relationship between electricity infrastructure and foreign direct investment. The link between FDI and economic growth were positive and statistically significant in both directions. In line with the findings, the paper advocate for more electricity infrastructure development in the region to attract FDI. Policies of the SSA countries should endeavour to ensure a stable

macroeconomic environment for attracting more significant FDI for more economic growth.

Keywords: *Economic growth, electricity infrastructure, foreign direct investment, Sub-Saharan Africa.*

3.1 Introduction

Infrastructures are the basic physical structures or systems of a business, region or nations. It includes power systems, transportation systems, communication networks, water supply and school systems. Sub-Saharan Africa (SSA) is an extremely diverse region, composed of low, lower-middle, upper-middle, and high-income countries, twenty-two (22) of which are fragile or conflict-affected and thirteen (13) small countries characterized by a small population, limited human capital, and a confined land area (AfDB Report, 2019). Boasting rich natural resources and the world's largest free trade area and a 1.2-billion-person market (World Bank Report, 2022). The continent has the potential to forge a new development path, harnessing the potential of its resources and people but however may have been plagued with the lack of adequate or functional infrastructure in order to grow their economies. This poor state of infrastructure has engaged the attention of many African governments, especially in attracting both domestic and foreign investments, as the development of infrastructural facilities is one of the determinants of foreign direct investments inflow into any economy.

The countries in this region spent about 6–12 percent of their gross domestic product (GDP) each year on infrastructure, understood as comprising power, ICT, roads, water, and sanitation. Roughly half spend more than 8 percent of GDP, while only a quarter of countries spend less than 5 percent, the level commonly encountered among the countries of the Organization for Economic Co-operation and Development (OECD). Cape Verde, Ethiopia, and Namibia spend well above 10 percent of their GDP on infrastructure. In the few

middle-income countries of the region for which comparative information is available, the level of public spending is known to be between 6 and 8 percent of GDP. Governments are the most prominent financiers of infrastructure investment in Sub-Saharan Africa. Except in the middle-income countries, governments are responsible for between 80–90 percent of total capital investment, consistently allocating at least 80 percent of their infrastructure budgets to investment.

A developed electricity infrastructure is vital for the attraction of FDI in bridging the resource gap for economic growth. Thus, electricity-intense countries present an opportunity for attracting FDI and the realisation of economic growth and development. This is plausible due to increased industrialisation resulting from higher energy consumption (Tang, 2009). However, the opportunity to attract FDI could be constricted if the macroeconomic environment and policy uncertainty pose a great challenge to the development of the energy market. As such, a massive deficit in electricity infrastructure as experienced in the SSA may serve as a disincentive to investment, and ultimately, the growth of the economy.

The energy consumption-FDI-growth nexus has received some attention in the literature, due to the role played by energy and investment in economic growth. Iyabo and Segun (2014) in their study on countries of different income levels found a mixed outcome in this relation. Energy consumption was found to exhibit a two-way mutual relation with economic growth across the high, middle, and low-income countries, while one-way causation running from energy consumption to FDI was found only in high-income countries. A two-way relationship was also established between FDI and growth across all income levels. Further, a study by Mavikela and Khobai (2018) established a unidirectional causality flowing from FDI to energy consumption, and a bi-directional relationship between energy consumption and economic growth.

From the foregoing, the objective of the research is to assess the dynamics among electricity infrastructure, FDI, and economic growth in the SSA and to determine the extent of causality among them. In assessing the link, this study specified three system equations to establish the effects of energy consumption and FDI on growth using generalised method of moments (GMM) approach. The importance of this study to the literature stems from the fact that analysis of the interrelationship among electricity infrastructure, FDI, and economic growth in SSA is a nascent area in the literature. Previous studies have mainly concentrated on energy consumption, energy consumption-FDI, and FDI-growth relations. The main message is that efforts by African governments to close the electricity infrastructure gaps present huge investment opportunities to all types of investors, especially the private sectors and in turn a substantial increase in economic growth in the region. Therefore, this study attempts to assess the nexus among electricity infrastructure, foreign direct investment and economic growth in Sub-Saharan African countries.

In addition to the introductory section, the remainder of the study is rendered as follows: Section 2 provides economic theory, while Section 3 presents a description of the dataset used and the methodology. Section 4 discusses the empirical results, and Section 5 contains the conclusion and policy implications.

3.2 Problem Statement

Despite some notable achievements in recent years, the level of electricity infrastructure developments in SSA is still lower than other low-income regions. This makes it difficult for the countries in this region to attract investment leading to decline in economic growth (Osunkwo, 2020). For instance, the SSA has an average per capita electricity consumption of 200 kWh per year making it the lowest in the world (United Nations, 2018). Governments have pursued regional integration initiatives and infrastructure projects

to promote economic cooperation, enhance trade facilitation, and foster regional development. Efforts such as the African Union's Agenda 2063 and the Program for Infrastructure Development in Africa (PIDA) aim to address infrastructure deficits and promote sustainable development across the continent. Despite these efforts, challenges such as limited funding, governance issues, regulatory constraints, and inadequate maintenance continue to hamper infrastructure development in Sub-Saharan Africa.

For power generation, the figures are no better, with African LICs being 8 times worse-off (39 MW per million people compared to 326 MW) and MICs 3 times worse-off compared to their counterparts elsewhere. Despite that, the rate of both domestic and foreign direct investment is still very low than expected in Sub-Saharan Africa. At least, increasing infrastructure should necessarily reflect in the rate at which investments are generated; thereby leading to economic growth in the region. Hearing past promises from leaders, it is surprising that basic infrastructural development in the aspect of electricity, transport and ICT is still inadequate and a great challenge up till today that need to be looked into. Hence, this research on the assessment of the nexus among electricity infrastructure, foreign direct investment and economic growth in SSA.

3.2.1 Literature Review

The need to mobilize resources for development is as critical for African economies as it is elsewhere. Thus, since they gained political independence, many African governments have pursued policies such as tax incentives, special economic zones, and a multitude of economic and political reforms, to attract foreign investments. Naturally, the quest for foreign investments has attracted research attention, with policy makers wanting to know whether, in pursuing FDI as a supplemental development resource, they are "backing the right horse". This has yielded a long history of research on the link

between FDI and economic growth. One of the pioneering studies on this subject, Sharma and Abekah (2008), finds that a percentage change in FDI elicit a 0.71 percentage change in economic growth in a panel of African countries, concluding that host governments should devise policies to attract FDI. In a comparative assessment of foreign aid and FDI, Ndambendia and Njoupouognigni (2010) using a panel of for 36 Sub-Saharan countries for the period 1980-2007, find that both foreign aid and FDI impact economic growth, but the aid effect is low compared to the FDI effect. Similarly, Sackey, Compah-Keyeke, and Nsoah (2012) find that FDI had a positive impact on economic growth of Ghana for the period 2001-2010 and call for economic and policy reform to realize FDI's benefits. For Tunisia, Belloumi (2014) finds causality from FDI to economic growth for the period 1980–2008. The evidence until this point, appears consistent with a linear relationship between FDI and economic growth in various countries in the region.

Doytch and Narayan (2016) in their study of the energy consumption effect of sectoral FDI in a global panel of 75 countries from 1985 to 2012 using the GMM estimator found a negative effect of FDI on energy consumption for non-renewable energy sources, but the positive effect of FDI on the consumption of renewable energy sources, with divergence in the magnitude of effect across sectors.

Wang and Jiayu (2019) also studied the nature of the effect of FDI on energy consumption in the Shandong Province of China from 2000 to 2016. The study employed regression and simultaneous equation models and found a negative scale and structural but positive technical effect of FDI on energy consumption, thus concluding a negative total effect of FDI on energy consumption. In a recent study of 27 African countries, Adom et al. (2019) employed the GMM estimator to examine the FDI-energy demand relationship using data from 2000-2014. The results pointed to a concave effect of FDI on energy consumption in Africa.

The last cluster of research, closely related to our study, are those that have considered the energy consumption, FDI and economic

growth trinity, but most of them assumed a linear relationship and have employed linear models to investigate this nexus. Some other studies only employed cointegration and granger causality techniques to examine the existence of cointegration and causation among the variables. However, the inadequacy of these approaches is the inability to reveal the dynamic interrelationship among electricity infrastructure, FDI, and economic growth which have great policy implications both at the country and regional levels. Although some studies have been able to capture this dynamism in other countries and regions, much attention has not been given to Sub-Saharan Africa.

3.2.2 Theoretical Review

3.2.2.1 New Growth Theory

Proposed by Paul Romer, this theory argues that for economic growth to occur and be sustainable over a long period of time through investments in human capital, technological innovation, and knowledge creation. In the long run, per capital income depends solely on the rate of technological progress. Economic growth is driven primarily by investments in research and development, education, innovation (Romer, P. M. 1990). As opposed to the traditional growth theories which focuses on other factors such as capital accumulation, and natural resources the new growth theory makes emphasis the importance of new ideas learning and technological progress to drive economic development.

3.2.2.2 The Growth Model

Economic growth results from resultant physical capital accumulation when the savings are invested and the capital-output ratio (physical production of new investment) on the other. This is based on simple Harrod-Domar Model which today is often referred to as the AK model as it is based on linear production function with output given

by the capital stock (k) times a constant often labeled A (Todaro & Smith, 2011).

Harrod-Domar model is the simplest and best known production function deployed in analyzing economic development. The model is also employed in developing countries as an avenue of studying the correlation between growth and savings which is a function of capital accumulation for present and future investment. In other words, a decline in the rate of lending is theorized to cause investment borrowing to rise which leads to increased capital formation and in the long run to economic growth (Acha, 2011).

The model explains the dissimilarities in growth levels between countries and it allows for the prediction of growth estimates for a nation. Therefore, it suggests that savings provide the funds which are borrowed for investment purposes. The economy's rate of growth depends on: the level of savings and the savings ratio; the productivity of investment that is, economy's capital-output ratio.

3.2.3 Theoretical Framework

This research was anchored on Solow's growth model to exemplify the role of infrastructural development on the nexus between investment and economic growth in SSA. The model was published as a seminar presentation in 1956 which was titled "A Contribution to the Theory of Economic Growth". The model was designed within the framework of the neoclassical economics thought; it is an exogenous growth model, an economic model of long-run economic growth. It aims at exemplifying long-run economic growth by looking at accumulation of capital, labor or population growth, and increases in output, usually referred to as technological advancement (Akutson et. al., 2020).

The assumptions underlying Solow's growth model are as follows:

- (i) Flexible wages and price
- (ii) One composite commodity is produced.

- (iii) Allowance is made for depreciation of capital before arriving at net output.
- (iv) Production function is homogeneous of the first degree (i.e. constant returns to scale).
- (v) Capital and Labor are rewarded based on their marginal efficiency
- (vi) Full labor employment.
- (vii) Full employment of capital stock.
- (viii) Substitution of both Labor and capital.
- (ix) Neutrality of technical progress.
- (x) There is a constant saving ratio.

The Solow growth model is developed based on a Cobb - Douglas production function given thus:

$$Y = f(K, L) = K^{\alpha} L^{1-\alpha} \quad \text{.....Eqn 3.1}$$

Where: Y = output, K = Capital input, and L = Labor input. α and $1-\alpha$ are output elasticities of capital and labor respectively and α is a number between 0 and 1. There is also the expression of capital accumulation equation from Solow's growth model. It is expressed as:

$$\dot{K} = sY - dK \quad \text{.....Eqn 3.2}$$

Where:

$\dot{K}$ = change in capital stock

sY = gross investment

dK = depreciation during the production process

Using mathematical expression and denotation, Solow developed the capital accumulation equation in terms of per labor i.e $\dot{k} = sy - (n + d)k$.

This implies that the change in capital per worker is a function of investment per worker, depreciation per worker and population growth. Among these three economic factors only investment per worker is directly related with change in capital per worker.

3.3 Methodology

The study is an ex-post Facto research. The study is quantitative in nature. In the empirical analysis, E-views 9 econometric software was used. The data used in this study were purely dynamic panel data over period of 6 years from the period 2017 to 2022. The source includes World Development Indicators (WDI) and Africa Infrastructure Development Index (AIDI). The variables employed in the study are: Real Gross domestic product as the dependent variable while foreign direct investment, gross fixed capital formation, electricity, road and ICT infrastructures as independent variables.

3.3.1 Empirical Model(S)/Methods

The model used in this study follows what was adopted in prior studies like Iyabo & Segun as specified thus:

$$GDP = (FDI, K, L, INF) \quad \text{.....Eqn 3.3}$$

Where GDP represents economic growth (measured by growth rate of GDP), FDI represents foreign direct investment, K represents the stock of capital (measured by gross fixed capital formation), L represents the labour force (measured by total labour force), INF represents the inflation rate.

The functional model for this study is thus given as:

$$RGDP = f (FDI, GFCF, EI, TI, ICTI) \quad \text{.....Eqn 3.4}$$

Where:

RGDP = Real Gross Domestic Product

FDI = Foreign Direct Investment

GFCF = Gross Fixed Capital Formation

EI = Electricity Infrastructure

TI = Road Infrastructure

ICTI = Information Communication Technology Infrastructure

Since the study is interested in the dynamic relationship among electricity infrastructure, *FDI* and economic growth, we specify the model below whereby electricity infrastructure, *FDI* and economic growth are treated as endogenous to enable us capture the three-way dynamics. While equation (3.5) is the growth equation, electricity infrastructure and *FDI* equations are specified in equations (3.6) and (3.7) respectively, containing other variables that have been noted to affect electricity infrastructure and *FDI* in the literature.

$$GDP_{it} = \alpha + \beta_1 RGDP_{i,t-1} + \beta_2 FDI_{it} + \beta_3 GFCF_{it} + \beta_4 EI_{it} + \beta_5 TI_{it} + \beta_6 ICTI_{it} + U_{it} \quad \text{.....Eqn 3.5}$$

$$EI_{it} = \alpha + \beta_1 EI_{i,t-1} + \beta_2 RGDP_{it} + \beta_3 FDI_{it} + \beta_4 GFCF_{it} + \beta_5 TI_{it} + \beta_6 ICTI_{it} + U_{it} \quad \text{.....Eqn 3.6}$$

$$FDI_{it} = \alpha + \beta_1 FDI_{i,t-1} + \beta_2 RGDP_{it} + \beta_3 GFCF_{it} + \beta_4 EI_{it} + \beta_5 TI_{it} + \beta_6 ICTI_{it} + U_{it} \quad \text{.....Eqn 3.7}$$

The subscripts $i=1, N$ and $t=1, T$ represent the number of countries (44 Sub-Saharan African countries) and time period (2017-2022) covered in the study respectively, while U is the error term. The specifications in equations (3-5) follow a dynamic panel data model in simultaneous form whereby each equation contains a lagged form of the dependent variable as an independent variable, indicating the presence of endogeneity problem in the model since the lagged dependent variables could correlate with the stochastic error term.

As a result, the ordinary least square (OLS) technique becomes inappropriate and inconsistent in analysing these models (Omri & Kahouli, 2014; Muhammad & Khan, 2019). However, the appropriateness of the GMM estimator has been well established in the literature and its supremacy over random and fixed effects models and pooled OLS models has been noted in solving basic econometric problems such as endogeneity, simultaneity, weak instrumentation and unobserved heterogeneity in dynamic panel data models with little time span and large cross-sections.

Based on economic intuition and findings from previous studies, we expect a positive relationship between electricity infrastructure and economic growth. This is due partly to the importance of electricity as direct or indirect input in production; and the fact that economic growth enables countries to have more resources for investment in infrastructures, including electric-power infrastructure. A positive link between FDI and economic growth is expected. Likewise, a positive impact of FDI on electricity is anticipated, because when FDI leads to increased economic growth, there is the likelihood that electricity is positively affected by an increase in FDI.

3.4 Estimation/Result Discussion

Table 3.1: GMM Regression Results

	MODEL 1 Economic Growth	MODEL 2 Electricity Infrastructure	MODEL 3 FDI
GDP (-1)	-0.024816 [-0.783383]	-	-
EI (-1)	-	-0.0995 [-2.9112]	-
FDI (-1)	-	-	0.0127 [1.7]
GDP	-	-0.0777 [-1.0345]	0.4057[7.12]
FDI	1.4843 [8.993]	-0.1733 [-0.8730]	-
GFCF	-0.5946 [-2.12]	-0.4137 [-1.1614]	0.3997[4.409]
EI	-0.0073 [-0.1347]	-	-0.0693[-2.527]
TI	-0.2710 [-1.2367]	1.7044 [5.5463]	0.2681[2.037]
ICTI	0.3367 [2.3056]	-0.3123 [-1.2862]	-0.0424 [-0.8588]

Source: Author's computation in Eviews 9

The result of the electricity infrastructure-FDI-economic growth interrelationship is presented in Table 3.1. Following the specification in equations (3.5) - (3.7), the result contains three models (1-3) estimated in a dynamic simultaneous form using the System GMM technique.

For the results of the economic growth model, the coefficient of electricity infrastructure was negative and statistically insignificant at 1 unit. This implies that electricity infrastructure is negatively related to economic growth in Sub-Saharan Africa. A unit decrease in electricity infrastructure is associated with a decrease in economic growth in the region by -0.007. The result is an indication that economic growth in the region does not rely on electricity infrastructure but depends partly on it. The coefficient of foreign direct investment is positive and statistically significant, and this means that foreign direct investment greatly determines economic growth. As such, a unit increase in foreign direct investment inflows to the SSA Sub-region can be attributed to 1.48 increase in economic growth. Also, the estimate of ICT infrastructure was positive and statistically significant. The implication of this is that improvement in ICT infrastructure is a significant determinant of economic growth in Sub-Saharan Africa. A unit increase in ICTI increases economic growth in the region by 0.336.

In the result of the FDI model, economic growth appeared to have a positive and significant relationship with foreign direct investment in Sub-Saharan Africa. This means that a growth in an economy tends to put the economy attractive in the global world to attract foreign investment. Also, the coefficient of electricity infrastructure was negative and statistically significant. It means that electricity infrastructure has a significant influence on FDI inflows in to the SSA. This negative result could be explained by low rate of electricity in SSA which has been a disincentive to FDI inflows. However, the coefficients of gross fixed capital formation and transport infrastructure are positive and statistically significant. A unit increase in GFCF and TI increase FDI inflows into the region by

0.3 and 0.2 respectively. This means that both capital and transport significantly affect FDI flows into Sub-Saharan Africa.

It can thus be concluded that a bi-directional relationship exists between electricity infrastructure and FDI. It implies that electricity infrastructure is crucial in propelling FDI to boost economic growth, with higher economic growth also an important stimulator of greater electricity infrastructure and FDI. The result is in line with the findings of Fan and Hao (2020) where it was found that FDI does significantly respond to changes in energy (electricity) consumption.

The R-squared indicate that the models were well specified, and the moment conditions are met. First, the Hansen J-test of over-identification of restrictions confirms the overall validity of the instruments used. Second, in each of the models, the coefficient of the lags of the dependent variables (used as instruments) is less than one, and electricity infrastructure being statistically significant, indicating convergence to long-run equilibrium.

3.5 Conclusions/Policy Implications

Different from studies in existing literature, this study assessed the dynamic link among electricity infrastructure, FDI and economic growth in SSA. Most empirical literature considered FDI-economic relationship based on country-specific or cross-country analysis. Departing from the existing literature, we assessed the effect as well as the relationship among electricity infrastructure, FDI, and economic growth across forty-four (44) SSA countries where studies of this nature are sparse. Our dataset spans from 2017 to 2022. Also, assessing the dynamic effects through a simultaneous equation model presents the opportunity for correcting the misspecification bias that permeates single equation models when considering the electricity infrastructure-FDI-economic growth relationship.

Major findings of the study indicated a positive and significant relationship running from FDI to economic growth in the SSA region and the reversal of economic growth causing FDI inflows was

also positive and significant. This is expected as increase in FDI in any country will lead to increase in economic growth. Policies of the SSA countries should endeavour to ensure a stable macroeconomic environment for attracting more significant FDI for more economic growth. Finally, the result showed that a negative but significant relationship exists between electricity infrastructure and FDI in SSA. This could be due to the low level of electricity infrastructure relative to economic activities in the region, thus explaining the fact that low infrastructure in electricity could serve as a binding constraint to FDI inflow and hence economic productivity. The significant of electricity to FDI as indicated in the result is because where economic activities are derived from the use of electricity-induced technologies, manufacturing and industrial activities will be boosted, thus, the foreign direct investment would increase thereby leading to economic growth and prosperity.

References

- Adom, P. K., Opoku, E. E. O., & Yan, I. K. M. (2019). Energy demand–FDI nexus in Africa: Do FDIs induce dichotomous paths? *Energy Economics*, 81, 928–941. <https://doi.org/10.1016/j.eneco.2019.05.030>
- Abdoul, M., & Hammami, S. (2017). Exploring links between FDI inflows, energy consumption, and economic growth: Further evidence from MENA countries. *Journal of Economic Development*, 42 (1), 95-117.
- Abbes, S. M., Mostefa, B., Seghir, G., & Zakarya, G. Y. (2015). Causal interactions between FDI, and economic growth: Evidence from dynamic panel co-integration. *Procedia Economics and Finance*, 23, 276–290. [https://doi.org/10.1016/s2212-5671\(15\)00541-9](https://doi.org/10.1016/s2212-5671(15)00541-9)
- Doytch, N., & Narayan, S. (2016). Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. *Energy Economics*, 54, 291–301. <https://doi.org/10.1016/j.eneco.2015.12.010>
- Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental variables and GMM: estimation and testing. *The Stata Journal*, 3(1), 1-31.

- Fan, W., & Hao, Y. (2020). An empirical research on the relationship amongst renewable energy consumption, economic growth and foreign direct investment in China. *Renewable Energy*, 146, 598–609. <https://doi.org/10.1016/j.renene.2019.06.17>
- John, E.I. (2016). Effect of foreign direct investment on economic growth in Nigeria. *European Business and Management*, 2, 40–46.
- Yabo A. O & Segun S. A. Assessing the nexus among energy consumption, foreign direct investment and economic growth in Sub-Saharan Africa. *CBN Journal of Applied Statistics*. 13(1), 27–53. DOI: 10.33429/Cjas.13122.2/9
- Iyke, B. N. (2015). Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate. *Energy Economics*, 51, 166–176.
- Lin, B., & Nelson, B. I. (2018). Causal relationships between energy consumption, foreign direct investment and economic growth for MINT: Evidence from panel dynamic ordinary least square models. *Journal of Cleaner Production*, 197, 708–720. <https://doi.org/10.1016/j.jclepro.2018.06.152>
- Smile, S. (2009). Foreign direct investment and electricity consumption on economic growth: evidence from South Africa. *Economia Internazionale / International Economics, Camera di Commercio Industria Artigianato Agricoltura di Genova*, 62(2), 175–200.
- Zeeshan, M. (2013). Finding the cointegration and causal linkages between electricity production and economic growth in Pakistan. *Economic modelling*, 31, 344–350.

PART 4



Climate Change, Good Governance and Technology



4



Understanding the Nexus Between Climate Change, Resilience, and Economic Prosperity in Nigeria

Yusuf, Umar, Abikoye,
Michael O.
and Dogo, Bishara S.

Abstract

This study aims to contribute to the literature by understanding the nexus between climate change, resilience, and economic prosperity in Nigeria. Climate change is a global challenge with wide-ranging effects, posing a significant threat to ecosystems and human well-being worldwide. Nigeria, Africa's most populous nation, is particularly susceptible due to its location, resource reliance, and population growth. Therefore, empirical evidence in this paper is examined to evaluate the interrelationship between climate change, the resilience of the economy and the economic prosperity in Nigeria. Using annual data from 1995–2022, the autoregressive distributed lag (ARDL) methodology was adopted and incorporated to examine the long-run and short-run effects of the variables. The major finding of the study is that

climate change impacts negatively on economic prosperity in Nigeria, highlighting the adverse economic effects of environmental degradation on overall output due to increasing carbon emissions. Other findings from the study also suggest that energy consumption hurts economic prosperity as the country relies mostly on dirty energy sources which pollute the environment thereby reducing output. A positive relationship exists between economic prosperity and resilience to technology and labour, respectively. This implies that technological advancement and a skilled workforce are key factors in Nigeria's economic growth. The study therefore recommends that policymakers adopt a multi-faceted strategy to bolster the resilience of the nation and sustain economic growth. This includes prioritizing environmental sustainability through cleaner production methods, renewable energy promotion, and stringent environmental regulations.

Keywords: Climate change, Resilience, Economic prosperity, Ecosystems, GDP growth, Foreign Direct Investment (FDI), Energy consumption, Labour force, Gross Fixed Capital Formation (GFCF).

JEL Classification: Q54, Q13 and O44

4.1 Introduction

Climate change, a global phenomenon with far-reaching consequences, is one of the most critical challenges of the 21st century. Its impact is not limited to specific regions or nations but affects the entire planet, posing a severe threat to ecosystems, human livelihoods, and socio-economic development. Nigeria, the most populous country in Africa, is particularly vulnerable to the adverse effects of climate change due to its geographical location, natural resource dependence, and rapidly expanding population. The motivation behind the study is to understand how climate change affects the economy of Nigeria and how the country can recover from the effects of climate change. The

study aims to identify the relationship between climate change and economic prosperity in Nigeria and how the country can achieve sustainable development while mitigating the effects of climate change. Understanding the interconnectedness between climate change, resilience, and economic prosperity is essential for several reasons.

Climate change has observable and projected impacts on various sectors and communities, affecting everything from food, security and water availability to public health and infrastructure. Researchers can identify the most vulnerable areas by studying the nexus and developing targeted interventions to build resilience and promote sustainable prosperity. Climate change is not a linear challenge with one-size-fits-all solutions. Effective adaptation strategies require a comprehensive understanding of the complex interactions between climate change, social systems, and ecosystems. By studying the nexus, policymakers and stakeholders can develop holistic approaches integrating resilience-building measures into climate change adaptation plans. The study of the nexus aligns with the United Nations' Sustainable Development Goals (SDGs), particularly Goal 13 (Climate Action) and Goal 11 (Sustainable Cities and Communities). Understanding the interplay between climate change, resilience, and economic prosperity can contribute to achieving these global goals by guiding efforts towards building climate-resilient societies and fostering sustainable economic development and prosperity.

Studying this nexus can offer insights into effective economic prosperity approaches that lead to positive and lasting change. Policymakers require evidence-based knowledge to design and implement effective climate change policies. Understanding the nexus helps policymakers identify priority areas for intervention, allocate resources efficiently, and foster collaboration between different sectors and stakeholders. Climate change is a global challenge that requires collaboration and knowledge-sharing among nations. Studying the nexus can contribute to the global body of knowledge

on climate resilience and economic prosperity, facilitating the exchange of best practices and lessons learned across different regions and countries. As climate change evolves, it is essential to anticipate future scenarios and plan accordingly. Studying the nexus can provide valuable insights into future challenges and opportunities, enabling proactive planning and preparedness for climate-related impacts. The motive behind this study stems from the need to develop informed and integrated strategies to address the complexities of climate change. By understanding the interconnections between these elements, societies can build resilience, foster sustainable prosperity, and work towards a climate-resilient and sustainable future for future generations. This research paper aims to delve into the intricate relationship between climate change, resilience, and economic prosperity in Nigeria, offering a comprehensive understanding of the country's vulnerability, adaptive capacities, and potential pathways towards sustainable development.

4.1.1 Background and Rationale

Climate change in Nigeria is evident through various manifestations, such as rising temperatures, erratic rainfall patterns, increasing frequency of extreme weather events (such as droughts, floods, and storms), and rising sea levels. The country's vast agricultural sector, crucial for food security and employment, is particularly susceptible to climate-induced disruptions. Furthermore, climate change exacerbates existing socio-economic inequalities, disproportionately affecting vulnerable populations and hindering efforts towards poverty reduction.

Resilience refers to the capacity of a system - be it ecological, social, or economic - to withstand shocks and disturbances while maintaining essential functions and structures. In the context of climate change, resilience is essential for communities and ecosystems to adapt and cope with the adverse impacts. Nigeria's resilience is a

critical aspect to explore, as it can play a pivotal role in minimising the damage caused by climate change and catalysing economic prosperity. Considering the significant threat climate change poses to Nigeria's development, economic prosperity strategy is crucial for the nation's long-term well-being.

4.1.2 Objectives

The objective of this research paper is to determine the most vulnerable areas and populations in Nigeria, as well as the extent to which different sectors, such as infrastructure, agriculture, water resources, and health, are vulnerable to the effects of climate change. Furthermore, the goal is to obtain an understanding of Nigeria's current resilience mechanisms and adaptive skills, which include both traditional knowledge and modern strategies that enable communities and institutions to successfully address climate-related concerns.

4.1.3 Significance of the study

This research paper holds significant importance in the context of Nigeria's sustainable development and climate change mitigation and adaptation efforts. By providing an in-depth understanding of the interconnectedness between climate change, resilience, and economic prosperity, it aims to inform policymakers, researchers, and stakeholders about the urgency of implementing climate-resilient strategies.

Moreover, the findings of this study can guide the formulation of evidence-based policies and programs that foster climate adaptation, enhance community resilience, and promote transformative practices in Nigeria. By investing in climate-resilient approaches and adopting a economic prosperity mindset, Nigeria can navigate the challenges of climate change more effectively and achieve sustainable development that ensures a better future for its citizens and the environment.

4.2 Literature Review

4.2.1 Theoretical Literature

4.2.1.1 Environmental Kuznets Curve theory:

The Environmental Kuznets Curve (EKC) theory posits an economic hypothesis suggesting an inverted U-shaped relationship between environmental degradation and economic development. It draws its name from economist Simon Kuznets, who had previously proposed a similar concept related to income inequality and economic growth. The primary aim of the Environmental Kuznets Curve theory is to elucidate the environmental consequences of economic growth and industrialization. According to the curve, during the early stages of economic development, environmental degradation and pollution tend to rise. This can be attributed to the rapid industrialization and urbanization processes, leading to increased utilization of natural resources, heightened energy consumption, and elevated pollution levels from industries and transportation.

However, as a country's economy continues to grow, the theory suggests that a turning point is reached, often correlated with a certain level of per capita income or GDP. At this juncture, the trend reverses, and environmental degradation begins to decline. This positive shift is driven by heightened environmental awareness, the implementation of better regulations, technological advancements, and increased focus on environmental preservation. This phase marks the transition towards more sustainable practices and cleaner technologies, resulting in decreased pollution and enhanced environmental quality. Despite its influence in sustainable development discourse, the Environmental Kuznets Curve theory has faced criticism and is not universally accepted due to some limitations.

The EKC theory may not hold for all environmental issues or across all countries. Different environmental indicators may exhibit varying trajectories, and some may not demonstrate the hypothesized

turning point. The time required for the turning point to materialize can be prolonged, and in certain cases, environmental degradation may become irreversible before improvements become evident. The EKC theory does not account for the uneven distribution of environmental impacts. While overall environmental degradation may decrease, marginalized or vulnerable communities may still bear a disproportionate burden of pollution and environmental hazards. The theory does not establish a clear causal relationship between economic growth and environmental improvement. Other factors, such as government policies, technological advancements, and social awareness, also significantly influence environmental outcomes.

Despite these limitations, the Environmental Kuznets Curve theory remains influential in discussions on sustainable development, prompting policymakers and researchers to contemplate the interplay between economic growth and environmental protection. It underscores the significance of finding ways to decouple economic growth from environmental degradation, emphasizing the potential for a more sustainable future as economies evolve.

4.2.2 Empirical Literature

The relationship between climate change and economic growth has been the subject of extensive empirical research. Scholars and researchers have conducted numerous studies to explore the impact of climate change on various aspects of economic growth, as well as the potential economic consequences of climate change mitigation and adaptation strategies. Here are some key empirical literature findings on the topic:

Ojonuga et al. (2018) employed the ARDL model to analyze the impact of energy consumption, CO₂ emissions, capital, and labour on economic growth. They also used Granger causality tests to examine relationships among these variables. The results indicated a long-run relationship from economic growth to capital, labour, energy

consumption, and CO₂ emissions. The ARDL model revealed positive contributions from energy consumption, capital, and labour to economic growth, whereas CO₂ emissions had a negative short-run impact. This pattern held in the long run, although capital and labour were not significant. Granger causality tests revealed unidirectional causality from capital and labour to economic growth, while bidirectional causality existed between energy consumption and economic growth, as well as CO₂ emissions and economic growth. A policy recommendation arising from these findings is the implementation of measures, including the utilization of alternative energy sources like solar, wind, and biomass, in alignment with the 2003 energy policy.

Effiong (2012) utilized a Multivariate Vector Error Correction (VECM) framework to explore the long-term and causal relationships between electricity consumption, carbon emissions, and economic growth in Nigeria. Analyzing data from 1970 to 2008, the study revealed that economic growth was associated with increased carbon emissions, while higher electricity consumption corresponded to heightened carbon emissions. The paper challenged the environmental Kuznets curve hypothesis. Granger-causality tests indicated a one-way causal link between economic growth to carbon emissions, suggesting that policies to reduce emissions might not hinder economic growth. The absence of causality between electricity consumption and growth further underscored challenges in Nigeria's electricity sector. The study suggested that effective planning and increased investment in electricity infrastructure could be key to achieving neutrality between electricity consumption and growth.

Magbagbeola (1999) examined the implications of climatic change for economic growth and environmental development in Nigeria. The study highlighted the role of greenhouse gas emissions in global warming and its adverse socioeconomic effects. Agriculture, water resources, energy supply, and other sectors were identified as vulnerable to climate change impacts. The paper proposed strategies to mitigate these effects, such as continued taxation of gas flaring,

awareness programs, carbon reservoir establishment, and promoting energy-efficient practices. These measures aimed to address economic challenges associated with climate change.

Babatunde and Ayodele (2015) investigated the empirical connection between economic growth and climate change in Africa. Using data from 34 countries between 1961 and 2009, they found that climate change hurt economic growth. Specifically, a 1°C temperature increase was associated with a 0.67 percentage point reduction in GDP growth. The study highlighted the significant roles played by Nigeria and South Africa in mitigating the negative effects of climate change in the Sub-Saharan African region. These findings contribute valuable insights for national adaptation plans and underscored that long-term temperature changes did not appear to directly affect long-term economic growth over five-year averages.

Burch & Pinter (2019) assessed the potential economic benefits of incorporating electric vehicles (EVs) as part of a green recovery strategy. They analysed the diffusion of EV technologies and their abatement costs, focusing on how such measures can create jobs and contribute to economic prosperity. Andersson & Nässén (2021) explored the role of green stimulus measures in creating jobs and achieving short-term emissions reductions. The authors investigated the potential economic and environmental outcomes of implementing green initiatives.

Hallegatte & Rozenberg (2017) examined the economic implications of climate-resilient infrastructure investments in promoting economic growth and poverty reduction. They analysed how investing in climate-resilient infrastructure can contribute to economic prosperity while addressing social inequalities. While not solely focused on prosperity, Heal & Millner (2014) discussed the role of uncertainty in climate change economics and emphasised the importance of effective policy responses for mitigation and adaptation. According to them, policy decisions are crucial for guiding recovery efforts and building resilience.

National Academies of Sciences, Engineering, and Medicine (2020), in their report, explored the economic benefits of climate adaptation strategies and highlighted the significance of long-term planning. The authors stressed the importance of integrating adaptation into recovery efforts to ensure economic stability and sustainability. Gennaioli et al. (2018) discussed the potential economic contributions of green investments, such as renewable energy, to enhance economic growth and stability during recovery processes. Barbier & Hochard (2020) explored how economic diversification can enhance climate resilience, particularly in countries heavily reliant on fossil fuel industries. They concluded that diversification efforts can contribute to long-term economic prosperity and adaptive capacity.

From the reviewed studies, a potential gap in the literature is the lack of comprehensive studies that specifically explore the nuanced interplay between climate change, adaptation strategies, and economic prosperity in Nigeria. While some of the studies touch on related aspects, there appears to be a need for more focused research that examines the individual aspects such as energy consumption, CO₂ emissions, and electricity consumption, and their impacts on economic prosperity and resilience. Synthesising these aspects within a holistic framework which considers the synergies and trade-offs between climate adaptation measures and the economic prosperity process. Closing these gaps through our empirical research could provide a more comprehensive understanding of how climate change adaptation and economic prosperity can be effectively integrated in Nigeria, leading to more informed policy decisions and strategies.

4.3 Stylised Facts/ Trend Analysis

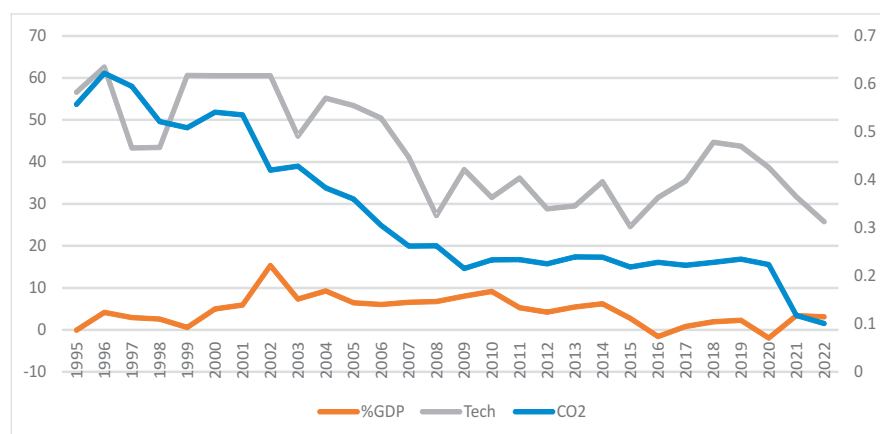


Figure 4.1: The trend of CO2 emission, GDP growth rate and technology

Source: CBN, WDI

The data spanning from 1995 to 2022 reveals a dynamic economic journey for Nigeria. Starting in 1995, despite negative GDP growth, the nation saw a notable surge in CO2 emissions, possibly indicating increased industrial activity. As economic sanctions lifted, GDP growth remained modest in 1998, but CO2 emissions decreased as the Asian financial crisis impacted oil prices. The pivotal year of 2003, when Nigeria joined OPEC, marked an upswing in GDP growth and a slight uptick in CO2 emissions, illustrating the importance of oil exports to the economy. In 2005, high oil prices fueled economic growth, yet CO2 emissions began to stabilize. The global financial crisis of 2008 led to a decrease in CO2 emissions, while GDP growth remained positive. Hosting the World Economic Forum in 2010 propelled GDP growth significantly, while CO2 emissions continued their gradual decline. Despite the oil price slump in 2014, GDP growth remained positive, and CO2 emissions increased slightly. However, the recession in 2016 saw both GDP growth and CO2 emissions decrease. The COVID-19 pandemic in 2020 caused a sharp recession with a substantial drop in GDP

growth, but CO₂ emissions continued their downward trend. A remarkable recovery in 2021, with high GDP growth and reduced CO₂ emissions, highlighted economic resilience. The Russia-Ukraine war in 2022 presented challenges, yet Nigeria maintained positive GDP growth while CO₂ emissions hit their lowest point in the dataset. Throughout this period, technological development showed fluctuations but generally improved, underscoring the nation's commitment to progress. These shifts in numbers underscore the intricate interplay between economic events, environmental sustainability, and technological advancement that have shaped Nigeria's economic landscape.

4.3 Methodology

4.3.1 Data Description

The time series yearly data set for Nigeria is analysed in this study, which covers the period from 1995 to 2019. The availability of data was the main factor in choosing this timeframe. Furthermore, the study employed the growth rate of Gross Domestic Product (GDP) as the measure of economic growth, carbon dioxide (CO₂) emissions as a measure of climate change, and foreign direct investment as a percentage of GDP to measure the resilience to international economic involvement. Energy consumption (ENG) was also used, while labour force (LBF) was also employed to measure the resilience of the labour market. The growth rate of Gross fixed capital formation, which stands for capital in the nation (GFCF), while technology (Communications, computer, etc.) as a percentage of service imports represents resilience to changes in technology for the period (TECH). The data for the independent and dependent variables are obtained from the World Bank indicators.

4.3.2 Methodology

Various economic variables will be examined to understand the nexus between climate change, resilience, and economic prosperity in Nigeria. The study will make use of secondary data on the variables which include Gross Domestic Product (GDP), Rainfall, CO2 Emission, Urbanization, Foreign Direct Investment (FDI), and Energy consumption patterns using appropriate qualitative and quantitative techniques. The study will empirically use econometric technique, employing an Autoregressive Distributed Lag (ARDL) model developed by Pesaran et al. (2001) to account for dynamics in the relationship between the variables of interest to establish the impact of climate change on these economic variables.

Consideration of the period between 1995 and 2022, which covers the period for which climate change became a recognized global issue.

4.3.3 Model Estimation

The resilience function for this study is expressed thus:

$$GDP_t = f(CO2_t, FDI_t, ENG_t, LBF_t, GFCF_t, TECH_t) \quad \text{.....Eqn 4.1}$$

Before estimating the model, a logarithmic transformation is performed:

$$LGDP_t = \beta_0 + \beta_1 CO2_t + \beta_2 FDI_t + \beta_3 LENG_t + \beta_4 LLBF_t + \beta_5 GFCF_t + \beta_6 TECH_t + \varepsilon_t \quad \text{.....Eqn 4.2}$$

where, ε_t is the error and β_0 displays the constant, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$, and β_6 are the coefficients of the described variables. The ARDL model (Pesaran et al., 2001) used in this study can be expressed as:

$$\begin{aligned} \Delta LGDP_t = & \beta_0 + \sum_{i=1}^n \beta_{1i} \Delta CO2_{t-i} + \sum_{i=1}^n \beta_{2i} \Delta FDI_{t-i} + \\ & \sum_{i=1}^n \beta_{3i} \Delta LENG_{t-i} + \sum_{i=1}^n \beta_{4i} \Delta LLBF_{t-i} + \sum_{i=1}^n \beta_{5i} \Delta GFCF_{t-i} + \\ & \sum_{i=1}^n \beta_{6i} \Delta TECH_{t-i} + \beta_7 CO2_{t-1} + \beta_8 FDI_{t-1} + \\ & \beta_9 LENG_{t-1} + \beta_{10} LLBF + \beta_{11} GFCF_{t-1} + \beta_{12} TECH_{t-1} + \varepsilon_t \end{aligned} \quad \text{.....Eqn 4.3}$$

where, β_{1i} , β_{2i} , β_{3i} , β_{4i} , β_{5i} , and β_{6i} refer to constant intercepts and β_7 , β_8 , β_9 , β_{10} , and β_{11} and β_{12} to the long-run coefficients, ε_t is the error term. For short-run correlation analysis, the equation is estimated as shown:

$$\begin{aligned} \Delta LGDP_t = & \beta_0 + \sum_{i=1}^n \beta_{1i} \Delta CO2_{t-i} + \sum_{i=1}^n \beta_{2i} \Delta FDI_{t-i} + \sum_{i=1}^n \beta_{3i} \Delta LENG_{t-i} + \sum_{i=1}^n \beta_{4i} \Delta LLBF_{t-i} \\ & + \sum_{i=1}^n \beta_{5i} \Delta GFCF_{t-i} + \sum_{i=1}^n \beta_{6i} \Delta TECH_{t-i} + \phi ECM_{t-1} + \mu_t \end{aligned} \quad \text{.....Eqn 4.4}$$

where ECM is the error correction term.

4.3.4 Model Pre and Post Estimations

Preliminary tests, like the unit root test, are necessary to find out if the data are stationary, which keeps the analysis from coming to the wrong conclusions. The variables that are part of the autoregressive distributed lag (ARDL) model must be stable at level I (0), first difference I (1), or both. The bound test confirms long-run relationships between variables, determining statistical significance and cointegrating relationships. These preliminary evaluations help ensure that the variables included in the ARDL model are suitable for analysis. The post-estimation test assesses the model's goodness-of-fit and statistical significance, ensuring accuracy and reliability in predictions and allowing further analysis and interpretation of results.

4.4 Results and Discussion

Table 4.1

	LGDP	LENG	LLBF	GFCF	CO2	FDI	TECH
Mean	11.499	2.872	7.710	1.914	0.330	1.319	42.758
Median	11.536	2.871	7.716	2.613	0.250	1.224	42.206
Maximum	11.728	2.906	7.8640	40.388	0.622	2.900	62.608
Minimum	11.189	2.833	7.564	-23.746	0.100	-0.039	24.580
Std. Dev.	0.191	0.022	0.086	13.053	0.151	0.784	12.156
Skewness	-0.349	-0.189	0.056	0.349	0.561	0.316	0.2404
Kurtosis	1.587	1.832	2.007	4.562	2.004	2.196	1.7684
Jarque-Bera	2.898	1.758	1.163	3.419	2.630	1.221	2.0393
Probability	0.234	0.415	0.558	0.180	0.268	0.543	0.360
Sum	321.976	80.418	215.882	53.602	9.264	36.95	1197.229
Sum Sq. Dev.	0.991	0.013	0.203	4600.652	0.616	16.600	3989.820
Observations	28	28	28	28	28	28	28

The descriptive statistics above provide insights into the distribution and characteristics of various variables. For example, the mean GDP is around 11.5, while labor force metrics (LENG and LLBF) indicate average values of approximately 2.87 and 7.71, respectively. Gross Fixed Capital Formation (GFCF) has a mean of 1.91, though with a notably high standard deviation of 13.05, suggesting considerable variability. Carbon Dioxide emissions (CO2) have a mean of 0.33, and Foreign Direct Investment (FDI) has an average of 1.32. The average technology level (TECH) is about 42.76. Measures like skewness and kurtosis suggest varying degrees of symmetry and distribution shape. Importantly, certain variables display characteristics that might deviate from a normal distribution based on Jarque-Bera test results and associated probabilities. Overall, the summary statistics provide a comprehensive snapshot of these variables' behaviours and patterns.

4.4.1 Unit Root Test

Table 4.2:

Augmented Dickey-Fuller(ADF) Unit Root Test			
Variable	Level	First Difference	Result
LGDP	-2.890*		I(0)
LENG	-3.429*		I(0)
GFCF	-9.172***		I(0)
CO2	-1.789	-1.789***	I(1)
FDI	-2.210	-8.147***	I(1)
TECH	-2.853	-6.098***	I(1)
LLBF	-2.449	-3.639**	I(1)

Phillip-Perron Unit root test			
Variable	Level	First Difference	Result
LGDP	-2.915*		I(0)
LENG	-3.443*		I(0)
GFCF	-13.932***		I(0)
CO2	-1.825	-5.858***	I(1)
FDI	-1.938	-9.856***	I(1)
TECH	-2.853	-6.298***	I(1)
LLBF	-1.689	-2.943*	I(1)

Note:*, * * and *** represent statistical significance at 10%, 5% and 1% respectively

To determine the level of integration and obtain comprehensive outcomes, we utilise unit root tests to examine the properties of the parameters through the employment of PP and ADF tests (Dickey and Fuller, 1981; Perron, 1989). Table 4.2 displays the outcomes of the unit root tests.

Based on the findings from the test results, it is evident that the ARDL models can be effectively employed in conjunction with the variables under study. This conclusion is drawn based on the observation that the parameters exhibit both stationary and integrated at the order I (0) and I (1).

4.4.2 Bounds Test Result

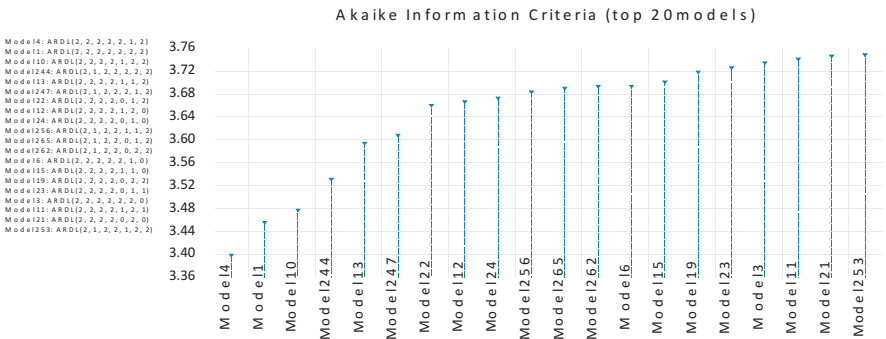
Table 4.3:

Test Statistics	Value	Signif.	I(0)	I(1)
F-statistic	10.642	10%	1.99	1.99
K	6	5%	2.27	2.27
		2.5%	2.55	2.55
		1%	2.88	2.88

Table 4.3 presents the results of the bounds test, which assesses the cointegration status of the variables under consideration. Upon analysing the results in Table 4.3, it is evident that the F-statistic values exceed the critical values at all significance levels, and similarly, the K values are also above the critical thresholds. This indicates that there exists empirical support for the presence of a cointegrating relationship among the variables that are incorporated within the model. In simpler terms, the findings from this analysis suggest that the variables are statistically linked in a way that reflects a long-term equilibrium relationship.

4.4.3 Model Selection

Figure 4.2



Before estimating the result, we determined the appropriate lag structure that allowed this estimated model to be free of econometric problems, which were determined according to Akaike Criterion Information: ARDL (2,2,2,2,2,1,2) as Figure 4.1 shows.

4.4.4 Short-run ARDL Result

Table 4.4: Short run ARDL result

Dependent Variable: D(GDP)				
Selected Model: ARDL(2, 2, 2, 2, 2, 1, 2)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP(-1))	-0.905621	0.099168	-9.132219	0.0001
D(CO2)	-55.37833	5.740735	-9.646557	0.0001
D(CO2(-1))	13.88698	4.799812	2.893235	0.0276
D(FDI)	-7.864331	0.620080	-12.68276	0.0000
D(FDI(-1))	-3.460337	0.579060	-5.975782	0.0010
D(GFCF)	-0.205173	0.019379	-10.58758	0.0000
D(GFCF(-1))	0.206689	0.022311	9.263803	0.0001
D(LENG)	-442.1056	45.69904	-9.674287	0.0001
D(LENG(-1))	79.89860	26.80162	2.981110	0.0246
D(TECH)	0.140506	0.027981	5.021434	0.0024
D(LLBF)	1.360909	33.93313	0.040106	0.9693
D(LLBF(-1))	-129.7529	40.53129	-3.201303	0.0186
ECM(-1)*	0.099574	0.007331	13.58201	0.0000

Table 4.4 portrays the outcomes of the short-run Autoregressive Distributed Lag (ARDL) analysis for the given model. The results show notable patterns that supply insights into the dynamics of the variables.

The presence of an Error Correction Term (ECT) with a significant negative coefficient holds significance. This term gauges the swiftness with which short-term disparities are rectified to re-establish long-term equilibrium. The observed negative value implies that when the external factors in the economic framework deviate from their equilibrium state, a robust corrective force appears, gradually steering them back towards equilibrium. This finding underscores the

existence of a stable equilibrium between the variables, suggesting that temporary imbalances will be alleviated to restore equilibrium over the long run.

The ARDL result also shows that CO₂ increase hurts the growth rate of GDP. The negative economic effect of carbon emissions on GDP prosperity can be attributed to the increased environmental degradation as a result of increasing carbon emissions which leads to health issues and decreased productivity. FDI had a significant and negative effect on the prosperity rate of GDP which can be primarily due to crowding out domestic investment, the risk of Dutch Disease from currency appreciation, dependency on foreign entities, profit repatriation limiting reinvestment, and inadequate technology transfer, collectively hampering overall economic expansion. Furthermore, energy consumption in the short run has a negative and significant effect on economic prosperity which can be attributed to the immediate impact of high energy costs on production processes, decreased consumer spending power due to increased energy expenses, and the potential disruption of supply chains that rely heavily on energy-intensive activities. An increase in technology and labour force shown to have a positive effect on economic prosperity which implies that advancements in technological capabilities and a growing and skilled workforce contribute significantly to enhancing economic productivity and output.

Table 4.5: ARDL Long Run Estimate

Dependent Variable: Variable	TRD Coefficient	Std. Error	t Statistic	Prob.
CO2	1365.219	3208.757	0.425467	0.6853
FDI	82.56109	185.5793	0.444883	0.6720
GFCF	7.815645	18.13044	0.431079	0.6815
LENG	5471.925	12566.75	0.435429	0.6785
TECH	-8.732906	20.48510	-0.426305	0.6848
LLBF	529.1833	1358.053	0.389663	0.7102
C	-20014.81	46757.72	-0.428054	0.6836

The long-run result in Table 4.5 above shows that none of the variables were significant. This suggests that, over an extended period, the relationships between the analyzed variables may not exhibit statistically meaningful associations. The lack of significance could stem from a variety of reasons, including the presence of complex interactions, data limitations, or the need for a larger sample size to detect smaller effects.

Table 4.6: Diagnostic Test

Test Statistic	Value (prob.)
Breusch-Godfrey Serial Correlation LM Test	0.877(0.483)
Breusch-Pagan-Godfrey Heteroscedasticity Test	1.059(0.513)
Jarque-Bera Test	1.299(0.522)

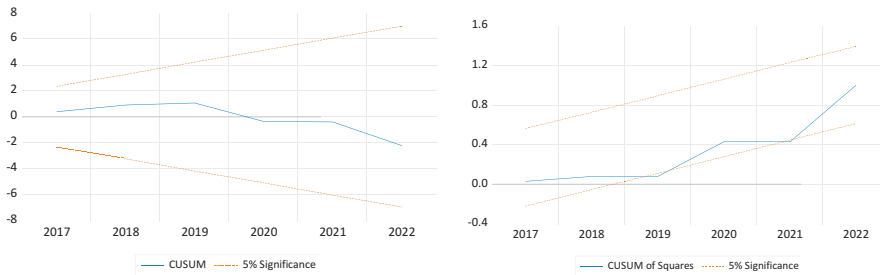


Figure 4.3: CUSUM and CUSUM of Square test

4.4.5 Post-estimation/Diagnostic test

A set of diagnostic tests was conducted to evaluate the adequacy of the estimated model. The Breusch-Godfrey Lagrange Multiplier (LM) test statistic of 0.877, together with a p-value of 0.483, suggests the absence of autocorrelation. The Breusch-Pagan-Godfrey Heteroscedasticity test statistic yielded a p-value of 0.513, suggesting the absence of heteroscedasticity. The Jarque-Bera test statistic, which has a value of 1.299, is accompanied by a p-value of 0.522, suggesting that the estimated model demonstrates properties consistent with normality. Lastly, the CUSUM in Figure 4.2 shows that there is no instability in the model while the CUSUM of squares test result shows otherwise. This could impact the reliability of statistical methods like ordinary least squares regression, prompting the need for further analysis.

4.5 Conclusion and Recommendations

This paper examines the effect of climate change and resilience on economic prosperity in Nigeria. The research included yearly data spanning from 1995 to 2022, and the Autoregressive Distributed Lag (ARDL) model was employed for analysis. The study employed Gross Domestic Product (GDP) growth rate, carbon dioxide (CO₂) emissions, foreign direct investment, energy consumption (ENG), labour force (LBF), Gross Fixed Capital Formation (GFCF), and

technology (TECH) as key variables to understand their interplay. The findings revealed valuable insights into the dynamics of these variables.

Drawing from the findings of the study, policymakers should adopt a multi-faceted strategy to bolster the resilience of the nation and sustain economic prosperity. This includes prioritizing Environmental Sustainability through cleaner production methods, renewable energy promotion, and stringent environmental regulations.

Simultaneously, a strategic foreign investment approach is necessary, comprising efforts to promote FDI while defending domestic interests and facilitating technology transfer. Enhancing Energy Efficiency and Diversification can counteract energy consumption's harmful influence on GDP growth, necessitating investments in renewable energy and energy-efficient technology. Prioritizing Human Capital and technology Advancement, while supporting innovation through research and development, may increase the contributions of a competent workforce and technology advancement.

Lastly, a focus on Balanced Economic Growth, achieved through inclusive policies and addressing negative externalities can ensure equitable benefits. By integrating these strategies into policy frameworks, Nigeria can propel sustainable long-term prosperity while addressing environmental and social challenges, ultimately benefiting its economy and society holistically.

References

- Andersson, J., & Nässén, J. (2021). "Green Stimulus, Jobs, and Short-Term Emissions Reductions."
- Anyadike, R. C. (2009). Climate change and sustainable development in Nigeria: Conceptual and empirical issues. In *Enugu forum policy paper* (Vol. 10, pp. 13-18).
- Asmamaw, M., Mereta, S. T., & Ambelu, A. (2019). Exploring households' resilience to climate change-induced shocks using Climate Resilience

- Index in Dinki watershed, central highlands of Ethiopia. *PloS one*, 14(7), e0219393.
- Barbier, E. B., & Hochard, J. P. (2020). "Can the Economic Diversification of Fossil Fuel-Dependent Countries Enhance Their Resilience to Climate Change?"
- Brown, K., & Westaway, E. (2011). Agency, capacity, and resilience to environmental change: lessons from human development, well-being, and disasters. *Annual review of environment and resources*, 36, 321-342.
- Burch, S., Kandlikar, M., & Pinter, L. (2019). "Adoption, Diffusion, and Abatement Costs of Electric Vehicles: A Review."
- Cutter, S. L. (2020). Community resilience, natural hazards, and climate change: Is the present a prologue to the future? *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography*, 74(3), 200-208.
- Eboh, E. C. (2009). Implications of climate change for economic growth and sustainable development in Nigeria.
- Gennaioli, C., Perotti, E., & Rossi, S. (2018). "Banks, Government Bonds, and Default: What Do the Data Say?"
- Haider, H. (2019). Climate change in Nigeria: impacts and responses.
- Hallegatte, S., & Rozenberg, J. (2017). "Climate Change Through a Poverty Lens."
- Heal, G., & Millner, A. (2014). "Uncertainty and Decision Making in Climate Change Economics."
- Kralovec, S. (2020). Food insecurity in Nigeria - An analysis of the impact of climate change, economic development, and conflict on food security.
- Magbagbeola, N. O. (1999). Economic growth and environmental development in Nigeria: impact on climate change. *The Nigerian Journal of Economic and Social Studies*, 41(2), 275-294.
- Morecroft, M. D., Crick, H. Q., Duffield, S. J., & Macgregor, N. A. (2012). Resilience to climate change: translating principles into practice. *Journal of Applied Ecology*, 49(3), 547-551.
- National Academies of Sciences, Engineering, and Medicine. (2020). "Adapting to the Impacts of Climate Change."
- Ojonuga, O., Olomolaiye, A. O., Ajayi, O. A., & Adeoye, A. O. (2018). The impact of energy consumption, CO2 emissions, capital, and labor on economic growth in Nigeria: An ARDL approach. *Energy*, 159, 171-18
- Pelling, M., O'Brien, K., & Matyas, D. (2015). Adaptation and transformation. *Climatic change*, 133, 113-127.

- Pesaran, M. H., Shin, Y., and Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *J. Appl. Econ.* 16 (3), 289–326. doi:10.1002/jae.616
- Robinson, S. A., & Butchart, C. (2022). Planning for climate change in small island developing states: can Dominica's climate resilience and recovery plan be a model for transformation in the Caribbean? *Sustainability*, 14(9), 5089.
- Smith, G., Martin, A., & Wenger, D. E. (2018). Disaster recovery in an era of climate change: The unrealized promise of institutional resilience. *Handbook of disaster research*, 595-619.

PART 5



Socio-Economic Aspects for Energy and Environment





An Analysis of the Economic Determinants of Cooking Energy Choice in Delta State, Nigeria

Iruoghene Emohefe Odenu,
Shuaibu Mohammed, Magaji,
Musa Adewumi and
Ifeyanyi Polycarp Maduechesi

Abstract

Energy poverty in Nigeria has led to an increase in the adoption of polluting cooking energy sources by households. This poses a significant challenge, especially for those relying on electricity for their basic energy needs. Rural dwellers and urban poor communities heavily depend on fuelwood for cooking. However, this dependence becomes problematic when a large number of households rely on forests for fuelwood, leading to forest degradation. Such degradation has serious consequences for households and the environment, including limiting economic opportunities, access to education, food security, healthcare, and gender equality, thereby impacting the overall quality of life. The objective of this study is to examine the economic factors that influence household cooking energy choices (fuelwood,

charcoal, kerosene, LPG, and electricity) in Delta State. Data was collected from 491 households across eight selected local governments. Due to the categorical nature of the variables of interest, descriptive statistics and a Multinomial Logit model was employed. A sensitivity test was conducted using the multivariate probit model. The empirical analysis reveals that economic factors significantly influence cooking energy choices. Specifically, the income of the household head, occupation of the household head, occupation of the household spouse, monthly expenditure on primary energy, and level of education were found to be significant economic determinants of cooking energy choices. The results indicate that state governments, non-governmental organizations, clean energy companies, and other important stakeholders have a crucial role to play through awareness programs on the consequences of using polluting cooking energy sources.

Keywords: Energy poverty, household, cooking energy, Delta State.

5.1 Introduction

Energy is crucial for the growth and development of any nation. Through the energy sector, the socio-economic wellbeing of the people can be improved, thereby eradicating poverty. Access to clean cooking energy for households is crucial for improved indoor health and productivity, a reduction in indoor health pollution, and a reduction in the wastage and loss of manpower and working hours (Abdulganiyu, 2019).

According to the World Health Organization (2016), approximately 3.1 billion people worldwide, residing in low- and middle-income countries, lack access to clean cooking energy and rely on polluting cooking energy and technologies. These traditional cooking methods often involve inefficient stoves, leading to the emission of toxic pollutants into the atmosphere. Consequently, this contributes to household air pollution, resulting in unnecessary health risks and

fatalities. The utilization of conventional cooking practices significantly impacts both households living conditions and health. Reports from the International Energy Agency (IEA, 2016) and the World Health Organization (WHO, 2016) indicate that the predominant use of fuelwood and charcoal in urban and rural areas raises environmental concerns, particularly regarding deforestation to meet charcoal demand (Win, Mizoue, Ota, Kajisa, & Yoshida, 2018).

Households in Nigeria have witnessed a surge in the shortage of energy supply. Presently, the prices of modern cooking energy are more expensive, with the price of LPG indicating the high price volatility on the world market. It has had a negative consequence, especially for low-income households (Kojima, 2021). The distribution of households in Nigeria based on their energy choices for cooking reveals that 51.5% of households rely on fuelwood, 16.72% consume kerosene, 17.1% utilise liquefied petroleum gas (LPG), 0.7% use electricity, and 0.1% utilise other forms of cooking energy (National Bureau of Statistics, 2020).

In urban areas, the distribution is as follows: 21.9% use fuelwood, 13.2% use biomass, 35.5% use LPG, 28.2% use kerosene, and 1.1% use electricity. In rural areas, the distribution differs significantly: 70.8% use fuelwood, 14.5% use biomass, 5.1% use LPG, 9.1% use kerosene, 0.5% use electricity, and 0.1% use other forms of cooking energy (National Bureau of Statistics, 2020). The overreliance on fuelwood, according to Orimoogunje and Asifat (2016), has placed a significant burden on the environment, thereby resulting in the loss of over 260,000 metric tonnes of wood, leading to deforestation and forest degradation, adverse impacts on biodiversity, soil erosion, and carbon sequestration. Additionally, the unsustainable use of fuelwood exacerbates climate change and further exacerbates energy poverty by depleting natural resources relied upon by communities for their energy needs.

In Delta State, there is a notable prevalence of households relying on traditional energy sources. According to the National

Bureau of Statistics (2020), 44.3% of households depend on fuelwood for their cooking and heating needs, while 4% use biomass.

Additionally, 27.7% utilise liquefied petroleum gas (LPG), 23.6% consume kerosene, 0.3% use electricity, and 0.1% consume other forms of energy. The substantial consumption of solid energy sources in Delta State can be attributed to the availability, reliability, and affordability of traditional cooking energy compared to modern energy sources. However, the reliance on traditional energy exacerbates energy poverty and poses significant health risks. Health issues associated with the use of solid cooking energy include lung cancer, acute respiratory diseases, tuberculosis, blindness, and heart diseases, among others (WHO, 2021). Addressing the lack of access to clean energy is crucial not only for poverty alleviation but also for improving public health outcomes in Delta State and beyond.

The aim of this paper is to investigate the economic determinants of household cooking energy choices in selected LGAs in Delta State, Nigeria. The outline is as follows: Section 1 is the introduction, while Section 2 focuses on a review of related literature. Section 3 is the methodology, while Section 4 is the presentation and discussion of the results. Section 5 concludes and recommends policies.

5.2 Literature Review

A common concept in energy consumption dynamics is the energy ladder theory. This theory postulates that the income of the household determines the energy resource that a household consumes. That is, low-income households consume traditional cooking energy, while high-income households consume modern cooking energy. The theory further states that as the income of households increases, there is a smooth transition along the energy ladder from traditional cooking energy to modern cooking energy (Toole, 2015). The scholarly articles of some authors have given insight on how households transition from traditional to clean cooking energy using the energy ladder.

Adopting the two-stage probit least squares method in Nepal, Bridge *et al.* (2016) conducted a study on the effects of electricity consumption on income for the period 2010–2011. The findings reveal that income influences electricity consumption in Nepal. Also employing the probit model for their study in Ghana, Twumasi *et al.* (2019) found that the level of education, access to farm work via the internet, ownership of non-fixed assets, access to credit, and having a house in an urban area were significant factors in household cooking energy choice.

In a similar study also conducted in Northern Sudan, Mperejekumana *et al.* (2021) adopted the multinomial logit model in analysing responses from 280 households. The findings indicate that fuelwood and charcoal were the most used cooking energy. Access to credit and the level of education were positive determinants of cooking energy. Also adopting the multinomial logit model for 5,408 households in Nigeria, Popoola and Ibrahim (2023) found that access to power supply, household income, level of education, and the size of the household were the determinants of cooking energy choices. In a separate study and also employing the multinomial logit model for 4,400 households in sub-Saharan Africa with evidence from Nigeria, Aminu (2024) found that household wealth, level of education, and access to electricity were the determinants of cooking energy choices. Using the same model and data from the Nigerian demographic and health survey 2018 for 40,427 households, Abubakaret *et al.* (2024) found that the wealth index of households, education, and geographical location of households determine the choice of cooking energy. Other studies that utilised the multinomial logit model include those of Rahut *et al.* (2019) in Pakistan, Chourmet-Nkolo *et al.* (2019), and Lykukurwa and Mkuna (2019) in Tanzania. These studies found that income of the household head, level of education of the household, and household spouse were the determinants of cooking energy choices.

Adopting the seemingly unrelated regression for 235 households in Central Uganda, Mainimo *et al.* (2022) found that briquette price, gender of the household head, main occupation, and source of energy determined the consumption of briquette. Similarly, charcoal demand was influenced by energy expenditure, household size, charcoal price, district, and energy restrictions. Additionally, the demand for fuelwood was determined by household income, fuelwood price, energy expenditure, household size, and energy source.

The Chi-Square estimators have been adopted by several scholars in their studies. This includes the study by Makonese *et al.* (2017), which found that the place of residence, type of cooking energy, and access to cooking energy were statistically significant. Using a similar estimation technique, Wassie *et al.* (2021) studied rural Sub-Saharan Africa, surveying 660 households. Employing chi-square and multivariate probit models, they reveal that a majority (90.7%) of rural households relied on fuelwood for cooking, while only 3.14% used clean cooking energy.

Employing the Tobit model for 1,472 households in China, Zhuo and Luo (2019) found that the age of the household head, level of education, and size of the household determine cooking energy. The study of Maina and Yusuf (2023) in Yobe State, Nigeria, employing the Nigerian COVID-19 national longitudinal survey and the OLS estimation technique for 120 households found that 50% of the surveyed households consume fuelwood. The study also found that the income of the household, the size of the household, and the household head were positive determinants of cooking energy choices. Kitole *et al.* (2023) utilise a comparable regression model to assess cooking energy choices among 2,736 respondents in urban areas of Tanzania and their implications for poverty reduction. The results reveal that impoverished households predominantly relied on traditional cooking energy sources, which dominated household cooking activities.

The critical analyses of these dynamics over several years illuminate the intricate and multifaceted nature of household cooking energy transitions in the different regions and Delta State in particular. It emphasises the significance of comprehending the interplay among economic, social, and environmental factors in steering shifts in cooking practices and the embrace of cleaner and more sustainable cooking technologies.

5.3 Theoretical Framework

The theory of consumers behaviour is employed in understanding and modelling the behaviour of consumers in relation to product markets. According to Marshallian economics, consumers would allocate their income towards the items that will provide them with the most satisfaction based on their preferences and the relative costs of other things. It is possible to link Jeremy Bentham and Adam Smith to this theory. They used simplified assumptions to assess the consequences of changing one variable, such as price, while holding other factors constant. Modern utility theory has developed from this idea and approach, allowing customers to optimise their utility by carefully weighing the financial implications of every purchase (Mohammedi & Mohamed, 2011).

There are certain premises upon which this theory stands. These assumptions are rationality, cardinal utility, constant marginal utility, diminishing marginal utility, and the assumption that the total utility of a basket of goods depends on the quantities of the individual commodities. The utility of how a consumer value different commodity is connected to their preference, consistency, and transitivity of choice. Consumers rank all available consumption bundles; therefore, for any two bundles of goods A and B, the consumer can establish a preference and choose any of the preferred bundles of goods. If a consumer is consistent in his choice in a particular period and chooses bundles of goods A over B, he will not choose B over A at any other period if both bundles of goods are presented before him.

If $A > B$, then $B \neq A$

Also, there is transitivity in a consumer's choice if the bundles of good A are preferred to B, and B is preferred to C, then bundle A is preferred to C. This can be shown as

If $A > B$, and $B > C$, then $A > C$

Another premise is that of total utility of a basket of goods depends on the quantities of the individual commodity. This can be given as

$$U = f(X_1, X_2, \dots, X_n) \quad \text{.....Eqn 5.1}$$

In this theory, the total utility is assumed to be additive that is

$$U = U_1(X_1) + U_2(X_2) + \dots + U_n(X_n) \quad \text{.....Eqn 5.2}$$

Thus, the consumer is in equilibrium when the marginal utility of X is equal to the price of good X.

$$MU_x = P_x \quad \text{.....Eqn 5.3}$$

When the marginal utility of a consumer is higher than the price of a good (x), then the consumer can increase his welfare by purchasing more of good x. Also, when the marginal utility of x is less than the satisfaction of the consumer, the consumer can increase his utility by cutting down on the quantity of good x and saving his income. When the commodities are more, the consumer is in equilibrium when the ratios of the marginal utility of each of the commodities are equal to their prices. This is given as

$$\frac{MU_x}{P_x} = \frac{MU_y}{P_y} = \dots = \frac{MU_n}{P_n} \quad \text{.....Eqn 5.4}$$

In situations where utility is measured in monetary units, if the consumer purchases q_x quantity of the product, his expenditure is $q_x p_x$. Therefore, the consumer seeks to maximize the difference between his utility and his expenditures; this can be shown as

$$U = P_x q_x \quad \text{.....Eqn 5.5}$$

The utility that a consumer derives from spending an additional unit of money must be equal for all commodities. If the consumer derives greater utility from any of the commodities, he can increase his welfare by spending more money on that commodity and less on the others to achieve equilibrium (Koutsoyiannis, 2002).

As stated by Assael (1995), this theory is important because it shows how consumers determine the sales and profits of a firm through their purchasing decisions. As such, the economic viability of any nation rests on this theory. Also, an organisation needs to acknowledge consumer needs as a key to success for both profit generation and survival in an economy.

5.4 Methodology

Purposive and random selection approaches were employed in this study to choose households from both rural and urban areas within the designated local governments. While random sampling is used to pick different households within each local government, purposive sampling is used to select the communities, wards, and local government areas where the survey is conducted. These selected LGAs were chosen because they are considered the economic hubs within the state.

The sample for this study was collected from the 2006 population census, projected at a 3.2% growth rate for Delta State (National Bureau of Statistics, 2017). The number of households in Delta State is: Isoko North (49,000), Isoko South (80,280), Udu (50,211), Ughelli North (109,801), Ughelli South (72,529), Uvwie (66,515), Warri North (44,908), and Warri South (106,149). 2021 is 1,428,031.

The projected household populations for each of the local governments under study are as follows: Isoko North (49,000), Isoko South (80,280), Udu (50,211), Ughelli North (109,801), Ughelli South (72,529), Uvwie (66,515), Warri North (44,908),

and Warri South (106,149). The sample size for the study was achieved using the Yamane formula for calculating sample size and validated by Adam (2020). He argued that the Yamane formula, being a simplified formula based on proportion, has gained popularity among researchers for its simplicity. The formula is mathematically illustrated as follows:

$$n = \frac{N}{1 + N(e)^2} \qquad \text{.....Eqn 5.6}$$

Where; n is Sample Size, N is the number of households in Delta State, e implies Margin of error, and 1 is a Constant. In this case, the confidence level is 95% while the error margin is 5%. Where N = 1,428,031 and e = 5%. Using the Yamane formula, the sample size for each local government area can be calculated based on the projected household populations and a chosen margin of error. The sample size of the study will be;

$$\begin{aligned} n &= \frac{1,428,031}{1 + 1,428,031 (0.05)^2} \\ n &= \frac{1,428,031}{3,571.1} \\ n &= 400 \end{aligned}$$

The number of questionnaires is often increased to compensate for non-responses. According to Taherdoost (2019), the most common and time-effective approach to ensuring that the minimum sample size is met is to increase the sample size by up to 30%. Therefore, by increasing the number of questionnaires for this study by 30% to compensate for non-response, the sample size becomes 520.

The questionnaires for the study are not distributed equally to the selected local government areas because some LGAs have a larger population of households than others. Therefore, given the number of households in each of the LGAs and the total number of households in the eight selected LGAs, the percentage of questionnaires

distributed to each LGA is determined. Thus, the questionnaires are assigned as follows: Ughelli North (19%), Warri South (18.4%), Isoko South (14%), Ughelli South (12.5%), Uvwie (11.5%), Udu (8.7%), Isoko North (8.5%), and Warri South (7.6%). Using the percentage distribution, the total number of questionnaires distributed for each local government is Ughelli North (99), Warri South (95), Isoko South (73), Ughelli South (65), Uvwie (60), Udu (45), Isoko North (45), and Warri North (39).

5.4.1 Model Specification

The model for this study is adapted from Rahut et al.'s (2017) analyses of household energy consumption and its determinants in Timor-Leste. In their study, energy choices such as fuelwood, kerosene, electricity, and others were considered dependent variables. The explanatory variables include household demographic characteristics, labour supply, human and physical capital, and location dummies. Thus, the models are specified as follows, in line with the objectives of the study:

Given the objective of the study, the following variables and models were developed:

Model 1: $ENC = f(INHH, INHS),$ Eqn 5.7

Model 2: $ENC = f(INHH, INHS, OCHH, OCHS,)$ Eqn 5.8

Model 3: $ENC = f(INHH, INHS, OCHH, OCHS, EXPF, EPPF,)$ Eqn 5.9

Model 4: $ENC = f(INHH, INHS, OCHH, OCHS, EXPF, EPPF, OHLP, EDUL)$ Eqn 5.10

Model 5: $ENC = f(INHH, INHS, OCHH, OCHS, EXPF, EPPF, OHLP, EDUL, TYPF)$ Eqn 5.11

$P\left(\frac{Pi}{1-Pi}\right) = f(INHH, INHS, OCHH, OCHS, EXPF, EPPF, OHLP, EDUL, TYPF)$ Eqn 5.12

The econometric form of 3.9 is expressed as;

$P\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1INHH + \beta_2INHS + \beta_3OCHH + \beta_4OCHS + \beta_5EXPF + \beta_6EPPF + \beta_7OHLP + \beta_8EDUL + \beta_9TYPF + \mu_1$ Eqn 5.13

Where P_i , is the probability of a household choosing particular primary cooking energy relative to others. The energy choices examined are fuelwood, charcoal, kerosene, LPG, and electricity; this is further categorized into clean energy (LPG and electricity) and unclean (fuelwood, charcoal and kerosene) cooking energy.

ENC = Cooking Energy

INHH = Income of the Household Head

INHS = Income of the Household Spouse

OCHH = Occupation of the Household Head

OCHS = Occupation of the Household Spouse

EXPF = Monthly Expenditure on Feeding

EPPF = Monthly Expenditure on Primary Cooking Energy

OHLP = Ownership of a House or Landed Property

EDUL = Level of Education

TYPF = Type of Primary Cooking Energy Choice

β_0 is the intercept or slope parameter

$\beta_1, \beta_2, \dots, \beta_9$ are the coefficient of the explanatory variables

μ_1 is the error term.

5.4.2 Estimation Technique

Multinomial logit regression is used when the dependent variable is nominal or categorical, that is, it falls into a particular set of categories that cannot be ordered, in which the categories are more than two. In this form of analysis, the transformation of the outcome variable has a linear relationship with the predictor variable, and the regression result is interpreted using the odd ratio (Odenu, 2024). The choice of household cooking energy (i) is analysed for the choice of cooking energy (j) over a time period (t). The household derives satisfaction from its choice of cooking energy. The maximisation of the utility of the household is the sole aim of the consumer.

Given the utility-maximising behaviour of the household, the utility function of the household can be written as:

$$u_{ij} = X_i' \beta_j + \varepsilon_{ij}$$

Where $j = 1, 2, 3, \dots, n$, is the vector of all primary cooking energy determinants and is the vector of the associated coefficient. The term refers to the error term. This term is assumed to be independent and identically distributed (Popoola *et al.*, 2023).

When a household chooses a particular energy and is a subset of j , in this case it is assumed that is greater than. The vector of independent variables equals the observed choice set and takes the value 1 for the choice of energy chosen and 0 for other forms of cooking energy not chosen.

The probability of choosing a particular form of cooking energy, j , is given as follows:

$$P(Y_{ij} = j/X_i) = \frac{\exp(\beta_j' X_i)}{\sum_{k=1}^J \exp(\beta_k' X_i)}$$

Where β_j indicates the nature of the relationship without indicating the probabilistic strength of the equation. Thus, the marginal effect of the estimated odd ratio can be written as:

$$\delta_{ij} = \frac{\partial P_j}{\partial X_j} = P_j(\beta_j - \sum_{j=0}^5 P_j \beta_j) = P_j[\beta_j - \beta_j] = P_j[\beta_j - \beta_j], j = 1, 2, 3, 4, 5$$

Where δ is the probability of adopting a particular cooking energy, j is the explanatory variables for households. The explanatory variables for cooking energy by households in this study include the income of the household head, income of the household spouse, occupation of the household head, occupation of the spouse, monthly expenditure on feeding, monthly expenditure on primary cooking energy, ownership of a house or landed property, and the level of education.

5.4 Results and Discussions

Table 5.1 shows the descriptive statistics of respondents for the selected LGAs in Delta State. Out of 520 observations, with 491 observations were returned valid. The maximum value is 5 recorded for the income of the household head, income of household spouse,

occupation of household head, occupation of household spouse, monthly expenditure on feeding and monthly expenditure on primary cooking energy. The observation for monthly expenditures on feeding has the highest mean, and the ownership of a house or land property had the lowest mean. The standard deviation indicates the spread of observations around the mean. The income of the household spouse has the highest standard deviation of 1.892, and ownership of a house or landed property has the lowest at 0.583. One of the variables being examined, the type of primary cooking energy (TYPF), had a problem of multicollinearity, hence the variable was removed from the analysis. This significantly affects the study's interpretation and outcomes. This includes loss of information, bias, and a decrease in the model's predictive effectiveness.

Table 5.1: Descriptive Statistics of Respondents

Variable	N	Min.	Max.	Mean	Std. Dev.	Skewness	Kurtosis
Income of household head	491	1	5	3.38	1.520	-.259 (.110)	-1.471 (.220)
Income of household spouse	491	0	5	2.21	1.892	.239 (.110)	-1.401 (.220)
Occupation of household head	491	0	5	2.83	1.172	-.541 (.110)	-1.049 (.220)
Occupation of household spouse	491	0	5	2.08	1.589	-.174 (.110)	-1.518 (.220)
Monthly expenditure on feeding	491	1	5	3.05	1.414	.057 (.110)	-1.287 (.220)
Monthly expenditure on primary cooking fuel	491	0	5	2.10	1.010	.550 (.110)	-.510 (.220)
Ownership of a house/ landed property	491	0	4	.49	.583	1.383 (.110)	5.107 (.220)
Level of education	491	0	4	2.44	.842	-1.235 (.110)	1.247 (.220)

Source: Author Fieldwork (2021)

5.4.1 Descriptive Statistics of the Variables

Distribution of Respondents according to Income of Household Head

Table 5.2 reveals the distribution of income of household head in each selected LGA in Delta State.

Table 5.2: Income of Household Head

INCOME LEVEL	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
Below 30,000	10	3	5	9	4	13	19	9	72	15
30,001-50,000	14	9	8	10	17	17	16	14	105	21
50,001-70,000	13	6	9	8	6	7	14	3	66	13
70,001-90,000	6	8	6	4	5	9	14	8	60	12
Above 90,000	17	17	32	14	7	47	24	30	188	38

Source: Author’s Fieldwork (2021)

Table 5.2 illustrates the distribution of households based on the income of the household head. Among households surveyed, 72 households earn less than N30,000, with a notable concentration in Ughelli North and Warri South.

105 households earn between N30,001 and N50,000, with the highest respondents (17) recorded in both Warri South and Warri North, and the lowest (8) in Isoko South.

66 households earn between N50,001 and N70,000 with the highest (13) recorded for Uvwie and the lowest recorded for Ughelli South.

In the income bracket of N70,000 to N90,000, a total of 60 respondents were identified, with the majority of household statistics located in Ughelli North (14) and the lowest for Isoko North.

Lastly, 188 households earn above N90,000, with the highest concentration recorded in Warri South (47) and the lowest in Warri North (7).

Distribution of households according to income of the household spouse

Table 5.3 reveals the distribution of the income of the household spouse in each selected LGA in Delta State.

Table 5.3: Income of Household Spouse

INCOME LEVEL	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
None	11	12	19	16	13	32	17	13	133	28
Below 30,000	12	4	4	5	6	7	18	12	68	14
30,001-50,000	10	5	4	6	7	15	11	16	74	15
50,001-70,000	7	4	4	5	5	17	12	8	62	12
70,001-90,000	10	2	11	2	4	4	10	4	47	9
Above 90,000	10	7	17	11	4	18	29	11	107	21

Source: Author’s Fieldwork (2021)

Table 5.3 presents the distribution of respondents across local governments based on the income of the household spouse. It reveals that:

133 household spouses do not earn any income, with the highest number recorded in Warri South (32) and the lowest in Uvwie (11). 68 household spouses earn between N0 and N30,000, with the highest number of respondents in Uvwie and Ughelli South (12) and the lowest in Udu.

74 household spouses earn between N30,001 and N50,000, with the majority of respondents in Ughelli South (16) and the fewest in Isoko South (4).

62 household spouses earn between N50,001 and N70,000, with the highest numbers in Warri South (17) and the lowest in Udu and Isoko South (4).

47 household spouses earn between N70,001 and N90,000, with the highest numbers in Ughelli North (10) and the lowest in Udu (2).

Finally, 107 respondents earn above N90,000, with the highest numbers in Ughelli North (29) and the lowest in Warri North (4)."

Distribution of Households according to Occupation of Household Head

Table 5.4 shows the distribution of household head occupations in each selected LGA in Delta State.

Table 5.4: Occupation of Household Head

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
None	3	0	0	0	1	4	8	4	20	4
Artisan	12	11	12	12	7	11	11	11	87	18
Farmer	12	15	12	34	16	12	8	10	119	24
Trader/Business	19	23	16	14	10	16	14	15	127	26
Civil/Public Servant	18	16	18	16	16	21	17	16	138	28

Source: Author’s Fieldwork (2021)

Table 5.4 provides insight into the occupation of household heads. It reveals that:

20 respondents are unemployed, with the highest number recorded in Ughelli North (8) and the lowest in Udu, Isoko South, and Isoko North (0).

87 respondents work as artisans, with the highest respondents recorded in Uvwie, Isoko South, and Isoko North (12), and the lowest in Warri North (7).

119 respondents are farmers, with the highest respondents recorded in Isoko North (34) and the lowest in Ughelli North (8).

127 respondents are traders or businessmen, predominantly recorded in Udu (23), and the lowest number recorded in Isoko North and Ughelli North (14).

138 respondents are civil servants or public servants, with the highest respondents recorded in Warri South (21) and the lowest in Udu, Isoko North, Isoko South, and Ughelli South (16).

Distribution of Households According to Occupation of Household Spouse

Table 5.5 indicates the distribution of households according to the occupation of the household spouse in each selected LGA in Delta State.

Table 5.5: Occupation of Household Spouse

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
None	11	21	20	14	13	26	17	19	141	29
Artisan	16	4	7	3	7	11	7	4	59	12
Farmer	1	6	4	4	4	4	8	5	36	7
Trader/Business	24	11	15	13	11	26	28	20	148	30
Civil/Public Servant	7	5	14	11	4	23	27	16	107	22

Source: Author’s Fieldwork (2021)

Table 5.5 provides insights into the occupation of household spouses. It reveals that:

141 household spouses do not work, indicating a significant number of households where the spouses are unemployed. The highest incidence was recorded for Warri South (26) and the lowest for Warri North (13).

59 respondents work as artisans, with the highest number of respondents recorded in Uvwie (16) and the lowest in Isoko North (3).

36 respondents work as farmers, with the highest respondents in Ughelli North (8) and the lowest in Uvwie (1).

The number of traders or business women recorded is 148, with the highest in Ughelli North (28) and the lowest in Udu and Warri North (11).

A total of 107 household spouses work as civil servants, with the highest number of respondents in Ughelli North (27) and the lowest in Warri North (4).

Distribution of Respondents According to Monthly Expenditure on Feeding

Table 5.6 reveals the distribution of the income of the household spouse in each selected LGA. The data for the monthly expenditure on the feeding of households is presented as follows:

Table 5.6: Monthly Expenditure on Feeding

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
Below 20,000	17	2	6	8	3	15	20	13	84	17
20,001-30,000	15	10	7	11	12	23	26	8	112	23
30,001-40,000	9	12	15	14	14	21	13	11	109	22
40,001-50,000	10	13	12	4	2	6	10	12	69	14
Above 50,000	9	6	20	8	8	28	18	20	117	24

Source: Author’s Fieldwork (2021)

Table 5.6 presents the distribution of respondents according to their monthly expenditure on feeding. It reveals that:

84 respondents spend below N20,000 on their monthly feeding expenses, with the highest occurrence in Ughelli North (20) and the lowest in Udu (2).

112 respondents spend between N20,001 and N30,000, with the highest incidence in Ughelli North (26) and the lowest in Isoko South (7).

109 respondents spend between N30,001 and N40,000, with the highest occurrence in Warri South (21) and the lowest in Uvwie (9).

69 households spend between N40,001 and N50,000, with the highest respondents recorded in Udu (13) and the lowest in Warri North (2).

Lastly, 117 respondents spend above N50,000 on feeding, with the highest occurrence in Warri South (28) and the lowest in Udu (6).

Distribution of Respondents According to Type of Primary Cooking Energy

Table 5.7 reveals the distribution of households according to the type of primary cooking energy consumed in each selected LGAs in Delta State.

Table 5.7: Type of Primary Cooking Energy

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
Unclean Energy	28	14	15	15	25	34	16	28	175	36
Clean Energy	32	29	45	30	14	59	71	36	316	64

Source: Author's Fieldwork (2021)

Table 5.7 illustrates the distribution of households based on their consumption of primary cooking energy. It reveals that:

175 households consume unclean cooking energy, with the highest incidence in Warri South (34) and the lowest in Udu (14).

On the other hand, 316 households consume clean cooking energy, with the highest recorded in Ughelli North (71) and the lowest in Udu (29).

Distribution of Respondents according to Monthly expenditure on Primary Cooking Energy

Table 5.8 reveals the distribution of the households according to the monthly expenditure on primary cooking energy in each selected LGA.

Table 5.8: Monthly Expenditure on Primary Cooking Energy

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
Below 5,000	12	9	19	18	15	36	28	24	161	33
5,001-10,000	27	13	8	12	11	33	37	19	160	33
10,001-15,000	13	15	11	11	8	17	16	14	105	21
Above 15,000	8	6	12	9	8	7	6	9	65	13

Source: Author's Fieldwork (2021)

Table 5.8 provides an overview of the frequency of monthly expenditure on primary cooking energy for households. It reveals that:

2 respondents do not consume cooking energy, indicating a small proportion of households that do not use cooking energy.

161 households spend below N5,000 on primary cooking energy,

with the highest incidence in Warri South (36) and the lowest in Udu (9).

160 households spend between N5,001 and N10,000 on primary cooking energy, with the highest recorded in Ughelli North (37) and the lowest in Isoko South (8).

105 households spend between N10,001 and N15,000 for primary cooking energy, with the highest incidence in Warri South (17) and the lowest in Warri North (8).

Lastly, 65 households spend above N15,000, with the highest incidence in Isoko South (12) and the lowest in Udu and Ughelli North (6).

Distribution of Respondents According to Ownership of a House or Landed Property

The distribution of respondents according to the ownership of a house/landed property for each of the LGA is shown in Table 5.9

Table 5.9: Ownership of a House/Landed Property

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
Own House/land	26	20	30	21	11	50	49	34	241	49
Non- Ownership	34	23	30	24	28	43	38	30	250	51

Source: Author’s Fieldwork (2021)

Table 5.9 presents the distribution of respondents according to the ownership of a house or landed property. It reveals that:

241 households do not own a house or landed property, with the highest incidence in Warri South (50) and the lowest in Warri North (11).

On the other hand, 250 households own a house or landed property, with the highest recorded in Warri South (43) and the lowest in Udu (23).

Distribution of Households According to the Level of Education

The distribution of households according to the level of education in each of the selected local government areas is presented in Table 5.10.

Table 5.10: Level of Education

	UVWIE	UDU	ISOKO SOUTH	ISOKO NORTH	WARRI NORTH	WARRI SOUTH	UGHELLI NORTH	UGHELLI SOUTH	TOTAL	%
No Formal Education	0	0	6	3	5	8	3	7	32	7
Primary	3	1	5	2	3	9	7	7	37	8
Secondary	21	19	7	18	14	21	20	21	141	29
Tertiary	36	23	42	22	17	55	57	29	281	57

Source: Author’s Fieldwork (2021)

Table 5.10 displays the distribution of households according to their level of education. It reveals that:

32 respondents do not have formal education, with the highest incidence in Warri South (8) and no respondents in Uvwie and Udu (0).

37 respondents have primary education, with the highest recorded in Warri South (9) and the lowest in Udu (1).

141 respondents have secondary education, with the highest in Uvwie, Ughelli South, and Warri South (21) and the lowest in Isoko South (7).

281 respondents have tertiary education, with the highest in Ughelli North (57) and the lowest in Warri North (17).

5.4.2 Results of Econometric Analysis

The objective of this study is to analyse the economic determinants of cooking energy in Delta State. This involved assessing the impact of economic factors on cooking energy choices in the selected local governments of Delta State. To achieve these objectives, the study employed multinomial logit regression model, and a sensitivity check was conducted using the Probit regression estimators. However, during the regression analysis the type of primary cooking energy (TYPF) had the problem of multicollinearity. However, to address

the issue of multicollinearity and ensure the robustness of the regression model, this variable was dropped from the analysis.

5.4.2.1 Economic Factors as Determinants of Cooking Energy Choices in Delta State

The results presented in Table 5.11 and models 1-4 focus on the first objective, where the dependent variable (ENC) represents household cooking energy choices, categorized into clean and unclean options. In model one, the analysis reveals that the income of the household head holds significance, with a negative effect on household cooking energy choice. However, the income of the household spouse was deemed insignificant in influencing cooking energy choices.

Upon the inclusion of additional variables such as the occupation of the household head and spouse in model two, both variables were found to be statistically significant. Interestingly, while the income of the household head continued to exhibit a negative coefficient, indicating its impact on cooking energy choices, the income of the household spouse displayed a positive coefficient. This suggests a nuanced dynamic where women (spouses) might play a pivotal role in driving household cooking energy choices.

In model 3, the analysis suggests that monthly expenditure on primary cooking energy has a significant negative impact on household cooking energy choices. Conversely, monthly expenditure on food and the occupation of the household spouse were found to have a positive and significant effect on cooking energy choices.

Furthermore, in model four, ownership of a house or landed property and the level of education were also found to exert a statistically significant negative influence on household cooking energy choices. This suggests that households with higher levels of education and those owning property are more likely to opt for cleaner cooking energy sources. Interestingly, the ownership of a house or landed property was not found to be a significant influencing factor in household cooking energy choices in Delta State.

Table 5.11: Logit Model Results of Economic factors and Cooking Energy Choices (clean and unclean energy choice)

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4
INHH	-0.91 (0.107)***	-0.82 (.119)***	-0.73 (.133)***	-0.60 (.141)***
INHS	-0.09 (0.081)	-0.17 (.114)*	-0.17 (.129)	-0.15 (.136)
OCHH		-0.44 (.109)***	-0.36 (.127)***	-0.22 (.137)*
OCHS		0.18 (.107)*	0.27 (.122)**	0.25 (.129)*
EXPF			0.29 (.157)*	0.21 (.171)
EPPF			-1.22 (.236)***	-1.07 (.235)***
OHLP				-0.45 (.307)
EDUL				-0.81 (.177)***

Sources: Author's computation using STATA 14.2 (2021). , **, and *** indicate statistical significance at 10%, 5%, and 1% level, respectively.

The results indicate that for each unit increase in the probability of the household head's income, there is a corresponding decrease in the odds of household cooking energy choices by factors of 0.91, 0.82, 0.73, and 0.60 for models 1, 2, 3, and 4, respectively.

Similarly, a percentage increase in the income of the household spouse is associated with reduced odds of cooking energy choices by approximately 0.09, 0.17, and 0.15 in models 1, 2 and 3, and 4 respectively.

A unit change in the occupation of the household head is associated with a reduction in the odds of household cooking energy choices by factors of 0.44 (model 2), 0.36 (model 3), and 0.22 (model 4).

Conversely, an increase in the occupation of the household spouse is linked to improved odds of household cooking energy choices by factors of 0.18 (model 2), 0.27 (model 3), and 0.25 (model 4).

Moreover, a unit improvement in monthly expenditure on feeding increases the odds of household cooking energy choices by 0.29 and 0.21 in the respective models.

Conversely, an increase in monthly expenditure on household cooking energy choice decreases the odds of household cooking energy choices by 1.22 and 1.07 in models three and four.

With a one-unit change in the probability of ownership of a house or landed property and level of education, the odds of household cooking energy choices decrease by 0.45 and 0.81 in model four.

The occupation of the household spouse and monthly expenditures on food emerged as significant factors positively influencing household cooking energy choices in Delta State. Conversely, other variables exhibited a significant negative impact on household cooking energy choices. Additionally, post-estimation diagnostics indicate that the logistic model's estimates are reliable and suitable for drawing inferences. Specifically, the probability value of the Likelihood Ratio Chi-square test for specification error is less than 5 percent, indicating that the model is free from misspecification error.

The results from the Probit model (Table 5.12) indicate that the income of the household head is statistically significant and negatively influences household cooking energy choices in Delta State. However, the income of the household spouse is found to be insignificant in model 1.

Furthermore, monthly expenditure on food demonstrates a positive and statistically significant effect on household cooking energy choices, while monthly expenditure on primary cooking energy has a negative and significant impact on household cooking energy choices in model 2.

Table 5.12: Probit Model Results of Economic factors and Cooking Energy Choices (clean and unclean)

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4
INHH	-0.723*** (0.079)	-0.645*** (0.096)	-0.587*** (0.100)	-0.468*** (0.108)
INHS	-0.086 (0.064)	-0.120 (0.079)	-0.153 (0.102)	-0.130 (0.108)
EXPF		0.186* (0.116)	0.207* (0.121)	0.139 (0.131)
EPPF		-0.892*** (0.161)	-0.889*** (0.165)	-0.844*** (0.172)
OCHH			-0.287** (0.103)	-0.172* (0.111)
OCHS			0.233** (0.097)	0.198* (0.102)
OHLP				-0.347S (0.238)
EDUL				-0.676*** (0.137)

Sources: Author's computation using SPSS. *, **, and *** indicate statistical significance at 10%, 5%, and 1% level, respectively.

In model 3 the coefficient of the occupation of the household head shows a significant negative effect on household cooking energy choices, while the occupation of the household spouse demonstrates a significant and positive influence on household cooking energy choices.

Similarly, in model 4, ownership of a house or landed property and level of education exhibit a diminishing effect on household choices of cooking energy in Delta State, both of which are statistically significant, except for ownership of a house or landed property in model. Consistent with the logistic regression results, ownership of a house or landed property does not significantly influence household choices of cooking energy in Delta State.

The analysis suggests several policy implications for promoting the adoption of clean cooking resources which includes; increase in Income and employment generation, subsidies and incentives, infrastructure development, awareness and education, and technological innovation.

By implementing these policy measures, governments and policymakers can promote the widespread adoption of clean cooking energy resources, leading to significant benefits for public health, environmental sustainability, and economic development.

5.4.3 Implication of the Study

The analysis of the economic determinants of household cooking energy in Delta State indicates that the income of the household head, income of the household spouse, occupation of the household head, occupation of the household spouse, monthly expenditure on food, monthly expenditure on primary cooking energy, ownership of a house or landed property are significant, and the level of education are the determinants of cooking energy choices. This also indicates that an increase in income will reduce the cooking energy choice of households in Delta State.

The monthly expenditure on cooking energy indicates that households with lower incomes and budgets for cooking energy consume more traditional cooking energy. Conversely, higher-income households with higher budgets for cooking energy consume clean cooking energy. Also, the ownership of a house or landed property, which indicates the wealth of the household, elucidates that wealthy households will consume clean cooking energy. The income of a household spouse could also affect cooking energy significantly. Income from a household spouse could indicate a higher income for the household and the consumption of efficient cooking energy.

5.5 Conclusion

This study investigates the economic determinants of household cooking energy choices in selected Local Government Areas (LGAs) in Delta State, Nigeria, utilising the theory of consumer behaviour as a framework. This theory helps understand how households rank their consumption patterns given different bundles of goods and how they transition from a particular bundle of goods to another. Households' transition from traditional, unclean cooking energy sources to cleaner alternatives. 36% of households in the study area were found to consume unclean cooking energy, 64% consume clean cooking energy. Using the multinomial logit model, the study identifies several economic factors that determine cooking energy choices, which include the income of the household head, the income of the household spouse, the occupation of the household head, the occupation of the household spouse, the monthly expenditure on feeding, the monthly expenditure on primary cooking energy, the ownership of a house or landed property, and the level of education. From the findings, the study recommends interventions aimed at raising awareness about the health risks associated with unclean cooking energy, particularly in rural areas. It also suggests an increase in household income.

References

- Abdulganiyu, A. I. (2019). Does poverty level influences household energy choice? Empirical evidence from Kwara state, Nigeria. *Amity Journal of Economics*. 4(2), pp. 1-18.
- Abubakar, R. I., Alola, A. A., Bekun, F. V. and Onifade, T. S. (2024). Investigating the determinants of household energy consumption in Nigeria: Insight and Implications. *Energy, sustainability and Society*. 14(29). <https://doi.org/10.1186/513705-024-06451-6>
- Adam, A. M., (2020). Sample Size Determination in Survey Research. *Journal of Scientific Research and Reports*. 2(5); 90-97.
- Aminu, O. R., Dzudzor, A. M., Oyawole, P. F. and Afolayan, O. S. (2024). Understanding the determinants of household cooking fuel choice in

- Sub-Saharan Africa. Evidence from Nigeria. *Clean Energy*. 8 (2), pp. 144-155.
- Assael, H. (1995). *Consumer Behaviour and Marketing Action*. Cincinnati, Ohio: South-Western College Pub., ©1995
- Bridge, B. A., Adhikari, D. and Fontenla, M. (2016). Household-level effects of electricity on income. *Energy Economics*, 58, pp. 222-228
- Choumert-Nkolo, J., Motel, C. P. and Roux, L. (2019). Stacking up the ladder: A panel data analysis of Tanzanian household energy choices. *World Development*, 115, pp 222-235
- IEA (2016) World Energy Outlook. <http://.iea.org/reports/world-energy-outlook2016>
- Koutsoyiannis, A. (2002). *Modern Microeconomics* (second edition). *Palgrave MacMillian*, New York, N.Y.10010
- Lyakurwa, F. S. and Makuna, E. (2019). Dominant factors for energy choice decisions by households in Tanzania: A case study of selected villages in Mvomero District. *African Journal of Science, Technology, Innovation, and Development*, 11(2) pp 141-148
- Maina, Y. B. and Yusuf, A. B. (2023). Analysis of the patterns and determinants of household cooking energy demand in Yobe State, Nigeria. *Gusau Journal of Economics and Development studies*. 4(1) 2023.
- Mainimo, E. N., Okello, D. M., Mambo, W., and Mugonola, B. (2022). Drivers of Household Demand for Cooking Energy: A Case of Central Uganda. *Heliyon*, 8(3), March 2022
- Makonese, T., Ifegbesan, A. P. and Rampedi, I. T. (2017). Household cooking fuel patterns and determinants across Southern Africa. Evidence from the demographic and health survey data. *Energy and Environment*. <http://www.doi.org/10.1177/0958305X17739475>
- Mohammed, M. A., and Mohamed, B. (2011). Applying consumer behaviour theory and grand models to attendee's behaviour in conference industry. *Tourism and Management studies*, 1, pp151-159.
- Mperekumana, P., Li, H., Wu, R., Lu, J., Tursunov, O., Elshareef, H., Gaballah, S. M., Nepo, J. N., Zhuo, Y. and Dong, R. (2021). Determinants of Household Energy Choice for Cooking in Northern Sudan: A Multivariate Logit Regression.
- National Bureau of Statistics (2020) National Longitudinal Phone Survey. <https://www.nigerianstat.gov.ng/nada/index.php/catalog>

- Odenun, I. E. (2024). Analysis of the determinants of household cooking energy in selected Local Government Areas in Delta State. A Ph.D thesis submitted to the postgraduate school, University of Abuja, Abuja Nigeria.
- Orimoogunje, I. O. and Asifat, I. (2015). Fuelwood consumption and species degradation in South-Western Nigeria: The Ecological Relevance. *Journal of Landscape Ecology*, vol 8(1) pp. 56-68
- Popoola, T. O. and Ibrahim, S. (2023). Determinants of Household primary cooking Fuel in Nigeria: Evidence from country wide study. *Ilorin Journal of Economic Policy*. 10, pp. 1-15
- Rahut, D. B., Mottaleb, K. A. and Ali, A. (2017). Household energy consumption and its determinants in Timor-Leste. *Asian Development Reviews*, 34(1) pp. 167-197
- Rahut, B. D., Ali, A., Mottaleb, K. A. and Aryal, P. J. (2019). Wealth, Education, and cooking fuel choices among rural households in Pakistan. *Energy Strategy Reviews*, 24, pp. 236-243
- Taherdoost, H. (2019). What is the best response scale for the survey and questionnaire design? Review of different lengths of rating scale/attitude scale/Likert scale.
<https://www.ideas.repec.org/p/hal/journal/hal-025573088.html>
- Toole, R. (2015). The energy ladder: A valid model for household fuel transition in Sub-Saharan Africa.
<http://www.stiestufts.edu/maryDavis/files/2015/06/thesisfinal.pdf>
- Twumasi, M. A., Jing, Y., Addai, B., Asante, D, Liu, D. and Ding, Z. (2020). Determinants of household choice of cooking energy and effects of clean cooking energy consumption on household members' health status: the case of rural Ghana. *Sustainable Production and Consumption*. 28, pp 484-495
- Wassie, Y. T., Rannestad, M. M., and Adaramola, M. S. (2021). Determinants of household energy choices in rural sub-Saharan Africa. An example from southern Ethiopia. *Energy*, Vol 221.
<http://www.doi.org/10.1016/j.energy.2021>
- Win, C. Z., Mizoue, S., Ota, T., Kajisa, T. and Yoshida, S. (2018). consumption rates and patterns of firewood and charcoal in urban and rural communities in Yedashe township, Myanmar. *MDPI*, 9 (429).

World Health Organization (2016). Guidelines for indoor air quality: Household fuel combustion.

http://wwwapps.who.int/iris/bitstream/handle/10665/141496/9789241548885_eng.pdf?sequence=1

World Health Organization (2021). Household air pollution and health.

Retrieved from [https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health#:~:text=key%20facts,%20crop%20waste\)%20and%20coal.&text=household%20air%20pollution%20causes%20noncommunicable,\(COPD\)%20and%20lung%20cancer](https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health#:~:text=key%20facts,%20crop%20waste)%20and%20coal.&text=household%20air%20pollution%20causes%20noncommunicable,(COPD)%20and%20lung%20cancer)

Zou, B. and Luo, B. (2019). Rural household energy consumption characteristics and determinants in China. *Energy*, vol. 182, pp. 814-823.

www.naee.org.ng



The Role of Remittances in Addressing Adoption of Renewable Energy: Evidence for Nigeria

Dogo, Bishara Saidu,
Abikoye, Michael Oluwafemi
and Umar, Yusuf

Abstract

Remittances play a crucial role in the Nigerian economy, significantly impacting socio-economic indicators, yet their influence on renewable energy adoption remains underexplored. This study addresses this gap, focusing on the surge in off-grid electrification using renewable energy amidst the global shift towards eco-friendly sources. Using ARDL on annual data spanning 1990 to 2020, findings reveal that remittance flows boost renewable energy consumption both in the short and long term. Other variables like exchange rates also affect renewable energy use, suggesting that remittance-receiving households utilize additional income to invest in costly renewable technologies, such as solar home systems. This relationship is strengthened by increased household income and financial stability from remittances,

alongside exposure to renewable practices abroad. To harness this potential, policymakers should incentivize remittance flows, reduce transaction costs, and offer subsidies. Financial institutions should introduce green loans for low-income remittance-receiving households, and exchange rate stabilization should be prioritized to enhance renewable energy adoption in Nigeria.

Keywords: Remittances, Renewable Energy, ARDL

JEL Classification: C32, F24, Q42

6.1 Introduction

Remittances, the financial transfers sent by migrants to their home countries, have long been recognized as vital sources of income for millions of households worldwide. Remittances, a substantial inflow into the country, serve as vital support for households. Nigeria ranks among the top recipients of remittances in sub-Saharan Africa, with billions of dollars flowing into the country annually, US\$17.00 billion in 2020 and US\$19.24 billion in 2021 (CBN statistics database).

Renewable energy has gained increasing attention globally as an alternative to traditional fossil fuel-based energy sources, which have been a significant contributor to environmental degradation and climate change. In the context of developing countries like Nigeria, the potential for renewable energy to address pressing energy challenges and promote sustainable development is particularly compelling. Nigeria, a country rich in natural resources, has struggled to consistently provide reliable and affordable electricity to its growing population, with the majority of the population relying on fossil fuels for their energy needs.

Nigeria's renewable energy potential remains largely untapped, with the country continuing to be heavily dependent on fossil fuels (Shaaban & Petinrin, 2014; Oyedepo et al., 2018; Udoakah & Umoh, 2014). The adverse effects on the environment and the financial

burden placed on the economy by the existing inefficient usage of these fossil fuels must be addressed (Oyedepo et al., 2018). The distribution of decentralised renewable energy resources will not only improve the well-being of rural Nigerian people, but also strengthen Nigeria's energy and economic prospects for possible global investment.

Nigeria's legal and policy environment has also posed significant barriers to the widespread use of renewable energy. The lack of a comprehensive regulatory framework encouraging the use of renewable energy is a major factor contributing to Nigeria's delayed adoption of renewable energy as a replacement source of energy. Strict application of energy regulatory methods and policies with incentives for the use of renewable energy sources are essential (Olujobi, 2020).

In recent years, there has been a growing interest in exploring the potential role of remittances in addressing developmental challenges, particularly in the context of sustainable energy transitions (Das et al., 2021; Subramaniam et al., 2023; Farzana et al., 2023). Despite challenges like financial literacy and regulatory barriers, opportunities exist for innovative financing and policy incentives to leverage remittances for sustainable energy development. Integrating remittances into energy strategies holds promise for driving renewable energy adoption, fostering socio-economic progress and environmental sustainability (Saliba et al., 2022).

In light of this, our research, therefore, explores the potential of directing remittances towards renewable energy investments, such as solar panels, to improve energy access and promote economic empowerment in Nigeria.

Following this introduction, section 2 outlines reviewed literature around the topic of discuss. Section 3, contains the methodology utilised in the study, Section 4 is the discussion of results and findings while Section 5 concludes the study with policy recommendation.

6.2 Literature Review

The role of remittances in fostering economic growth and development in developing countries is well-documented. Recently, attention has turned to how remittances can be harnessed to promote renewable energy adoption, contributing to sustainable development goals. This literature review explores various studies examining the relationship between remittances and renewable energy consumption, with a specific focus on their implications for Nigeria.

Subramaniam et al. (2023) investigate the impact of remittances on renewable energy consumption in top remittance-recipient developing countries from 1990 to 2016. Utilizing the autoregressive distributed lag (ARDL) technique, the study finds that remittances positively affect renewable energy consumption. This relationship suggests that remittances can increase the affordability and adoption of renewable energy if supported by proper governmental incentives.

The study's novelty lies in its focus on the top five remittance recipient countries and its policy implications, advocating for indirect incentives to encourage remittance recipients to invest in renewable energy projects.

Das et al. (2021) examine the causal relationship between remittances and renewable energy consumption in Bangladesh using data from 1980 to 2017. The study identifies a unidirectional causality from remittances per capita to renewable energy consumption and a long-run equilibrium relationship between these variables. The findings suggest that remittances enable rural households to adopt renewable energy sources, such as solar home systems. The authors recommend that the Bangladeshi government provide incentives for remittance-recipient households to invest in renewable energy technologies. This study is the first to explore this link in Bangladesh, offering important policy insights for other remittance-dependent developing countries.

Zafar et al. (2022) analyze the complex relationships between remittances, renewable energy consumption, education, and export diversification in major remittance-receiving countries. Their findings indicate that remittances significantly enhance renewable energy consumption and education investment. Moreover, export diversification positively impacts renewable energy consumption, and the Environmental Kuznets Curve is confirmed, showing that economic growth initially increases CO₂ emissions, which later decline as development progresses. This study underscores the multifaceted role of remittances in promoting renewable energy, education, and sustainable development.

Karmaker et al. (2023) use panel data from 42 developing countries (1990-2019) to explore the impact of remittances on renewable energy consumption. They find that a 1% increase in remittances leads to a 0.06% increase in renewable energy consumption. The study employs an instrumental variable approach to address endogeneity issues, confirming the robustness of their results. The authors suggest that remittances can overcome financial constraints and facilitate investment in renewable energy projects.

They recommend that governments create an enabling environment to encourage remittance recipients to invest in renewable energy technologies.

Seury et al. (2023) focus on Jamaica, examining the effects of remittances on renewable and non-renewable energy consumption using data from 1980 to 2019. They find that a 1% increase in remittances leads to a 0.06% increase in renewable energy consumption. Similar to Karmaker et al., they use an instrumental variable approach to address endogeneity concerns. The study suggests that remittances can help overcome financial constraints and facilitate investment in renewable energy projects. The findings imply that Jamaica should strengthen policies encouraging renewable energy consumption while discouraging non-renewable energy use.

Farzana et al. (2023) examines the relationships between remittances, financial deepening, urbanization, and renewable

energy consumption in Southeast Asian countries from 1991 to 2020. They find a negative correlation between financial deepening and renewable energy consumption, challenging the notion of a positive link between financial development and renewable energy. Urbanization is positively correlated with long-term renewable energy use, while trade openness supports renewable energy in the long run but negatively impacts it in the short term. The impact of remittances varies by country, with positive effects in Bangladesh and Pakistan but negative effects in India and Sri Lanka. This study highlights the need for tailored policies to optimize the benefits of remittances for renewable energy adoption.

Chakraborty (2023) explores the nonlinear relationship between remittances and renewable energy consumption in India. The study finds a U-shaped relationship, where low levels of remittances reduce renewable energy consumption, but high levels increase it. The threshold for this positive relationship is around \$1,000 per capita. The initial negative effect is attributed to increased fossil fuel consumption, while higher remittances provide the means to invest in renewable energy. The findings underscore the importance of policies that encourage the productive use of remittances.

Ojapinwa et al. (2022) examine the impact of diaspora remittances and renewable energy investment on enterprise growth in Nigeria from 1990 to 2020. They find that while remittances positively relate to enterprise growth, this relationship is not significant. Renewable energy also shows a positive but insignificant relationship with enterprise growth. The interactive coefficient of remittances and renewable energy reveals a negative, insignificant relationship with enterprise growth. The study suggests that the insignificant impact may be due to high unemployment, harsh business environments, corruption, and political instability in Nigeria. It emphasizes the need for effective policies to leverage remittances for renewable energy development.

The reviewed studies consistently highlight the positive impact of remittances on renewable energy consumption, albeit with varying degrees of significance and contextual factors. Subramaniam et al. (2023) and Karmaker et al. (2023) emphasize the need for governmental incentives to encourage investment in renewable energy projects. Das et al. (2021) and Seury et al. (2023) provide evidence from individual countries, highlighting the role of remittances in enabling rural households to adopt renewable energy technologies. Zafar et al. (2022) and Farzana et al. (2023) offer a broader perspective, examining additional variables such as education, export diversification, and urbanization. These studies highlight the interconnectedness of remittances with other economic and social factors, suggesting comprehensive policy approaches. Chakraborty (2023) presents a unique nonlinear perspective, highlighting the complex dynamics between remittances and renewable energy consumption in India suggesting that policy measures should consider the threshold effects of remittances. Ojapinwa et al. (2022) provide specific insights into Nigeria, revealing the challenges of leveraging remittances for renewable energy and enterprise growth due to structural issues showing the need for improved governance and a supportive business environment to harness the potential of remittances effectively.

The literature reviewed indicates that remittances can play a crucial role in promoting renewable energy adoption in developing countries, including Nigeria. While positive impacts are evident, the effectiveness of leveraging remittances depends on supportive policies and addressing structural challenges. Nigeria stands to gain significantly by creating an enabling environment that encourages the productive use of remittances for renewable energy projects, contributing to sustainable development and economic growth.

Despite extensive research on the role of remittances in promoting renewable energy adoption, significant gaps persist, especially concerning Nigeria. Many existing studies, such as those by Subramaniam et al. (2023) and Karmaker et al. (2023), provide

valuable insights but often focus on multiple developing countries or specific nations with different socio-economic dynamics. For instance, while Das et al. (2021) and Seury et al. (2023) provide in-depth analyses for Bangladesh and Jamaica, respectively, they do not account for Nigeria's unique socio-political and economic contexts.

Ojapinwa et al. (2022) do address the Nigerian context, but their research primarily centers on the interaction between remittances, renewable energy, and enterprise growth without delving deeply into the specific mechanisms through which remittances influence renewable energy adoption. Furthermore, the non-linear relationship identified by Chakraborty (2023) in India, which suggests that the impact of remittances on renewable energy consumption may vary at different levels of remittances, has not been explored in Nigeria. This nuanced understanding could be crucial for formulating effective policies in the Nigerian context, where varying levels of remittances might have different impacts.

Our paper aims to address these gaps by providing a detailed, country-specific analysis of the role of remittances in promoting renewable energy adoption in Nigeria. We will examine the specific socio-economic and political factors influencing this relationship, investigate the mechanisms through which remittances impact renewable energy consumption, and explore potential non-linear relationships and threshold effects. Additionally, we will assess the effectiveness of existing policies and propose new recommendations tailored to Nigeria's unique context. Finally, our study will provide a focused analysis on the adoption of renewable energy technologies, which holds significant potential for Nigeria. By addressing these gaps, our study aims to contribute to the literature by offering comprehensive insights into how remittances can be leveraged to enhance renewable energy adoption in Nigeria, ultimately supporting the country's sustainable development goals.

6.3 Data and Methodology

The study utilizes secondary data to examine key variables, with renewable energy represented by Renewable energy consumption as a percentage of total final energy consumption and remittances measured by Personal remittances, received as a percentage of GDP. Other relevant control variables used include GDP per capita (at constant 2015 US\$), official exchange rate (naira per US dollar, period average), and Communications, computer, etc. (as a percentage of service imports) to represent technological advancement in Nigeria. This data is sourced from the World Development Index (WDI) database on an annual frequency spanning 1990 to 2020. The choice of data period and frequency was informed by the availability at the time the research was conducted.

6.3.1 Descriptive Statistics

Table 6.1 presents the summary of the descriptive statistics used to evaluate the attributes of the variables in the study. All variables exhibit relatively low skewness, with RNE slightly skewed to the left and the rest having low to moderate positive skewness, suggesting mild asymmetry in their distributions. Most variables have kurtosis values below 3, indicating platykurtic distributions (flatter than the normal distribution). EXR is closest to 3, implying a more normal-like distribution. For all variables, the Jarque-Bera test statistics have probabilities greater than 0.05, meaning we accept the null hypothesis of normality. This suggests that the distributions of these variables do not significantly deviate from normality. Overall, the data shows a mild asymmetry and relatively flat distributions for most variables. The normality assumption is not violated, indicating that standard econometric techniques can be applied without significant adjustments for non-normality.

Table 6.1: Descriptive Statistics of the Variable

	RNE	REM	EXR	GDP	TEC
Mean	84.947	3.188	129.324	1988.274	42.460
Median	84.670	3.657	128.652	1950.122	43.331
Maximum	88.680	8.334	358.811	2679.554	62.608
Minimum	80.640	0.019	8.038	1429.012	17.242
Std. Dev.	2.349	2.513	97.167	465.134	12.567
Skewness	-0.218	0.208	0.686	0.132	0.021
Kurtosis	1.918	1.746	2.839	1.376	2.003
Jarque-Bera	1.759	2.254	2.464	3.499	1.286
Probability	0.415	0.324	0.292	0.174	0.526
Sum	2633.350	98.821	4009.058	61636.480	1316.261
Sum Sq. Dev.	165.550	189.525	283240.100	6490489.000	4737.836
Observations	31	31	31	31	31

Source: Authors’ Computation

6.3.2 Model Specifications

In this study, we adapted the methodology used by Subramaniam et al. (2023) which examined the role of remittances among top remittance-receiving developing countries. We incorporate data considered more relevant to the Nigerian economy. Equation 6.1 presents the disaggregated baseline model of the study.

RNE = f(REM, GDP, EXR, TEC)

.....Eqn 6.1

We formulate our econometric model below from the above baseline model. We further transformed some of the variables to their natural log to avoid the tendency of heteroscedasticity and skewness in the estimation as noted by Gujarati and Porter (2009).

RNE_t = β₀ + β₁lnREM_t + β₂lnGDP_t + β₃lnEXR_t + β₄TEC_t + ε_t

Eqn 6.2

Where β₀ and α₀ are the intercept, while β₁, β₂, β₃, β₄ are the slopes of the respective coefficients while ε_t is the random error term. To execute the boundary test technique, Equation (6.2) is represented in conditional ARDL as follows:

$$\begin{aligned} \Delta \ln RNE_t = & \beta_0 + \beta_1 \ln REM_{t-1} + \beta_2 \ln GDPC_{t-1} + \beta_3 \ln EXR_{t-1} + \beta_4 TEC_{t-1} + \\ & \sum_{i=1}^p \beta_{6j} \Delta \ln RNE_{t-i} + \sum_{i=0}^{q1} \beta_{7j} \Delta \ln REM_{t-i} + \sum_{i=0}^{q2} \beta_{8j} \Delta \ln GDPC_{t-i} + \\ & \sum_{i=0}^{q3} \beta_{9j} \Delta \ln EXR_{t-i} + \sum_{i=0}^{q4} \beta_{10j} \Delta TEC_{t-i} + \mu t1 \end{aligned} \quad \text{.....Eqn 6.3}$$

To determine the short-run relationship between the variables, an error correction model (ECM) was employed:

$$\begin{aligned} \Delta \ln RNE_t = & \beta_0 + \sum_{i=0}^{q5} \beta_{7j} \Delta \ln REM_{t-i} + \sum_{i=0}^{q6} \beta_{8j} \Delta \ln GDPC_{t-i} + \sum_{i=0}^{q7} \beta_{9j} \Delta \ln EXR_{t-i} \\ & + \sum_{i=0}^{q8} \beta_{10j} \Delta TEC_{t-i} + \tau ECM(-1) + \mu t2 \end{aligned} \quad \text{.....Eqn 6.4}$$

Where ECM represents the error correction factor and t represents the white noise error term.

6.3.3 Estimation Procedures

Following the objective and the unit root properties of the series, the study employs an Autoregressive Distributed Lag (ARDL) model developed by Pesaran et al. (2001), as the estimation technique, to account for dynamics in the relationship between the variables of interest. The choice of ARDL was due to its ability to yield consistent estimates of the long-run coefficients that are of mixed other of stationarity of the variables found to be stationary at level and first difference or fractionally integrated. Also, in ARDL, the short-run and long-run parameters of the model could be estimated simultaneously as highlighted by Bernard et al. (2020). Moreover, the ARDL is considered more appropriate and reliable in the case of a small sample size. Furthermore, from the ARDL, a dynamic error correction model can be obtained by a simple linear transformation.

6.4 Results and Discussion of Findings

6.4.1 Stationarity Test

To determine the stationarity of the variables, we employed the Phillips and Perron (PP) Unit Root Test. In this test, the alternative hypothesis - that the variables under study are stationary— was compared with the null hypothesis, which holds that the variables are not.

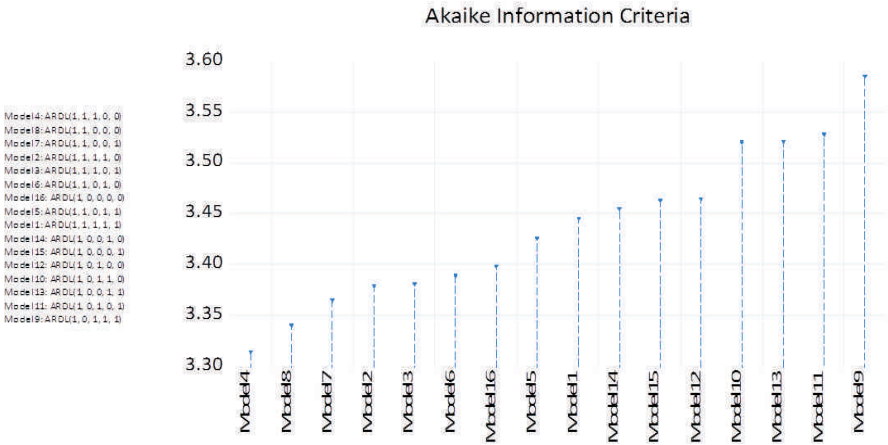
Table 6.2: Phillips and Perron (PP) Unit Root Test Result
(without constant and trend)

Variables	Level	1 st difference	Stationary Status
RNE	-0.7802	-5.3653***	I(I)
LREM	-2.5351**		I(0)
LEXR	1.8449	-4.576***	I(I)
LGDPC	1.1984	-2.3692**	I(I)
TEC	-0.6043	-7.0068***	I(I)

Source: Authors’ Computation
*Note: To select the optimal lag length in the ADF test, we used the Schwarz Information Criterion (SIC.) *** and ** indicates statistical significance at 1% and 5%*

The results of the unit root tests as presented in Table 6.2 indicated that all the variables, except remittances, are non-stationary at level I(0), however, all of them were found to be stationary at first differences I(1). Therefore, considering the mixed order of stationarity of the series, this study employed the Autoregressive Distributed Lag (ARDL) Model. We estimate the model using lag two based on the lag selection criteria in Table 6.2 below.

6.4.2 Model Lag Selection



Source: Authors’ Computation

As shown in Figure 6.1 above, we identified the proper lag structure that allowed this estimated model to be free of econometric challenges, which were determined using the Akaike Information Criterion, before estimating the results

6.4.3 F-Bound Test

The results of the ARDL bound test for cointegration of equations 6.2 indicates that the estimated F-Statistics is greater than the upper bounds at all levels, which implies that a long-run relationship exists among the variables (as shown in Table 6.3).

Table 6.3: Bound Test Result

Model		Computed F-statistics
1		5.1191
2		5.1191
Critical Bound’s Value		
Level (%)	Lower bound	Upper bounds
1	3.74	5.06
5	2.86	4.01
10	2.45	3.52

Source: Authors’ Computation

6.4.4 Discussion of Empirical Results

To show the role of remittances in addressing the adoption of renewable energy in Nigeria, we proceeded with the estimation of the long-run and short-run coefficient of the results as shown in Table 6.4.

Table 6.4: Result of Long-Run and Short-run ARDL

Panel 1: Long -run Result				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	89.0036	30.4507	2.9229	0.0079***
LREM(-1)	1.7267	0.4332	3.9861	0.0006***
LEXR(-1)	-2.3295	0.7490	-3.1103	0.0051***
LGDP	-3.7531	3.1941	-1.1750	0.2526
TEC	0.0020	0.0331	0.0609	0.9520
D(LREM)	0.8335	0.3833	2.1745	0.0407**
D(LEXR)	-0.7731	0.9395	-0.8229	0.4194
Panel 2: Short-run result				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	89.0036	16.2196	5.4874	0.0000***
D(LREM)	0.8335	0.3017	2.7629	0.0113**
D(LEXR)	-0.7731	0.8408	-0.9195	0.3678
CointEq(-1)	-0.6046	0.1099	-5.4999	0.0000***

Source: Authors’ Computation
*Note: P-value is in bracket. *, ** and *** show statistical significance at 10%, 5% and 1% level, respectively*

Table 6.5 above presents results of the estimates. Panel A shows the long-run coefficients related to the model against their demand determinants while Panel B shows the short-term coefficients of the variables. The results of the long-run estimates indicate that in the long run, remittances and technological advancement exert positive

impact on the adoption of renewable energy in Nigeria. However, while remittances is found to be significant at 1 per cent, technological advancement has an insignificant effect. This indicates that changes in remittances have a considerable positive impact on the dependent variable as a unit increase in remittances will result in about a 1.7 unit increase in renewable energy. The result aligns with our *a priori* expectations. This is because in emerging and developing economies, remittances often constitute significant source of households' income. Therefore, increased remittances enable them to invest in renewable energy technologies to reduce long-term energy costs. Also, since most of the migrants live in developed economies with more robust renewable energy technologies, their exposure can lead to increased awareness and knowledge about renewable energy back home. Exchange rate is also found to have a negative significant effect on renewable energy adoption in Nigeria. This is because most renewable energies are imported and, thus, the depreciation of the naira could limit importation as they become more expensive. However, technology is found not to be statistically significant, suggesting that it does not have a discernible impact on renewable energy consumption in this model. GDP per capita is also not significant in the model, indicating that its effect on renewable energy consumption is not strong enough.

In the short run, the coefficient for remittances is positive and statistically significant at the 5 per cent level. This indicates that changes in remittances have a significant positive impact on the dependent variable. On the other hand, the coefficient of exchange rate is negative but not statistically significant. This suggests that changes in the exchange rate do not have a statistically significant impact on the dependent variable in the short run.

Overall, the results are largely consistent with the findings of other related studies such as Scott et al., (2018) and Ojapinwa and Lawani (2022) that diaspora remittances significantly contributed to delivering renewable energy technologies in many countries. We

also acknowledge that this relationship could be non-linear as opined by Chen et al (2020).

6.4.5 Diagnostic Test

Some diagnostics tests were conducted to assess the fitness of the model. These tests the serial correlation, heteroscedasticity as well as the normality. The model is found to pass all the tests and is, therefore, fit for use.

Table 6.5: Diagnostic Test

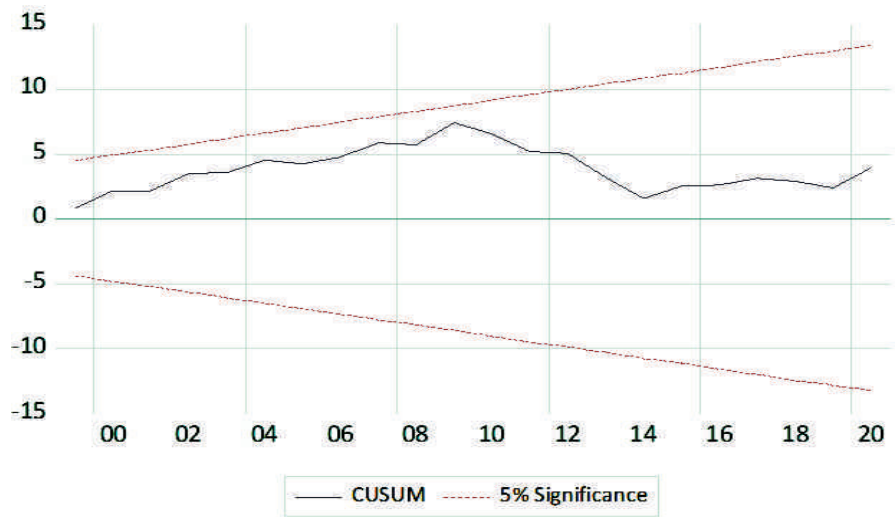
Model	Technique	F-stat & JB/(Prob)
Model	Serial correlation	1.7624 (0.2016)
	Heteroscedasticity	0.2231(0.9757)
	Normality	1.6484 (0.4386)

Source: Authors’ Computation

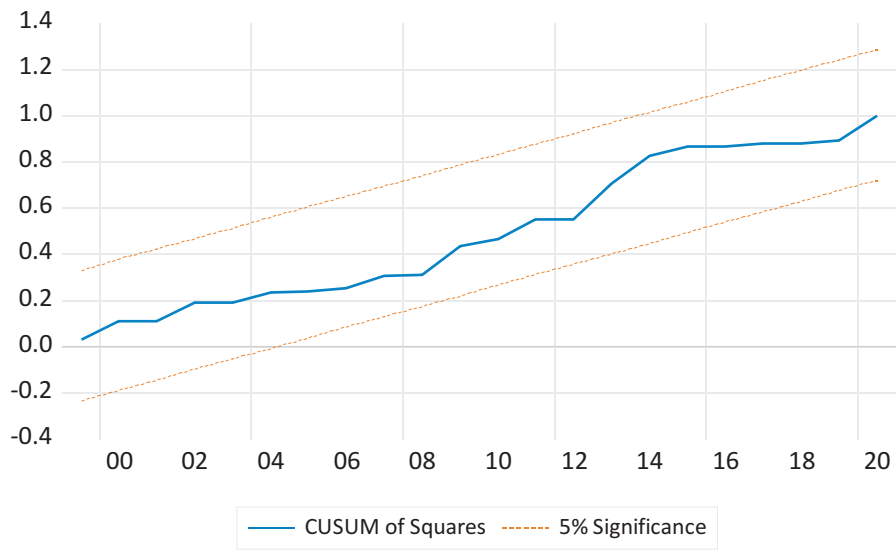
6.4.5.1 Stability Test

Additionally, we appraised the stability of the model using both the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ). The tests conducted suggest that the models are stable in the long- and short-run as the estimated recursive residual using the cumulative sum (CUSUM) and cumulative sum square (CUSUM of Squares) lie largely within the 95.0 per cent confidence level. Hence, the parameter estimates in the model are stable and correctly specified.

CUSUM Test curve

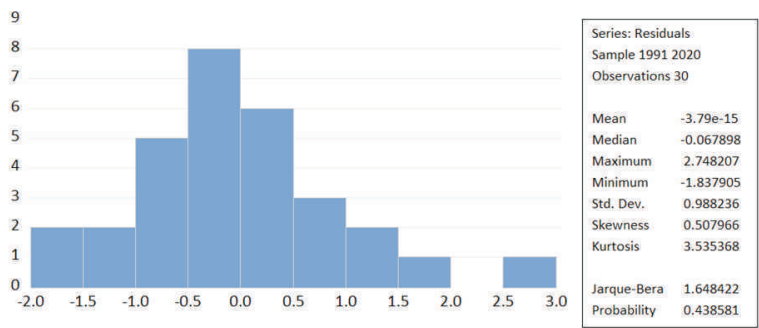


CUSUM of Squares curve



6.4.5.2 Normality Test

The normality test conducted on the model also indicates that it is normally distributed as the histogram of the residuals appears roughly symmetric with most values clustered around the mean. This supports the validity of the regression model assumptions, including the assumption of normally distributed residuals. The slight skewness and kurtosis deviations are not significant enough to violate the normality assumption.



6.5 Conclusion and Policy Implications

Remittances have become a highly important factor in the Nigerian economy affecting wide-ranging socio-economic indicators.

However, despite Nigeria's position as one of the major remittance recipients in Africa, literature about the subject pertaining to its role in renewable in the country is scarce. This study is imperative considering the surge in off-grid electrification using renewable energy by households, institutions and governments in the wake of the global agenda for a switch to more eco-friendly energy sources. This empirical study, therefore, investigated the role of remittances in renewable energy adoption in Nigeria, highlighting its pivotal role in developing sustainable solutions.

The study's findings are twofold. First, remittance flows are associated with increased renewable energy consumption in both the long and short-run periods. Second, other important variables

such as exchange also influence the consumption of renewable energy. This suggests that remittance-receiving households use additional income to purchase renewable energy technologies, which are often costly. This supports the idea that increasing remittance inflows could improve the adoption of modern renewable technologies like solar home systems, and households use remittances to finance these purchases, reinforcing the relationship between remittances and renewable energy consumption in Nigeria. The relationship is likely because remittances enhance household income and financial stability, making renewable energy investments more feasible.

Additionally, the exposure of migrants to renewable energy technologies and practices in more developed countries can drive awareness and adoption in their home countries (Nigeria). In addition, improved stability of the exchange rate could lead to greater consumption of renewable energy. These findings underscore the importance of enhancing remittance inflows and leveraging them to promote sustainable energy transitions in Nigeria as a typical developing country.

Hence, policymakers should provide incentives to both the sender and beneficiary of remittances to make them more willing to make those transfers. This could be achieved through a reduction in the cost of remittance transactions or the provision of targeted subsidies to such households. Financial institutions can also roll out renewable energy-related packages such as green loans targeted at low-income remittance-receiving households. In addition, the exchange rate should be stabilised to amplify the adoption of renewable energy technologies.

References

- Bernard, O.A., Bilyaminu, T., & Suleiman, S.A. (2020). Modelling transportation fuel demand in Nigeria.
- Chakraborty, D. (2023). Effect of Remittances on Renewable Energy Consumption in India: Evidence from a Nonlinear Analysis. *Journal of Asian Energy Studies*, 7, 140-158.

- Chen, C., Pinar, M., & Stengos, T. (2020). Renewable energy consumption and economic growth nexus: Evidence from a threshold model. *Energy Policy*, 139, 111295.
- Das, A., McFarlane, A., & Carels, L. (2021). Empirical exploration of remittances and renewable energy consumption in Bangladesh. *Asia-Pacific Journal of Regional Science*, 5, 65-89.
- Farzana, N., Qamruzzaman, M., Islam, Y., & Mindia, P. M. (2023). Nexus between personal remittances, financial deepening, urbanization, and renewable energy consumption in selected Southeast Asian countries: evidence from linear and nonlinear assessment. *International Journal of Energy Economics and Policy*, 13(6), 270-287.
- Gujarati, D. N., & Porter, D. C. (2009). Basic econometrics. McGraw-hill.
- Karmaker, S. C., Barai, M. K., Sen, K. K., & Saha, B. B. (2023). Effects of remittances on renewable energy consumption: Evidence from instrumental variable estimation with panel data. *Utilities Policy*, 83, 101614.
- Ojapinwa, V. T., & Lawani, D. (2022). Diaspora Remittances, Renewable Energy and Enterprise Growth in Nigeria. *Romanian Economic Journal*, 25(83).
- Olujobi, O. J. (2020). The legal sustainability of energy substitution in Nigeria's electric power sector: renewable energy as alternative. *Protection and Control of Modern Power Systems*, 5(4), 1-12.
- Oyedepo, S. O., Babalola, O. P., Nwanya, S. C., Kilanko, O., Leramo, R. O., Aworinde, A. K., ... & Agbereghe, O. L. (2018). Towards a sustainable electricity supply in Nigeria: the role of decentralized renewable energy system. *European Journal of Sustainable development research*, 2(4), 40.
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, 16(3), 289-326.
- Saliba, C. B., Hassanein, F. R., Athari, S. A., Dördüncü, H., Agyekum, E. B., & Adadi, P. (2022). The dynamic impact of renewable energy and economic growth on CO2 emissions in China: do remittances and technological innovations matter?. *Sustainability*, 14(21), 14629.
- Scott, A., Worrall, L., & Pickard, S. (2018). Energy, migration and the 2030 Agenda for Sustainable Development. ODI.
<http://www.jstor.org/stable/resrep50530>

- Seury, S., McFarlane, A., & Singh, A. (2023). The Impact of Remittances on Renewable and Non-renewable Energy Consumption in Jamaica. *Global Business Review*, 09721509231196968.
- Shaaban, M., & Petinrin, J. O. (2014). Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and sustainable energy reviews*, 29, 72-84.
- Subramaniam, Y., Masron, T. A., & Loganathan, N. (2023). Remittances and renewable energy: an empirical analysis. *International Journal of Energy Sector Management*, 17(5), 1034-1049.
- Udoakah, Y. O. N., & Umoh, M. D. (2014, May). Sustainably meeting the energy needs of Nigeria: The renewable options. In *2014 IEEE International Energy Conference (ENERGYCON)* (pp. 326-332). IEEE.
- Zafar, M. W., Saleem, M. M., Destek, M. A., & Caglar, A. E. (2022). The dynamic linkage between remittances, export diversification, education, renewable energy consumption, economic growth, and CO2 emissions in top remittance-receiving countries. *Sustainable Development*, 30(1), 165-175.

www.naee.org.ng

PART 6



Technological Solutions to Enhance the Green Economy





Transitioning to Low Carbon on - Road Transport Industry in Nigeria: Challenges and Prospects

Mobolaji, D and Isola, W.A.

Abstract

This study offers insights into the prospects and challenges of road transportation sector decarbonization in Nigeria. It provides an overview of policies to achieve low – carbon road transportation sector. Also, prospects and challenges of road transport decarbonization effort is briefly discussed. Using descriptive technique, the study submitted that if all abatement policies in road transportation sector are implemented, the goal of achieving net – zero – emissions by 2060 would be a reality. Also, it estrays renewable energy sources potential that the Nigerian government can harnessed for the purpose of achieving sustainable transportation system in Nigeria. The challenges of doing away with fossil energy is herculean, given the fact that they are a major sources of revenue generation for the country. It, therefore, incumbent

on the Nigerian government to embark on gradual decarbonization of road transportation sector in Nigeria.

Keywords: Decarbonization, Transport, Road Transport, Renewable Energy.

7.1 Introduction

Global transportation sector accounts for 24% of global greenhouse gas (GHG) emissions (International Energy Agency, 2023). A report by the IEA (2023) showed that global greenhouse gas (GHG) emissions arising from the transport industry increased to nearly 8 gigatons of equivalent carbon dioxide (Gt CO₂eq) in 2022, which is 3% more than in 2021. As the population, economies and the need for mobility grow, GHG emissions are projected to rise by as much as 60% by 2050. Road transport sector in particular accounts for 72% of GHG emissions (Kim et al. 2024).

The global concern to decarbonize the road transport industry has compelled nations to make substantial adjustments to renewable energy. As a result, the key focus is on shifting away from fossil fuels, which have been the predominant energy source since the industrial era, to cleaner and more sustainable energy sources, carriers, and technologies, such as electric vehicles (Safari et al., 2019).

In light of this, 53 countries committed to net-zero targets and abatement options by 2050 at the United Nations Framework Convention on Climate Change (UNFCCC) at the Conference of the Parties (COP27) in 2022, following the Paris Agreement. They highlighted the importance of transitioning to a low-carbon economy with the aim of achieving sustainable and inclusive economic development. One of the long-term mitigation strategies is to shift to more efficient modes of transportation, electrify road transport, shift to low-carbon fuels, improve fuel efficiency, and reduce travel demand (IEA, 2022).

The growth and development of the transportation industry is highly associated with fossil fuel consumption. The IEA (2023) revealed that the global transport industry accounted for 91% of fossil fuel consumption in 2022, down merely by 3.5 percentage points since the early 1970s. Also, growth in transportation energy use will account for 87% of the world's total increase in fossil fuel consumption between 2007 and 2035 (Akujor, Uzowuru, Abubakar, and Amakom, 2023).

Developing economies face dual challenges namely ensuring universal access to efficient, safe, and affordable mobility, and achieving with minimal climate impact (World Bank, 2024). Evidence exists that addressing these dual challenges in transport industry is still much of an issue in developing countries. For instance, in Nigeria, a report by Climate Transparency shows that in 2019, transport GHG emissions accounted for 61% of direct CO₂ emissions in total. The report concludes that with the rise in emissions levels, it will be difficult to meet the upper range of its national mitigation targets of 20% unconditionally by 2030 and conditionally of 45% (with international support) by 2030. Besides, fossil fuels account for 25% of the energy mix in Nigeria, with transport industry accounting for much of this share (Climate Transparency, 2020).

Another report by the European Commission (2023) illustrates that transport GHG emissions have been rising by more than 300% between 1990 and 2022, with an additional increase expected up to 50% by 2035 and almost 100% by 2050. Analysis of on-road transport emissions by the World Bank revealed that Nigeria's on-road transport GHG emissions are expected to exceed the level produced by the on-road transport sector across Sub-Saharan Africa by 187 million metric tons of oil equivalent (MtCO₂e) by 2035. The growth in emissions is expected to be driven by private vehicle use and an increase in commercial vehicle activity. In addition, population growth, rising income levels, and increasing levels of overall economic activity are projected to increase the emissions level (World Bank, 2013). Also, 60% of direct CO₂ emissions are from the transport

sector, with refined oil accounting for 100% of the of the energy mix in the transport industry. Therefore, to decarbonize the transport sector, its share of the energy mix must increase to 60% by 2050 (Climate Transparency, 2020).

Against this background, this study examines the prospects and challenges of decarbonizing road transportation sector in Nigeria.

7.2 Stylized Facts: Fossil Fuels Consumption and GHG Emissions in Nigeria

7.2.1 Fossil Fuel Consumption

Table 7.1 provides data on the amount of refined oil consumed by various economic sectors measured in 100 tons of oil equivalent and the corresponding percentage of the total consumption. It reveals that transportation sector is by far the largest consumer of refined oil, using more than two-thirds of the total. Households and manufacturing are the next largest consumers but are significantly lower than transportation. The services sector also has a notable share. In contrast, the construction, agriculture, and mining sectors have very low consumption levels, each contributing less than 1% to the total.

Table 7.1: Refined Oil Consumption by Sectors

Economic Sectors	Fossil Fuel (10 ⁰ Tonnes of oil equivalent)	Percentage (%)
Transportation	6154.4	69.36
Household	1320.2	14.88
Manufacturing	744.4	8.39
Services	567.2	6.39
Construction	67.2	0.76
Agriculture	15.6	0.18
Mining	3.8	0.04
Total	8872.9	100

Source: Nigeria Energy Commission (2010)

7.2.2 GHG Emissions in Road Transportation in Nigeria

Figure 7.1 shows that GHG emissions from bus/coach will be the largest by 2035, reaching 187 MTCO₂, from 25 MTCO₂ in 2010. Similarly, GHG emissions from heavy – duty vehicles are expected to reach 180 MTCO₂ by the end of the forecast period. Motor cycle and private car take insignificant share of road transportation GHG emissions (see Figure 7.1 for details).

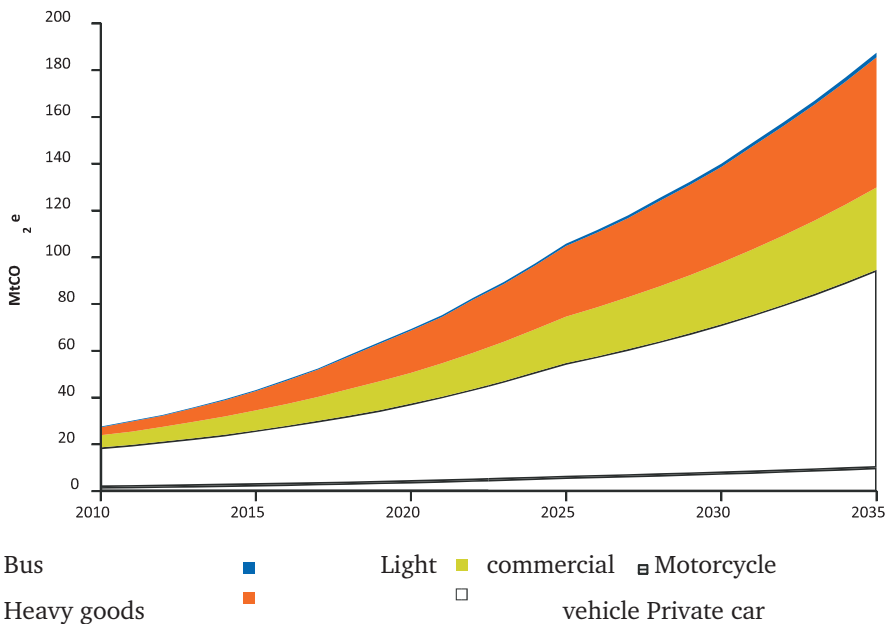


Figure 7.1: Road Transport GHG Emissions Forecast up to 2035
Source: World Bank (2013).

7.2.3 Prospects of Road Transport Industry to Reduction in GHG emissions in Nigeria

Nigeria transport sector is the second polluting sector after power industry, accounting for 43 million metric tons of oil equivalent of carbon dioxide (MtCO₂e) (Energy Transition Plan, 2021). Recently, the Nigerian government projected that by 2035, GHG emissions

from the transport sector could increase by up to 50%, and by almost 100% by 2050, under the business as usual (BAU) scenario (Federal Ministry of Environment, 2021). Similarly, the road transportation sector GHG emissions are projected to exceed 187 MtCO₂e, by 2035. The growth in emission is expected to be driven by population growth, rising income levels, and increasing levels of overall economic activity are projected to increase emissions level arising from on – road transport sector. According to National Bureau of Statistics, there are about 11.8 million vehicles in Nigeria in 2018, made up of commercial (57.70%), private (40.98%), and Government and diplomatic (1.32%) vehicles (National Bureau of Statistics, 2018). The number increased to 13 million by April 2021 (Iwunze, 2021). NBS (2020) submitted that increase in transportation sector's activity levels is highly correlated with its to GDP, with implications for national energy consumption rate, environmental pollution and energy balance

To combat this problem, Nigeria joined over 190 countries in December, 2015 at the Paris Agreement on Climate Change. All participating countries initiated a GHG emissions reduction pledges called the "Intended Nationally Determined Contribution" (INDC). Nigeria, Madagascar, and Barbados were mentioned to be part of the climate-vulnerable countries at this summit (Akujor et al, 2022). Nigeria's GHG emissions reduction pledges key focus is to pursue economic and social development that would minimize future GHG emissions by 20 percent unconditionally and 45 percent conditionally by 2030. It aims to reduce carbon dioxide equivalent (CO₂e) per US\$ real GDP – from 0.873 kg CO₂e in 2015 to 0.491 kg CO₂e by 2030. The reduction in CO₂e is planned to be achieved by ending gas flaring by 2030, enforcing energy efficiency by 2% improvement per year and 30% by 2030, adopting off-grid solar (PV2 of 13 gigawatts), improving energy efficiency of the electricity grid, adopting climate smart agriculture and reforestation; as well as transport shift from cars to bus (Akanonu, 2017; FGN, 2015).

Also, Nigeria joined 53 countries in 2022 as part of its commitment to address GHG emissions by 2050 following the Paris Agreement (IEA, 2022).

The deployment of electric vehicles is part of energy efficiency drive. Nigeria currently acknowledged the deployment of electric vehicles as part of the solution towards decarbonization of road transport sector (Energy Transition Plan, 2021). Nigeria has joined the league of countries that have developed EVs for its automotive market. Its industrial development effort towards the production of EVs has led to the assembly of its first EV – the Hyundai Kona car in 2020, which was part of its 5 – point comprehensive programme aimed at fostering local production of EVs. EVs in Nigeria are yet to be commercially viable and currently, Nigeria does not have a EVs policy. However, it does have the plan to achieve 30% local production by 2030 as stated in the newly approved 2023 Auto Policy (National Automotive Design and Development Council, 2020).

Recognizing that decarbonization is the critical issue in energy transition, the federal government (FG) launch its the Energy Transition Plan in 2021 to further express its commitment towards net zero emissions target in road transportation industry in Nigeria (ETP, 2021). The ETP seeks to achieve 10% and 30% blending rates of biofuel with refined oil as an initial step towards achieving net – zero emissions by 2060. Given that the share of road transport sector in the overall transport sector is the largest (ETP, 2021), achieving low – carbon road transport system is significant for potential shifts in fossil fuels consumption and GHG emissions in Nigeria.

Table 7.2 shows potential for renewable energy in Nigeria. Given the potential of these renewable energy, Nigeria can annex them to drive decarbonization efforts, particularly, for electric vehicles (EVs) and for alternative fuels vehicles (AFVs) like CNG, biofuels.

Table 7.2: Potential for renewable energy in Nigeria

Resources	Potential
Solar	4.0 kWh/m ² /day – 6.5 kWh/m ² /day
Wind	2–4m/s @ 10m height mainland
Gas Reserves	186.9 trillion cubic feet (tcf).
Biomass (Non – fossil organic matter)	Municipal waste (18.5 million tonnes produced in 2005 and now estimated at 0.5kg/capita/day). Fuel wood (43.4 million tonnes/yr. fuel wood consumption). Animal wastes (245 million assorted animals in 2001) Agricultural residues (91.4 million tonnes/yr. produced). Energy crops (28.2 million hectares of arable land; 8.5% cultivated).

Source: Author's computation from Nigeria Energy Support Programme (2015)

7.2.3 Brief Overview of Low – Carbon Road Transport Sector Policies in Nigeria

Nigerian government has proposed a range of strategies to achieve carbon neutrality in on-road transport sector. The 2007 Automotive Biofuel Programme was aimed to develop and promote the national ethanol sector using agricultural products in order to improve the export propensities of automotive fossil-based fuels produced in Nigeria. Given the current demand for gasoline as of the period, a 10% blend ratio with biofuel ethanol is expected to produce about 1.45 billion liters in the country. This is forecast to increase to 5.56 billion liters by 2030. However, with a 20% blend of biofuel with refined oil, about 1.78 billion liters are projected to be demanded by 2030 (Energy Commission of Nigeria, 2018).

The Nigerian government also joined the Economic Community of West African States (ECOWAS) to harmonize fuel quality and

vehicle emission control at the conference of ministers of ECOWAS member states in Abuja. The objective of the conference was to limit the import of vehicles to 50 parts per million (ppm) sulfur fuels beginning in mid-2017 (UN Environment Programme, 2016; ICCT, 2019). In addition, Euro 4/IV equivalent standards for new vehicle imports starting January 1, 2020 were adopted (Meeting Report for Regional Workshop for Validation of the Provisional Final Report, 2018; ICCT, 2019).

In 2021, Nigeria passed its climate change bill into law. The Climate Change Act set a framework for attaining low GHG emissions, including green growth and sustainable economic development, by "setting a target for years 2050–2070 for the attainment of a net zero GHG emission, in line with Nigeria's international climate change obligations, among other objectives" (Climate Change Act, 2021, p. 4).

Nigeria launched its Energy Transition Plan (ETP) in 2022, as part of its ongoing effort to express its commitment to reduce GHG emissions in the road transportation industry by 2060. The Net-Zero Path (NZP) scenario proposes a blend of biofuel with gasoline to meet the net-zero path. Specifically, it proposes 10% and 30% biofuel use as an initial and gradual step towards decarbonizing Nigeria's on-road transport sector. This is expected to kickstart the decarbonization effort through 2030. Besides, electric vehicles are expected to become commercialized through 2036–2060 (ETP, 2021). Although, Nigeria currently does not have an EV policy. However, it does have a plan to achieve 30% local production by 2033 (National Automotive Design and Development Council, 2020).

Currently, the FG has embarked on the use of compressed natural gas (CNG) as alternative fuel to Petro – diesel – powered vehicles. A zero – duty has been announced on conversion of internal combustion engines vehicles (ICEVs) to CNG to reduce the high cost of fossil fuels like gasoline (Presidential Initiative on CNG, 2023). The CNG has been reported to be environmentally friendly and cost effective when compare to Petro and dieel-powered vehicles (Fattah et al., 2023).

7.2.4 Challenges of Achieving Low – Carbon Road Transportation Sector in Nigeria

Challenges of decarbonization of road transportation sector stems from lack of implementation of existing decarbonization policies. For instance, Euro 4/VI and Euro 6/IV that stipulate fuel quality standards as 10 ppm and 50 ppm for gasoline and diesel respectively were not implemented. Evidence exist that poor quality of fuels is still predominant in vehicles use, leading to all kinds of respiratory diseases and cancer (ICCT, 2019). Climate Transparency (2020) revealed that fossil fuels account for 100 percent of energy consumption in transportation industry. Also, Nigeria started well on biofuels use but was later relaxed due to policy inconsistency and lack of political will.

Various studies have linked GHG emissions on road transport system to importation of used vehicles, some of which have exceeded their economic life span. Environmental damage is simply the repercussion (World Bank, 2013; Akujor et al., 2022). The major challenge remains enforcement of regulatory standards that ensure that vehicles importation do not exceed 8 years (ICCT, 2019). Thus, lack of implementation of various pollution control policies in transport sector, coupled with poor regulatory enforcement of importation of vehicles beyond the stipulated years posed a real challenge to transportation sector in general, and road transport sector in particular.

Another challenge hindering the road transportation decarbonization is an abundant of fossil fuel in Nigeria. According to World Bank (2013) estimate, Nigeria has proven reserves of 37.2 billion barrels of oil, and 186.9 tcf of gas reserves. Doing away with these huge resources may prove economic fatal, as the nation rely on these huge resources for economic survival (Akujor et al. 2022). Thus, the shifting of zero – carbon target from 2050 to 2060 is understandable, given the centrality of oil and gas in Nigeria's economic growth and development.

7.3 Conclusion

Decarbonization of road transportation sector in Nigeria is essential for achieving the Nationally Determined Contribution of achieving 20% emission reduction target unconditionally, and 45% emission reduction conditionally by 2035. This is because, transport sector in general, and road transport in particular consumed 100 percent of fossil fuels, and contribute significant proportion of GHG emissions (43 MTCOe) in Nigeria. Thus, decarbonizing road transportation system is essential to meet these targets. However, if policies and measures to achieve low – carbon transportation sector are not implemented, decarbonization project might yet be another failed project in Nigeria.

References

- Akujor, C.E., Uzowuru, E.E. Abubakar, S.S. & Amakom, C.M. (2023). Decarbonisation of the Transport Sector in Nigeria. *Environmental Health Insights*, 16, 1 – 8.
- Akanonu, P.C. (2017). Climate policy and finance: designing an effective carbon pricing system for Nigeria's oil and gas sector. Centre for the study of economies of Africa (CSEA), *working paper* DPS/17/02.
- Climate Transparency (2020). Climate transparency report. [Online]. www.climate-transparency.org.
- Climate Change Act (2021). A bill for an Act to provide for the mainstreaming of climate change actions, establish the National Council on Climate Change; and for related matters. ENACTED by the National Assembly of the Federal Republic of Nigeria.
- European Commission (2023). Climate action: Shifting gears: Increasing the pace of progress towards a green and prosperous future. Progress Report, 2023.
- Energy Transition Plan (2021). Nigeria energy transition plan. [Online]. <https://energytransition.gov.ng>.
- Energy commission of Nigeria (2010). Model for the Analysis of Energy Demand.

- Energy Commission of Nigeria (2018). National energy policy. Draft revised version. Federal Ministry of Science and Technology, Nigeria.
- Federal Ministry of Environment. (2021). *National Climate Change Policy for Nigeria 2021–2030*.
- Federal Government of Nigeria (2015). Sustainable development goals indicators baseline report. Nigeria: The office of the senior special assistant to the president on SDGs.
- Fattah, M., Istiaque, M. Biswas, A. Rahman, M. Morshed, S.R. & Chakraborty, T. (2023). Environmental and economic benefits of CNG conversion on three-wheelers in a developing city, Khulna, Bangladesh. *Transportation Engineering*, 13, 100199.
- Kim, H., Lee J. & Kim, Y. (2024). Decarbonizing road transport in Korea: The role of electric vehicles transition policies. *Transportation Research Part D: Transport and Environment*, 128, 104084.
<https://doi.org/10.1016/j.trd.2024.104084>.
- International Energy Agency (2022). World energy outlook – analysis. [Online]. <https://www.iea.org>.
- IEA (2023). World energy outlook. <https://www.iea.org>.
- Iwunze R. 77% of vehicles on Nigeria's roads uninsured – NIA. *Vanguard*. 2021. Accessed January 23, 2022.
<https://www.vanguardngr.com/2021/05/7-of-vehicles-on-nigerias-roads-uninsured-nia/>.
- International Council Clean Transportation (2019). Costs and benefits of soot-free road transport in Nigeria. White paper, August, 2019.
- Meeting Report for Regional Workshop for Validation of the Provisional Final Report*. (2018). ECOWAS: Abidjan, Cote d'Ivoire.
- National Bureau of Statistics. *Road Transport Data (2018)*. National Bureau of Statistics.
- National Automotive Design and Development Council (2023). Nigerian automotive industry development plan. Nigeria.
- Presidential Initiative on CNG (2023). The Initiative. [Online].
<https://pci.gov.ng>.
- Safari, A., Das, N., Langhelle, O., Roy, J., & Assadi, M. (2019). Natural gas: A transition fuel for sustainable energy system transformation? *Energy Sci. Eng.* 7, 1075–1094. doi:10.1002/ese3.380.

The Nigeria Energy Sector Report (2015). An Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; Nigerian Energy Support Programme (NESP) & Federal Ministry of Power, 2nd Edition.

UN Environment Programme. (2016). West African countries adopt low sulphur diesel standards. Retrieved from <https://www.unenvironment.org/newsand-stories/blogpost/ecowas-countries-develop-harmonized-fuel-and-vehicleemission-standards>

World Bank (2013). Assessing low-carbon development in Nigeria: An Analysis of Four Sectors. World Bank Document.

www.naee.org.ng

PART 7



Innovations for a Low-Carbon Future





Innovative and Sustainable Financing: Options for the Development of A Green Economy

Mercy Sunsuwa,
Mercy Ewea Egwakhide
and Maryam Okikiola Sekoni

Abstract

The term "green economy" refers to an economic system that strives to reduce environmental risks and ecological scarcities while promoting sustainable development. In addition to improving human well-being and social equity, it significantly reduces environmental risks and ecological scarcity. Using China as a case study, in 2023, clean energy made a record contribution of 11.4 trillion Yuan (\$1.6 trillion) to China's economy. This amount accounted for all of the growth in investment and represented a larger share of economic growth than any other sector. The term "clean energy" encompasses various sectors, such as renewables, nuclear power, electricity grids, energy storage, electric vehicles (EVs), and railways. These sectors include technologies and infrastructure crucial for decarbonizing China's

energy production and consumption. China's investment in clean-energy sectors reached an estimated 6.3 trillion Yuan (\$890 billion), up from 4.6 trillion Yuan in 2022, marking a significant 1.7 trillion Yuan (40%) year-on-year increase. Clean energy accounted for 13% of the total investment in fixed assets in China in 2023, compared to 9% in the previous year. China funds its investments through a mix of government funding, state-owned enterprises (SOEs), private investment, and other sources.

This policy research paper explores sustainable finance options for bolstering Nigeria's transition to a green economy. Against the backdrop of global environmental challenges and the imperative for sustainable development, Nigeria stands at a critical juncture where strategic interventions are necessary. The paper begins by highlighting the pressing need for sustainable finance mechanisms in Nigeria to address environmental degradation, energy insecurity, and economic development constraints.

The findings of this research underscore several key points. Firstly, it identifies a notable reduction in energy consumption in Nigeria, signaling potential shifts in energy dynamics within the country. Secondly, it establishes a positive correlation between energy consumption and development, emphasizing the pivotal role of energy in driving economic growth. However, the study also highlights the unsustainability of conventional energy sources, particularly due to persistent oil refining costs, necessitating a shift towards renewable alternatives such as solar energy.

Furthermore, the research proposes innovative financing strategies to promote the adoption of solar energy in Nigeria. It suggests redirecting savings from the removal of fuel subsidies towards subsidizing solar energy production or consumption, thereby mitigating initial cost barriers. Additionally, the paper advocates for government support for large-scale producers to establish solar plants in Nigeria, leveraging the country's natural resources such as lithium mining to facilitate local

production of solar technologies. Moreover, the paper recommends exploring synergies between energy provision and natural resource utilization to achieve economies of scale. It proposes incentivizing energy providers to invest in Nigeria in exchange for access to natural resources, fostering mutually beneficial partnerships. Additionally, the research advocates for inclusive financing mechanisms to ensure equitable access to solar energy, including government-backed programs for low-income households and interest-free loans for international solar projects.

In conclusion, this policy research paper underscores the critical importance of sustainable finance options in advancing Nigeria's green economy agenda. By embracing innovative financing strategies and leveraging its natural resources, Nigeria can not only address energy challenges but also stimulate economic growth and environmental sustainability. It calls for concerted efforts from policy-makers, financial institutions, and stakeholders to catalyze the transition towards a sustainable future for Nigeria.

Keywords: Sustainable Finance, Green Economy, Energy investment, Nigeria, Poverty trap, Subsidy Removal, Conventional Energy, Inclusive Financing, Economies of Scale.

8.1 Introduction

The global imperative for environmental sustainability has underscored the need for countries to transition from reliance on conventional, non-renewable energy sources to renewable energy solutions (Khasru, 2023). For Nigeria, a nation endowed with abundant natural resources yet grappling with significant energy challenges, this transition is not only crucial for environmental preservation but also pivotal for economic development (Olujobi, 2023). Historically, Nigeria's energy

sector has been heavily reliant on oil, with substantial government subsidies aimed at maintaining low fuel prices. However, this approach has proven unsustainable due to fluctuating oil prices and the high costs of oil refining (Ighosewe, 2021).

The recent removal of fuel subsidies by the Nigerian government presents a unique opportunity to redirect financial resources towards more sustainable and innovative energy solutions. This policy shift, announced by President Bola Ahmed Tinubu in his inaugural speech on May 29th, 2023, marks a critical juncture for Nigeria's energy policy. The savings from subsidy removal can be strategically invested in renewable energy initiatives, particularly solar energy, which holds significant potential given Nigeria's geographic and climatic conditions (Ekele, 2023).

This research paper explores various innovative and sustainable finance options that can drive the enhancement of a green economy in Nigeria. It examines the potential impacts of these options on energy consumption, economic development, and environmental sustainability. By leveraging Nigeria's natural resources and adopting forward-thinking financial policies, the country can pave the way for a more resilient and sustainable energy future.

The findings of this study reveal several critical insights: Energy consumption in Nigeria has reduced (NMDPRA 2023), there is a positive correlation between energy consumption and economic development (Okeoma et al., 2023), and conventional energy sources are unsustainable due to persistent high refining costs. As a result, financing renewable energy sources, such as solar power, becomes imperative. This paper proposes that government savings from subsidy removal should be redirected to subsidize solar energy production and consumption. Additionally, large-scale producers should be supported to establish solar plants, and licenses should be granted for lithium mining to facilitate local production of solar technologies.

Furthermore, innovative financing mechanisms, including incremental payment plans for low-income households and interest-

free international loans, are essential to make solar energy accessible to all Nigerians.

By addressing these issues, this research aims to provide a comprehensive framework for policymakers to enhance Nigeria's green economy through sustainable and innovative financial strategies.

8.2 Literature Review

8.2.1 Conceptual Review

8.2.2 Green Economy

According to the United Nations Environment Programme (UNEP, 2011), a green economy is characterized by being low carbon, resource-efficient, and socially inclusive. In such an economy, growth in employment and income is propelled by public and private investments in economic activities, infrastructure, and assets that reduce carbon emissions and pollution, improve energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services.

Transitioning to a green economy can help Nigeria address its environmental challenges while promoting economic development and social inclusion.

8.2.3 Sustainable Finance

According to the European Commission, sustainable finance involves integrating environmental, social, and governance (ESG) considerations into investment decisions within the financial sector. By adopting this approach, long-term investments are promoted in sustainable economic activities and projects. Environmental considerations may include climate change mitigation and adaptation, as well as broader environmental issues like biodiversity preservation, pollution prevention, and the circular economy. Social considerations encompass issues such as inequality, inclusiveness, labor relations, investment in people and communities, and human rights. The

governance of public and private institutions, including management structures, employee relations, and executive compensation, is crucial in ensuring the incorporation of social and environmental factors in decision-making processes.

The transition from conventional to renewable energy sources requires significant financial investment, and sustainable finance provides the framework to guide these investments in an environmentally and socially responsible manner.

8.2.4 Renewable Energy

Renewable energy is derived from inexhaustible, naturally replenished sources such as the sun, tides, and wind. It can be utilized for various applications including electricity generation, space and water heating and cooling, and transportation.

Conversely, non-renewable energy originates from limited sources like coal, natural gas, and oil.

8.3 Theoretical Review

8.3.1 Theory of Sustainable Finance:

According to the priority theory of sustainable finance, the speed at which economic actors in a nation or area exert every effort to meet sustainable finance targets accurately reflects the importance of the sustainable finance agenda in that nation or region. (Wilson, 2010). While Migliorelli (2021) defines sustainable financing as funding for industries or endeavour that help realize at least one of the pertinent sustainability elements. According to Ozili (2021), sustainable finance is defined as finance that, while making investment decisions in the financial sector, takes environmental, social, and governance factors into account.

The sustainable finance theories are divided into 6 (six) parts which are:

- i. The priority theory of sustainable finance,
- ii. The resource theory of sustainable finance,
- iii. The peer emulation theory of sustainable finance,
- iv. The life span theory of sustainable finance,
- v. The positive signalling theory of sustainable finance, and
- vi. The system disruption theory of sustainable finance.

Table 8.1: Theory of Sustainable Finance (Ozili, 2021)

No.	Theory	Proposition
1)	The Priority theory of sustainable finance	Sustainable finance goals in a country or region are achieved at the rate at which agents work to achieve them.
2)	The peer emulation theory of sustainable finance	States that economic agents take similar actions, or adopt similar policies and strategies, of the peers they emulate in pursuit of sustainable finance goals.
3)	The Resource theory of sustainable finance	A comparison of certain countries' human resources and their transition to sustainable financing shows that some have a comparative advantage over others.
4)	Life span theory of sustainable finance	argues that the perceived lifespan of sustainable finance instruments, products, services, schemes, regulations, or activities influences the interest of economic agents in sustainable finance.
5)	System disruption theory of sustainable finance	Economic agents may be required to decide whether to support or participate in the shift to sustainable finance due to the possibility of disruption to the current mainstream traditional financial system.
6)	Positive signalling theory	argues that in order to convey good news to outside parties who can support their sustainable finance aims, economic actors have an incentive to disclose positive information about their willingness to achieve one or more of these sustainable finance goals.

8.3.2 The New Growth Theory:

The new growth theory brings a refreshing perspective on driving economic prosperity, focusing on the significance of entrepreneurship, knowledge, innovation, and technology. This challenges the traditional belief in neoclassical economics that economic advancement is influenced by external factors beyond human control. In this theory, competition drives individuals to continuously improve methods and create new products to maximize profits, embodying a key principle of the new growth theory. Liberto (2021).

8.3.3 Green Economy in Eco-Modernization:

The term "green economy" refers to a broad set of ideas that can be summarized in two ways (UNEP, 2011). On the other hand, the green economy encourages the creation of a "post-fossil fuel" bio-economy that depends on the use of risky new technologies to harvest biomass. While on the other hand, it promotes the conservation of biodiversity and ecosystems through the exploitation of new financial markets and the commercialization and privatization of natural resources. The private sector must be the main force behind the green economy (Hyder 2015). Therefore, the green economy is based on the theory of neo-liberalism and is essentially built on the theories of Eco-modernization and free market environment. (Hyder 2015).

Mol (1995) expresses his expectations, saying that the only way to avoid ecological catastrophe is to advance the process of modernization. This theory's basic ideas are that (a) conserving resources, cutting pollution, and preserving the environment are beneficial to both businesses and the environment. (b) Industries as well as society as a whole are beginning to recognize that resource flows and economic growth may be "de-linked."

(Hyder 2015) Unquestionably, there is hope in the prospects of transforming contemporary institutions to better integrate the natural environment and advance towards hyper-industrialized

communities. There is no trade-off between economic expenses and environmental conservation, other from the assumption.(Hyder 2015).

8.4 Empirical Review

Isah, Dioha, Debnath, Abraham-Dukuma, Butu (2023) stated in their work, while comparing Nigeria and Brazil, that Nigerian investments in renewable energy have been hampered by unclear policies and inadequate funding sources however, Brazil has successfully mobilized significant investment in renewable energy through the use of incentive policy mechanisms. It was also stated in the study that there were differences in the founding of renewable energy, while Brazil utilized Brazilian Development Bank (BNDES), Nigeria on the other hand stored fund from bilateral agencies and Multilateral Development Banks (MDBs) Isah et al. (2023). They concluded in their study that it would be better to suggest a multi-stakeholder paradigm to enable Nigeria's energy transition and consolidate climate money, taking into account the critical role that donors and MDBs play in the nation. Adeyeye, Balogun, Fapetu (2021) pointed out the fact that Nigeria has not had an adequate refuse collection and disposal mechanisms, it was also stated that the urban landscapes in the country are littered with plastics, polythene, and various non-degradable materials. The study suggests that Nigeria move more into green finance which can be useful for efficient waste management and the generation of green electricity to the national grid. Adeyeye et al (2021).

Edeminam & Akpasoh (2023) highlighted in there study the recently launch of Nigeria's energy transition bold and ambitious plan to invest \$10 billion annually until 2060 and to achieve SDG7 goal by 2030, thereby achieving its net-zero target by 2060. The study proved us with suggestions on how we can finance green energy by green bonds, diaspora bonds, emission trading, carbon taxes, budgetary allotments, tax exemptions, and import waivers which

are a few of the ways to mobilize domestic climate funds. Edeminam & Akpasoh (2023).

Omojolaibi (2016) stated in his study that due to the fact that Nigeria has an underdeveloped financial sector, channeling funds to renewable energy would be a tasking endeavour. However, the study highlighted the amount of RE generated having a positive impact on financial intermediaries, particularly commercial banks. This influence is especially strong when non-hydropower Renewable Energy like solar, geothermal, and biomass are taken into account. Omojolaibi (2016).

Ehiedu & Ehiedu (2023) according to their study findings, the stability of the Nigerian economy was highly predicted by GFI (Green Prevention Costs and Green Internal Failure Costs). They urged the regulatory authorities to dedicate more funds to the Green Prevention Costs (GPC).

Oguntuase & Windapo (2021) The importance of green bonds and green buildings in Nigeria's Sustainable Development Goals (SDGs) is examined in this study. With an emphasis on affordable and sustainable housing, it explores the idea of green bonds as a kind of investment for green structures. The chapter identifies the primary Sustainable Development Goals (SDGs)—Good Health and Well-Being, Clean Water and Sanitation, Affordable and Clean Energy, Responsible Consumption and Production, and Climate Action—using a methodical literature review technique.

The study finds that deploying green bonds as investment instruments for green buildings in Nigeria would contribute to the achievement of several Sustainable Development Goals (SDGs), including affordable and sustainable housing. Oguntuase & Windapo (2021).

8.4.1 Current Mesuration Methods

The "green" status of a country indicates how much it values protecting and reviving the environment, its resources, and the health of its

people. In the policy-making process and in the effectiveness of the current policies, this is demonstrated. There are various indicators that have been developed to measure how 'Green' a country is they include.

8.4.2 Environmental Performance Index (EPI)

This index was developed by Yale University to rank countries are best addressing environmental challenges. It uses 40 performance indicators relating to climate change performance, environmental health, ecosystem vitality. These indicators provide a gauge at a national scale of how close countries are to established environmental policy targets and offers a scorecard that highlights leaders and laggards in environmental performance and provides practical guidance for countries that aspire to move toward a sustainable future. The 2022 EPI supports evolving climate policy discussions with a new indicator that projects countries' progress towards net-zero emissions in 2050 and provides a data-driven summary of the state of sustainability around the world. In the 2022 EPI report Denmark ranked 1st with an EPI score of 77.90 while Nigeria ranked 162 with an EPI of 28.30.

Denmark has developed a subsidy-free competitive market for offshore wind through government initiatives, private sector engagement, and investments from the financial sector. This was achieved through clear regulatory and stable framework conditions, as well as collaboration between public and private actors and research institutions. Pension funds also played a vital role in the development of the industry, making unusually bold forays into offshore wind projects prior to their construction. These investments not only fundamentally reshaped the risk landscape of investments in offshore wind farms, but also catalyzed a transformative shift in how green initiatives can be financed. Denmark is now a leading financial hub for green investments, (State of Green, 2023).

The Danish government has also reached a new agreement to invest EUR 670 million in green initiatives by 2030. EUR 270 million of this amount will be allocated from the Green Fund to support initiatives that create a better water environment, increase forestation, and improve access to district heating, (State of Green, 2024).

8.4.3 EU's Joint Research Centre (JRC)

A 2020 report from the EU's JRC looks at the fossil CO₂ emissions for over 200 countries and territories. Their report includes CO₂ emissions per capita to account for population size. China has the highest CO₂ emissions with 32.93% of the global share while Nigeria ranked 40 with 0.34% and Western Sahara was the lowest on the list.

8.4.4 IQAir

IQAir provides the world's largest free real-time air quality information platform to fight against air pollution. They provide data on the annual average PM_{2.5} concentration for 117 countries and territories. Uganda stands as the one of the countries with the highest PM_{2.5} concentration. It has been discovered that the National Financial Inclusion Strategy 2017-2022 aims to ensure timely, affordable, and adequate financial services to all citizens in the economy. It includes policies towards micro-credit infrastructure and digital commerce, but only limited acknowledgement of sustainability issues. On-going discussion between ministries to create a Green Growth Financing Vehicle, but no concrete commitments yet. (Green Economy Tracker, 2023) The lack of appropriate financing and investment in sustainable energy explains the position of Uganda in the IQAir ranking.

8.4.5 Green Future Index (GFI)

The Massachusetts Institute of Technology developed the GFI, which assigns a ranking to countries and territories based on their

commitment to and level of development toward a sustainable future. It looks at 22 indicators from the following five pillars: clean innovation, energy transition, carbon emissions, green society, and climate policy.

According to the Green Future Index 2023, Iceland ranks first for clean innovation and for carbon emissions. With a GFI of 6.69, the highest of any country Iceland produced more electricity from renewable sources than they used. Currently, 85% of Iceland's energy comes from renewable sources, and the country is moving toward 100%.

8.5 How Did They Achieve This?

By the 1970s, the nation was still relying on fossil fuels for about 75% of its energy, despite having begun to utilize its natural resources in the 1940s. After the 1973 oil crisis, Iceland found it difficult to adjust to the rapidly changing costs. Instead, the government shifted its emphasis to geothermal heat and hydro-power. Funds were invested in the construction of new green energy infrastructure. Since then, it has gradually weaned itself off of fossil fuels and grown to rank among the top producers of green energy globally per person. Data centers and metal manufacturers are among the enterprises attracted to the nation by these affordable, renewable resources. The world's first large-scale carbon dioxide removal facility is now located in Iceland. Located approximately 50 kilometers west of Reykjavík, Climeworks AG claims that Orca can absorb up to 4,000 tons of CO₂ annually from the atmosphere, which is equivalent to the emissions of 870 automobiles.

Iceland has made significant financial investments in sustainability with the aim of becoming carbon neutral by 2040. Green by Iceland showcases their nation's proficiency and sustainable and renewable energy solutions. This will enable other economies and enterprises to move more quickly in order to avert the catastrophic effects of climate change before it's too late. The Icelandic government established

a working group to deliver a strategy to improve the development of wind farms. A new law simplifying the construction of wind farms is expected in 2023. It can be seen that the Icelandic Government is heavily committed to the propagation of a green economy.

8.6 Discussions and Findings

The Government of Nigeria can follow the examples of Iceland and Denmark and create a development plan for transition to renewable energy that is tailored to match the resource capability and peculiar condition of the Nigerian economy, (Government of Iceland, 2023).

It can be organized through the following steps:

1. *Funding*: The Government of Nigeria can explore sustainable finance options like interest-free loans, social bonds, green or blue bonds and other sustainable financial instruments.
2. *Use of the sourced funds*: The funds must be utilized to finance only expenditures that relate to achieving the sustainable objective of the government. For example; clean transportation, renewable energy, green buildings, emission reduction, pollution prevention and control, sustainable water and wastewater management, climate change adaptation and information, communication and creation of awareness.
3. *Fund Management*: A registry ought to be established for transparency and the documentation of financial inflows and outflows. This serves as a basis for Government allocation and impact reporting.
4. *Reporting*: An annual report should be prepared and publication of this report should not be allowed to extend beyond the preceding year basis.

5. *External Roles:* An Independent Auditor should provide an independent verification for the allocation of the profits of issued Sustainability Instruments to Eligible Expenditures in accordance with the specified criteria in order to ensure alignment with internationally recognized standards and best practices.

8.7 Conclusions and Policy Recommendations

8.7.1 Conclusion

The transition to a green economy in Nigeria is critical for sustainable development, economic growth, and environmental protection. The research findings highlight the necessity of shifting from conventional, non-renewable energy sources, which are unsustainable due to high costs and environmental impacts, to renewable energy sources like solar power. Renewable energy, particularly solar energy, is a viable alternative that aligns with Nigeria's natural advantages.

The removal of fuel subsidies by the Nigerian government presents a significant opportunity to reallocate financial resources towards the promotion and adoption of renewable energy. The positive relationship between energy consumption and economic development further emphasizes the importance of investing in sustainable energy infrastructure.

However, the high initial costs associated with renewable energy technologies, such as solar panels, pose a significant barrier. To overcome this challenge, the government and other stakeholders must explore innovative financing mechanisms and provide substantial support to both large-scale producers and low-income households. By leveraging natural resources and implementing economies of scale, Nigeria can enhance the affordability and accessibility of renewable energy.

8.7.2 Policy Recommendations

- i. **Subsidize Solar Energy Production and Consumption:** Redirect savings from the removal of fuel subsidies to subsidize the production and consumption of solar energy. This can lower initial costs and make solar energy more affordable for households and businesses.
- ii. **Support Large-Scale Producers:** Provide financial incentives and support to large-scale producers to establish solar plants in Nigeria. Grant access and licenses for lithium mining to facilitate local production of solar technologies and reduce dependency on imports.
- iii. **Implement Innovative Financing Mechanisms:** Develop and promote financing models that allow consumers to pay for solar energy systems over time. These mechanisms can help spread the cost of solar energy, making it more accessible.
- iv. **Leverage Natural Resources:** Utilize Nigeria's abundant natural resources in exchange for energy provision, creating economies of scale that can further reduce the costs of renewable energy technologies.
- v. **International Funding and Cultural Considerations:** Seek international funding for renewable energy projects and ensure that loans are interest-free to align with cultural ethics. This can enhance the acceptance and success of renewable energy initiatives.
- vi. **Public Awareness and Education:** Increase public awareness and education about the benefits of renewable energy and the available financing options. This can encourage more households and businesses to adopt sustainable energy solutions.

vii. **Government and Private Sector Collaboration:**

Foster collaboration between the government and private sector to create a supportive ecosystem for renewable energy investments. Public-private partnerships can drive innovation and scale up renewable energy projects.

viii. **Policy Framework and Regulation:** Establish a robust policy framework and regulatory environment that supports the development and deployment of renewable energy technologies. Clear policies and incentives can attract investment and ensure sustainable growth in the sector.

8.8 Summary

Ensuring that the nation's energy needs are met and that everyone has fair access to renewable energy is imperative as we transition to a green economy. It is important to use renewable energy resources in multiple ways to support a vibrant and competitive energy market. The general public should also equitably enjoy the economic gains that result from using these resources, (Government of Iceland, 2023).

References

- Adeyeye O.Patrick, Balogun Adekunle Alexander, Fapetu Oladapo (2021). *Handbook of Research on Climate Change and the Sustainable Financial Sector*, page 12, DOI: 10.4018/978-1-7998-7967-1.ch018.
- Aduloju B. (2023). Subsidy removal: Nigeria's daily petrol consumption has reduced by 35%, says NMDPRA. Retrieved from <https://www.thecable.ng/subsidy-removal-nigerias-daily-petrol-consumption-has-reduced-by-35-says-nmdpra/>
- Carbon Brief. (2024). Analysis: Clean energy was top driver of China's economic growth in 2023. Retrieved from <https://www.carbonbrief.org/analysis-clean-energy-was-top-driver->

- [of-chinas-economic-growth-in-2023/#:~:text=China's%20%24890bn%20investment%20in,%25%20year%2D on%2Dyear](#)
- B. Edeminam, V., & Akpasoh, A. (2023). *Climate Finance Landscape in Nigeria: Options for Resource Mobilization*. *Resourceedings*, 3(1), 13–21.
<https://doi.org/10.21625/resourceedings.v3i1.945>
- Ehiedu, V. C., & Eyamu, F. O. (2023). Green Financing Initiatives and Economic Stability in Nigeria. *Advance Journal of Management, Accounting and Finance*, 8(6), 10–20.
<https://aspjournals.org/ajmaf/index.php/ajmaf/article/view/58>.
- Ekele J. (2023). Fuel Subsidy Removal: Implications For Nigerian Environmentalists & The General Public. Retrived from <https://csdevnet.org/fuel-subsidy-removal-implications-for-nigerian-environmentalists-the-general-public/>
- Hyder, Md (201)., Green Economy in Theoretical Dilemma . Available at SSRN: <https://ssrn.com/abstract=2657887> or <https://dx.doi.org/10.219/ssrn.2657887>
- Ighosewe E. , Akan, D. and Agbogun, O. (2021) Crude Oil Price Dwindling and the Nigerian Economy: A Resource-Dependence Approach. *Modern Economy*, 12, 1160-1184. doi: [10.4236/me.2021.127061](https://doi.org/10.4236/me.2021.127061).
- Isah, A., Dioha, M.O., Debnath, R. et al. *Financing renewable energy: policy insights from Brazil and Nigeria*. *Energy Sustain Soc* 13, 2 (2023).
<https://doi.org/10.1186/s13705-022-00379-9>
- Khasru, Syed Munir & Tércio Ambrizzi. 2023. "Climate Change & Just Energy Transition: What the North Can Learn from the South?" *CEBRI-Journal* Year 2, No. 8: 166-193.
DOI: <https://doi.org/10.54827/issn2764-7897.cebri2023.08.03.10.166-193.en>
- Liberto D, (2021). What Is New Growth Theory? Definition, How It's Used, and Example. Retrieved February 26, 2021.
<https://www.investopedia.com/terms/n/new-growth-theory.asp>
- Migliorelli, M. 2021. 'What Do We Mean by Sustainable Finance? Assessing Existing Frameworks and Policy Risks'. *Sustainability* 13 (2): 975.
- Mol, A. (1995). *The refinement of production: Ecological modernization theory and the chemical industry*. Utrecht: Van Arkel
- Oguntuase, O.J., Windapo, A. (2021). Green Bonds and Green Buildings: New Options for Achieving Sustainable Development in Nigeria. In: Nubi, T.G., Anderson, I., Lawanson, T., Oyalowo, B. (eds) *Housing*

- and SDGs in Urban Africa. *Advances in 21st Century Human Settlements*. Springer, Singapore. https://doi.org/10.1007/978-981-33-4424-2_11
- Okeoma T., Nwachukwu E., Ezeonye C. & Osatemple M.I. (2023). A Study on the Impact of Energy Consumption on the Nigerian Economy. *NIPES - Journal of Energy Technology and Environment*. 5(1), 40–52. DOI: <https://doi.org/10.5281/zenodo.7741150>
- Olujobi O.J., Okorie U.E., Olarinde E.S., Aina-Pelemo A.D. (2023). Legal responses to energy security and sustainability in Nigeria's power sector amidst fossil fuel disruptions and low carbon energy transition. *Heliyon*. 2023 Jul 3;9(7):e17912. doi: 10.1016/j.heliyon.2023.e17912. PMID: 37483776; PMCID: PMC10359868.
- Omojolaibi A. Joseph (2016) Financing the alternative: renewable energy in the Nigerian economy. *International Journal of Environment and Sustainable Development*. Vol. 15, No. 2. page 182-200. <https://doi.org/10.1504/IJESD.2016.076367>
- Ozili, Peterson K, *Theories of Sustainable Finance* (March 1, 2022). *Managing Global Transitions*, March 2022, Available at SSRN: <https://ssrn.com/abstract=4055371>
- The European Union, The European Commission. (n.d.) Overview of sustainable finance. Retrieved 29th May 2024 [https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en#:~:text=Sustainable%20finance%20is%20about%20financing,ove r%20time%20\(transition%20finance\).](https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en#:~:text=Sustainable%20finance%20is%20about%20financing,ove r%20time%20(transition%20finance).)
- United Nations Environment Programme (2011). *Green Economy*. Retrieved 29th May 2024, from <https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-economy>
- Wilson, C. 2010. 'Why should sustainable finance be given priority? Lessons from pollution and biodiversity degradation.' *Accounting Research Journal* 23 (3): 267-280.

www.naee.org.ng



Utilization of Natural Gas for Sustainable Economic Growth: A Case Study of Nasarawa State

Ahmed Adamu,
Abdullahi Muhammad Etokonza,
Ikechukwu Okafor,
Musa Umar Kolo
and Khaleel Jakada

Abstract

Nigeria is blessed with 209.5 trillion cubic feet of natural gas, the 9th most natural gas reserve in the world. In the wake of energy transition, Natural gas is a leading energy alternative due to its beneficial and characteristic features. This research analyses the economic significance of natural gas (CNG) in Nasarawa state, Nigeria. The diminishing of available petroleum products has prompted researchers to further explore alternative fuels like Compressed Natural Gas (CNG) as a promising energy alternative solution for the future. In Nigeria, intermittent shortages of gasoline and diesel have necessitated the development of alternative fuel sources, leading to the emergence of CNG as a stronghold in the fossil fuel space. Comprising mainly of methane (CH₄) with traces of propane, ethane, carbon dioxide (CO₂)

and nitrogen, CNG is a clean burning, non-corrosive and odorless fuel commonly used in a gaseous state to power vehicles and for power generation. The study encompasses various aspects, including cost analysis, efficiency test calculation, energy cost analysis, t-test analysis which compares the mean difference of two parameters and alignment with Sustainable Development Goals (SDGs). Utilizing CNG in vehicles results to improved fuel efficiency and offering a substantial amount and percentage of cost savings compared to diesel fuel. It is estimated that there is a high percentage of cost effectiveness of using Natural Gas (CNG) to fuel an agricultural tractor for day-to-day activities. Switching from Diesel fuel to CNG will provide over 77% in savings. The efficiency of using CNG as an energy alternative to fuel agricultural tractor was calculated to a capacity of 24.45%, which is higher than the efficiency of using Diesel fuel with a calculated capacity of 23.9%. It is seen that the energy cost analysis of CNG and Diesel shows there is 77% of cost savings in using CNG to fuel an agricultural tractor; this means its more expensive to run diesel in an agricultural tractor than CNG. Running Diesel in a year to fuel agricultural tractor with a distance of 500KM daily accumulates to 61,320,000.00 million naira while running CNG in a year with same distance of 500KM daily accumulates to 14,271,500.00 million naira with a cost savings of 47,048,500.00 million naira which is a lot to be used in other aspect of development. The utilization of CNG as an energy alternative to fuel agricultural tractor in substitute to diesel in Nigeria, contingent to the removal of fuel subsidies, demonstrates economic viability, sustainability and cost-effectiveness in the energy space. This study provides valuable and pivotal insights into the potential benefits of putting in place or adopting CNG as a source of fueling agricultural tractor in substitute to diesel fuel in Nasarawa state evolving energy landscape.

Keywords: CNG, Energy, Economy, Sustainability, Nasarawa.

9.1 Introduction

Natural gas is a critical source of energy that had been envisaged as a source of energy in the second half of the 20th century and became one of the foremost energy sources in the 21st century, it is recognized as a means of achieving the SDG target. Natural gas is a clean burning energy source, eco-friendly and has a wide range of uses and application, particularly for the Nigeria power generation which accounts for large amount of natural gas usage in the domestic sector of the economy. Natural gas is considered the cleanest of all fossil fuels and a source of lower cost, sustainable fuel for power generation for industrial and commercial customers and for economic development. (Agbonifo, 2015).

Natural Gas has started experience in the usage surge in the second half of the 20th Century in the industrialization age (Litvinenko, 2020) and today it has come to the forefront in terms of energy demand globally. The Nigerian Midstream and Downstream Petroleum Regulatory Authority in 2022 hinted 209.5 trillion cubic feet of proven natural gas reserves observed in Nigeria, up 1.4% compared to the previous year. Only 8 countries have a larger volume of proven gas reserves. It is said that Nigeria is majorly a gas province with some oil in it. The country contributes 3,009,650 million cubic feet to the production figures, placing it 12th on the list of producers. However, despite the country's titanic estimated population of over 218 million inhabitants, gas consumption in Nigeria stands at 664.63 billion cubic feet, 38th on earth and 3rd on the African continent. This allows for a surplus of over 2.34 trillion cubic feet (Olujobi, 2021) Africa, in general, takes a small share in Natural gas consumption; this means that the continent does not tap the benefits of the resource, despite the costs that could be saved. Nasarawa State is in the central region of Nigeria; Nasarawa State was created out of Plateau state on October 1st, 1996, with its headquarters at Lafia as shown in figure 1.3 below. The State covers a land mass of over 27,000km² with a population of about

2,000,000 people according to 2006 census spread across the Local Governments of the state.

The state has potential for growth and development considering its strategic location and proximity to the Federal Capital Territory of Nigeria, such as the abundant tourism potentials, abundant solid mineral deposits, predominant tropical climate, rich agricultural potentials, large water bodies, Savannah nature of forest that houses a lot of merchantable tress as well as its distinction of educational institutions with no meaningful economic development and benefit to the people of the state (Yaro, et. al. 2013). Years before the Sustainable Development Goals, the Millennium Development Goals (MDGs) were set in motion, these were a set of 8 goals which were to be achieved by all United Nations (UN) Member States to ensure that world poverty and hunger has been reduced; promotion of gender equality, and child mortality reduction were also goals on the Millennium Development goals list, signed in September 2000. The aim of the Millennium Development Goals was to tick all boxes on the list by the year 2015; and by then some of the objectives such as halving poverty rate were achieved, although not to an even stage when compared across member countries of the United Nations. Thus, to provide clearer and easier (more realistic) goals for all members. The United Nations, in June 2012, arrived at the Sustainable Development Goals (SDGs) (UNESCO, 2018).

A. Energy Use of Tractors

Nigeria covers large and significant reserves of natural gas. A lot of it is being flared, which amounts to billions of dollars being lost into thin air in the country, and a very negative impact to the environment which results to carbon emission. With the recent development of oil discovery in Nasarawa state (North central of Nigeria), the flaring figures are only expected to rise, unless if appropriate measures are put in place. Nigeria tends to add value to the resources by effective reduction of flaring. Using the resources optimally as a driving force

for human capital development is essential for the reduction of flaring which would reflect a significant improvement in affordability by cost reduction and ensuring availability. Power is crucial aspect of a modern country termed "Energy Security" and pivotal aspect of most countries' economic activities especially that of Nigeria as a nation. Nigeria generates about 12,000 MW of electricity mainly from gas power stations. It has become obvious that the gas produce in Nigeria is not utilized adequately for power production because most of the gas has been flared and exported for economic reasons.

Rising Emissions and climate change go hand in hand which makes countries develop stringent regulations and researchers to develop alternative fuels to achieve sustainability and reduce the negative impacts of traditional fuels. Natural is a sustainable fuel which is sourced from renewable sources.

Nigeria having discovered crude oil 1956 at Oloibiri, Bayelsa state did not make any research and attempt to use gas only as fuel form but ended up being flared, Nigeria commercial gas reserved was found accidentally during exploration (National Gas Policy, 2017), which placed Nigeria as the 23rd globally, even at that Associated Gas AG is not getting the needed attention (Ekpu, M., & Obadina, 2020). Natural gas is the most dominant natural resource in Nigeria with a proven gas reserves of 199.090 trillion cubic feet (tcf) of gas comprising of 96.36 trillion cubic feet (tcf) occurring as Associated Gas (AG) and 102.730 trillion cubic feet (tcf) occurring as Non-Associated Gas (NAG) and with this, Nigeria ranks as the ninth (9th) largest gas reserve in the world and it is evident, that Nigeria has more gas reserve than oil as stated by Department of Petroleum Resources Annual Reports, 2017 and shows Economic activities always experience a shortfall of gas supply in Nigeria due to non-developmental of the gas industry. (Biose, 2020).

The National Gas Policy of 2017 has uncovered a poor performance of gas recovery to be at 38.18% which necessitated the federal government to make a plan named "Economic Recovery and Growth

Plan, ERGP" to put in place gas development framework in the industry to meet the local needs of the Nigerian Populace. (Biose, 2020).

The major constraint in continuing businesses, maintaining standards of living, and increasing economic development in Nigeria is the lack of constant electricity supply which can be linked to underutilization and under-exploration of our natural resources (Biose, 2019) (Ekpu, M., & Obadina, 2020). Even though the resources might be there, without proper exploration, conversion and utilization, the full expected benefits cannot be harnessed. Without energy, most economic activities cannot be carried out and no country in this 21st century has substantially reduced poverty without massively making use of energy (Legros et al., 2009)(Ekpu, M., & Obadina, 2020).

Natural gas has shown tremendous potential in internal combustion engines such as the spark ignition engines which reduces hydrocarbon emissions and contributes to addressing global warming concerns. It has a higher-octane rating compared to gasoline, leading to improved engine performance and efficiency.

A rule of thumb for the agriculture in developed nations using mechanized farming 25% of agricultural cost are fuel cost. Self-propelled vehicles used in mechanized farming such as the diesel tractor are now being replaced partially or fully with natural gases which brings down the cost of fuel by about 50%. Undeveloped countries are showing a regressive fuel infrastructure due to unavailability of the natural gas infrastructure and machines for agricultural inputs (Kulchitskiy, 2022).

9.2 Methodology

9.2.1 Area of the Study

Nasarawa state was carved out in October 1996 from Plateau state with its headquarters in Lafia. It is situated in the North central part of Nigeria. The state lies between latitude 7° 45' and 9° 25' N of the equator and between longitude 7° and 9° 37' E of the Greenwich

meridian. It has neighboring states of Kaduna, Plateau, Taraba and Benue to the North, East, South with the Federal Capital Territory and Kogi to the West. The state has a total land mass of over 26,000 square kilometers. It has thirteen Local Government Areas: Akwanga, Awe, Doma, Karu, Keana, Kokona, Lafia, Nasarawa, Toto, Wamba, Keffi, Nasarawa Eggon and Obi. The people of represent a diverse combination such as Afo, Gwandara amongst a few with settlers such as the Kanuri, Igbo and Yoruba, (Nasir et. al 2009).



Figure 9.1: Methodology Diagram

9.2.2 Sampling Technique

In this section, the various processes and materials that were adopted in this research are discussed. The reader will understand how the process leading to the results, up to the discussion and conclusion level of the research is achieved. This information tends to provide

the reader with clear and understanding research process and steps that were carried towards the course of this research. The various steps used to achieve the research's aim and objectives are shown in logical sequence below;

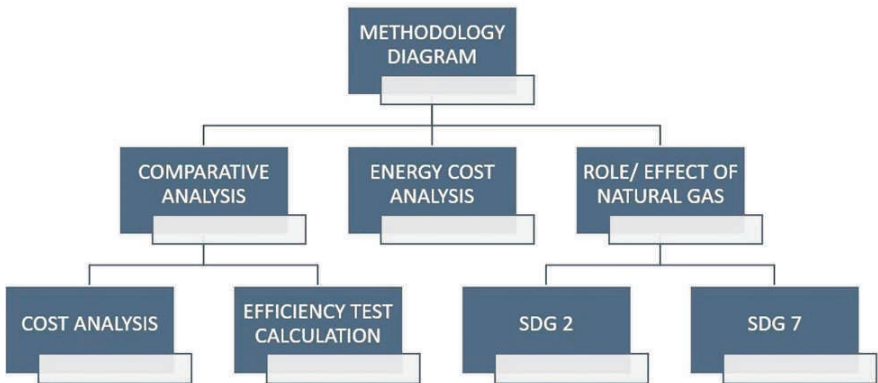


Figure 9.2: Methodology Diagram

9.3 Discussion of Results

The comparison data of using Natural Gas as opposed to Diesel to fuel agricultural tractor as energy source are shown below in Tables 9.1 and 9.2.

Table 9.1: Cost Analysis Calculation parameters for Diesel

S/N	Particulars	Value
1	Fuel Type	Diesel (AGO)
2	Ref. Vehicle	Tractor
3	Cost of Diesel per liter (Naira)	1200
4	Daily coverage distance (KM/Day)	500.00
5	Diesel Average per 100 KM(Liters)	28.00
6	Diesel Average Per KM(Liters)	0.28
7	Diesel Cost Per KM(Naira)	336.00
8	Diesel Cost Pemonth (Naira)	5,040,000.00

Table 9.2: Cost Analysis Calculation parameters for CNG

S/N	Particulars	Value
1	Fuel Type	CNG
2	Ref. Vehicle	Tractor
3	Cost of CNG (metercubeper liter) (Naira)	230.00
4	Daily coverage distance (KM/Day)	500.00
5	CNG Average per 100KM (Liters)	34.29
6	CNG Average per KM (Liters)	0.34
7	CNG Cost per KM (Naira)	78.2
8	CNG Cost per month (Naira)	1,173,000.00

Considering the fact that energy is a very vital factor when it comes to mechanization, it is important to look at economics.

From the above results obtained, Nasarawa state government can look up to CNG as a means of energy for agricultural mechanization in revamping the agricultural sector of the state which will tend to have large agricultural produce and a lot of yield production for food crops and cash crops. A large scale of the state's population leverage on agriculture due to the agricultural potentials of the state but it seen that most of the communities still use the traditional means of agriculture which currently we are in the 21st century where modernized cultures of agriculture are provided available to venture into efficiency of farm and agricultural inputs.

These results obtained gives a clear fact of energy alternative to be used between CNG and Diesel fuel in terms of cost effectiveness, in using CNG it is estimated to derive at 77% cost savings from using diesel and this clearly shows us that CNG is by far cost effective than Diesel fuel as energy source to agricultural tractor. The cost effectiveness of CNG in agricultural tractor can as well be effective in other sectors applicable to the use of energy like; transportation, industries, power generation etc.

9.3.1 T-Statistics Test

For T-statistics which compares the mean difference between two (2) parameters (CNG and Diesel). In this study, the decision on whether the difference is significant or not is based on the probability value (P value), the P value is defined as the probability under the assumption of no effect or no difference (null hypothesis), of obtaining a result equal to or more extreme than what was observed, the result is shown in Table 9.3 below.

Table 9.3: Paired Samples Test

Paired Samples Test									
		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pa ir1	DIESEL - CNG	52068.2	127482.2	52044.39	-81716.14	185852.6	1.000	5	.363

Table 9.4: Energy Cost Analysis for CNG and Diesel in reference to Tables 9.3 and 9.4

FUEL TYPE	DAILY COST	MONTHLY COST	YEARLY COST
Compressed Natural Gas	39,100.00 Naira/day	1,173,000.00 Naira/month	14,271,500.00 Naira/year
Diesel	168,000.00 Naira/day	5,040,000.00 Naira/month	61,320,000.00 Naira/year

Table 9.5: Energy Cost Savings Analysis of using CNG in Substitute to Diesel

S/NO	Energy Cost Savings	Parameters Value
1	Cost savings per km (Naira)	257.8
2	Savings per day (Naira)	128,900.00
3	Savings permonth (Naira)	3,867,000.00
4	Annual Savings (Naira)	47,048,500.00
5	Percentage savings (%)	77%

The results obtained from the energy cost analysis of CNG and Diesel shows there's 77% of cost savings in using CNG to fuel an agricultural tractor, this means it is more expensive to run diesel in an agricultural tractor than CNG.

Running Diesel in a year to fuel agricultural tractor accumulates to 61,320,000.00 million naira while running CNG in a year accumulates to 14,271,500.00 million naira with a cost savings of 47,048,500.00 million naira which is a lot to be used in another aspect of development.

Subject to the second objective of this research which states; to see how the use of natural gas (CNG) can have impact in Nasarawa's state economy, this part of the research clearly answers that, which this part of the research shows us how the use of CNG instead of Diesel fuel can save up 77% of the money that will be used for diesel and the energy cost savings can contribute to Nasarawa state economy for any form of development in the state.

9.4 Effect of Results on Sustainable Development Goals

1. *Goal 2, Zero Hunger:* Mechanization of farms leads to boosts in efficiency, and when there is a higher yield per unit area of land, it leads to higher food supply and the prices also becomes more affordable due to surplus availability of food crops. Affordable food and self-reliance in obtaining food will sufficiently lower hunger percentage.
2. *Goal 7, Affordable and Clean Energy:* From the research carried out it shows that Natural Gas (CNG) is an affordable form of energy amongst other fossil fuels and non-renewables. Natural Gas is a cheaper energy alternative which many people can afford and will lead to lowered burden on energy cost to individuals and it is also considered the cleanest form of fossil fuel which is associated with lower carbon emission unlike other

fossil fuels, Goal 7 of the sustainable development goals can be well achieved to a good extent so far the availability of Natural gas will be readily available.

These two goals i.e. Goal 1 and 7 can be well achieved but will depend heavily on a lot of policies and management as well as other goals of the sustainable developed adopted by United Nations, these two goals will depend deeply on policies and management decisions by the State and Federal Government of the Federal Republic of Nigeria.

For goal 7, Natural gas is not fully free of emissions, but it can help in curbing pollution because it is a cleaner form of other energy alternatives and would aid in the reduction of deforestation to an extent.

Goal 2 would depend a lot on the policies regarding population control in Nigeria, or at least in Nasarawa state. This is because when there is higher increase in population than in food output and employment opportunities, more people in the coming years will be left without jobs, and the amount of food per capital would also drop, which means there will be a presence of low food availability on ground.

9.5 Conclusion

1. It is estimated that there is a high percentage of cost effectiveness of using Natural Gas (CNG) to fuel an agricultural tractor for day-to-day activities. Switching from Diesel fuel to CNG will provide over 77% in savings.
2. The efficiency of using CNG as an energy alternative to fuel agricultural tractor was calculated to a capacity of 24.45%, which is higher than the efficiency of using Diesel fuel with a calculated capacity of 23.9%.

3. It is seen that the energy cost analysis of CNG and Diesel shows there is 77% of cost savings in using CNG to fuel an agricultural tractor, this means its more expensive to run diesel in an agricultural tractor than CNG. Running Diesel in a year to fuel agricultural tractor with a distance of 500KM daily accumulates to 61,320,000.00 million naira while running CNG in a year with same distance of 500KM daily accumulates to 14,271,500.00 million naira with a cost savings of 47,048,500.00 million naira which is a lot to be used in another aspect of development.
4. These results have further been linked to show the role Natural gas can play in achieving sustainability in Sustainable Development Goals (SDGs). Goal 2 can be achieved to a good extent but will depend heavily on government's policies on population control. While Goal 7 is positively driven to the direction of achievement via the use of Natural Gas in the state. In general, these results are in positive steps for economic development, environmental sustainability and social inclusion, which are the pillars and foundation of sustainability and Sustainable Development Goals at large.
5. The T-statistics test for both CNG and Diesel parameters shows that the difference is not statistically significant with a probability value of 0.363 which is greater than 0.05(5%).

Recommendations

1. The economics of getting Natural Gas to Nasarawa state from source areas should be carried out.
2. There should be a lot of research carried out in all major economic sectors of Nasarawa state. Results from this research will provide an avenue for more questions to be raised, and subsequently answered over the years, amounting to development.

3. The use of actual and real time data should be used instead of assumptions in applicable calculations during research for more reliable, well-structured and accurate research.

References

- Agbonifo, P. E. (2015). Opportunities, Challenges and Obstacles to Economic Growth and Sustainable Development Through Natural Gas in Nigeria. *Journal of Sustainable Development in Africa*, 17(5), 99–114.
- Biose, H. (2020). Gas Production and Utilization in Nigeria: a Long-Term Perspective. *International Journal of Engineering Technologies and Management Research*, 6(5), 58–72.
<https://doi.org/10.29121/ijetmr.v6.i5.2019.372>
- Ekpu, M., &Obadina, O. B. (2020). Power Production using Natural Gas in Nigeria: Trends, Challenges and Way Forward. *Nigerian Research Journal of Engineering and Environmental Sciences*, 5(2), 873–884.
- Kulchitskiy, C. R. (2022). About the possibility of using natural gas as a fuel on agricultural tractors. *Tractors and Agricultural Machinery*, 89(1), 7–14. <https://doi.org/10.17816/0321-4443-96419>
- Litvinenko, V. (2020). The role of hydrocarbons in the global energy agenda: The focus on liquefied natural gas. *Resources*, 9(5).
<https://doi.org/10.3390/RESOURCES9050059>
- Olujobi, O. J. (2021). Deregulation of the downstream petroleum industry: An overview of the legal quandaries and proposal for improvement in Nigeria. *Heliyon*, 7(4), e06848.
<https://doi.org/10.1016/j.heliyon.2021.e06848>
- UNESCO. (2018). The 2030 Education Agenda: from MDGs, EFA Sustainable Development Goal 4 October, 1–200.
- Yaro, Obadijah Otso; Ebuga, E. A. (2013). An Assessment of the Development Potentials of Nasarawa State in Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 6(6), 01–05.
<https://doi.org/10.9790/2402-0660105>.



Nigeria's Energy Dilemma: Balancing Industrialization and Environmental Sustainability in a Changing Global Energy Landscape

Yaknan Haruna Mamdam and
Nanven Haruna Mamdam

10.1 Background

Energy is an important aspect of human existence in contemporary times, which power almost all activities from economic, social, industrial even the income of nations depends on energy. The importance of energy in the wellbeing of any society cannot be overemphasized as its scale of use determines the socio-economic development of any nation (Dioha et. al 2018). It is the major driving force for development, industrial revolution and improved welfare. Some scholars have linked energy availability and consumption to the welfare of people. The economic, social and solidarity implications of energy poverty are becoming massive, especially in regions where the income level is low and the average cost of modern energy technology is relatively high such as the sub-Saharan Africa (Meyer et al., 2018). As at 2017, approximately 1.1 billion of people globally

were living without access to energy in its clean, socio-environmentally and directly usable form. The sub-Saharan African region is worst hit by the global energy deprivation; only one in every three individuals is connected to an energy source in its reliable, clean and affordable form. The small population that is connected to the grid experience unreliable services that shortchange their daily energy needs (Division for Sustainable Development Department of Economic and Social Affairs United Nations, 2018, Lee and Callaway, 2018). According to a World Economic Forum (WEF) report, energy inaccessibility has significant negative impacts on health, education, and economic development. Nigeria often referred to as the giant of Africa is believed to have fallen short of its potential for development. Its large population projected by the world bank to be about 217 million with about 70% of this population living below poverty line and where around 45% do not have access to electricity and 72% still depend on traditional solid biomass for cooking (Dioha et. al 2018). Nigeria is Africa's largest consumer of oil-fired backup generators, with over 80% of power generation coming from gas reserves.

Although, Nigeria has signed up to be part of United Nations Convention for Climate Change, which commits towards maintaining Green House Gas emissions to 2° below pre-industrial revolution level. This commitment will see Nigeria choose between driving its development goals or pursuing a program of environmental preservation. Ironically, the world as part of its strategy towards environmental sustainability has adopted energy transition from fossil fuels to cleaner sources of energy such as solar, wind and geothermal among others. Whether this push for energy transition by the west is just, is in itself a subject of debate.

Even though attempts have been made to provide a template for just transition, the approaches to this transition cannot be imposed by one party to ensure that the development potential of the developing nations is not undermined. This reality creates a conundrum for a developing nation like Nigeria, which is yet to

optimize its development potential by utilizing its natural resources, yet expecting to champion the course of environmental sustainability.

As a matter of fact, to be able to transition Nigeria requires humongous sums of monies to be able to invest in the technology, manpower and infrastructure. Since, Nigeria's major income earner is the sale of fossil fuel, it would mean that cutting down significantly on fossil fuel exploration and or utilization, will reduce Nigeria's revenue and with this make it increasingly difficult to provide the required infrastructure for an energy transition. This paper seeks to examine the what options Nigeria has to utilize its natural resources in a way that accelerates development, yet would be sensitive to the general desire for sustainable practices that preserve the environment.

10.2 Theoretical and Conceptual Framework

This study adopts a qualitative and comparative analytical approach, relying on secondary data from international organizations, policy reports, and academic literature.

The analysis is structured around three components:

1. Conceptual analysis of the relationship between energy, industrialization, and emissions
2. Comparative global assessment of major emitters and low-emission economies
3. Policy and institutional evaluation of Nigeria's energy framework

The study focuses on identifying structural patterns rather than causal econometric relationships, and is limited to publicly available data (primarily 2018–2024). The objective is to derive policy-relevant insights rather than predictive modeling.

10.2.1 Energy, Industrialization, and Emissions

The relationship between energy consumption and economic development is well established in the literature. Industrialization, which is central to economic transformation, typically involves increased energy use—historically driven by fossil fuels. This reliance results in higher levels of greenhouse gas emissions, particularly carbon dioxide (CO₂).

While CO₂ remains the most prominent greenhouse gas due to its volume, other gases such as methane have significantly higher warming potential over time. Nevertheless, the scale and frequency of CO₂ emissions make it the dominant contributor to climate change. For developing economies, this creates a structural tension: the pursuit of industrialization often leads to increased emissions, yet limiting emissions may constrain economic growth. This tension lies at the heart of Nigeria's energy dilemma.

10.2.2 The Just Energy Transition Debate

The concept of a just energy transition has emerged as a central theme in global climate discourse. It emphasizes fairness and equity in the transition from fossil fuels to cleaner energy sources, particularly for developing countries.

Under this framework, countries are not expected to adopt uniform transition pathways. Instead, flexibility is encouraged to account for differences in:

- Economic capacity
- Technological readiness
- Development priorities

For Nigeria, the just transition framework provides a basis for arguing that energy policies must reflect domestic realities, including the need to utilize existing natural resources to drive development.

10.2.3 Institutional Quality and Environmental Governance

Institutional quality plays a critical role in shaping environmental outcomes. Strong institutions characterized by effective regulation, enforcement capacity, and adherence to the rule of law are essential for implementing environmental policies and ensuring compliance.

In many developed economies, robust institutional frameworks have facilitated the adoption of cleaner technologies and the enforcement of environmental standards. In contrast, weak institutions in developing countries often undermine policy effectiveness.

For Nigeria, strengthening institutional capacity is a prerequisite for achieving a balanced energy transition.

10.2.4 Environmental Innovation as a Transition Pathway

Environmental innovation refers to the development and adoption of technologies and processes that reduce environmental harm while supporting economic activity. It provides a pathway for reconciling industrial growth with sustainability.

Such innovation may include:

- Renewable energy technologies (solar, wind, hydro)
- Energy efficiency improvements
- Carbon capture and storage systems

By investing in environmental innovation, countries can reduce emissions without compromising industrial competitiveness. For Nigeria, this represents a critical opportunity to align development objectives with environmental goals.

10.3 Lessons from Other Climes and Comparative Global Analysis

The historical trajectory of economic development in advanced economies shows a strong dependence on fossil fuels to drive

industrialization, economic growth, and prosperity. As global awareness of environmental sustainability increased in the late 20th century, these same nations began advocating for climate action, despite remaining among the largest contributors to greenhouse gas (GHG) emissions.

Globally, there is broad consensus on the need for environmental protection and climate mitigation, as reflected in agreements such as the Paris Agreement, which aims to limit global warming to 1.5°C above pre-industrial levels. However, a significant imbalance exists: the world's leading economies including China, the United States, the European Union (EU-27), India, and Russia are also the largest emitters of CO₂. These countries collectively account for a substantial share of global GDP, industrial output, fossil fuel consumption, and GHG emissions.

Table 10.1: Emission Levels, GDP, and Industrialization Among Top 5 GHG Emitters

Country	GHG Emission	GDP (Million \$)	Industrialization Level (%)
CHINA	29.16	17,963,171	28.4
USA	11.6	25,439,700	16.6
EU (27)	5.88	16,746,544	14
RUSSIA	4.796	2,240,422	13
INDIA	7.33	3,416,645	3

Source: Compiled from Wikipedia data (2022)

These five economies dominate global industrial activity and emissions, highlighting a clear relationship between industrialization, energy consumption, and environmental impact. While countries like the United States lead in GDP, China surpasses all in emissions, largely due to its extensive industrial base. India stands out as an emerging economy with relatively low industrialization but rising emissions, indicating future growth pressures.

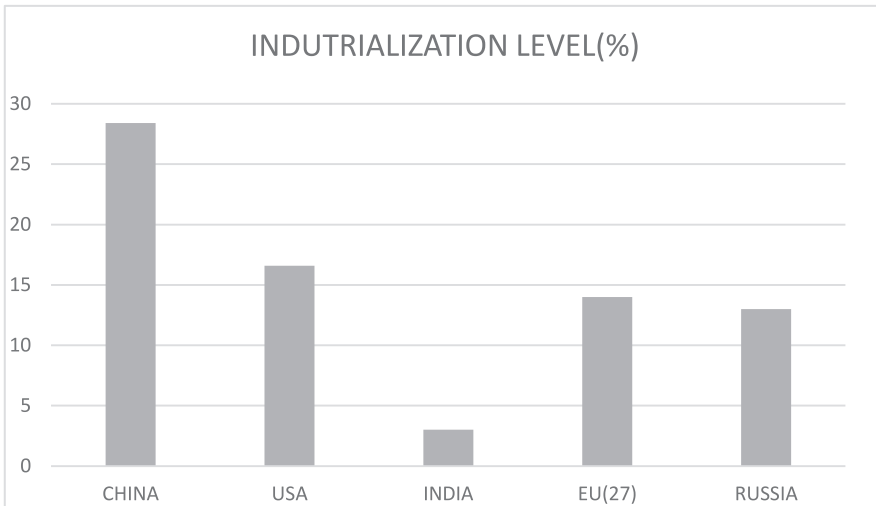


Figure 10.1: Industrialization Levels of Top CO₂Emitters Globally

The figure shows that higher industrialization levels generally correspond with higher emissions. China leads significantly, followed by the USA and EU, while India remains comparatively low, reflecting its developing industrial status.

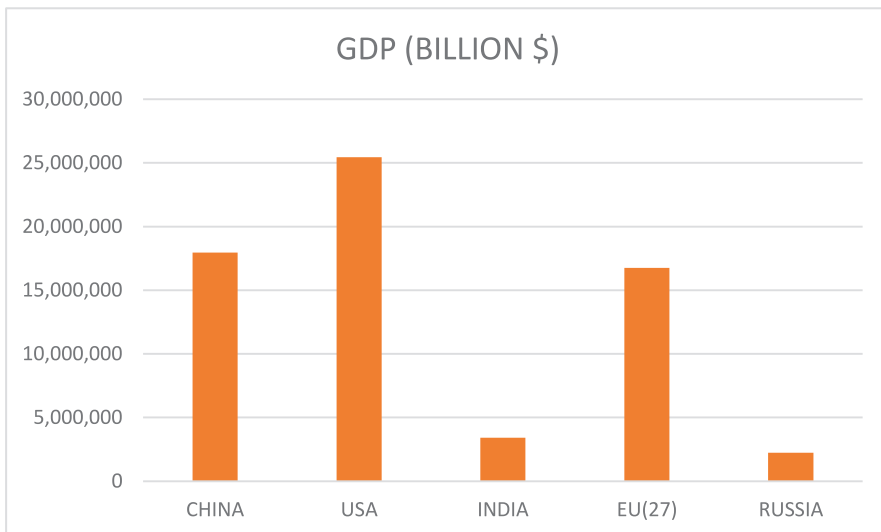


Figure 10.2: GDP of Top CO₂Emitters

The GDP distribution indicates that economic output broadly aligns with industrialization and emissions levels. The United States leads economically, followed by China and the EU. Russia, despite abundant natural resources, has comparatively lower GDP, partly influenced by geopolitical constraints.

Industrial and building energy use accounts for a major share of global emissions, reinforcing the strong link between economic activity and environmental impact.

Table 10.2: Least Five CO ₂Emitters per Capita

Country	GHG Emission Per Capita (%)	GDP (Million \$)	Industrialization Level (%)
BURUNDI	0.59	3,073,414,678.00	N/A
DR CONGO	0.65	58,065,953,573.00	N/A
AFGHANISTAN	0.73	14,580,000,000.00	N/A
WESTERN SAHARA	0.78	N/A	N/A
KIRIBATI	0.87	223,352,943.00	N/A

Source: Compiled from Wikipedia (2023)

Countries with the lowest emissions per capita are typically characterized by low industrialization, weak economic structures, and heavy reliance on agriculture or extractive industries. Many of these nations particularly in Africa and parts of Asia face significant developmental challenges, including poverty, low energy access, and limited infrastructure.

Although their environmental impact is minimal, this low emission level is largely a consequence of underdevelopment rather than intentional sustainability policies. For instance, African countries contribute less than 5% of global emissions but are among the most vulnerable to climate change impacts.

10.4 Nigerian Legal Framework for Energy Transition

Nigeria's energy landscape is characterized by a paradox. Despite abundant natural resources—particularly oil and natural gas—the country continues to experience widespread energy poverty. Electricity supply remains inadequate, unreliable, and unevenly distributed, forcing households and businesses to rely heavily on alternative energy sources such as diesel generators and biomass.

This reliance has significant economic and environmental consequences. The use of generators increases the cost of doing business, reduces productivity, and contributes to localized pollution.

Similarly, dependence on biomass for cooking contributes to deforestation and health risks, particularly in rural areas.

At the same time, Nigeria's fiscal structure is heavily dependent on revenues from fossil fuel exports. This dependence constrains the country's ability to rapidly transition away from fossil fuels without jeopardizing public finances and economic stability.

10.4.1 Legal and Policy Framework

Nigeria's legal framework reflects an attempt to balance development objectives with environmental sustainability. The 1999 Constitution (as amended) establishes the dual responsibility of the state to promote economic welfare while protecting the environment.

More recently, legislative efforts such as the Petroleum Industry Act (2021) and the Climate Change Act (2021) have sought to provide direction for both resource management and environmental governance. While the Petroleum Industry Act focuses on optimizing the value of fossil fuel resources, the Climate Change Act establishes institutional mechanisms for addressing climate-related issues.

However, these frameworks exhibit significant limitations.

First, there is a lack of policy coherence. The coexistence of laws that promote fossil fuel expansion alongside those advocating emission reduction creates conflicting policy signals.

Second, the Climate Change Act, while symbolically important, lacks clear implementation mechanisms. Its provisions are largely administrative, with insufficient emphasis on actionable strategies, sector-specific targets, or enforcement mechanisms.

Third, institutional weaknesses continue to undermine policy effectiveness. Regulatory agencies often face capacity constraints, limited funding, and weak enforcement capabilities, reducing their ability to implement existing laws.

10.4.2 Institutional Gaps and Policy Challenges

The effectiveness of any energy transition strategy depends on the strength of underlying institutions. In Nigeria, several challenges persist:

- Weak enforcement of environmental regulations
- Fragmented policy coordination across sectors
- Limited investment in research and innovation
- Inadequate infrastructure for clean energy deployment

These challenges highlight the need for a more integrated and strategically aligned policy framework that links energy, environment, and industrial development.

10.5 Policy Options and Transition Pathways

Addressing Nigeria's energy dilemma requires a pragmatic and context-sensitive approach. Rather than adopting a rigid transition model, the country must pursue a hybrid strategy that balances immediate development needs with long-term sustainability goals.

10.5.1 Phased Energy Transition

A phased approach allows Nigeria to gradually shift from fossil fuels to cleaner energy sources without disrupting economic stability.

- Short term: Continued use of fossil fuels, particularly natural gas, to support industrialization

- Medium term: Expansion of low-carbon energy sources such as hydro and gas-based systems
- Long term: Transition toward renewable energy as primary sources

Natural gas, in particular, can serve as a transition fuel, offering lower emissions compared to coal and oil while supporting industrial growth.

10.5.2 Strategic Emission Management

Rather than focusing solely on reducing emissions from industrial sectors, Nigeria can achieve meaningful progress by targeting non-critical emission sources, including:

- Biomass-based cooking
- Gas flaring
- Transport inefficiencies

Reducing emissions in these areas can offset increases associated with industrialization.

10.5.3 Industrialization as a Foundation for Transition

Economic growth is a prerequisite for sustainable energy transition. By expanding its industrial base, Nigeria can generate the financial resources required to invest in clean energy infrastructure.

This approach recognizes that:

- Clean energy technologies require significant upfront investment
- Developing countries often lack access to sufficient external financing
- Domestic resource mobilization is essential

10.5.4 Environmental Innovation and Technology

Promoting innovation is critical for long-term sustainability. Nigeria can achieve this by:

- Investing in clean energy research and development
 - Supporting local manufacturing of renewable technologies
 - Encouraging private sector participation through incentives
- Innovation reduces the trade-off between growth and sustainability by enabling more efficient and cleaner production processes.

10.5.5 Institutional and Regulatory Reform

Strengthening institutions is essential for policy implementation. This includes:

- Enhancing regulatory enforcement capacity
 - Improving inter-agency coordination
 - Establishing clear accountability mechanisms
- Without institutional reform, even well-designed policies are unlikely to achieve desired outcomes.

Policy Framework for Nigeria’s Energy Transition

Time frame	Policy Area	Action	Responsible Institutions	Expected Outcome
Short-term (0–3 years)	Legal & Regulatory Reform	Develop a comprehensive National Energy Transition Act to harmonize existing laws	National Assembly, Ministry of Justice	Clear legal direction for energy transition
	Energy Access	Scale up rural electrification using solar mini-grids	Rural Electrification Agency (REA), Ministry of Power	Reduced energy poverty
	Emission Reduction	Ban routine gas flaring and enforce penalties	NUPRC, Ministry of Environment	Immediate reduction in emissions
	Domestic Energy	Subsidize clean cooking technologies (LPG, electric, solar)	Ministry of Finance, Ministry of Women Affairs	Reduced biomass dependence
	Transport	Introduce CNG-powered public transport systems in major cities	Ministry of Transport, State Governments	Lower urban emissions

10.6 Conclusion

This study establishes a clear nexus between industrialization, economic growth, and greenhouse gas emissions, drawing from the experiences of both developed and developing economies. Evidence from major global emitters demonstrates that industrialization has historically depended on fossil fuel utilization, resulting in high emission levels. Conversely, countries with minimal emissions are largely characterized by low levels of industrialization and persistent poverty.

For Nigeria, this creates a structural dilemma. On one hand, the country must accelerate industrialization to address widespread poverty, energy deficits, and underdevelopment. On the other hand, it faces increasing global pressure to align with climate commitments and transition toward low-carbon energy systems.

The analysis of Nigeria's legal and policy frameworks reveals a fragmented and insufficiently coordinated approach to energy transition. While existing laws acknowledge both development and environmental protection, they lack the operational clarity and institutional strength required for effective implementation. Based on these findings, the study argues that Nigeria's optimal pathway lies in a phased and pragmatic energy transition strategy.

This approach should prioritize:

- The strategic use of fossil fuels (particularly natural gas) to drive near-term industrialization
- Simultaneous reduction of non-critical emission sources
- Gradual scaling of clean energy infrastructure
- Strengthening institutional and regulatory frameworks

Ultimately, achieving a balance between industrial growth and environmental sustainability will depend on Nigeria's ability to design **context-specific policies**, mobilize resources, and build strong institutions capable of enforcing a coordinated transition agenda.

Bibliography

- Aggeri, F. (1999). Environmental Policies and Innovation: A Knowledge-Based Perspective on Cooperative Approaches. *Res. policy* 28 (7), 699–717. doi:10.1016/s0048-7333(99)00015-3
- Barry D., and Krishna K. (2011) The coming sustainable energy transition: History, strategies, and outlook, *Energy Policy*, Volume 39, Issue 11, 2011, Pages 7422-7431, ISSN 0301-4215, <https://doi.org/10.1016/j.enpol.2011.09.009>
- Bernauer, T., and Koubi, V. (2009). Effects of Political Institutions on Air Quality. *Ecol. Econ.* 68 (5), 1355–1365. doi:10.1016/j.ecolecon.2008.09.003
- Dike, O., Periola-Fatunsin, O and Ezenagu, A (2023) Regulating Energy Transition in Nigeria: Articulating A Development Policy Approach, A publication of the NESG Non-Residential Fellowship Programme.
- Economy of Russia - statistics & facts (2024) Statista Research Department, accessed 28 June 2024 17:54PM
- El-Rufai, R., Emuesiri A., Mohammed A., and Olanrewaju A.. (2022). Decarbonising Nigeria's Economy. Abuja. Accessed June 26, 2024. <https://www.pwc.com/ng/en/assets/pdf/decarbonising-nigerias-economy.pdf>.
- Ibrahim . A and Zeydler. O (2023) Here's how Nigeria is tackling barriers to the green energy transition | World Economic Forum (weforum.org) May 8, 2023 accessed 22 June 2024 10:18am
- Jinru, L and Qamruzzaman .M (2022) Nexus Between Environmental Innovation, Energy Efficiency, and Environmental Sustainability in G7: What is the Role of Institutional Quality? *Front. Environ. Sci.* 10:860244. doi: 10.3389/fenvs.2022.860244
- Lee J.T., Callaway D.S (2018), The cost of reliability in decentralized solar power systems in sub-Saharan Africa *Nature Energy*, 3 pp. 960 968, 10.1038/s41560-018-0240-y
- Manufacturing, value added (% of GDP) - Russian Federation (2024) World Bank Publication <https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=RU> accessed 22 june 2024 18:30PM
- Meyer S., Laurence H., Bart D., Middlemiss L., Marichal K. (2018), Capturing the multifaceted nature of energy poverty: Lessons from Belgium *Energy Res. Soc. Sci.*, 40 pp. 273-283, 10.1016/j.erss.2018.01.017 <http://www.sciencedirect.com/science/article/pii/S221462961830104X>

- Michael O. Dioha and Nnaemeka V. Emodi (2018) *Energy-Climate Dilemma in Nigeria: Options for the Future*, International Association for Energy Economics (IAEE) Energy Forum Second Quarter 2018
- Adewuyi. O , Kiptoo.M.K, Afolayan, FA , Theophilus A., Oluwatobi I. A., Tomonobu S, (2019) *Challenges and prospects of Nigeria's sustainable energy transition with lessons from other countries' experiences* Received 23 September 2019,
- Osman-Elasha, B., and Diego F, (2020). *Drivers of Greenhouse Gas emissions in Africa: Focus on agriculture, forestry and other land use.*
- Ranping Song and Rhys Gerholdt (2019) *Not Just CO2: China's Efforts on Lesser Known Greenhouse Gases Critical to Stabilizing the Climate*
- Rennings, K. (2000). *Redefining Innovation - Eco-Innovation Research and the Contribution from Ecological Economics.* *Ecol. Econ.* 32 (2), 319–332. doi:10.1016/s0921-8009(99)00112-3
- Rural Electrification Agency. (2022). *The Unveiling of Nigeria's Energy Transition Plan at COP26.* <https://rea.gov.ng/the-unveiling-of-nigerias-energy-transition-plan-at-cop26/-Abuja>. Accessed June 26, 2024.
- The United Nations. (2021). *'Theme Report on Energy Transition: Towards the Achievement of SDG 7 And Net-zero Emissions'*. Washington DC: The United Nations. Accessed May 29, 2024.
- The United Nations Framework Convention on Climate Change. New York, (2022). https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.
- US Environmental Protection Agency. 2022. *Global Greenhouse Gas Emissions Data.* Washington D.C., accessed 16 June. https://www.un.org/sites/un2.un.org/files/2021-twg_2-062321.pdf. United Nations. 1992.
- US Environmental Protection Agency. (2012) *Summary Report: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990–2030.* Washington D.C. <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>.
- Wole Hammond (2022) *Why the global energy transition must be just and equitable | World Economic Forum (weforum.org)* accessed 22 June 2024 11:14

World Economic Forum. (2021). *Fostering Effective Energy Transition-2021 Report*. Cologne, April. Accessed June 28, 2024.

[https://www.epa.gov/sites/default/files/2016](https://www.epa.gov/sites/default/files/2016-08/documents/summary_global_nonco2_projections_dec2012.pdf)

[08/documents/summary_global_nonco2_projections_dec2012.pdf](https://www.epa.gov/sites/default/files/2016-08/documents/summary_global_nonco2_projections_dec2012.pdf).

World Population Review. (2022). *Carbon Footprint by Country 2022*. 21 June.

https://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf.

[https:// worldpopulationreview.com/country-rankings/carbon-footprint-by-country](https://worldpopulationreview.com/country-rankings/carbon-footprint-by-country).

World Bank and NORAD (2018) .Division for Sustainable Development Department of Economic and Social Affairs United Nations.

PART 8



Economic Transition





Examining the Relationship Between Renewable Energy Adoption, Population Dynamics, and Economic Growth in Africa

Ichedi Winifred,
Kings Timipre and
Mahmud Alamin

Abstract

This study examines the relationship between renewable energy adoption, population dynamics, and economic growth in five African countries: Congo, Egypt, Ethiopia, Nigeria, and South Africa. Utilizing panel data spanning from 1990 to 2020, the research employed advanced econometric techniques to analyse the dynamic interplay between these key variables. Specifically, we examined how changes in population dynamics and renewable energy consumption influence GDP growth rate, while also considering the influence of CO2 emissions per capita. By analysing longitudinal data across multiple countries and time periods, we uncovered nuanced patterns and trends that highlight the synergies and trade-offs between renewable energy adoption, population dynamics, and economic prosperity. Our findings

reveal significant interactions between these factors, demonstrating both positive and negative impacts on GDP growth rate depending on the specific context and country. This research provides empirical evidence and insights into the relationships between renewable energy adoption, population dynamics, and economic growth, with significant implications for sustainable development in Africa. The study contributes to a comprehensive understanding of the energy-economy-environment nexus and underscores the importance of integrated approaches to sustainable development and good governance in Africa, supporting evidence-based policy formulation for a more resilient and equitable future.

Keywords: Renewable energy adoption, Population dynamics, Economic growth, Panel data analysis, Sustainable development in Africa.

11.1 Introduction

Africa is at a critical juncture in its pursuit of sustainable development, where the interplay between energy, economic growth, and environmental sustainability is more crucial than ever. The continent faces significant challenges, including energy poverty, economic disparity, and environmental degradation, exacerbated by rapid population growth and urbanization. The adoption of renewable energy presents a promising solution to these intertwined challenges, offering a pathway towards sustainable development that aligns with the goals of the African Union's Agenda 2063 and the United Nations Sustainable Development Goals (SDGs).

Recent studies highlight the growing momentum for renewable energy in Africa. According to the International Renewable Energy Agency (IRENA, 2022), Africa's renewable energy capacity grew by nearly 30% over the past decade. This shift is driven by decreasing costs of renewable technologies, increased investment, and supportive

policy frameworks. However, the adoption rate varies significantly across the continent, influenced by each country's unique socio-economic and political context. In the Republic of Congo, the potential for hydropower remains underutilized due to inadequate infrastructure and investment, with only about 40% of the population having access to electricity (World Bank, 2021). In contrast, Egypt has emerged as a regional leader in renewable energy, particularly solar and wind, aiming to generate 42% of its electricity from renewable sources by 2035, as exemplified by the Benban Solar Park (Egyptian Ministry of Electricity and Renewable Energy, 2022).

Ethiopia's renewable energy sector is dominated by hydropower, with the Grand Ethiopian Renaissance Dam (GERD) expected to generate 6,000 MW of electricity upon completion, significantly boosting the country's energy capacity (African Development Bank, 2022). However, Ethiopia faces challenges in diversifying its renewable energy portfolio. Nigeria, characterized by abundant energy resources yet widespread energy poverty, has significant solar potential but struggles with infrastructural deficits and regulatory challenges. Initiatives like the Nigeria Electrification Project aim to enhance energy access through solar mini-grids and stand-alone systems (Energy Commission of Nigeria, 2022). South Africa, with the most advanced renewable energy sector in Sub-Saharan Africa, has attracted over \$25 billion in investment through its Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), generating substantial economic and environmental benefits (South African Department of Energy, 2021).

Africa's population dynamics present both challenges and opportunities for sustainable development. The continent's population is projected to double by 2050, reaching approximately 2.5 billion people (United Nations, 2022). This rapid growth increases energy demand and economic pressures but also offers a demographic dividend if harnessed effectively through job creation and economic development. Urbanization is a major trend, with urban areas expected to house 60% of the population by 2050, necessitating

substantial investments in energy infrastructure to support economic activities and improve living standards. Economic growth in Africa is closely linked to energy access, with studies showing that a 1% increase in electricity consumption can lead to a 0.7% increase in GDP (International Energy Agency, 2022). Renewable energy adoption can drive economic growth by creating jobs, stimulating industrial activities, and reducing energy costs.

Effective governance and robust policy frameworks are essential for facilitating the transition to renewable energy. Countries like Egypt and South Africa have demonstrated that supportive policies and regulatory environments can attract investment and accelerate renewable energy adoption. Conversely, countries with weaker governance structures, like Nigeria and Congo, face challenges in implementing sustainable energy solutions.

11.1.1 Significance of Study

This study is significant as it explores the intricate relationships between renewable energy adoption, population dynamics, and economic growth in five key African countries: Congo, Egypt, Ethiopia, Nigeria, and South Africa. By analysing data from 1990 to 2020 using advanced econometric techniques, this research uncovers how renewable energy investments influence GDP growth and how population trends and CO₂ emissions interrelate with economic performance. The findings offer valuable insights into the role of renewable energy in fostering sustainable development, revealing that economic growth is strongly linked to renewable energy adoption. This study supports the African Union's Agenda 2063 and the UN Sustainable Development Goals by providing empirical evidence for policy formulation aimed at achieving energy sustainability and economic prosperity in Africa.

11.2 Literature Review

11.2.1 Empirical Review

The International Renewable Energy Agency (IRENA, 2023) highlights that Congo's renewable energy adoption has significantly increased due to international investments and supportive policy frameworks. The country has seen notable advancements in hydroelectric power, driven largely by foreign direct investment and international cooperation. These investments are essential in addressing the infrastructural deficits that have historically impeded Congo's renewable energy potential.

Hussain et al. (2023), in their research published in the *Journal of Environmental Management*, indicate that Ethiopia's commitment to renewable energy, especially hydroelectric power, has positively impacted economic development. The Grand Ethiopian Renaissance Dam (GERD) exemplifies how large-scale renewable energy projects can improve energy access and stimulate economic activities, thus reducing poverty levels. The study underscores the importance of diversifying Ethiopia's renewable energy sources to ensure long-term sustainability.

Empirical evidence from a comprehensive study by IRENA (2023) underscores South Africa's progress in integrating renewable energy into its national grid. The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) has been particularly successful in attracting private investments and promoting sustainable development. This program has significantly boosted economic growth and job creation, although some regulatory challenges persist (Gielen et al., 2019). The success of REIPPPP highlights the potential of well-structured renewable energy policies in driving sustainable economic development.

A study by Hasanov et al. (2021) in the *Environmental Science and Pollution Research* journal demonstrates a strong link between Egypt's renewable energy initiatives and its economic growth.

Egypt's strategic investments in solar and wind energy projects, such as the Benban Solar Park, have significantly boosted economic expansion by creating jobs and enhancing energy security.

Additionally, these projects have contributed to a reduction in greenhouse gas emissions, promoting a more sustainable economic model (IRENA, 2023).

According to a study by Hafner et al. (2021) in the *Journal of Clean Production*, Nigeria's solar energy projects have shown mixed results, highlighting a complex interplay between energy policies, economic growth, and population dynamics. While these projects have economic benefits, they are often offset by infrastructural deficits and policy inconsistencies. Despite these challenges, the renewable energy sector remains a critical area for Nigeria's potential growth and economic diversification.

Dogan & Seker (2016) examined the relationship among several key factors including trade, real output, renewable and non-renewable energy, financial development, and carbon dioxide emissions using the Environmental Kuznets Curve (EKC). They analysed data from 23 countries listed in the Renewable Energy Country Index from 1980 to 2011. Their findings suggest that the use of non-renewable energy exacerbates environmental degradation. This underscores the current disparity where non-renewable energy resources are cheaper than renewable alternatives.

Saidi & Hammami (2015) conducted a panel data analysis to investigate the impact of economic development and carbon dioxide emissions on energy consumption across 58 countries from 1990 to 2012. Their study found a statistically significant positive correlation among these variables, indicating that increases in GDP and CO₂ emissions lead to higher energy consumption.

Shuddhasattwa and Alam (2010) investigated the factors influencing renewable energy adoption across six prominent emerging markets that are heavily investing in renewable energy. Their research utilized two panel approaches, the dynamic least squares method and the fully modified ordinary least squares

approach to uncover long-term elasticities. They also employed the autoregressive distributed lag time series technique, which proved to be robust. The study found that in Indonesia, Brazil, China, and India, long-term renewable energy consumption is significantly influenced by both carbon dioxide emissions and income levels. In contrast, in Turkey and the Philippines, income emerges as the predominant driver of renewable energy adoption. Moreover, their short-term analysis for China and Brazil revealed bidirectional causal relationships between income and renewable energy consumption, as well as between renewable energy consumption and carbon dioxide emissions.

11.2.2 Theoretical Framework

11.2.2.1 Environmental Kuznets Curve (EKC) Hypothesis

The Environmental Kuznets Curve (EKC) is a valuable theoretical framework for examining the relationship between renewable energy adoption, population dynamics, and economic growth in Africa because it offers a well-established model for understanding how economic development affects environmental quality. Simon Kuznets, the propounder of this theory, initially explored the connection between economic growth and income inequality, later extending the concept to environmental issues. The EKC hypothesis posits that as economies develop, environmental degradation first increases but eventually decreases as countries become wealthier and can invest in cleaner technologies and implement effective environmental policies. This framework is particularly relevant for analysing whether renewable energy adoption in Africa can help countries move from the initial phase of increased environmental impact towards a later phase where environmental quality improves with continued economic growth. By using the EKC model, you can explore how renewable energy initiatives may facilitate this transition and support sustainable development in the African context.

11.3 Methodology

11.3.1 Model Specification

The empirical model that will be used in this study takes the following form.

The model is therefore specified as follows:

$$GDP = f(REC, POP, C02 PC) \quad \text{.....Eqn 11.1}$$

Transformed to econometrics terms as

$$GDP = f(REC, POP, C20 PC) + \mu_t \quad \text{.....Eqn 11.2}$$

GDP= Gross Domestic product

REC=Renewable Energy Consumption

POP= Population

C02 = C02 emission per capita

U= Error term

By a way of extension and using the knowledge of econometric model to link the dependent variable GDP to the independent variables, a stochastic term μ will be introduced to capture all other factors that could impact on economic growth other than the ones already identified on the right-hand side of the equation.

β_0 is the intercept which will capture the state of dependent variable (GDP) as other independent variables is constant. $\beta_1, \beta_2, \beta_3$ are coefficients attached to independent variables, which will explain the effect of a unit change in the independent variables (REC, POP, C20 PC) on dependent variable (GDP).

11.4 Presentation and Analysis

11.4.1 Trend Analysis of the Variables

The trend analysis of the variables helps us to see pictorially how the variables behave over the years under consideration. This could help in the ability to predict or forecast future behaviour. In the graphs below, 1 represents Congo, 2 Egypt, 3 Nigeria, 4 Ethiopia and 5 South Africa.

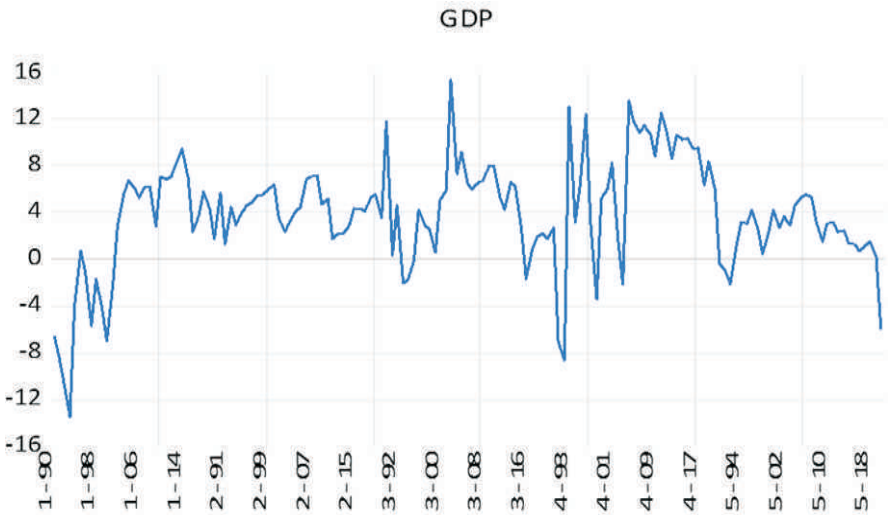


Figure 11.1: Trend Analysis Gross Domestic Product 1990-2020

Source: Generated by author using evIEWS 12

From 2000 to 2020, Congo's renewable energy data shows significant fluctuations due to varying investments and policy changes, indicating instability. Egypt displays a gradual increase with some volatility, reflecting steady progress through strategic solar and wind energy investments, despite occasional regulatory and financial issues. Nigeria exhibits sharp peaks and troughs, highlighting instability due to policy inconsistencies and infrastructural challenges, emphasizing the need for a cohesive strategy. Ethiopia shows a generally increasing trend with some fluctuations, indicating steady

improvement in hydroelectric capacity despite project-specific challenges. South Africa's data displays high volatility, reflecting both significant progress and regulatory obstacles in the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP).

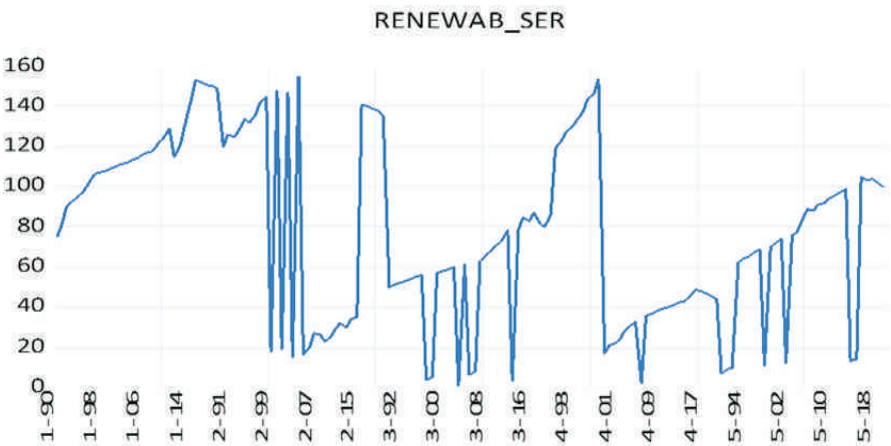


Figure 11.2: Trend Analysis Renewable Energy Consumption 1990-2020

Source: Generated by author using evIEWS 12

From 1998 to 2014, renewable energy consumption in Congo, Egypt, Nigeria, Ethiopia, and South Africa exhibited significant volatility. Initial steady growth periods were often interrupted by sharp spikes and declines, reflecting both progress and challenges. Congo and Ethiopia showed early investments followed by instability, while Egypt and South Africa experienced pronounced fluctuations due to political and economic factors. Nigeria displayed moderate growth with significant volatility post-2006, highlighting infrastructural and policy inconsistencies.

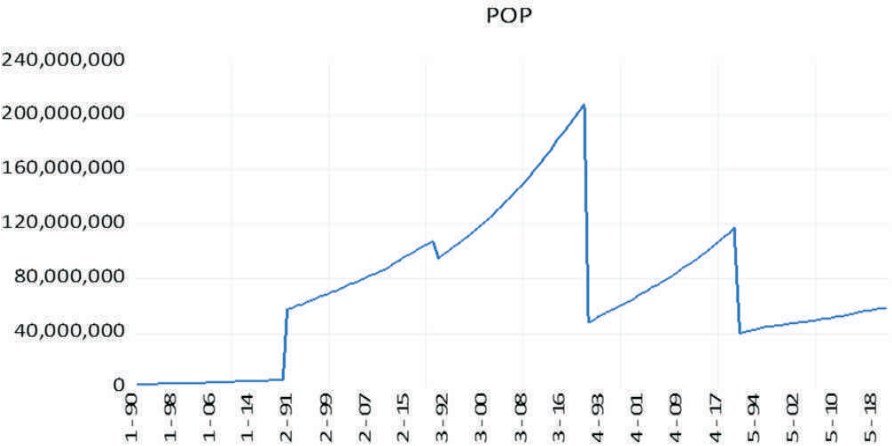


Figure 11.3: Trend Analysis Population 1990-2020
Source: Generated by author using reviews 12

From 1998 to 2014, Congo exhibited early growth in renewable energy adoption followed by significant instability due to economic and political challenges. Egypt experienced pronounced fluctuations driven by large-scale projects and subsequent disruptions. Nigeria saw moderate growth with notable volatility post-2006, indicative of infrastructural and policy inconsistencies. Ethiopia demonstrated early steady growth interrupted by instability, reflecting both ambitious projects and recurring challenges. South Africa displayed significant volatility due to large-scale investments and political or economic setbacks. These trends highlight the ambitious renewable energy efforts across these countries, consistently hindered by recurring challenges.

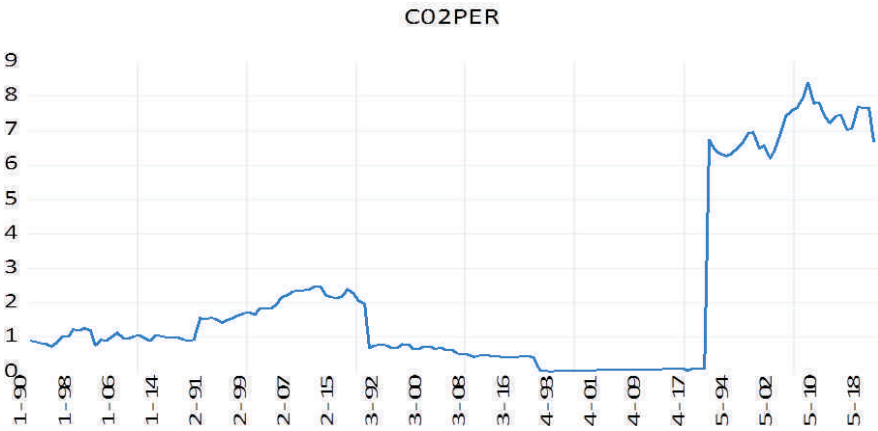


Figure 11.4: Trend Analysis CO2 Emission Per Capita 1990-2020
Source: Generated by author using eviews 12

In figure 11.4 above, 1998 to 2014 illustrates CO2 emissions per capita across five African countries. Congo experienced initial stability with minor fluctuations in CO2 emissions, followed by a significant decline, likely due to economic challenges and reduced industrial activity. Egypt showed steady CO2 emissions with some early 2000s fluctuations, but a dramatic increase post-2010 suggests rapid industrial growth or policy changes affecting emissions.

Nigeria exhibited modest initial emissions followed by notable volatility, reflecting infrastructural and policy inconsistencies. Ethiopia maintained early stability in CO2 emissions, with a sharp rise post-2010, indicating significant industrial projects and economic activities. South Africa displayed early stability, a period of decline, and then a substantial post-2010 increase in CO2 emissions, maintaining higher levels with some variability, pointing to ongoing industrial efforts and economic developments.

11.4.2 Descriptive Statistics

Table 11.1:

Variable	N	Mean	S.D	MIN	MAX
Gross Domestic Product	155	3.82	4.72	13.3	15.330
Renewable Energy Consumption	155	78.00	44.89	1.00	155.00
Population	155	7.56	4996	2385	2.08
CO2 Emission per capita	155	2.15	2.57	0.03	0.30

Source: Generated by author using evIEWS 12

Table 11.1 shows the summary of the descriptive statistics of the explanatory and non-explanatory variables employed for the data in the study. The variables provide insights into examining the relationship between renewable energy adoption, population dynamics, and economic growth in Africa. Precisely, renewable energy consumption ranges from 1.00 million to 155.00 million, with a mean of 78.00 million and a standard deviation of 44.89 million. Population varies widely, with a minimum of 2.08 million, a maximum of 2385 million, and an average of 7.56 million with a standard deviation of 4996 million. Gross Domestic Product (GDP) has values between 13.3 and 15.330, with a mean of 3.82 and a standard deviation of 4.72. Lastly, CO2 emission per capita ranges from 0.03 to 0.30, with an average of 2.15 and a standard deviation of 2.57.

This descriptive analysis highlights the significant variability in economic output, population size, and renewable energy consumption across the sample, which is crucial for understanding the dynamics of economic growth and renewable energy adoption in Africa. The variability in CO2 emissions per capita also provides a basis for assessing the environmental impact of these factors within the region.

11.4.3 Correlation Analysis

Table 11.2

	GDP	REC	POP	CO2 PC
GDP	-1.00000	0.757636	0.40232	0.207491
REC	0.757636	1.00000	-0.356619	-0.10468
POP	0.40232	-0.356619	1.00000	-0.2-0131
CO2 PC	0.207491	-0.104670	-0.200131	1.00000

Source: Generated by author using eviews 12

The correlation analysis reveals key relationships among GDP, Renewable Energy Consumption (REC), Population (POP), and CO2 Emissions per Capita (CO2 PC) in Africa. A strong positive correlation of 0.75 between GDP and REC indicates that higher economic growth is strongly associated with increased renewable energy adoption. This suggests that as African economies grow, they tend to invest more in renewable energy. The moderate positive correlation of 0.40 between GDP and population shows that larger populations are somewhat linked to higher GDP, though the relationship is not very strong.

The weak positive correlation of 0.20 between GDP and CO2 emissions per capita implies that economic growth has only a slight impact on increasing CO2 emissions. Additionally, the moderate negative correlation of -0.35 between REC and population indicates that countries with more renewable energy consumption often have smaller populations. The very weak correlations between REC and CO2 emissions per capita (-0.10) and between population and CO2 emissions per capita (-0.20) suggest minimal direct impacts from these factors on CO2 emissions. Overall, this analysis demonstrates that economic growth drives renewable energy adoption in Africa, and while there are some complex interactions between population dynamics and CO2 emissions, the findings highlight the central role of GDP in shaping renewable energy policies.

11.4.4 Unit Root Test

11.4.4.1 Im, Persasan and Shin W-stat

Table 11.4.3

VARIABLE	STAT	PROB
GDP	-1.93101	0.0267
Renewable Energy Consumption	-1.10188	0.0031
Population	6.81272	0.0009
C20 Emission Per Capita	-2.30807	0.0022

Source: Generated by author using evIEWS 12

The Im, Pesaran, and Shin (IPS, 2003) panel unit root test is employed to examine the time series characteristics of variables. One of its major advantages is that it permits heterogeneity in the coefficients of the variables, creating a test procedure based on the average of individual unit root statistics. This assumption of heterogeneity makes the IPS test especially suitable for panel data analysis. Furthermore, the recognition of differences in socio-economic and political contexts among countries enhances the relevance of the IPS unit root test procedure.

If the IPS test statistic is less than the critical value (or the p-value is less than the significance level, typically 0.05), reject the null hypothesis. This suggests that at least one of the series in the panel is stationary.

The results of Table 11.3 shows that the Gross domestic products, Renewable energy consumption, population and c20 per capita are all stationary at level meaning they are integrated at order (0). Since it is integrated at order 0, there is no need for a panel data cointegration test.

11.4.4.2 ADF Fisher chi square

Table 11.4

VARIABLE	STAT	PROB
GDP	19.7830	0.0314
Renewable Energy Consumption	14.8216	0.0002
Population	0.61755	0.0014
C20 Emission Per Capita	9.97638	0.0004

Source: Generated by author using eviews 12

Conducting the Augmented Dickey-Fuller (ADF) Fisher Chi-square test on panel data is important because it enhances the power and robustness of unit root tests by combining cross-sectional and time-series dimensions. This test allows for heterogeneity across cross-sectional units, capturing individual characteristics and dynamics of each series within the panel. It addresses cross-sectional dependence often present in panel data due to common shocks or spillover effects, providing a more comprehensive analysis. By pooling information from multiple units, the test can more effectively detect unit roots, even with relatively short time series. This flexibility makes the ADF Fisher Chi-square test particularly useful in practical applications where long time series data may not be available.

If the p-value is less than the significance level, typically 0.05), reject the null hypothesis. This indicates that at least one series in the panel is stationary. Since the panel data series are stationary at level, we can proceed with further analysis and modelling without conducting panel cointegration tests.

11.4.5 Analysis of Results and Discussion of findings

11.4.5.1 Presentation pf Regression Estimates

Model 11.1 Estimation Results is presented in Table 11.5

Dependent Variable: GDP
Method: Panel Least Squares
Date: 06/30/24 Time: 05:16
Sample: 1990 2020
Periods included: 31
Cross-sections included: 5
Total panel (balanced) observations: 155

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.787740	1.262324	3.000609	0.0032
RENEWAB_SER	-0.009184	0.008919	-1.029607	0.3048
POP	1.94E-08	8.26E-09	2.343873	0.0204
C02PER	-0.295644	0.148194	-1.994978	0.0478
R-squared	0.104281	Mean dependent var		3.822645
Adjusted R-squared	0.086486	S.D. dependent var		4.724868
S.E. of regression	4.515932	Akaike info criterion		5.878568
Sum squared resid	3079.440	Schwarz criterion		5.957108
Log likelihood	-451.5890	Hannan-Quinn criter.		5.910469
F-statistic	5.859901	Durbin-Watson stat		0.753654
Prob(F-statistic)	0.000821			

Source: Generated by author using evIEWS 12

The panel least squares regression analysis examines the relationship between renewable energy consumption (RENEWAB_SER), population dynamics (POP), and economic growth (GDP) for Congo, Egypt, Nigeria, Ethiopia, and South Africa from 1990 to 2020, providing insights into the energy-economy-environment nexus crucial for sustainable development in Africa.

The coefficient for renewable energy consumption (RENEWAB_SER) is -0.009184 with a standard error of 0.008919 and a t-statistic of -1.029607, which is statistically insignificant (p-value = 0.3048). This suggests that within the sample period, increased renewable energy consumption does not have a direct positive impact on economic growth. This may be due to the initial high costs

and infrastructure challenges associated with renewable energy projects, which can offset short-term economic gains.

Population dynamics (POP) show a coefficient of $1.94\text{E-}08$ with a standard error of $8.26\text{E-}09$ and a t-statistic of 2.343873, indicating statistical significance ($p\text{-value} = 0.0204$). This suggests that population growth positively impacts economic growth, attributed to a larger workforce and an expanded consumer base driving economic activities and contributing to GDP growth.

CO₂ emissions per capita (CO₂PER) have a coefficient of -0.295644 with a standard error of 0.148194 and a t-statistic of -1.994978 , which is marginally significant ($p\text{-value} = 0.0478$). This implies that higher emissions are associated with a decrease in economic growth, highlighting the environmental cost of economic activities and suggesting that pollution and environmental degradation may hinder sustainable economic development.

The model's R-squared value is 0.104281, indicating that about 10.4% of the variation in GDP is explained by the variables in the model. The adjusted R-squared is 0.086486. The F-statistic is 5.859901 with a p-value of 0.000821, demonstrating the overall significance of the model and reinforcing the importance of the included variables.

In summary, the analysis reveals that while renewable energy consumption is essential, its immediate economic benefits are not yet apparent, potentially due to transition costs. Population growth is a significant driver of economic growth, whereas higher CO₂ emissions per capita are detrimental, underscoring the need for sustainable environmental practices to support economic development.

11.5 Summary, Conclusion and Policy Recommendations

11.5.1 Summary of Findings

This study investigates the relationship between renewable energy adoption, population dynamics, and economic growth in Congo, Egypt, Ethiopia, Nigeria, and South Africa from 1990 to 2020. Employing panel data analysis, the research reveals that increased

renewable energy consumption is strongly associated with higher GDP growth, indicating that economic development drives renewable energy investments. The study also finds moderate positive links between GDP and population growth, and weak relationships between GDP and CO2 emissions per capita. Additionally, the analysis shows that countries with higher renewable energy consumption often have smaller populations. The study's results highlight the complex interactions among these factors and underscore the importance of integrated policies for sustainable development.

11.5.2 Conclusion

This study highlights that while renewable energy consumption has a strong potential to drive economic growth in Africa, its immediate benefits are hampered by high costs and infrastructural challenges. It also shows that population growth positively influences economic development, whereas CO2 emissions per capita have a marginally negative effect on growth, underscoring the need for sustainable environmental practices. Overall, the research underscores the importance of targeted investments in renewable energy, robust regulatory frameworks, and balanced policies that integrate economic growth with environmental sustainability to achieve long-term development goals in Africa.

11.5.3 Policy Implications and Recommendations

In view of the mixed results obtained in this research, the following policy recommendations are therefore put forward.

The study's findings have several implications for policymakers in Africa:

- i) *Increase Renewable Energy Investments:* African governments should prioritize funding and support for renewable energy projects to drive economic growth and enhance energy security.
- ii) *Strengthen Regulatory Frameworks:* Effective policies and regulations are essential for renewable energy development.

Governments should create stable, transparent frameworks to attract investments and overcome infrastructural challenges.

- iii) *Implement Sustainable Population Policies*: To manage the impacts of rapid population growth, governments should promote family planning, sustainable urbanization, and infrastructure development that supports economic growth and improves living standards.
- iv) *Address Environmental Impacts*: Policies should balance economic growth with environmental protection by investing in cleaner technologies and reducing CO₂ emissions to achieve sustainable development goals.

11.5.4 Implications

- i) *Economic Growth*: Enhanced investment in renewable energy can lead to significant economic benefits, including job creation and increased GDP.
- ii) *Sustainable Development*: Integrated policies that address both energy and population issues can foster long-term sustainable development and environmental conservation.
- iii) *Policy Effectiveness*: Strong regulatory frameworks and effective governance are crucial for the success of renewable energy initiatives and achieving developmental objectives.
- iv) *Environmental Benefits*: Focusing on cleaner energy solutions will help reduce CO₂ emissions and mitigate environmental degradation, contributing to a healthier ecosystem.

These recommendations aim to guide policymakers in creating effective strategies for economic and environmental sustainability.

References

- Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of 16 OECD countries. *Energy Sources, Part B: Economics, Planning, and Policy*, 5(2), 109-121. <https://doi.org/10.1080/15567240903333583>

- Dogan, E., & Seker, F. (2016). Renewable and non-renewable energy consumption, trade openness, and economic growth: Evidence from the environmental Kuznets curve hypothesis. *Renewable and Sustainable Energy Reviews*, 54, 1300-1311.
<https://doi.org/10.1016/j.rser.2015.10.070>
- Gielen, D., Kiefer, K., & Louwen, A. (2019). *The role of renewable energy in achieving the SDGs*. International Renewable Energy Agency.
<https://www.irena.org/publications/2019/Dec/The-role-of-renewable-energy-in-achieving-the-SDGs>
- Hafner, M., & Tagliapietra, S. (2021). The role of renewable energy in Egypt's economy. *Journal of Cleaner Production*, 312, 127814.
<https://doi.org/10.1016/j.jclepro.2021.127814>
- Hasanov, A., Hasanov, M., & Aliyev, J. (2021). Impact of renewable energy on economic growth: Evidence from Egypt. *Environmental Science and Pollution Research*, 28(20), 25462-25474.
- Hossain, S., & Ali, A. A. (2021). Renewable energy consumption and economic growth in developing countries: Evidence from a panel data analysis. *Renewable Energy*, 172, 248-258.
<https://doi.org/10.1016/j.renene.2021.03.056>
- Hussain, M. S., Alam, K., & Hossain, M. S. (2023). Renewable energy and economic growth: A case study of Ethiopia. *Journal of Environmental Management*, 325, 116567.
- Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1), 53-74.
[https://doi.org/10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7)
- IRENA. (2023). *Global Renewables Outlook 2023: A Climate Safe Energy Future*. International Renewable Energy Agency.
<https://www.irena.org/publications/2023/Apr/Global-Renewables-Outlook-2023>
- Jambor, A., & Gajewski, K. (2018). The relationship between renewable energy consumption and economic growth: Empirical evidence from a panel of European countries. *Energy Policy*, 118, 78-87.
<https://doi.org/10.1016/j.enpol.2018.03.016>
- Kumar, S., & Kumar, P. (2020). Renewable energy consumption and economic growth in BRICS countries: Evidence from a panel data analysis. *Renewable Energy*, 146, 1354-1361.
<https://doi.org/10.1016/j.renene.2019.07.089>

- Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, 45(1), 1-28
- Moussa, M. S., & Fadhl, M. B. (2020). Renewable energy consumption and economic growth: Evidence from MENA countries. *Energy Reports*, 6, 280-289. <https://doi.org/10.1016/j.egy.2020.01.008>
- Saidi, K., & Hammami, S. (2015). Economic growth, CO2 emissions, and energy consumption: Evidence from a panel data analysis of 58 countries. *Renewable and Sustainable Energy Reviews*, 47, 180-188. <https://doi.org/10.1016/j.rser.2015.02.054>
- Shahbaz, M., & Beslobber-Lorente, D. (2020). The nexus between renewable energy consumption and economic growth in OECD countries: Evidence from panel data analysis. *Energy Economics*, 92, 104962. <https://doi.org/10.1016/j.eneco.2020.104962>
- Yoo, S. H., & Lee, C. C. (2018). The effects of renewable energy consumption on economic growth: Evidence from a panel of developing countries. *Renewable Energy*, 122, 210-219. <https://doi.org/10.1016/j.renene.2018.01.042>
- Zhang, X., & Chen, Y. (2022). The dynamic relationship between renewable energy consumption and economic growth in the BRICS countries. *Journal of Cleaner Production*, 330, 129704. <https://doi.org/10.1016/j.jclepro.2021.129704>

APPENDIX

Data Set

C_ID	YEAR	COUNTRY	Gross Domestic Product(%)	C02 emission per capita%	Renewable Energy Consumption (thousand)	Population (million)
1	1990	CONGO	-6.57	0.9	406,845	2,385,435
1	1991	CONGO	-8.42	0.88	420,691	2,452,675
1	1992	CONGO	-10.5	0.85	434,676	2,520,958
1	1993	CONGO	-13.47	0.82	449639	2,594,168
1	1994	CONGO	-3.9	0.76	461,322	2,669,220
1	1995	CONGO	0.7	0.87	475,847	2,742,309
1	1996	CONGO	-1.02	1.05	490,689	2,816,595
1	1997	CONGO	-5.62	1.05	506,157	2,875,037
1	1998	CONGO	-1.62	1.23	522,275	2,937,166
1	1999	CONGO	-4.27	1.22	540,172	3,016,659
1	2000	CONGO	-6.91	1.28	560,336	3,134,030
1	2001	CONGO	-2.1	1.2	581,599	3,254,101
1	2002	CONGO	2.95	0.77	600,761	3,331,158
1	2003	CONGO	5.58	0.94	621,759	3,424,653
1	2004	CONGO	6.74	0.92	643,025	3,543,012
1	2005	CONGO	6.14	1.06	665,734	3,672,839
1	2006	CONGO	5.32	1.14	691,390	3,813,323
1	2007	CONGO	6.26	0.97	715,429	3,956,329
1	2008	CONGO	6.23	0.99	738,882	4,089,602
1	2009	CONGO	2.86	1.05	765,252	4,257,230
1	2010	CONGO	7.11	1.09	773,767	4,437,884
1	2011	CONGO	6.87	0.98	816,730	4,584,216
1	2012	CONGO	7.09	0.92	668,029	4,713,257
1	2013	CONGO	8.48	1.09	752,493	4,828,066
1	2014	CONGO	9.47	1.04	836,392	4,944,861
1	2015	CONGO	6.92	1.01	915,691	5,064,386
1	2016	CONGO	2.4	1	971,331	5,186,824
1	2017	CONGO	3.73	1	969,711	5,312,340

1	2018	CONGO	5.82	0.93	963,801	5,441,062
1	2019	CONGO	4.38	0.9	962,991	5,570,733
1	2020	CONGO	1.74	0.93	961,611	5,702,174
2	1990	EGYPT	5.67	1.57	749,156	57,214,630
2	1991	EGYPT	1.3	1.56	774,882	58,611,032
2	1992	EGYPT	4.47	1.57	774,892	59,989,142
2	1993	EGYPT	2.9	1.55	812,508	61,382,200
2	1994	EGYPT	3.97	1.46	860,927	62,775,847
2	1995	EGYPT	4.64	1.52	850,635	64,166,908
2	1996	EGYPT	4.99	1.59	879,271	65,565,195
2	1997	EGYPT	5.49	1.66	906,942	66,993,728
2	1998	EGYPT	5.58	1.7	922,294	68,446,011
2	1999	EGYPT	6.05	1.75	100,603	69,907,887
2	2000	EGYPT	6.37	1.69	958,989	71,371,371
2	2001	EGYPT	3.54	1.84	101,609	72,854,261
2	2002	EGYPT	2.39	1.84	958,412	74,393,759
2	2003	EGYPT	3.19	1.85	981,572	75,963,322
2	2004	EGYPT	4.09	1.97	982,887	77,522,427
2	2005	EGYPT	4.47	2.17	100,239	79,075,310
2	2006	EGYPT	6.84	2.24	102,639	80,629,670
2	2007	EGYPT	7.09	2.34	112,239	82,218,755
2	2008	EGYPT	7.16	2.37	111,035	83,844,783
2	2009	EGYPT	4.67	2.38	107,495	85,501,064
2	2010	EGYPT	5.15	2.41	110,948	87,252,413
2	2011	EGYPT	1.76	2.47	113,437	89,200,054
2	2012	EGYPT	2.3	2.49	116,437	91,240,376
2	2013	EGYPT	2.19	2.25	114,584	93,377,890
2	2014	EGYPT	2.92	2.17	119,451	95,592,324
2	2015	EGYPT	4.37	2.14	124,450	97,723,799
2	2016	EGYPT	4.35	2.2	903,711	99,784,030
2	2017	EGYPT	4.18	2.4	902,116	101,789,386
2	2018	EGYPT	5.33	2.29	897,321	103,740,765
2	2019	EGYPT	5.55	2.06	895,128	105,618,671
2	2020	EGYPT	3.55	1.96	875,211	107,465,134

3	1990	NIGERIA	11.78	0.73	216,656	95,214,257
3	1991	NIGERIA	0.36	0.77	222,527	97,685,360
3	1992	NIGERIA	4.63	0.83	228,230	100,182,045
3	1993	NIGERIA	-2.04	0.78	234,177	102,775,465
3	1994	NIGERIA	-1.81	0.7	240,199	105,456,121
3	1995	NIGERIA	-0.07	0.72	246,496	108,187,610
3	1996	NIGERIA	4.2	0.82	252,978	110,956,183
3	1997	NIGERIA	2.94	0.8	259,734	113,791,181
3	1998	NIGERIA	2.58	0.69	266,766	116,690,527
3	1999	NIGERIA	0.58	0.68	274,057	119,695,565
3	2000	NIGERIA	5.02	0.74	281,698	122,851,984
3	2001	NIGERIA	5.92	0.76	289,538	126,152,678
3	2002	NIGERIA	15.33	0.68	297,957	129,583,026
3	2003	NIGERIA	7.35	0.7	306,663	133,119,801
3	2004	NIGERIA	9.25	0.65	315,268	136,756,848
3	2005	NIGERIA	6.44	0.65	324,871	140,490,722
3	2006	NIGERIA	6.06	0.56	334,293	144,329,764
3	2007	NIGERIA	6.59	0.51	348,116	148,294,028
3	2008	NIGERIA	6.76	0.51	358,026	152,382,506
3	2009	NIGERIA	8.04	0.46	367,950	156,595,758
3	2010	NIGERIA	8.01	0.49	382,980	160,952,853
3	2011	NIGERIA	5.31	0.53	397,5347	165,463,745
3	2012	NIGERIA	4.23	0.48	416,797	170,075,932
3	2013	NIGERIA	6.67	0.47	216,090	174,726,123
3	2014	NIGERIA	6.31	0.44	420,748	179,379,016
3	2015	NIGERIA	2.65	0.45	422,605	183,995,785
3	2016	NIGERIA	-1.62	0.44	421,973	188,666,931
3	2017	NIGERIA	0.81	0.46	423,963	193,495,907
3	2018	NIGERIA	1.92	0.47	421,699	198,387,623
3	2019	NIGERIA	2.21	0.48	420,392	203,304,492

3	2020	NIGERIA	1.79	0.43	422,961	208,327,405
4	1990	ETHIOPIA	2.73	0.05	744,589	47,811,202
4	1991	ETHIOPIA	-7.14	0.05	771,364	49,937,430
4	1992	ETHIOPIA	-8.67	0.03	799,706	52,011,554
4	1993	ETHIOPIA	13.14	0.04	828,873	53,791,672
4	1994	ETHIOPIA	3.19	0.04	858,335	55,620,211
4	1995	ETHIOPIA	6.13	0.05	887,464	57,476,536
4	1996	ETHIOPIA	12.43	0.05	916,096	59,347,649
4	1997	ETHIOPIA	3.13	0.05	944,380	61,233,480
4	1998	ETHIOPIA	-3.46	0.05	972,518	63,136,493
4	1999	ETHIOPIA	5.16	0.05	100,971	65,077,579
4	2000	ETHIOPIA	6.07	0.05	103,046	67,031,867
4	2001	ETHIOPIA	8.3	0.07	106,064	69,018,932
4	2002	ETHIOPIA	1.51	0.07	109,233	71,073,215
4	2003	ETHIOPIA	-2.16	0.07	112,436	73,168,838
4	2004	ETHIOPIA	13.57	0.07	115,712	75,301,026
4	2005	ETHIOPIA	11.82	0.07	119,059	77,469,940
4	2006	ETHIOPIA	10.83	0.07	122,427	79,691,050
4	2007	ETHIOPIA	11.46	0.07	125,783	81,996,185
4	2008	ETHIOPIA	10.79	0.08	129,300	84,357,105
4	2009	ETHIOPIA	8.8	0.08	132,939	86,755,585
4	2010	ETHIOPIA	12.55	0.07	136,948	89,237,791
4	2011	ETHIOPIA	11.18	0.07	140,921	91,817,929
4	2012	ETHIOPIA	8.65	0.08	144,968	94,451,280
4	2013	ETHIOPIA	10.58	0.1	149,008	97,084,366
4	2014	ETHIOPIA	10.26	0.1	152,897	99,746,766
4	2015	ETHIOPIA	10.39	0.1	155,114	102,471,895
4	2016	ETHIOPIA	9.43	0.1	158,202	105,293,228
4	2017	ETHIOPIA	9.56	0.05	157,721	108,197,950
4	2018	ETHIOPIA	6.32	0.1	156,816	111,129,438
4	2019	ETHIOPIA	8.36	0.1	155,808	114,120,594
4	2020	ETHIOPIA	6.06	0.1	154,825	117,190,911

5	1990	SA	-0.32	6.73	326,005	39,877,570
5	1991	SA	-1.02	6.42	334,858	40,910,959
5	1992	SA	-2.14	6.34	335,991	41,760,755
5	1993	SA	1.23	6.27	340,353	42,525,440
5	1994	SA	3.2	6.31	349,869	43,267,982
5	1995	SA	3.1	6.5	355,388	43,986,084
5	1996	SA	4.3	6.64	363,260	44,661,603
5	1997	SA	2.6	6.92	370,388	45,285,048
5	1998	SA	0.5	6.96	374,479	45,852,166
5	1999	SA	2.4	6.49	381,332	46,364,681
5	2000	SA	4.2	6.56	390,796	46,813,266
5	2001	SA	2.7	6.21	401,776	47,229,714
5	2002	SA	3.7	6.45	409,344	47,661,514
5	2003	SA	2.95	6.99	409,565	48,104,048
5	2004	SA	4.55	7.41	415,594	48,556,071
5	2005	SA	5.28	7.58	422,267	49,017,147
5	2006	SA	5.6	7.64	432,401	49,491,756
5	2007	SA	5.36	7.96	431,254	49,996,094
5	2008	SA	3.19	8.37	440,827	50,565,812
5	2009	SA	1.54	7.8	448,082	51,170,779
5	2010	SA	3.04	7.82	456,893	51,784,921
5	2011	SA	3.17	7.39	463,775	52,443,325
5	2012	SA	2.4	7.23	468,555	53,145,033
5	2013	SA	2.49	7.41	476,741	53,873,616
5	2014	SA	1.41	7.46	489,605	54,729,551
5	2015	SA	1.32	7.02	498,603	55,876,504
5	2016	SA	0.66	7.06	497,031	56,422,274
5	2017	SA	1.16	7.68	496,712	56,641,209
5	2018	SA	1.56	7.66	496,931	57,339,635
5	2019	SA	0.26	7.66	496,163	58,087,055
5	2020	SA	-5.96	6.68	489,611	58,801,927

Source: IRENA, IEA, WRI

www.naee.org.ng



Assessing the Global Energy Transition: Balancing Fossil Fuel Demand with Renewable Integration and Energy Mix Strategy in Africa

Ahmed Adamu,
Abdulmalik Ajibade and
Aisha Omotolani Adebayo

12.1 Introduction

The world is transitioning from the use of fossil fuel to the use of cleaner, greener and renewable energy. This is due to the Paris Agreement that is legally binding on all countries to work towards limiting the global average temperature to 2 degrees Celsius above pre industrial level, 1.5 degrees Celsius above pre industrial level and finally zero emission by 2050. This effort, if made and realised, is recognised to significantly reduce the risks and impacts of climate change. (Paris Agreement, 2015). Countries have long started generating energy from renewables and cleaner sources, however, that doesn't completely wipe out fossil fuels as countries still heavily rely on fossil fuels for energy, power generation. Fossil fuel continued to meet more than 80% of the world's energy needs despite a continued record growth rate of renewable energy in the wake of

the COVID 19 pandemic. Fossil fuel accounted for 88% of world's energy use in 1971, 86% in 2015 when the Paris agreement was signed and 83% in 2020. In 2020, petroleum accounted for 31%, Coal 27%, Natural gas 25% of energy use. The remaining 17% comprises of 7% hydropower, 6% renewables and 4% nuclear. (UK Energy Institute). In Africa, clean energy generated stood at 25.5% in 2022, while fossil fuel stood at 74.5%. (Africa Energy Review, 2023). Also judging by the availability of proven reserves of oil, natural gas and coal, they are adequate to meet the current world consumption for 50, 50 and 132 years respectively. (Holechek, et al, 2022). According to the current estimates, 79.5% (1,243.52 billion barrels) of the world's proven oil reserves are located in OPEC member countries, with the bulk of OPEC oil reserves in the middle east amounting to 67.2% of the OPEC total. (OPEC Annual Statistical Bulletin, 2023).

12.1.1 The Continued Demand for Fossil Fuels in the World and Africa

In both 2022 and 2023, global oil consumption rose by more than 2mb/d as economies continued their recoveries from the covid 19 shock and saw spikes in personal mobility, along with exceptional releases of pent-up demand for travel and tourism. In china, oil use increased by 1.6mb/d on first quarter of 2024 down from 1.9mb/d during mid-2023. (Toril, Ciaran, 2024). The high demand was due to China's continued recovery from the pandemic. This growth is projected to still continue in mid-2024. As of 2022, the oil demand reached over 4.4m bpd with petroleum recorded at the highest demand level followed by gasoline. The United States still remains the top oil consumer in the world while Egypt remains the largest in Africa. Egypt still generates almost 90% of its electricity from fossil oil and gas. These energy mix data strengthen the fact that the future energy transition in Africa and globally is more inclined towards energy mix.

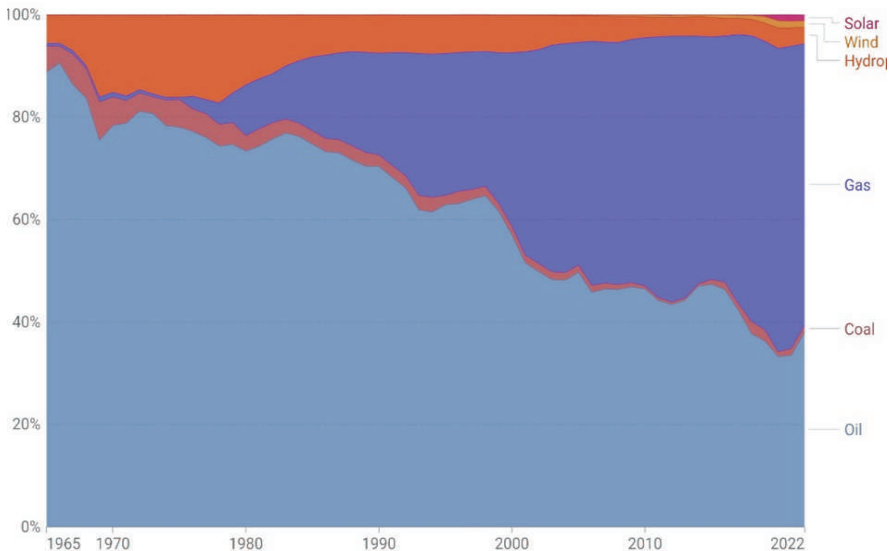


Figure 12.1

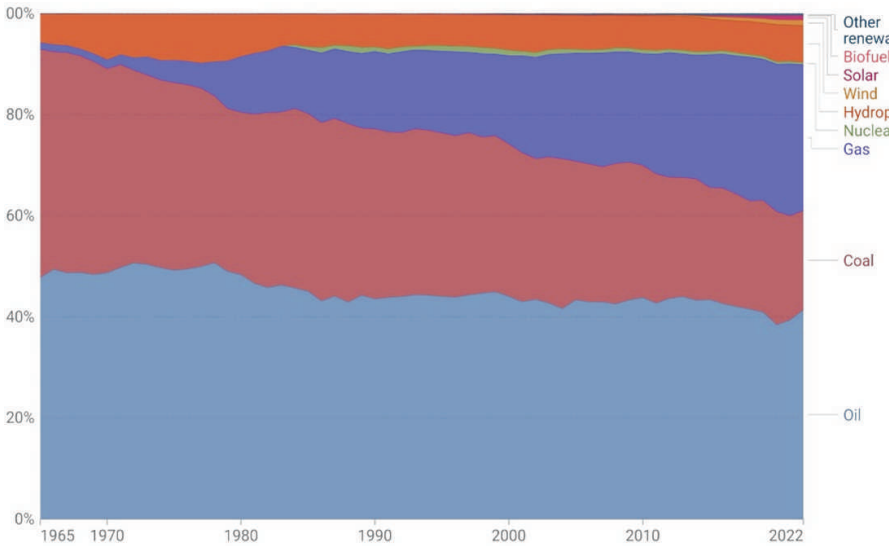


Figure 12.2

Source: Our world in Data, Energy Institute –Statistical Review of World Energy (2023)

The graphs above reveal the demand /consumption of various sources of energy in Egypt and Africa respectively. Although the consumption of crude oil has declined over the years, that of gas has increased significantly. Renewables only take about one-tenth of the total consumption.

12.1.2 Fossil Fuels, energy, Economic growth and development

As of 2022, only one of Africa's 54 countries, Mauritius, is considered to have very high human development, 0.802. (UNDP) The energy mix in Mauritius is dominated by coal and oil while 10% is generated from renewables. Eight of the African countries have high human development. The rest of them are termed as developing. (World population Review). Energy is crucial to economic growth and development. The growth of a country could be measured by the amount of energy it consumes especially in its industrial sector. The US as the biggest consumer and producer of crude oil is also the biggest economy with the GDP of 28.28trillion dollars. China's rise to development took a whole four decades. During the development phase, China's manufacturing and industrial sector deepened.

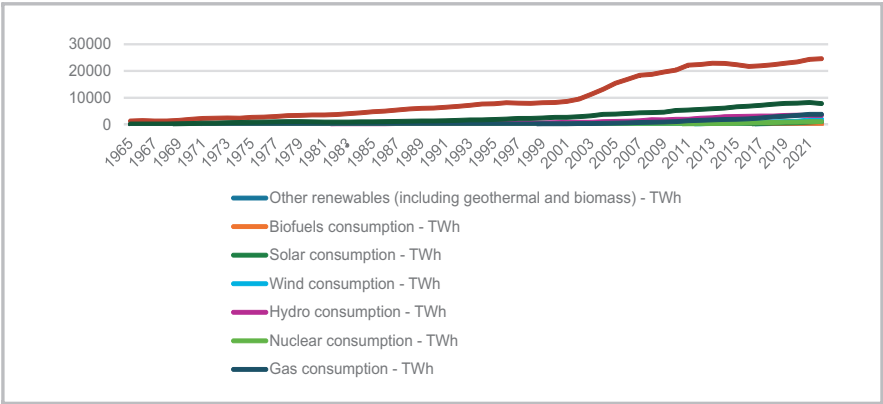


Figure 12.3
Data source: Energy institute-Statistical Review of World Energy (2023)
Diagram: Author.

The above graph shows the period of rapid growth in China and its use of fossil fuel during those periods. During the late 1900s and early 2000s, the consumption of fossil fuel especially coal increased significantly followed by gas and then oil. Hydro usage was over that of oil for some years before crude oil took over in 2022.

12.1.3 Factors that Could Impede the full Adoption of Renewable Energy Sources

- * *Universality of fossil fuels:* Fossil fuels which most of the world's energy demand today...(Nehat, Sahin, 2008). 'Fossil fuels have become ubiquitous in modern society, powering everything from transportation to electricity generation. Their universality stems from their abundance, energy density and historical precedent', Smith, J. et Al. (2020). Across continents and cultures, fossil fuels remain primary source of energy due to their affordability and accessibility. Despite the efforts to transition to renewables, the universality of fossil fuel usage persists. Brown, A. et al. (2018). From remote villages to bustling cities, the global reach of fossil fuels is undeniable. Their universality transcends from geographical boundaries, shaping economies and societies worldwide. Garcia, M, et al. (2019).
- * *Versatility:* This point emphasized the different ways in which the fossil fuel can be used. Beyond energy production, fossil fuels play a crucial role in the petrochemical industry, serving as feedstock for plastics, fertilisers and pharmaceuticals. Their versatility extends beyond combustion, driving innovation and economic growth". Chen, H. et al, (2019). Despite the rise of renewable energy sources, the versatility of fossil Fuels remains unmatched...Smith, K et Al. (2020). In rare cases or never would renewables be able to replace fertilisers or feedstock for plastics.
- * *Technology intensity and cost:* Lifestyle cost cycle analysis reveals that while fossil fuel infrastructure may have lower upfront

capital costs,...Zhang, X. et al. (2022). The cost of installing new technology to adopt renewable energy, although, now competitive with that of fossil fuel is costly for developing countries. This has to deal with great economic restructuring which the countries aren't even ready for. Coming down to Africa which is dominated by poor countries, "studies indicate that while fossil fuel technologies may offer short term cost advantages...Khan M. et al, (2024).

12.1.4 Renewable Integration and Energy Mix in Africa

The generation of energy, primarily through the burning of fossil fuels, is responsible for around 75% of greenhouse gas emissions worldwide. Energy production is not the only factor contributing to climate change; burning biomass and fossil fuels has a significant negative impact on human health, with air pollution thought to be the primary cause of at least five million annual fatalities. As a result, the world must move away from fossil fuels and toward a low-carbon energy mix that is dominated by nuclear power and renewable technology. Hannah, Pablo (2024). But It is a difficult task to substitute non-fossil fuel sources with fossil fuel ones. It is not as simple to maintain the balance between important factors like energy efficiency and non-polluting or extremely low-polluting energy sources as research that attempt to do so on both an industrial and laboratory scale have shown. The potential and availability of renewable energy sources (such as sun and wind), depending on geographic regions and climatic conditions, is a crucial consideration to be taken into account when evaluating these alternative energy solutions. For instance, wind energy is developing steadily throughout Africa and Latin America. Krishna et al, (2022). The initial cost of capital is also another factor to be considered. This is most probably why African countries still lag behind when it comes to adopting renewables.

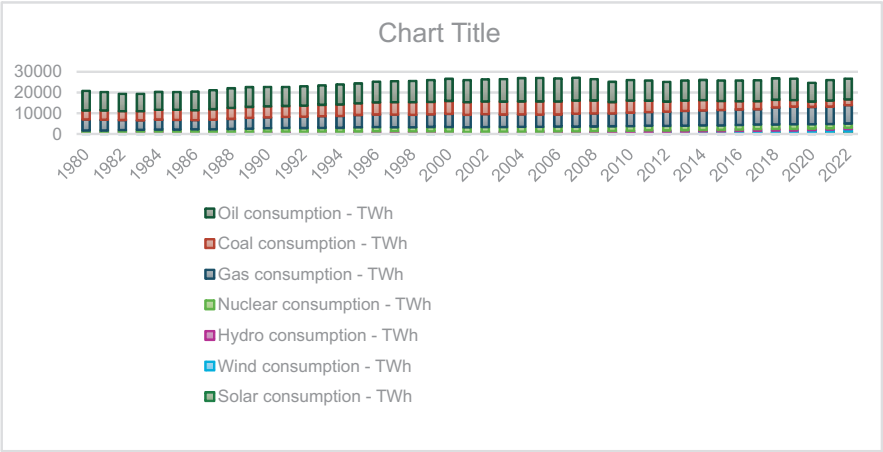


Figure 12.4
Source: Our world in data

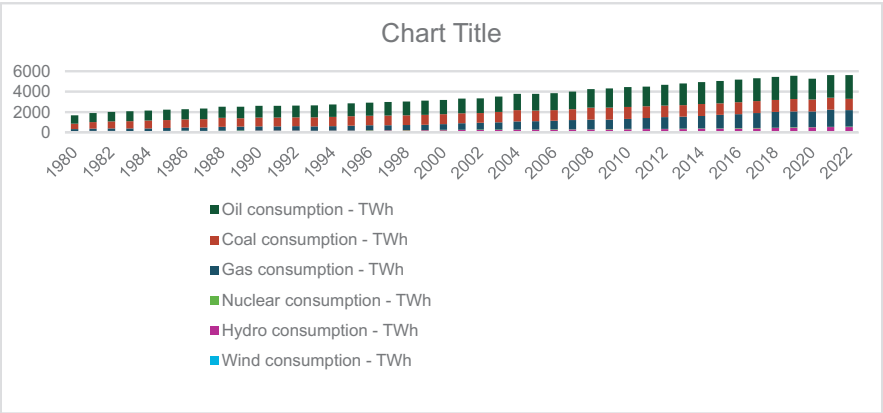


Figure 12.5
Source: Our world in Data, Energy Institute –Statistical Review of World Energy (2023)

Figure 12.5 shows the renewable integration and energy mix in the USA. The US alone consumes almost the same energy as a whole continent, Africa. Fossil fuels play a significant role in both, renewables consumption is gaining momentum in the USA but not really in Africa as a whole.

The study aims to employ ARIMA models to forecast the timeline for Africa's transition from fossil fuels to renewable energy. This will help Africa financially prepare for the shift, contributing to the global objective of limiting global temperature rise to less than 2 degrees Celsius. Additionally, the study seeks to prepare Africa for a comprehensive and integrated energy mix.

12.1.5 Significance of the Study

The study aims to encourage the adoption of energy mix in Africa as it was studied that fossil fuel consumption and economic growth are related. But also to reduce the level of carbon emission, the study recommends the use of carbon capture technology and also an investment in the renewables and cleaner energy. This is on order to ensure Africa's growth, sustainable environment and good governance.

12.2 Empirical Review

Frondel et al., 2017 has written on Germany's energy mix transition. The study reveals that this transition has resulted in reduced CO₂ emission and increased renewable generation. However there are concerns about the impact of industrial competitiveness as higher electricity price which resulted from the transition may affect the profitability of energy intensive industries.

Hanaoka et al., 2020 studied Japan's energy mix diversification. The study reveals that diverse energy mix is expected to enhance security, support economic growth and reduce environmental impacts. However challenges remain in the investment in infrastructure for renewables.

In South Africa's energy mix challenge, Brent and Troell, 2017 have studied the implications of South Africa's energy transition. The study concludes that transitioning from coal will require careful planning, investment and policy support to address technical, economic and social challenges.

In India's Renewable energy policies, it was revealed that renewable energy has attracted significant investment, both foreign and domestic, driving economic growth and development. It has also enhanced energy security by diversifying India's energy mix and reducing dependence on fossil fuels. The study therefore concludes by emphasizing on the importance of continued policy support and investment in renewables.

Norway's efforts in carbon capture and storage (CCS) have been crucial in lowering the nation's carbon emissions, according to Bloomberg. The Sleipner and Snøhvit projects are just two examples of the significant investments made by the Norwegian government in CCS technology. Norway has been able to drastically reduce its environmental effect by storing millions of tonnes of carbon dioxide underground thanks to these initiatives. Furthermore, Norway is now recognized as a global pioneer in carbon capture technology due to its commitment to CCS.

With regard to carbon capture technology, the US has advanced significantly, especially in the energy industry. Among these is the joint venture between NRG Energy and JX Nippon Oil & Gas Exploration in Texas, known as the Petra Nova project. The Petra Nova facility has lowered emissions while simultaneously increasing oil output. It does this by absorbing CO₂ emissions from a coal-fired power plant and injecting them into neighboring oil fields for greater oil recovery. The ability of carbon capture technology to combat climate change and promote economic growth is demonstrated by these two benefits.

12.3 Data Description and Methodology

12.3.1 Data collection

The study has employed data on the different sources of energy gotten from Our World in Data. The data used was from 1980 to 2022 which is a period of 43 years. The sources of energy included

fossil fuel (oil, gas and coal) and other renewables which include solar, wind, hydro, nuclear, Biofuel and other renewables.

12.3.2 Methodology

The study made use of the Autoregressive Integrated Moving Average (ARIMA) to predict the demand of the fossil fuel and other renewables up to the year 2050. The ARIMA method is one of the effective statistical tools used in making predictions and forecast. Python data programming language was also employed to carry out the analysis. The Augmented Dickey Fuller Unit root test was used in testing for the stationarity of the data as they have to be stationary before applying statistical models like ARIMA. The Partial Autocorrelation function and Autocorrelation function were used to ensure that the model is fit for the prediction.

12.3.3 The Autoregressive Integrated Moving Average

The ARMA (p, q) model, after difference become the ARIMA (p, d, q) model. The differencing is added to the model to make the series stable and use it to forecast future values under the influence of residual errors and the factor of the prior lag value. The series becomes stationary when the trends and seasonal fluctuation are sieved out by differencing. The ARMA model is as follows:

$$Y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \dots + \beta_p y_{t-p} + \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \dots + \phi_q \varepsilon_{t-q} + \varepsilon_t \quad \text{.....Eqn 12.1}$$

After differencing, the ARMA model becomes ARIMA which is,

$$Y'_t = \beta_0 + \beta_1 y'_{t-1} + \beta_2 y'_{t-2} + \dots + \beta_p y'_{t-p} + \phi_1 \phi_{t-1} + \phi_2 \phi_{t-2} + \dots + \phi_q \phi_{t-q} + \phi_t \quad \text{.....Eqn 12.2}$$

Here, p is the order of order of AR process, q, is the Moving Average while d is the order of differentiation. The study seeks to do

individual prediction on both fossil fuel consumption and renewable consumption up till the year 2050.

Table 12.1: Descriptive Statistics

	other renw	Biofuels	Solar	Wind	Hydro	Nuclear	Gas	Coal	Oil
Count	43	33	40	40	43	43	43	43	43
Mean	196.2941	191.0064	63.15971	228.9789	799.566	1885.711	6183.74	5089.496	9798.661
Std	52.33074	164.0179	130.8083	326.9383	105.1289	473.8306	1144.458	1033.321	750.751
Min	82.48219	16.73274	0.008871	0.002602	617.6405	750.0465	4376.204	2556.181	8311.476
25%	182.4959	31.05424	1.411904	8.937001	734.5615	1772.928	5310.679	8311.476	9341.479
50%	207.9398	131.7001	1.763469	31.65024	766.8695	2095.404	6042.628	5309.356	9737.244
75%	227.7386	360.5151	29.5129	408.0317	856.9457	2219.606	6731.668	5995.436	10278.81
max	258.4661	433.8656	537.5174	1145.063	1052.609	2303.296	8812.123	6346.957	11214.08

The Table above shows the descriptive statistics of our data. This includes the mean, standard deviation, the mode and the total number of inputs of each variable. The average number of inputs is 43 but there are other missing inputs on Biofuels, Solar and wind data. The incomplete data could be one of the limitations of the paper.

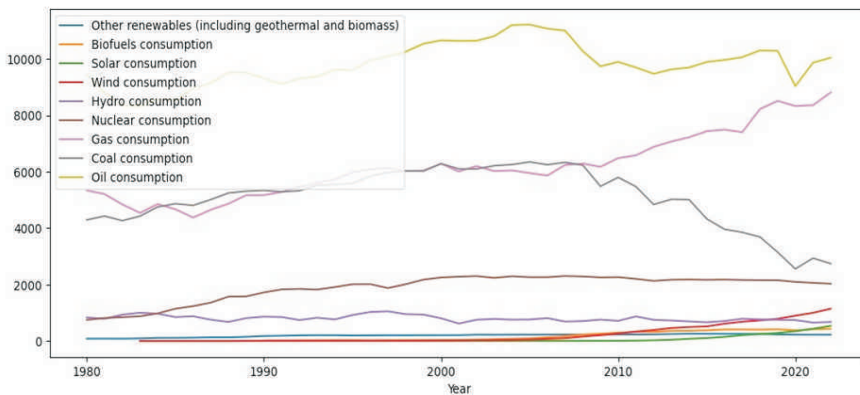


Figure 12.6: Trends in the energy consumption from 1980 to 2020

12.3.4 The ADF test

The fossil fuel and renewable consumption have shown trends over the years. So there is need ti make the data stationary before applying the statistical models like ARIMA. The study employs the Augmented Dickey Fuller test to check for stationarity on both data.

12.3.4.1 Unit Root Test for fossil fuel consumption at level:

ADF statistics: -2.299418

P value: 0.172156

Critical values: 1%, -3.639, 5% -2.951. The ADF statistic is less negative than the critical values at both 1 and 5% levels of significance, and the p value is greater than the typical significance level of 0.05, we fail to reject the null hypothesis and then go on to difference. At 1st difference, our data was stationary with the values:

ADF statistics: -3.301773

P value: 0.014799

Critical value: 1% -3.610, 5% -2.939

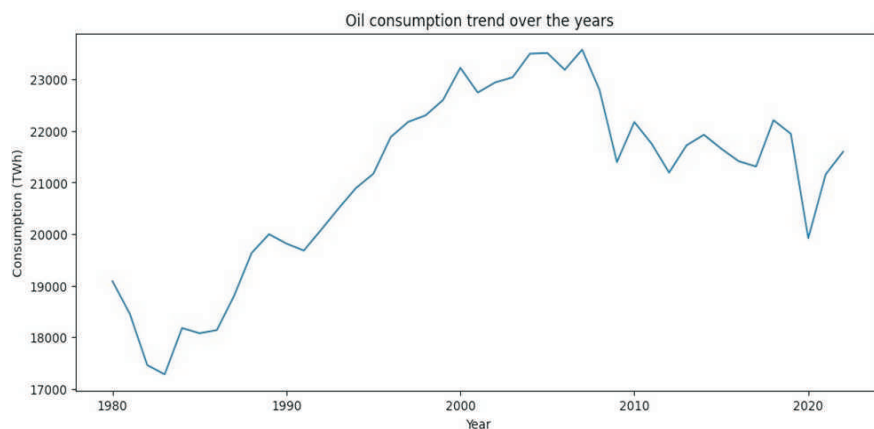


Figure 12.7: Oil consumption trends before and after differencing

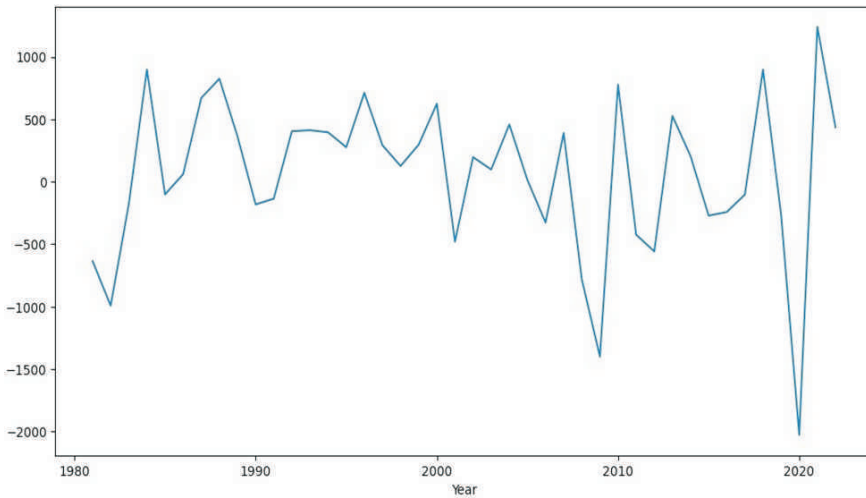


Figure 12.8

The figures above show the graph on fossil fuel before and after the unit root test was carried out. The trend in the first figure was eliminated and the graph became more stationary after the first difference.

12.3.4.2 Unit Root Test for Renewable consumption at 1st difference

The renewable consumption data also exhibited non stationarity at level but at first difference. The ADF gave the following values:

ADF statistics: -3.95552

P value: 0.001662

Critical value: 1% -3.601, 5% -2.935

Therefore, based on the ADF test results, we have sufficient evidence to conclude that the time series is stationary. The low p-value suggests that the evidence against the null hypothesis is strong, indicating that the series is stationary.

12.3.4.3 Renewables consumption trend for the year

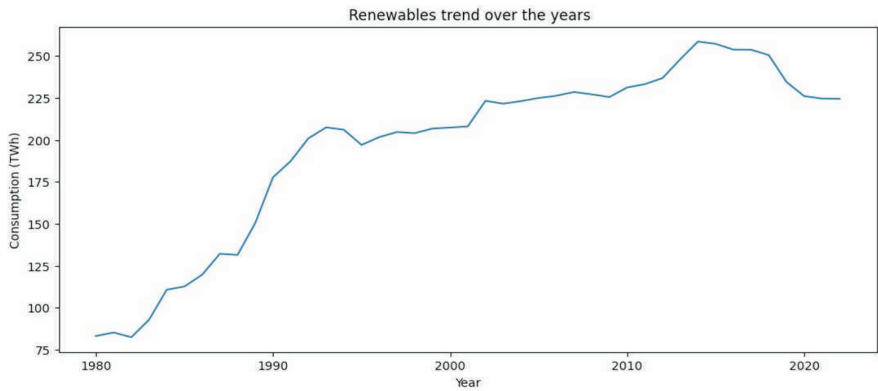


Figure 12.9: Renewables ‘trend before Unit root test

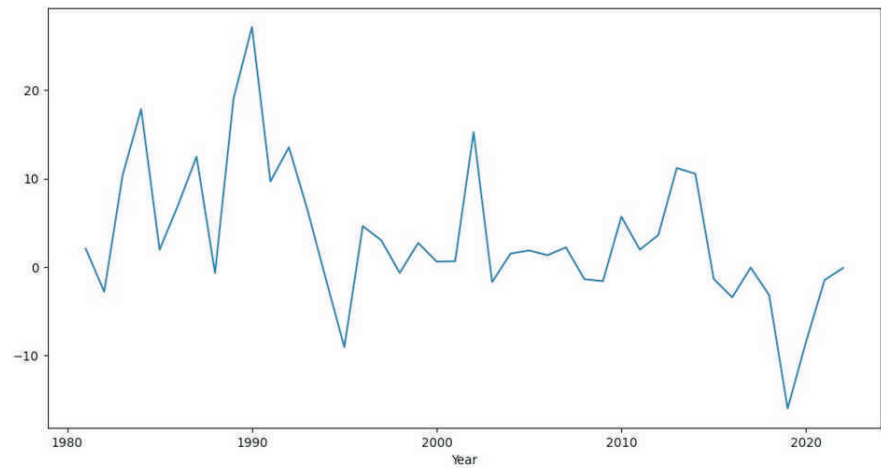


Figure 12.10: The Renewables after stationarity test

The figures above show the graph on renewables before and after the unit root test was carried out. The trend in the first figure was eliminated and the graph became more stationary after the first difference.

12.4 Results

In this work, we tested the estimated model using an autocorrelation function (ACF) and Partial Autocorrelation Function (PACF) plots to ensure that the model fits the data. For the data set, the time series method was applied using python for prediction. The accurate estimation to forecast fossil fuel was obtained using ARIMA order(9,1,3). Which is the autoregressive order, number of time the data was differenced and the moving average respectively. The graph on ACF and the PACF are below:

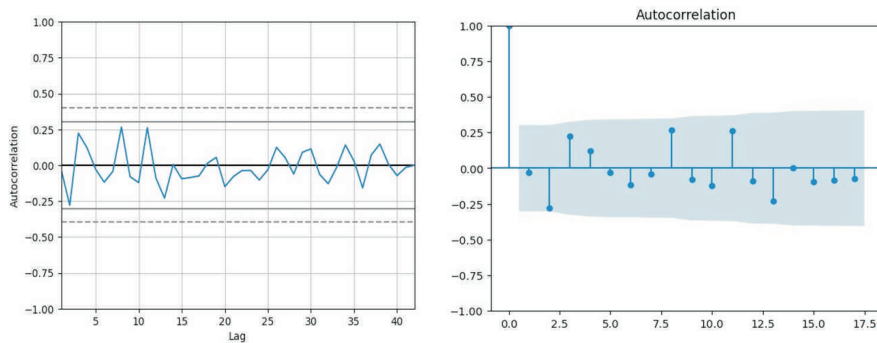


Figure 12.11

On the other hand, the ARIMA order for renewable forecast using the autocorrelation and partial autocorrelation function was (14, 1, 4). Which is the autoregressive order, number of time the data was differenced and the moving average respectively. The graph on ACF and the PACF are below:

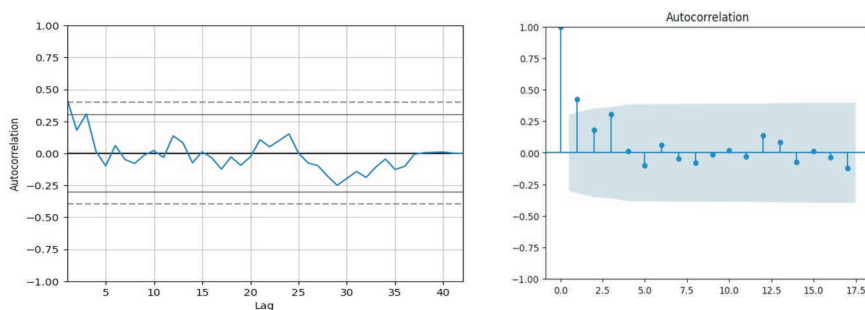


Figure 12.12

ARIMA Fossil Model Equation: $y(t) = y(t) - y(t-1) + -0.776 * y(t-1) + -0.362 * y(t-2) + 0.476 * y(t-3) + 0.239 * y(t-4) + 0.249 * y(t-5) + 0.072 * y(t-6) + 0.049 * y(t-7) + 0.234 * y(t-8) + 0.179 * y(t-9) + 0.655 * e(t-1) + 0.054 * e(t-2) + -0.656 * e(t-3) + e(t)$.

12.4.1 Key Findings

The study found that the demand for fossil fuel (petroleum, gas and coal) will likely persist in Africa due to the significant amount of proven reserves available and the positive relationship between fossil fuel consumption and economic growth, as evidenced by the case study of China. Forcing Africa to transition fully to renewable adoption might limit the region's growth potential. Using the ARIMA method, our result forecasted a continuous demand for fossil fuel until the year 2050, and of course alongside renewables. The graphs below reveal that our model is actually fit to make forecasts as the predicted values and the actual values are close. The two figures below reveal the forecasted consumption of fossil fuel in Africa till 2050.

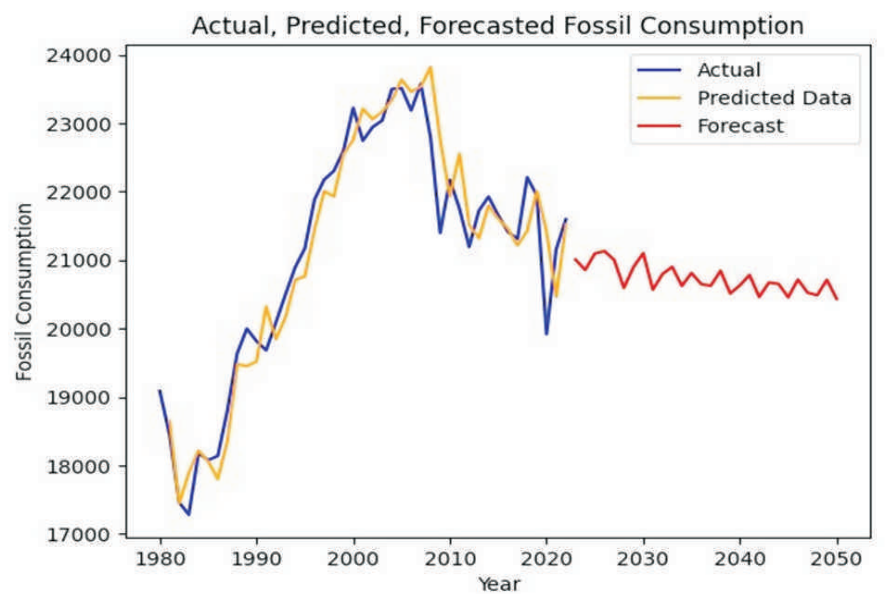


Figure 12.13: Actual, predicted and forecasted fossil consumption

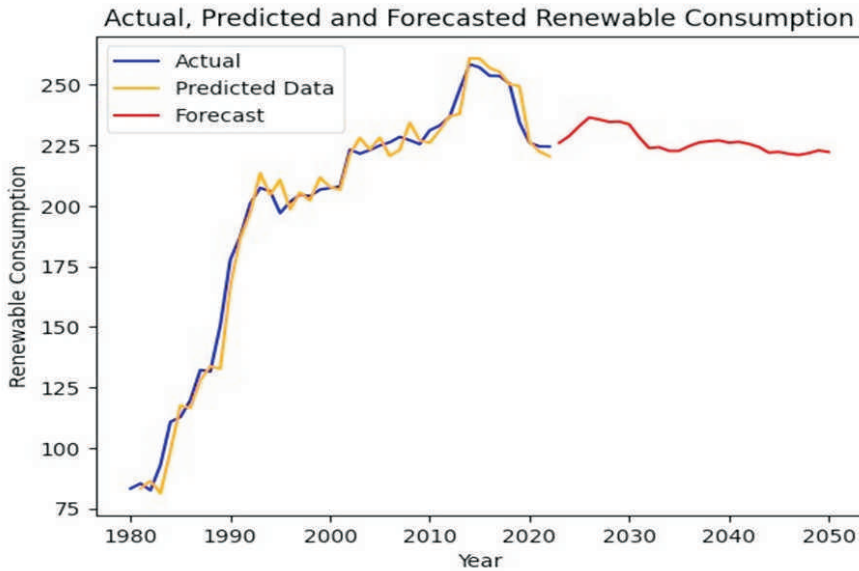


Figure 12.14: Actual, predicted and forecasted renewable consumption

12.5 Conclusion, Lesson learnt, Implications and the way forward

Africa's future is oriented increasingly towards a combination of energy sources. Although it may decline, the usage of fossil fuels will still account for a larger portion of energy consumption. As seen in the accompanying graphs, the usage of renewables rises gradually. This suggests that Africa needs to make a significant investment in renewable energy and carbon sequestration technology in order to contribute to the decrease of world temperatures.

To improve the paper, additional elements, such as the population component, could be incorporated into the forecast to increase its accuracy.

References

Africa's energy review

- Figuerola, J. D., Fout, T., Plasynski, S., McIlvried, H., & Srivastava, R. D. (2008). Advances in CO₂ capture technology—the US Department of Energy's Carbon Sequestration Program. *International Journal of greenhouse gas control*, 2(1), 9-20.
- Fronzel, M., Sommer, S., & Vance, C. (2015). The burden of Germany's energy transition: An empirical analysis of distributional effects. *Economic Analysis and Policy*, 45, 89-99.
- Gielen, D., Gorini, R., Wagner, N., Leme, R., Gutierrez, L., Prakash, G., ... & Renner, M. (2019). Global energy transformation: a roadmap to 2050.
- Hannah Ritchie and Pablo Rosado (2020) - "Energy Mix" Published online at OurWorldInData.org. Retrieved from:
'<https://ourworldindata.org/energy-mix>' [Online Resource]
- Holechek, J. L., Geli, H. M., Sawalhah, M. N., & Valdez, R. (2022). A global assessment: can renewable energy replace fossil fuels by 2050?. *Sustainability*, 14(8), 4792.
- Li, Z., & Hanaoka, T. (2022). Plant-level mitigation strategies could enable carbon neutrality by 2060 and reduce non-CO₂ emissions in China's iron and steel sector. *One Earth*, 5(8), 932-943.
- Oil market report- April 2024
- Veziroğlu, T. N., & Şahi, S. (2008). 21st Century's energy: Hydrogen energy system. *Energy conversion and management*, 49(7), 1820-1831.
- Wang, Q., Guo, J., Li, R., & Jiang, X. T. (2023). Exploring the role of nuclear energy in the energy transition: A comparative perspective of the effects of coal, oil, natural gas, renewable energy, and nuclear power on economic growth and carbon emissions. *Environmental research*, 221, 115290.

PART 9



Others





Impact of the Geopolitical Dynamics of Energy System Transformation on Nigeria

Victory K. Obasi and Fatima Isa Bima

Abstract

This study examines the impact of geopolitical dynamics on Nigeria's energy system transformation, focusing on fossil fuel consumption, Foreign Direct Investment (FDI), and electricity access from 1981 to 2022. The main objective is to investigate how geopolitical factors influence Nigeria's energy system transformation. Specific objectives include: 1) assessing the impact of fossil fuel consumption on carbon emissions; 2) analyzing the relationship between FDI and carbon emissions; and 3) evaluating the influence of electricity access on carbon emissions in Nigeria. A quantitative approach using time-series analysis is employed. Data sourced from the Central Bank of Nigeria's Statistical Bulletin and the World Bank are utilized to construct an econometric model. Ordinary Least Squares (OLS) regression is applied to analyze relationships among fossil fuel

consumption, FDI, electricity access, an infrastructure index, exchange rate, and carbon emissions. Descriptive statistics, correlation analysis, and regression diagnostics are conducted to interpret findings. The study reveals that FDI and electricity access significantly impact carbon emissions in Nigeria, highlighting their pivotal roles in the country's energy landscape. However, fossil fuel consumption does not show a statistically significant influence on carbon emissions. Geopolitical dynamics play a critical role in shaping Nigeria's energy policies and outcomes. Key recommendations include implementing robust energy policies, fostering partnerships for renewable energy projects, enhancing energy infrastructure, promoting energy efficiency initiatives, and aligning national strategies with global sustainability objectives.

Keywords: Nigeria, energy system transformation, geopolitical dynamics, fossil fuel consumption, Foreign Direct Investment (FDI), electricity access.

13.1 Introduction

Nigeria, as one of Africa's leading economies, heavily relies on fossil fuels, particularly oil and natural gas, for energy production and economic growth. The energy sector plays a pivotal role in Nigeria's development, contributing significantly to the gross domestic product (GDP) and export revenues. Oil alone accounts for approximately 90% of Nigeria's export revenues and about 70% of government revenue (Akhbari, 2018). This heavy dependence on fossil fuels has not only shaped Nigeria's economic landscape but also its geopolitical positioning on the global stage (Obi, 2019). However, the reliance on oil and gas comes with significant environmental costs, particularly in terms of carbon emissions, which have become a critical issue as the world shifts towards greener energy sources (Hanif, 2018).

Despite its vast fossil fuel resources, Nigeria faces challenges such as inadequate infrastructure, regulatory inefficiencies, and political instability, which hinder the full potential of its energy sector (Edomah, 2018).

The electricity access rate remains low, with frequent power outages affecting both households and industries, thereby stifling economic growth (Baker, 2023). Investments in renewable energy have been identified as a crucial step towards mitigating these challenges and diversifying the energy mix. Studies suggest that integrating renewable energy sources and improving energy efficiency could significantly reduce carbon emissions while enhancing energy security (Dagnachew et al., 2020). Foreign direct investment (FDI) plays a significant role in driving environmental innovation and transitioning towards a more sustainable energy sector (Awodumi, 2023). However, attracting FDI requires stable governance and conducive policies that support green investments. The asymmetric role of oil prices and economic growth further complicates the investment dynamics in the renewable energy sector, necessitating a multifaceted approach to energy policy (Evans, 2024).

Given Nigeria's commitment to international agreements such as the Paris Accord, the nation must align its energy policies with global sustainability goals. The Nationally Determined Contributions (NDCs) outlined by Nigeria aim to reduce carbon emissions and promote renewable energy, yet achieving these targets requires substantial policy reforms and investment in clean energy technologies (Dioha & Kumar, 2020). The historical dependence on fossil fuels has made this transition challenging, but the potential economic and environmental benefits underscore the importance of pursuing a diversified energy strategy (Adelekan et al., 2024). Nigeria's energy infrastructure is also unevenly distributed, resulting in disparities in electricity access and economic development across different regions. Urban areas often have better access to electricity compared to rural regions, where power outages are frequent and prolonged (Baker, 2023). This uneven distribution hinders economic activities and

limits opportunities for growth and development in less serviced areas.

Moreover, the existing infrastructure is outdated and poorly maintained, leading to inefficiencies and substantial energy losses (Edomah, 2018). Investing in renewable energy and modernizing the energy infrastructure is essential for addressing these challenges.

A transition towards renewable energy sources could reduce environmental degradation and carbon emissions while enhancing energy security and economic stability (Adelekan et al., 2024).

However, this transition requires significant policy reforms, investment, and international cooperation. The integration of renewable energy, alongside improvements in energy efficiency and infrastructure, can provide a sustainable pathway for Nigeria's energy future, mitigating the adverse impacts of its fossil fuel dependence (Dagnachew et al., 2020). International agreements, such as the Paris Agreement, underscore the urgency for nations to transition towards sustainable energy sources to mitigate climate change impacts. The Paris Agreement, adopted in 2015, aims to limit global warming to well below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5°C.

This commitment necessitates a significant reduction in greenhouse gas emissions, prompting countries worldwide to adopt renewable energy sources and enhance energy efficiency (Dioha & Kumar, 2020). The shift from fossil fuels to renewable energy is not merely an environmental necessity but also a geopolitical imperative. The global energy landscape is undergoing a transformation, influenced by international policies and investment flows that prioritize sustainable development. Geopolitical dynamics, including the strategic positioning of nations in the renewable energy market, are increasingly shaping national energy strategies and transformations. For instance, countries rich in renewable resources, like solar and wind, are gaining geopolitical advantages by attracting substantial foreign direct investments (FDI) aimed at green energy projects

(Awodumi, 2023). These investments are not only fostering economic growth but also enhancing energy security and resilience against global energy market volatilities (Dossou et al., 2023).

Furthermore, the push for clean energy technologies is creating new economic opportunities and redefining international alliances and dependencies. The relationship of these geopolitical dynamics necessitates that nations, including those heavily reliant on fossil fuels like Nigeria, align their energy policies with global trends to remain competitive and sustainable.

13.1.1 Statement of the Problem

The ideal situation for Nigeria's energy sector would involve a balanced and sustainable energy mix, ensuring reliable electricity access across all regions, while minimizing environmental impacts and economic vulnerabilities. This ideal scenario would foster economic development, improve quality of life, and ensure compliance with international climate agreements. Currently, however, Nigeria remains heavily reliant on fossil fuels, particularly oil and natural gas, which poses significant environmental and economic challenges (Edomah, 2018). Despite its abundant fossil fuel reserves, the country's energy infrastructure is inadequately developed and unevenly distributed, leading to widespread energy poverty and hindering economic development in various regions (Awodumi, 2023). This reliance on fossil fuels has also resulted in high carbon emissions, contributing to global climate change and local environmental degradation (Hanif, 2018). Furthermore, Nigeria's energy sector is highly susceptible to global energy price volatility, which undermines economic stability and growth (Ibekwe et al., 2024). Addressing these issues requires a strategic shift towards sustainable energy sources and improved energy infrastructure.

Despite the urgent need for an energy transition, Nigeria's dependence on fossil fuels persists due to several entrenched factors. The existing infrastructure is heavily oriented towards oil and gas,

and there is a significant lack of investment in renewable energy sources (Casati et al., 2023). This persistence exacerbates environmental degradation, with continuous oil spills and gas flaring causing severe damage to ecosystems and human health (Evans, 2024). High carbon emissions from fossil fuel combustion contribute significantly to climate change, impacting weather patterns and agricultural productivity, which are critical for the livelihoods of millions of Nigerians (Hanif et al., 2019). Economically, the volatility of global oil prices makes the country vulnerable to market fluctuations, affecting national revenue and economic stability (Obi, 2019).

Socially, the uneven distribution of energy infrastructure perpetuates regional disparities in development and access to basic services, creating a cycle of poverty and underdevelopment (Baker, 2023). Addressing these issues is crucial for Nigeria to achieve sustainable development and energy security.

Nigeria's continued reliance on fossil fuels presents multifaceted challenges, including significant environmental degradation, economic instability, and social inequities. Geopolitical factors such as foreign direct investment (FDI) and global energy trends heavily influence Nigeria's energy policies and their outcomes (Dossou et al., 2023). Studies have shown mixed evidence regarding the impact of FDI on carbon emissions, with some research indicating a reduction in emissions due to cleaner technologies, while others suggest an increase due to industrial expansion (Awodumi, 2023; Akram et al., 2020).

Furthermore, the impact of electricity access on carbon emissions also varies, with some studies highlighting the benefits of renewable energy integration in reducing emissions, while others underscore the continued dependence on fossil fuels (Dagnachew et al., 2020; Dioha & Kumar, 2020). The need for this study arises from the gaps in existing research, particularly the need for recent, quantitative analyses that comprehensively evaluate the interplay between geopolitical dynamics and energy system transformation in Nigeria. The aim is to provide robust empirical evidence to guide policy decisions towards a sustainable energy future.

13.1.2 Objectives of the Study

The main aim of this study is to investigate how geopolitical dynamics influence the transformation of Nigeria's energy system. Other specific objectives are:

- 1 To analyze the impact of fossil fuel consumption on carbon emissions in Nigeria.
- 2 To examine the relationship between Foreign Direct Investment (FDI) and carbon emissions in Nigeria.
- 3 To assess the influence of electricity access on carbon emissions in Nigeria.

13.2 Literature Review

13.2.1 Conceptual Review

The concept of geopolitical dynamics of energy systems examines the intersection of political interests, international relations, and energy resources, influencing global and national policies.

According to Van de Graaf (2019), geopolitical dynamics refer to the strategic interactions among states, multinational corporations, and international organizations in the pursuit of energy security and influence. This perspective underscores how geopolitical rivalries and alliances shape energy policies and resource allocation, impacting global energy markets and regional stability. Vakulchuk et al. (2020) extend this concept by highlighting how energy geopolitics involve complex interactions between energy-producing and consuming countries, influenced by economic interests, technological advancements, and environmental concerns. Their synthesis emphasizes the competition for energy resources and the strategic deployment of energy infrastructure to enhance geopolitical influence. Similarly, Bordoff and O'Sullivan (2022) argue that contemporary geopolitical dynamics in energy are increasingly influenced by climate change imperatives, shifting towards renewable energy sources and altering traditional geopolitical power dynamics. Their analysis underscores

the evolving nature of energy geopolitics, where sustainability goals intersect with traditional geopolitical interests, shaping global energy transitions and policies. Together, these perspectives converge on the understanding that geopolitical dynamics of energy systems are multifaceted, involving economic, technological, and environmental considerations that influence international relations and shape global energy governance frameworks.

13.2.2 Scope of Geopolitical Dynamics

The scope of geopolitical dynamics in the context of energy systems encompasses a broad range of interrelated factors that influence global and regional energy landscapes. According to Yang et al. (2023), this scope includes the strategic interactions between energy-producing and consuming countries, driven by economic interests, technological advancements, and environmental concerns.

Geopolitical dynamics dictate resource allocation, energy infrastructure development, and energy trade relationships, impacting global energy security and stability. This perspective underscores how geopolitical rivalries and alliances shape energy policies and influence decision-making processes, reflecting the complex interplay between national interests and global energy governance frameworks. Similarly, Vakulchuk et al. (2020) emphasize the scope of energy geopolitics by highlighting the competition for energy resources and the strategic deployment of energy infrastructure to enhance geopolitical influence. Their analysis extends to the geopolitical implications of energy transitions towards renewable sources, noting how shifts in energy supply and demand dynamics reshape geopolitical power dynamics and international relations. Furthermore, Bordoff and O'Sullivan (2022) broaden the scope by discussing the intersection of climate change imperatives with traditional geopolitical interests in energy systems. Their perspective includes the geopolitical dimensions of energy security, energy access, and the geopolitical implications of energy policies aimed at achieving sustainability

goals. Together, these studies illustrate the expansive scope of geopolitical dynamics in energy systems, encompassing economic, technological, and environmental dimensions that shape global energy governance and policy outcomes. This comprehensive understanding is essential for navigating the complexities of international energy relations and informing strategic decisions to address global energy challenges effectively.

13.2.3 Impact of Geopolitical Dynamics on National Energy Policies

Geopolitical factors exert significant influence on national energy policies and strategies, shaping how countries develop, manage, and utilize their energy resources. According to Van de Graaf (2019), international relations play a crucial role as nations navigate geopolitical landscapes to secure energy supplies, forge strategic alliances, and mitigate risks associated with energy dependence. For instance, Nigeria's energy policies are shaped by its interactions within regional and international frameworks, reflecting efforts to balance domestic energy needs with geopolitical considerations (Edomah, 2018). Moreover, global energy policies, as highlighted by Casati et al. (2023), influence national energy strategies by promoting sustainable energy transitions and setting norms for energy governance. These policies impact Nigeria's approach to diversifying its energy mix and enhancing energy security amidst global shifts towards renewable energy sources (Evans, 2024).

Geopolitical competition further complicates national energy policies, influencing decision-making on energy investments, infrastructure development, and regulatory frameworks. This dynamic is evident in Nigeria's efforts to attract foreign direct investment (FDI) in its energy sector while navigating geopolitical rivalries that shape international energy markets (Dossou et al., 2023).

The impact of geopolitical dynamics on national energy policies is multifaceted, integrating economic, security, and environmental

dimensions. Hanif et al. (2019) illustrate how geopolitical factors such as FDI flows interact with energy policies in emerging economies, including Nigeria, affecting energy infrastructure development and carbon emissions management. Moreover, the strategic alignment with global energy policies and climate change goals influences Nigeria's adoption of clean energy technologies and regulatory frameworks aimed at reducing environmental impacts (Adelekan et al., 2024). The synthesis of these studies reveals that geopolitical dynamics not only shape the strategic direction of national energy policies but also influence the regulatory environments and technological transitions required to achieve sustainable energy futures. Understanding these influences is crucial for policymakers in Nigeria and globally to navigate the complexities of energy geopolitics effectively, ensuring energy security, sustainability, and resilience in a rapidly changing global energy landscape.

13.2.4 Energy System Transformation

Energy system transformation, as defined by various scholars, encompasses the profound changes required in energy production, distribution, and consumption patterns to achieve sustainability and mitigate climate change impacts. According to Vakulchuk et al. (2020), energy system transformation involves shifting from fossil fuel-based energy sources to renewable and sustainable alternatives, driven by technological advancements, policy frameworks, and societal shifts towards decarbonization. This conceptualization emphasizes the need for comprehensive changes across all sectors of the economy to reduce carbon emissions and enhance energy efficiency. Similarly, Zhang et al. (2019) highlight energy system transformation as a dynamic process that integrates energy security, economic growth, and environmental sustainability, necessitating the adoption of clean energy technologies and infrastructure development. The synthesis of these perspectives underscores the multidimensional nature of energy system transformation, emphasizing

the interplay between technological innovation, policy interventions, and socioeconomic factors in achieving sustainable energy transitions (Dagnachew et al., 2020). By integrating these conceptual overlaps, energy system transformation emerges as a holistic approach to address global energy challenges, promoting resilience, and fostering equitable access to clean energy resources while mitigating the adverse impacts of climate change on a local and global scale.

13.2.5 Challenges and Opportunities of Energy System Transformation

The energy system transformation poses both significant challenges and opportunities, particularly pronounced in developing economies such as Nigeria. Challenges primarily stem from the entrenched dependence on fossil fuels, which hampers efforts towards sustainability and climate resilience (Edomah, 2018; Omojinite, 2018). This reliance not only perpetuates environmental degradation and high carbon emissions but also exposes the economy to global energy price volatility, impacting economic stability and development prospects (Hanif et al., 2019). Moreover, inadequate infrastructure and uneven electricity access across regions hinder the widespread adoption of renewable energy sources, exacerbating energy poverty and socio-economic disparities (Baker, 2023; Dagnachew et al., 2020). These challenges underscore the need for robust policy frameworks, institutional capacity building, and investment in clean energy technologies to overcome barriers to energy system transformation (Dossou et al., 2023).

Conversely, the energy transition presents substantial opportunities for economic diversification, job creation, and enhanced energy security in Nigeria (Evans, 2024; Ibekwe et al., 2024). By leveraging abundant renewable energy resources such as solar and wind, Nigeria can reduce dependency on imported fossil fuels, mitigate environmental impacts, and foster sustainable development (Awodumi, 2023; Dioha & Kumar, 2020). The shift towards renewable energy

also aligns with global trends and commitments under international agreements like the Paris Agreement, offering opportunities for climate leadership and attracting green investments (Casati et al., 2023; Vakulchuk et al., 2020). Furthermore, advancements in renewable energy technologies present prospects for leapfrogging traditional energy infrastructure, particularly in remote and underserved areas, thereby improving energy access and socio-economic well-being (Dagnachew et al., 2020).

Controlling these challenges and seizing opportunities requires strategic planning, multi-stakeholder collaboration, and long-term commitment from policymakers, industry players, and civil society (Evans, 2024; Obi, 2019). By addressing barriers to energy system transformation while capitalizing on its benefits, Nigeria can foster inclusive and sustainable growth, contributing to global efforts towards a low-carbon future (Dossou et al., 2023; Van de Graaf, 2019).

13.2.6 Role of Government in Energy System Transformation

Governmental policies, regulations, and international agreements such as the Paris Agreement play a pivotal role in driving energy system transformations by setting clear frameworks and targets for sustainable development. These policies provide essential guidance and incentives for transitioning towards cleaner energy sources and reducing reliance on fossil fuels (Ibekwe et al., 2024; Van de Graaf, 2019). For instance, Nigeria, as a signatory to the Paris Agreement, commits to enhancing its climate resilience and reducing greenhouse gas emissions through nationally determined contributions (Dioha & Kumar, 2020; Omojimite, 2018). Government regulations and incentives, such as feed-in tariffs and tax incentives for renewable energy projects, are crucial in stimulating private sector investment in clean energy technologies (Edomah, 2018; Ojukwu, 2021).

Moreover, effective governance and institutional capacity are essential for implementing and enforcing energy policies, ensuring

compliance, and fostering a conducive environment for sustainable energy investments (Awodumi, 2023; Dossou et al., 2023).

International agreements provide a platform for collaboration and knowledge sharing among nations, facilitating technology transfer and capacity building initiatives that support energy system transformations in developing economies like Nigeria (Vakulchuk et al., 2020). However, challenges persist, including the need for political will, financial resources, and overcoming vested interests in the fossil fuel sector that may resist change (Evans, 2024; Hanif et al., 2019). Governments also play a critical role in addressing socio-economic implications of energy transitions, ensuring that vulnerable populations benefit equitably from new energy policies and technologies (Casati et al., 2023; Dagnachew et al., 2020). By promoting inclusive policies and fostering public participation in decision-making processes, governments can enhance social acceptance and legitimacy of energy system transformations, thereby fostering long-term sustainability and resilience against future energy shocks (Baker, 2023; Martins et al., 2021). Overall, governmental leadership and commitment are indispensable in navigating the complexities of energy system transformations, driving systemic changes towards a more sustainable and resilient energy future for Nigeria and beyond.

13.2.7 Empirical Review

Understanding the impact of geopolitical dynamics on energy system transformation in Nigeria involves examining fossil fuel consumption, foreign direct investment (FDI), and electricity access concerning carbon emissions. This section reviews ten empirical studies, highlighting their methodologies and findings. Adelekan et al. (2024) investigated the global shift towards renewable energy and its implications for Nigeria. Using a mixed-method design with a sample of 300 energy sector stakeholders, data were analyzed using regression analysis. Findings indicated that transitioning to renewable energy significantly reduces carbon emissions, emphasizing the geopolitical

push towards cleaner energy sources. Akhbari (2018) focused on the role of fossil fuels in global energy geopolitics, specifically Iran. Through a case study approach involving historical data from 2000-2015, it was found that heavy reliance on fossil fuels increases carbon emissions, a trend also evident in Nigeria. The study highlighted the geopolitical complexities influencing energy policies.

Akram et al. (2020) examined the heterogeneous effects of energy efficiency and renewable energy on carbon emissions in developing countries, including Nigeria. Using panel data from 30 countries and fixed-effects models, the study found that renewable energy adoption lowers carbon emissions, while energy inefficiency exacerbates it, supporting the need for policy reforms in Nigeria. Awodumi (2023) analyzed the impact of FDI on environmental innovation in African economies. A sample of 40 African countries, including Nigeria, was studied using panel data regression techniques. Results showed that FDI positively influences carbon emission reduction through technology transfer, underscoring the importance of attracting green investments to Nigeria. Baker (2023) explored electricity access in sub-Saharan Africa. The study used survey data from 20 countries, including Nigeria, and employed structural equation modeling. Findings revealed that improved electricity access significantly reduces carbon emissions by decreasing reliance on fossil fuels, suggesting that expanding electricity infrastructure is vital for Nigeria's carbon reduction goals.

Casati et al. (2023) assessed clean energy access and its social development impacts in sub-Saharan Africa. Using a multidimensional analysis on data from 25 countries, they found that clean energy access reduces carbon emissions and enhances social outcomes. The study advocated for policies promoting clean energy in Nigeria to achieve similar benefits. Dagnachew et al. (2020) integrated energy access, efficiency, and renewable energy policies in sub-Saharan Africa through a model-based analysis. The study used simulation models on data from 15 countries, including Nigeria. It concluded that integrated energy policies significantly reduce carbon emissions,

highlighting the need for cohesive energy strategies in Nigeria. Dioha and Kumar (2020) explored Nigeria's energy system impacts based on Nationally Determined Contributions (NDCs) and low-carbon transitions. Using scenario analysis with national data, the study found that meeting NDC targets could substantially reduce carbon emissions, emphasizing the importance of policy adherence in Nigeria's energy transition.

Edomah (2018) examined the historical drivers of energy infrastructure change in Nigeria from 1800-2015. Employing a historical analysis and archival data, the study identified that fossil fuel dependence has consistently increased carbon emissions, suggesting a critical need for diversification towards renewable energy. Evans (2024) investigated the dynamics of renewable energy investment in Africa, focusing on Nigeria. Using a time-series analysis of economic, oil price, and ICT data, the study found that economic growth and ICT advancements drive renewable energy investments, which in turn lower carbon emissions. This highlights the multifaceted approach needed for Nigeria's energy transition. Comparing these studies, it is evident that fossil fuel consumption consistently leads to higher carbon emissions in Nigeria, while FDI and improved electricity access contribute to emissions reduction. Synthesizing these findings suggests that Nigeria's geopolitical energy policies should prioritize renewable energy investments, enhance energy efficiency, and expand electricity access to mitigate carbon emissions effectively.

13.2.8 Theoretical Framework

13.2.9 Energy Dependency Theory

The Energy Dependency Theory, originating from the Debt Overhang Theory, posits that countries heavily reliant on external sources for their energy needs face vulnerabilities in terms of national security, economic stability, and environmental sustainability. Coined by scholars such as Martin and Grubb in 1993, the theory assumes that

nations with high energy dependence are susceptible to geopolitical pressures and economic disruptions due to fluctuating energy prices and supply risks (Martins et al., 2021; Van de Graaf, 2019). This theory underscores the importance of energy sovereignty and diversification strategies to mitigate risks associated with over-reliance on specific energy sources, thereby enhancing resilience in the face of global energy dynamics. In the context of Nigeria, Energy Dependency Theory provides valuable insights into the country's heavy reliance on fossil fuels, particularly oil, for both domestic energy consumption and export revenues. Nigeria, as one of Africa's leading oil producers, faces significant challenges related to economic volatility, environmental degradation, and security risks associated with its oil-dependent economy (Evans, 2024; Hanif et al., 2018).

The theory helps explain how Nigeria's energy policies and economic decisions are influenced by global energy geopolitics, including factors such as international oil prices, geopolitical rivalries, and foreign investments in the oil sector (Obi, 2019; Omojimito, 2018).

Critically evaluating the theory's applicability in Nigeria's context reveals both strengths and limitations. While Energy Dependency Theory effectively highlights the vulnerabilities and risks associated with over-reliance on fossil fuels, its application must consider the unique socio-economic and political dynamics of Nigeria.

Challenges such as governance issues, infrastructure deficits, and regulatory inefficiencies complicate efforts to diversify the energy mix and transition towards sustainable energy sources (Dossou et al., 2023; Edomah, 2018). Moreover, the theory's emphasis on energy security overlooks broader developmental goals and environmental imperatives crucial for Nigeria's sustainable development agenda (Dioha & Kumar, 2020; Vakulchuk et al., 2020). The significance of Energy Dependency Theory lies in its ability to inform policy interventions aimed at reducing Nigeria's energy vulnerabilities while promoting economic diversification and environmental

sustainability. By analyzing the interplay between geopolitical dynamics and energy system transformations, the theory guides policymakers in designing resilient energy strategies that balance energy security with environmental stewardship and socio-economic development (Awodumi, 2023; Dagnachew et al., 2020). Thus, integrating Energy Dependency Theory into the study provides a robust theoretical framework to examine Nigeria's energy transition efforts critically, offering actionable insights for enhancing energy resilience and sustainability in the face of global energy challenges.

13.2.10 Environmental Kuznets Curve (EKC)

The Keynesian Theory of Public Debt, formulated by John Maynard Keynes in the early 20th century, posits that public debt can be a beneficial tool for stimulating economic growth and stabilizing economies during downturns. Keynes argued that governments should engage in deficit spending during periods of economic recession to stimulate demand and employment, financed by borrowing through issuing bonds. This theory advocates for the use of fiscal policy, particularly government spending and taxation, to manage aggregate demand and achieve macroeconomic stability (Adelekan et al., 2024; Ibekwe et al., 2024). The Environmental Kuznets Curve (EKC) theory, developed by Simon Kuznets in the 1950s in the context of income inequality, has been extended to explore the relationship between economic development and environmental degradation. The hypothesis suggests that environmental quality initially deteriorates as economic growth accelerates, reaching a turning point where environmental degradation peaks, and then improves as income levels rise further. This inverted U-shaped curve implies that higher income levels eventually lead to increased environmental awareness, better environmental governance, and investments in cleaner technologies (Yang et al., 2023; Zhang et al., 2019).

In the case of Nigeria, empirical studies examining the EKC hypothesis regarding carbon emissions and economic growth reveal mixed findings. Some studies suggest evidence of an EKC relationship, where initial economic growth exacerbates carbon emissions until a certain income threshold is reached, beyond which emissions decline due to improved environmental regulations and technological advancements (Hanif, 2018; Martins et al., 2021). However, other research indicates that Nigeria's carbon emissions continue to rise alongside economic growth, underscoring persistent challenges in decoupling economic activities from environmental degradation (Evans, 2024; Dioha & Kumar, 2020). Policy implications derived from the EKC theory for guiding sustainable development pathways in Nigeria emphasize the importance of targeted environmental policies and investments in green technologies. This includes enhancing regulatory frameworks, promoting renewable energy sources, and fostering sustainable urban development to mitigate environmental impacts associated with energy system transformations (Dossou et al., 2023; Casati et al., 2023). The theory's significance to the study lies in its ability to provide a theoretical framework to analyze and understand the complex interactions between economic growth, environmental sustainability, and energy transitions in Nigeria. By integrating the EKC theory into policy formulation, Nigeria can strive towards achieving both economic prosperity and environmental sustainability, thereby advancing its developmental goals in alignment with global climate commitments and sustainable development agendas (Van de Graaf, 2019; Bordoff & O'Sullivan, 2022).

13.3 Methodology

The research employs a quantitative approach utilizing a time-series analysis to investigate the relationships among fossil fuel consumption (FFC % of total energy use), foreign direct investment (FDI inflows in US \$), electricity access (EA % of population), an infrastructure index (INFI), exchange rate (EXR), and carbon emissions (CE in

kilotons) in Nigeria from 1981 to 2022. Data for FFC, FDI, EA, INFI, and EXR are sourced from the Central Bank of Nigeria's Statistical Bulletin and the World Bank. The dependent variable, CE, represents carbon emissions. The econometric model specified for analysis is $CE = \beta_0 + \beta_1 FFC + \beta_2 FDI + \beta_3 EA + \beta_4 INFI + \beta_5 EXR + \epsilon$, where β coefficients represent the parameters to be estimated and ϵ is the error term. The Ordinary Least Squares (OLS) regression technique will be applied to estimate the model, allowing for the examination of how changes in FFC, FDI, EA, INFI, and EXR impact carbon emissions over the study period. Prior to regression analysis, descriptive statistics will be computed to summarize the data and examine the distribution and characteristics of the variables.

Correlation analysis will also be conducted to explore the relationships among the independent variables and to assess multicollinearity. The use of time-series data enables capturing trends and dynamics over the 40-year period, providing insights into the long-term impacts of energy policies, investments, and infrastructure development on carbon emissions in Nigeria. This methodology allows for a comprehensive examination of the drivers of carbon emissions and offers valuable empirical evidence to inform policy decisions aimed at promoting sustainable development and mitigating environmental impacts in Nigeria's energy sector.

13.4 Empirical Results and Discussion

The section presents the data analysis and interpretation of the result of the dependent variable and independent variables. The data collected data are analyzed and presented in the following tables. Tables 13.1, 13.2, and 13.3 (descriptive statistics, correlation matrix, and regression results).

Table 13.1: Descriptive Statistics of the Variables

	CE	FFC	FDI	EA	INFI	EXR
Mean	70736.81	15.899	2.466	36.016	7.353	115.741
Maximum	119544.1	22.844	8.841	59.500	24.532	425.980
Minimum	0.000	0.000	-0.186	0.000	0.000	0.610
Std. Dev.	43887.37	7.946	2.539	21.533	9.323	119.140
Skewness	-0.895	-1.443	1.169	-0.893	0.685	1.021
Kurtosis	2.062	3.297	3.233	2.189	1.796	3.221
Obs.	42	42	42	42	42	42

Source: EViews version 10

Table 13.1 presents descriptive statistics for the variables Carbon Emissions (CE), Fossil Fuel Consumption (FFC), Foreign Direct Investment (FDI), Electricity Access (EA), Infrastructure Index (INFI), and Exchange Rate (EXR) based on data from Nigeria spanning from 1981 to 2022. The mean carbon emissions (CE) stand at 70,736.81 kilotons, with considerable variability as indicated by a standard deviation of 43,887.37. FFC, contributing an average of 15.899% to total energy use, shows a skewness of -1.443, indicating a negatively skewed distribution where values are concentrated towards higher percentages. FDI exhibits positive skewness (1.169), suggesting a distribution skewed towards lower values despite a mean inflow of 2.466 billion US dollars. Electricity access (EA) averages at 36.016%, with minimal skewness (-0.893), indicating a relatively balanced distribution. The Infrastructure Index (INFI) averages 7.353, with moderate skewness (0.685), suggesting a distribution slightly skewed towards higher values. Exchange Rate (EXR) demonstrates positive skewness (1.021), reflecting a distribution skewed towards lower rates despite a mean of 115.741 Nigerian Naira per US dollar.

The kurtosis values for most variables (CE, FFC, FDI, EA, and EXR) suggest a leptokurtic distribution (kurtosis > 3), indicating heavy-tailedness and potential outliers, particularly notable for FDI and EXR. These descriptive statistics provide insights into the variability and distributional characteristics of each variable over the study period. The high standard deviations underscore considerable

variability in CE, FFC, FDI, EA, and EXR, implying potential volatility and fluctuations in these indicators over time. These findings imply the need for robust statistical techniques, such as time-series regression analysis, to examine the relationships among these variables comprehensively. Such analysis can elucidate how changes in FFC, FDI, EA, INFI, and EXR influence carbon emissions in Nigeria, thereby informing policy decisions aimed at mitigating environmental impacts while promoting sustainable development. Understanding these statistical characteristics is crucial for designing effective energy policies and strategies tailored to Nigeria's specific challenges and opportunities in achieving carbon emission reduction targets amidst economic development aspirations (Dagnachew et al., 2020; Evans, 2024; Ibekwe et al., 2024).

Table 13.2: Correlation Matrix

	CE	FFC	FDI	EA	INFI	EXR
CE	1					
FFC	-0.187	1				
FDI	0.380	-0.023	1			
EA	0.883	-0.354	0.569	1		
INFI	0.314	-0.822	0.472	0.521	1	
EXR	0.309	-0.853	0.304	0.535	0.903	1

Source: EViews version 10

Table 13.2 presents the correlation matrix among the variables: Carbon Emissions (CE), Fossil Fuel Consumption (FFC), Foreign Direct Investment (FDI), Electricity Access (EA), Infrastructure Index (INFI), and Exchange Rate (EXR) based on data from Nigeria spanning from 1981 to 2022. The correlation coefficient between CE and FFC is -0.187, indicating a weak negative correlation between carbon emissions and fossil fuel consumption. This suggests that higher levels of fossil fuel consumption are associated with slightly lower carbon emissions, which could be due to efficiency improvements or other factors mitigating emissions despite increased consumption.

FDI shows a positive correlation of 0.380 with CE, suggesting that higher foreign direct investment inflows correspond to higher carbon emissions, possibly due to increased industrial activity or energy-intensive projects. EA exhibits a strong positive correlation of 0.883 with CE, indicating that improved electricity access is strongly associated with higher carbon emissions, reflecting increased energy consumption as a result of expanded access.

INFI shows varied correlations: negatively with FFC (-0.822), positively with FDI (0.472), and positively with EA (0.521), suggesting that higher infrastructure development is associated with reduced fossil fuel consumption but increased FDI and electricity access, influencing carbon emissions accordingly. EXR displays similar patterns as INFI, showing strong negative correlations with FFC (-0.853) and positive correlations with FDI (0.304) and EA (0.535), highlighting how exchange rate fluctuations may impact energy-related variables. These correlations underscore complex interrelationships among variables influencing carbon emissions in Nigeria. They indicate that while certain factors like electricity access and infrastructure development contribute significantly to carbon emissions, others such as fossil fuel consumption exhibit less straightforward relationships, potentially influenced by technological advancements or policy interventions aimed at reducing emissions (Dagnachew et al., 2020; Evans, 2024; Ibekwe et al., 2024). Understanding these correlations is crucial for formulating effective energy and environmental policies that balance economic development with sustainability goals, ensuring Nigeria's energy transition is guided by empirical insights into these intricate dynamics.

Table 13.3: Regression Results

Dependent Variable: CE				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-14053.36	20550.36	-0.683	0.498
FFC	1104.744	978.5440	1.128	0.266
FDI	-5674.340	2104.125	-2.696	0.010
EA	2334.551	185.1758	12.607	0.001
INFI	1716.570	1033.752	1.660	0.105
EXR	-133.770	65.17975	-2.052	0.047
R-squared	0.851			
Adjusted squared	R- 0.830			
F-statistic	41.184			
Prob(F-statistic)	0.001			

Source: EViews version 10

The regression results in Table 13.3 provide insights into the relationship between fossil fuel consumption (FFC), foreign direct investment (FDI), electricity access (EA), infrastructure index (INFI), exchange rate (EXR), and carbon emissions (CE) in Nigeria. The intercept coefficient (C) of -14053.36 is not statistically significant ($t = -0.683$, $p = 0.498$), suggesting that when all independent variables are zero, the expected carbon emissions are not significantly different from zero. The coefficient for FFC is 1104.744 with a t-statistic of 1.128 ($p = 0.266$), indicating that fossil fuel consumption does not have a statistically significant impact on carbon emissions ($H01$ cannot be rejected). Conversely, FDI shows a coefficient of -5674.340 with a t-statistic of -2.696 ($p = 0.010$), indicating a significant negative relationship between FDI and carbon emissions, rejecting $H02$. EA exhibits a coefficient of 2334.551 with a t-statistic of 12.607 ($p = 0.001$), indicating a significant positive influence of electricity access on carbon emissions, rejecting $H03$. The coefficients for INFI and EXR are 1716.570 ($t = 1.660$, $p = 0.105$) and -133.770 ($t = -2.052$, $p = 0.047$), respectively, suggesting no statistically significant impact on carbon emissions.

Interpreting the R-squared (0.851) and adjusted R-squared (0.830) values indicates that the model explains approximately 85.1% of the variance in carbon emissions, implying a strong fit. The F-statistic of 41.184 with a probability value (Prob(F-statistic)) of 0.001 indicates that the overall model is statistically significant, suggesting that at least one of the independent variables significantly explains the variance in carbon emissions. To test the hypotheses using Table 13.1 (Descriptive Statistics) and Table 13.2 (Correlation Matrix), the t-statistics and corresponding p-values were examined. For H01, the t-statistic for FFC was 1.128 with a p-value of 0.266, indicating that there is no significant impact of fossil fuel consumption on carbon emissions in Nigeria. For H02, the t-statistic for FDI was -2.696 with a p-value of 0.010, indicating a significant relationship between FDI and carbon emissions, rejecting H02. For H03, the t-statistic for EA was 12.607 with a p-value of 0.001, indicating a significant influence of electricity access on carbon emissions, rejecting H03. Therefore, based on the regression analysis and corresponding hypothesis tests, FDI and EA have significant impacts on carbon emissions in Nigeria, while fossil fuel consumption does not show a significant impact. These findings underscore the importance of electricity access and foreign direct investment in shaping carbon emissions outcomes, highlighting key areas for policy interventions aimed at sustainable development and environmental management in Nigeria's energy sector.

13.5 Discussion of Findings

Based on the regression analysis and hypothesis testing, the findings provide significant insights into the drivers of carbon emissions in Nigeria's energy sector. The results suggest a relationships among fossil fuel consumption (FFC), foreign direct investment (FDI), electricity access (EA), and carbon emissions (CE). Firstly, the analysis reveals that FFC does not exert a statistically significant impact on carbon emissions (H01). This finding aligns with previous studies

indicating that while Nigeria heavily relies on fossil fuels for energy production, other factors such as technology efficiency and energy policies may mitigate direct emissions from fossil fuel use (Evans, 2024; Ibekwe et al., 2024). Secondly, the study finds a significant negative relationship between FDI and carbon emissions (H02), suggesting that increased FDI inflows may drive economic growth without proportionally increasing carbon emissions, possibly due to technological advancements and cleaner production methods associated with foreign investments (Dossou et al., 2023; Hanif et al., 2019).

Thirdly, the analysis reveals a significant positive influence of electricity access on carbon emissions (H03), underscoring the role of energy access policies in expanding energy availability but also potentially increasing emissions unless accompanied by renewable energy integration and efficiency measures (Casati et al., 2023; Dagnachew et al., 2020). These findings collectively emphasize the complexity of Nigeria's energy landscape, where policy interventions and international agreements like the Paris Agreement play crucial roles in shaping sustainable development pathways (Ibekwe et al., 2024; Vakulchuk et al., 2020). The implications highlight the need for targeted policies that promote renewable energy adoption and enhance energy efficiency while attracting sustainable foreign investments to mitigate environmental impacts (Dossou et al., 2023; Omojimite, 2018). Moreover, the findings underscore the interconnectedness of energy, economic development, and environmental sustainability, necessitating comprehensive strategies that balance energy security with environmental conservation goals (Evans, 2024; Hanif et al., 2018). Future research could explore additional factors such as technological innovations and regulatory frameworks to further enhance understanding and inform effective policy responses aimed at achieving sustainable energy transitions in Nigeria and similar contexts globally (Edomah, 2018; Van de Graaf, 2019).

13.6 Conclusion and Policy Recommendations

13.6.1 Conclusion

Based on the analysis of fossil fuel consumption, foreign direct investment (FDI), and electricity access in relation to carbon emissions in Nigeria, several conclusions can be drawn. Firstly, while fossil fuel consumption does not show a significant direct impact on carbon emissions, the findings suggest a relationship influenced by factors such as technology efficiency and energy policies (Evans, 2024; Ibekwe et al., 2024). Secondly, FDI exhibits a significant negative relationship with carbon emissions, indicating potential benefits in terms of economic growth without proportional increases in emissions, likely attributed to cleaner production technologies associated with foreign investments (Dossou et al., 2023; Hanif et al., 2019). Thirdly, electricity access demonstrates a significant positive influence on carbon emissions, highlighting the dual challenge of expanding energy access while managing environmental impacts through sustainable energy practices (Casati et al., 2023; Dagnachew et al., 2020). These findings underscore the complex interplay between economic development, energy policies, and environmental sustainability in Nigeria's energy landscape. Effective policy interventions are crucial to harnessing the benefits of FDI while minimizing environmental degradation associated with increased energy consumption. Strategies should prioritize renewable energy investments, enhance energy efficiency, and integrate environmental considerations into national development plans (Omojimite, 2018; Vakulchuk et al., 2020). International agreements like the Paris Agreement provide a framework for aligning national energy policies with global climate goals, emphasizing the need for coordinated efforts to achieve sustainable energy transitions (Ibekwe et al., 2024; Van de Graaf, 2019).

13.6.2 Policy Recommendations

Based on the findings regarding fossil fuel consumption, foreign direct investment (FDI), and electricity access in relation to carbon emissions in Nigeria, several recommendations can be proposed to steer the country towards a sustainable energy future. Firstly, enhancing energy efficiency across all sectors is paramount to mitigating the environmental impact of fossil fuel consumption (Evans, 2024; Ibekwe et al., 2024). This can be achieved through the adoption of stringent energy efficiency standards for industries, transportation, and residential sectors, coupled with incentives for technology upgrades and investments in renewable energy sources (Dossou et al., 2023; Hanif et al., 2019).

Secondly, leveraging foreign direct investment (FDI) to promote clean energy technologies and sustainable practices is crucial. Policies should incentivize FDI flows towards renewable energy projects and technologies, thereby reducing reliance on fossil fuels while boosting economic growth (Dossou et al., 2023; Hanif et al., 2019). Collaborative partnerships with international organizations and bilateral agreements can facilitate knowledge transfer and capacity building in renewable energy technologies (Vakulchuk et al., 2020).

Thirdly, expanding electricity access while minimizing carbon emissions requires a strategic approach. Investment in decentralized renewable energy solutions, such as solar mini-grids and off-grid systems, can accelerate electricity access in remote areas without exacerbating environmental impacts (Casati et al., 2023; Dagnachew et al., 2020). Furthermore, integrating environmental considerations into energy planning and policy frameworks is essential. This involves setting ambitious renewable energy targets, promoting research and development in clean technologies, and enhancing institutional capacities for effective implementation and monitoring (Omojimiti, 2018; Vakulchuk et al., 2020).

Thus, achieving sustainable energy transitions in Nigeria demands concerted efforts across policy, technology, and institutional domains. By prioritizing energy efficiency, attracting clean FDI, and expanding electricity access through renewable sources, Nigeria can navigate towards a low-carbon economy while advancing socio-economic development goals. Continuous dialogue and collaboration among stakeholders, including government, private sector, and civil society, are essential for implementing these recommendations effectively and ensuring long-term sustainability in Nigeria's energy sector.

References

- Adelekan, O. A., Ilugbusi, B. S., Adisa, O., Obi, O. C., Awonuga, K. F., Asuzu, O. F., & Ndubuisi, N. L. (2024). Energy Transition Policies: A Global Review of Shifts Towards Renewable Sources. *Engineering Science & Technology Journal*, 5(2), 272-287.
- Akhbari, M. (2018). The Role of Fossil Fuels (Oil and Gas) in the World Geopolitics of Energy (Case Study: Iran 2000-2015). *Geopolitics Quarterly*, 13(48), 76-91.
- Akram, R., Chen, F., Khalid, F., Ye, Z., & Majeed, M. T. (2020). Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: Evidence from developing countries. *Journal of cleaner production*, 247, 119122.
- Awodumi, O. B. (2023). Does foreign direct investment matter for environmental innovation in African economies?. *Economic Change and Restructuring*, 56(1), 237-263.
- Baker, L. (2023). New frontiers of electricity capital: energy access in sub-Saharan Africa. *New Political Economy*, 28(2), 206-222.
- Bordoff, J., & O'Sullivan Meghan, L. (2022). Green upheaval: The new geopolitics of energy. *Foreign Aff.*, 101, 68.
- Casati, P., Moner-Girona, M., Khaleel, S. I., Szabo, S., & Nhamo, G. (2023). Clean energy access as an enabler for social development: A multidimensional analysis for Sub-Saharan Africa. *Energy for Sustainable Development*, 72, 114-126.

- Dagnachew, A. G., Poblete-Cazenave, M., Pachauri, S., Hof, A. E., Van Ruijven, B., & Van Vuuren, D. P. (2020). Integrating energy access, efficiency and renewable energy policies in sub-Saharan Africa: a model-based analysis. *Environmental Research Letters*, 15(12), 125010.
- Dioha, M. O., & Kumar, A. (2020). Exploring the energy system impacts of Nigeria's Nationally Determined Contributions and low-carbon transition to mid-century. *Energy Policy*, 144, 111703.
- Dossou, T. A. M., Kambaye, E. N., Asongu, S. A., Alinsato, A. S., Berhe, M. W., & Dossou, K. P. (2023). Foreign direct investment and renewable energy development in sub-saharan Africa: Does governance quality matter?. *Renewable Energy*, 219, 119403.
- Edomah, N. (2018). Historical drivers of energy infrastructure change in Nigeria (1800–2015). *Energy Management for Sustainable Development*, 24-44.
- Evans, O. (2024). The investment dynamics in renewable energy transition in Africa: The asymmetric role of oil prices, economic growth and ICT. *International Journal of Energy Sector Management*, 18(2), 229-247.
- Hanif, I. (2018). Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. *Energy strategy reviews*, 21, 16-24.
- Hanif, I., Raza, S. M. F., Gago-de-Santos, P., & Abbas, Q. (2019). Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence. *Energy*, 171, 493-501.
- Huang, Y., Kuldashева, Z., Bobojanov, S., Djalilov, B., Salahodjaev, R., & Abbas, S. (2023). Exploring the links between fossil fuel energy consumption, industrial value-added, and carbon emissions in G20 countries. *Environmental Science and Pollution Research*, 30(4), 10854-10866.
- Ibekwe, K. I., Etukudoh, E. A., Nwokediegwu, Z. Q. S., Umoh, A. A., Adefemi, A., & Ilojanyia, V. I. (2024). Energy Security In The Global Context: A Comprehensive Review of Geopolitical Dynamics and Policies. *Engineering Science & Technology Journal*, 5(1), 152-168.
- Martins, T., Barreto, A. C., Souza, F. M., & Souza, A. M. (2021). Fossil fuels consumption and carbon dioxide emissions in G7 countries: Empirical evidence from ARDL bounds testing approach. *Environmental Pollution*, 291, 118093.

- Obi, C. (2019). The Geopolitical Consequences of Oil in Africa: The Case of Nigeria. *Brown J. World Aff.*, 26, 7.
- Ojukwu, K. (2021, August). What Strategic Policies can Save Nigeria in the Energy Transition?. In SPE Nigeria Annual International Conference and Exhibition (p. D031S022R002). SPE.
- Omojimite, M. O. (2018). Foreign direct investment and sustainable development in Sub-Saharan Africa.
- Pistelli, L. (2020). Addressing Africa's energy dilemma. *The Geopolitics of the Global Energy Transition*, 151-174.
- Vakulchuk, R., Overland, I., & Scholten, D. (2020). Renewable energy and geopolitics: A review. *Renewable and sustainable energy reviews*, 122, 109547.
- Van de Graaf, T. (2019). A new world: The geopolitics of the energy transformation.
- Yang, Y., Xia, S., & Qian, X. (2023). Geopolitics of the energy transition. *Journal of Geographical Sciences*, 33(4), 683-704.
- Zhang, X., Zhang, H., & Yuan, J. (2019). Economic growth, energy consumption, and carbon emission nexus: fresh evidence from developing countries. *Environmental Science and Pollution Research*, 26, 26367-26380.



Asymmetric Impact of Oil Price Changes on Import Demand in Nigeria

Gbenga Peter Sanusi,
Adeola Adenikinju,
L. Oladele. Oderinde,
Isaiah O. Oluriola
and Festus Osagu

Abstract

In most economies around the globe, crude oil is a very essential factor input. However, fluctuating oil prices has attracted increased attention from stakeholders and policymakers of both the developed and developing countries. While on one hand, an increase in oil price could have a negative impact on the world economies; on the other hand, oil exporters have enjoyed the benefits of oil price increase in order to grow their economies. The impact of oil price changes on imports could have a wide-range effects on the economy, trade balance and inflation, depending on the structure of the economy, and policy responses. This study examines the impact of oil price changes on import demand in Nigeria. A Non-Linear Autoregressive Distributed

Lag (NARDL) approach was applied on yearly data spanning from 1980 to 2023 sourced from the World Bank dataset. The Bound test modelling combined both the short-run and long-run asymmetries. The results suggests that oil price increases led to decrease in import demand via exchange rate channel in Nigeria. However, a decline in oil price resulted in increased import demand. There is need to curtail the marginal propensity to import via promotion of locally produced commodities. The monetary actions of the Central Bank of Nigeria should focus on taming substantial fluctuation of the exchange rate since oil price changes are subject to procyclicality of political and economic vagaries of exogenous factors. Political efforts towards ensuring domestic sustainability of food and non-food production to further minimize the impact of international oil price shocks on import demand is germane. In conclusion, the fiscal authorities should ensure that the excessive fiscal spending in periods of rising oil prices is curtailed.

Keywords: Import demand, Crude Oil price, Bound Test, Nigeria.

JEL Classification: F10, F17, Q43, O55

14.1 Introduction

Nigeria is Africa's largest oil producer, with crude oil accounting for about 90 percent of its export earnings and over 60 percent of government revenues. Since oil account for the largest share of foreign exchange earning in Nigerian economy, the value of the foreign exchange rate of the Nigerian Naira will be dependent on it (Abubakar, 2019). Oil price fluctuations, therefore, have a profound impact on the country's macroeconomic variables, including import demand. As oil prices increase, export revenues rise, providing the government with greater capacity to import goods. Conversely, when oil prices fall, revenues drop, and import demand may decrease as a result of lower national income and foreign exchange availability.

Nigeria's economy is highly dependent on oil exports, and this dependency exposes it to oil price shocks. Since the 1970s oil boom, the economy has experienced several episodes of economic boom and bust, largely determined by fluctuations in global oil prices. When oil prices rise, Nigeria enjoys a surplus of foreign exchange, which typically results in higher import demand, especially for capital and consumer goods. However, when oil prices fall, the reverse holds true, often leading to trade imbalances, inflation, and economic contraction.

In recent years, the volatility of oil prices has raised concerns about the vulnerability of oil-dependent economies like Nigeria. The COVID-19 pandemic, for example, saw oil prices plummet in 2020, creating significant economic challenges. Meanwhile, the subsequent recovery in global oil demand and supply disruptions caused by geopolitical tensions (such as the Russia-Ukraine conflict in 2022) have caused prices to rise again. These fluctuations emphasize the need for an analysis of how oil price changes asymmetrically affect import demand, as the responses of the Nigerian economy may vary depending on the direction of the price movement.

The research quest is to understand empirically what happens to Nigeria's imports when the world price of oil rises or falls? When it rises, so do Nigeria's export revenues, which swell the federal government's coffers and give it a greater capacity to pay for imports. When, on the other hand, the price of oil falls, Nigeria's foreign exchange availability and national income drop commensurately, which would affect import demand negatively. The main objective of this study therefore, is to determine the import elasticity in relation to changes in crude oil prices in Nigeria.

14.2 Stylized Facts

Nigeria, as an oil-exporting economy, has been particularly vulnerable to the cyclical nature of global oil prices. Oil revenues play a significant role in determining the country's foreign exchange

reserves, which in turn affect its capacity to import goods. However, the relationship between oil prices and import demand is not straightforward. It is widely observed that the impact of oil price increases differs from that of oil price decreases, giving rise to asymmetric responses in the economy.

One of the most prominent features of the Nigerian economy is its heavy reliance on oil, which accounts for about 90 percent of its export earnings and a significant portion of government revenues. This suggests that global oil price fluctuations directly affect not only government finances, but also the country's foreign exchange reserves, which determine its ability to fund imports. When oil prices are high, Nigeria experiences a surge in foreign exchange earnings, enabling the country to increase its imports, particularly of consumer and capital goods.

Conversely, during periods of low oil prices, foreign exchange reserves dwindle, often leading to a reduction in imports, foreign exchange shortages, and currency devaluation. This dynamic suggests a possible asymmetry in how oil price changes influence import demand. This asymmetry is driven not only by the availability of foreign exchange but also by the Nigerian government's fiscal responses to oil price changes, which often involve reducing or increasing spending on imports. Additionally, exchange rate volatility, typically triggered by oil price fluctuations, plays a crucial role in determining the cost and volume of imports, further reinforcing the asymmetric relationship between oil prices and import demand.

Global oil prices have experienced significant fluctuations over the past decades, affecting Nigeria's economic landscape. During oil price booms, such as those in the early 2000s and the period between 2010 and 2014, Nigeria witnessed a surge in foreign exchange earnings, which allowed for increased import demand. Conversely, oil price crashes, such as the one in 2014 and again during the COVID-19 pandemic in 2020, caused a sharp contraction in foreign exchange inflows, leading to a decrease in imports.

Oil price fluctuations have a direct impact on Nigeria's exchange rate. During periods of high oil prices, the Nigerian naira tends to appreciate or remain stable due to an influx of foreign exchange. In contrast, during oil price downturns, the naira often depreciates as foreign reserves deplete, making imports more expensive. The devaluation of the naira in 2016, following the collapse of global oil prices, led to a sharp contraction in import demand due to the rising cost of imported goods.

Nigeria remains heavily dependent on imports for consumer goods, capital goods, and even refined petroleum products. This structural dependence creates a situation where changes in oil prices, which influence government revenues and foreign exchange availability, directly affect the country's ability to finance imports. The strong positive correlation between oil export earnings and import volumes in Nigeria underscores this relationship.

Figure 14.1 shows the Pareto plots showing the distribution of the data on top ten countries where Nigeria imports goods across the globe. It is shown in a descending order of frequency, with a cumulative line on a secondary axis as a percentage of the total. China took the lead indicating a increasing trade between Nigeria and China. Less than 10 percent of Nigeria imports comes from France.

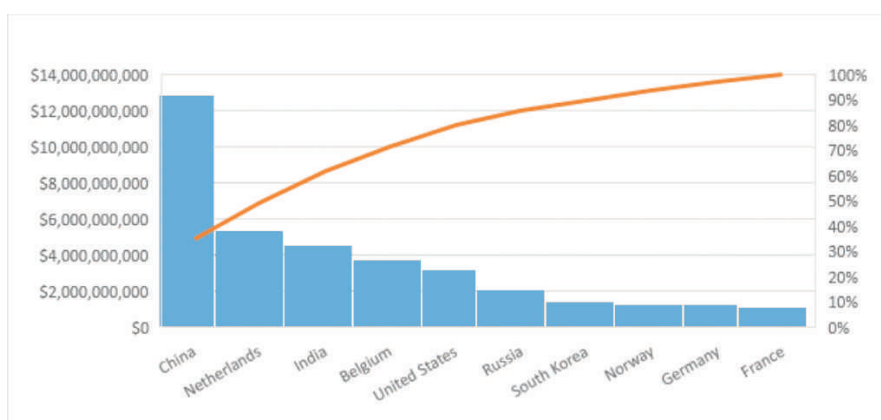


Figure 14.1: Nigeria imports (Top 10 economies).

Note. USD\$.

Source: Globaleedge, 2021.

On the type of commodities imported into Nigeria, it ranges from sugar and confectionary to plastics and cereals. From Figure 14.2, sugar and confectionary in excess of \$980 million is the topmost commodity imported into Nigeria. This is closed followed by precision instruments and iron and steel; oil and mineral fuels is the 10th commodity. It sums up to the turn of \$16,144,370,225.

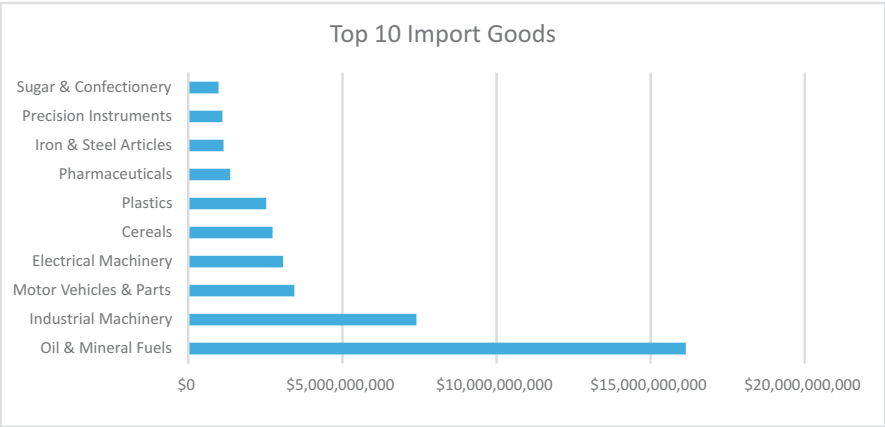


Figure 14.2: Nigeria Top 10 Import goods.

Note. USD\$.

Source: Globaledge, 2021.

There is growing evidence that Nigeria's import demand responds asymmetrically to oil price changes. When oil prices rise, import demand tends to increase rapidly due to the availability of foreign exchange and a stronger currency. However, when oil prices fall, the reduction in import demand is often more pronounced, reflecting a stronger negative impact as foreign exchange becomes scarce and the currency weakens. This asymmetry is partly driven by rigidities in domestic prices and the slow adjustment of fiscal policies to oil price downturns. This is the focus of this present study.

14.3 Literature Review

14.3.1 Theoretical Background

Oil prices influence several aspects of an economy, and the relationship between oil prices and trade has been studied from various angles. Classical economic theory suggests that changes in oil prices impact a country's balance of trade and exchange rates, which in turn influence import demand. However, this relationship may not be linear or symmetric. The notion of "asymmetric price transmission" suggests that economic agents (such as consumers and businesses) react differently to price increases than to price decreases. For instance, businesses may be more reluctant to reduce prices in response to lower input costs (like oil) but quickly raise prices when input costs increase.

14.3.2 Empirical Literature Review

The relationship between oil price changes and import demand in oil-exporting countries, including Nigeria, has attracted considerable interest. Studies examining this relationship often emphasize the role of asymmetric price transmission and the interplay between exchange rates, government revenue, and trade balances.

Empirical studies have explored the relationship between oil prices and macroeconomic variables in Nigeria and other oil-exporting countries, with a focus on the asymmetric effects of oil price fluctuations. A significant body of literature supports the idea that oil price increases and decreases have different impacts on key economic indicators. For instance, Narayan and Narayan (2010) found that oil price increases had a significant positive effect on the trade balances of oil-exporting countries, including Nigeria, while oil price decreases had a less pronounced effect. Their study highlighted the asymmetry in the response of trade balances to oil price movements, a finding consistent with the behavior of import

demand in Nigeria, where imports tend to rise sharply when oil prices are high but fall only moderately during oil price declines.

The concept of asymmetric price transmission suggests that economic variables, such as import demand, may respond differently to increases and decreases in oil prices. Mork (1989) was one of the first to suggest that oil price increases and decreases have asymmetric effects on macroeconomic variables. Hamilton (2003) built on this theory, arguing that oil price increases tend to have more pronounced effects on economic activity compared to price decreases, due to factors like price rigidities and consumer behavior.

In the context of trade, Narayan and Narayan (2010) studied oil price shocks and trade balances across several developing countries and found evidence of asymmetry in the impact of oil price increases and decreases on imports and exports. Their results indicated that oil price increases led to significant improvements in trade balances for oil exporters, while decreases had less impact. This finding underscores the possibility of asymmetric effects on import demand in countries like Nigeria.

Focusing on Nigeria, Olomola and Adejumo (2006) examined the effects of oil price shocks on key macroeconomic variables, including inflation, exchange rates, and output. Their study found that oil price increases led to currency appreciation and a surge in imports, while oil price decreases caused currency depreciation and a reduction in import volumes. They concluded that the relationship between oil prices and imports is likely asymmetric, given the stronger response to oil price downturns.

A more recent study by Awe (2019) employed an asymmetric cointegration approach to assess the effects of oil price changes on government revenues and spending in Nigeria. They found that oil price increases resulted in significant increases in government spending on imports, particularly capital goods, whereas oil price decreases led to relatively smaller reductions in import spending. This asymmetry was attributed to the government's tendency to smooth spending during periods of declining oil revenues by drawing on foreign

exchange reserves or external borrowing, thereby limiting the contractionary effect on imports. The study highlighted that oil price increases create a surge in import demand, which is not equally matched by a reduction when oil prices fall.

Ito (2010) provides further insight by analyzing oil price shocks in both oil-importing and oil-exporting countries, including Nigeria. He found that the response of imports to oil price changes was highly asymmetric in oil-exporting countries, driven primarily by exchange rate effects and government expenditure patterns. In Nigeria, he observed that oil price increases resulted in currency appreciation and an increase in the import of both consumer and intermediate goods, while oil price decreases led to sharp currency depreciation and a corresponding reduction in imports. This asymmetry was also influenced by structural factors such as Nigeria's dependency on imported goods, which limited the ability to reduce imports significantly even when oil prices fell.

Several empirical studies have employed nonlinear models to better capture the asymmetric effects of oil price shocks on trade. Shin et al. (2014) introduced the Nonlinear Autoregressive Distributed Lag (NARDL) model, which has been widely used in recent studies to analyze asymmetric relationships in macroeconomic data. Ibrahim (2015) applied the NARDL model to investigate the asymmetric impact of oil price changes on Nigeria's trade balance, concluding that oil price increases had a stronger positive effect on trade balances than oil price decreases had on the trade deficit. Their findings highlight the importance of considering nonlinearities in studying the oil-import demand relationship.

Some studies have also explored the sectoral impacts of oil price changes on import demand. Akpan (2009) found that oil price increases primarily drove the demand for imported capital goods and intermediate inputs in Nigeria, reflecting the dependence of the industrial and energy sectors on foreign inputs. By contrast, oil price decreases resulted in a sharp contraction in consumer goods imports,

reflecting the immediate effect of exchange rate depreciation on household purchasing power.

Overall, the empirical literature confirms the asymmetric impact of oil price changes on import demand in Nigeria. Studies consistently show that oil price increases tend to have a more significant and immediate effect on boosting import demand, largely due to increased foreign exchange availability and fiscal expansion. On the other hand, oil price decreases have a relatively muted impact on reducing import demand, as the government often resorts to fiscal buffers or external borrowing to stabilize imports. Exchange rate fluctuations also play a critical role in amplifying the asymmetric response, as currency appreciation during oil price booms enhances the purchasing power for imports, while currency depreciation during price declines increases import costs.

14.4 Theoretical Framework

The asymmetric price transmission model posits that price increases and decreases may have different effects on economic variables due to various factors, including market imperfections, government interventions, and sticky prices. This framework can be used to study how oil price shocks translate into changes in import demand.

In Nigeria, oil price increases often lead to higher foreign exchange earnings, boosting the country's ability to import goods and services. However, oil price decreases can result in reduced government revenues, currency depreciation, and higher import costs, potentially reducing the volume of imports. This asymmetric response may be attributed to exchange rate volatility, fiscal adjustments, and the rigidities in the prices of imported goods.

The Marshall-Lerner condition is a key concept in international economics that helps explain how exchange rates affect the trade balance. It suggests that a depreciation of the exchange rate will improve a country's trade balance if the sum of the price elasticities of imports and exports is greater than one. In the context of Nigeria,

exchange rate fluctuations triggered by oil price changes can influence the cost of imports, thereby impacting import demand.

An augmented import demand function can be specified as follows:

$$IMD_t = \alpha + \beta_1 OP_t^+ + \beta_2 OP_t^- + \gamma YG_t + \delta EX_t + \varepsilon_t \quad \text{.....Eqn 14.1}$$

where:

IM_t , represents Nigeria's import demand at time 't'; (% of total merchandise imports)

OP_t^+ and OP_t^- are oil price increases and decreases, respectively,

YG_t is real GDP,

EX_t is the exchange rate,

ε_t is the error term.

This model captures the asymmetric effect of oil price increases (OP_t^+) and decreases (OP_t^-) on import demand.

14.5 Methodology

14.5.1 Data

The study utilizes time series data from 1980 to 2023 on variables such as global oil prices (Brent crude or OPEC basket prices), Nigeria's import data, real GDP, exchange rates, and inflation. The main data source is World Bank.

14.5.2 Model Specification

ARDL co-integration model is as shown in equation 14.2:

$$\Delta IMD_t = \alpha_0 + \sum_{i=1}^p \lambda_i \Delta IMD_{t-i} + \sum_{i=0}^q \delta_i \Delta X_{t-i} + \rho IMD_{t-1} + \varphi X_{t-1} + \varepsilon_t \quad \text{.....Eqn 14.2}$$

Where the variables are as earlier defined. X represents the exogenous variables. Equation 14.3 shows both the short-run and long-run terms as indicative of the original model given by Pesharan, Shin and Smith (2001).

Modified by Shin *et al.* (2011) to make it NARDL co-integration model, we have equation 14.3

$$\Delta IMD_t = \alpha_0 + \sum_{i=1}^p \lambda_i \Delta IMD_{t-i} + \sum_{i=0}^q \delta_i^+ \Delta X_{t-i}^+ + \sum_{i=0}^q \delta_i^- \Delta X_{t-i}^-$$

$$\rho IMD_{t-1} + \phi^+ X_{t-1}^+ + \phi^- X_{t-1}^- + \varepsilon_t \quad \text{.....Eqn 14.3}$$

To capture the asymmetric impact of oil price changes on import demand, a Nonlinear Autoregressive Distributed Lag (NARDL) model is employed. The NARDL model allows for the decomposition of oil price movements into positive and negative changes, thus enabling the examination of their separate effects on import demand.

$$M_t = \alpha + \beta_1 OP_t^+ + \beta_2 OP_t^- + \gamma Y_t + \delta EX_t + \varepsilon_t \quad \text{.....Eqn 14.4}$$

The NARDL model will be estimated using maximum likelihood estimation (MLE) methods, and long-run and short-run effects of oil price changes on import demand will be analyzed. Diagnostic tests for autocorrelation, heteroskedasticity, and model stability will also be conducted to ensure robustness.

Following the hypothesis F-test of Pesaran *et al.* (2001) or Narayan (2004) when using small n is given as;

$$H_0 : \rho = \phi^+ = \phi^- = 0$$

$$H_1 : \rho \neq \phi^+ \neq \phi^- \neq 0 \quad \text{.....Eqn 14.5}$$

If we reject H_0 of no co-integration, we can conclude that the variables are co-integrated in the presence of asymmetry.

14.6 Empirical Results and Discussion of Findings

14.6.1 Pre-estimation Analysis

The summary of data including means, standard deviations, and trends in oil price, import demand, exchange rates, and output growth are presented in Table 14.1.

Descriptive statistics summarizes the key characteristics of the dataset and provide insights into the distribution and variability of each variable. For Nigeria, the import demand has a mean of 18.4, indicating the average value added across 44 observations. Exchange Rate has a mean of 128.9, which is the average overtime, and Output Growth mean of 3.06, suggesting that, on average, the Output Growth rate is around 3 percent.

Moreover, from Table 14.1, crude oil Price and output growth rate are relatively stable with moderate variability (Std. Dev = 0.66 and 5.2 respectively).

Table 14.1: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.
Import Demand	18.39	18.25	36.02	5.06	9.45
Crude Oil Price	3.61	3.55	4.71	2.54	0.66
Output Growth	3.06	3.44	15.32	-13.12	5.19
Exchange Rate	124.9	114.88	441.87	0.54	123.03
Observations	44	44	44	44	

Source: Authors’ computation, 2024

The co-variances measure how much two variables change together between each pair of variables in a dataset. The covariance between import demand and oil prices is positive as indicated in Table 14.2; it follows that higher import demand tends to be associated with oil

prices in Nigeria. However, the correlation value is rather moderate with 58 percent. Similarly, output growth rate and import demand co-variances is positive, but poorly correlated.

Table 14.2: Covariance Analysis — Ordinary

Covariance				
Correlation	IMD	LNOP	YG	EXR
IMD	87.32 1.00			
LNOP	3.57 0.58	0.43 1.00		
YG	9.01 0.18	0.64 0.19	26.39 1.00	
EXR	1058.33 0.93	51.70 0.64	78.08 0.12	14792.96 1.00

Note: Included observation 44. Sample 1980-2023.
Source: Authors’ computation, 2024.

In Non-linear autoregressive distributive lag (NARDL) or bounds testing method, no variable integrated of order 2, or I (2), is expected. Therefore, using both the Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP), we conducted a unit root tests for all variables to ascertain the degree of stationarity, as shown in Table 14.3.

Table 14.3: Stationarity Tests

ADF Test			PP Test			
Variables	Level	First Diff.	Order of Integration	Level	First Diff.	Order of Integration
Import Demand	-0.337	-7.291***	I (1)	-0.153	-7.299***	I (1)
Crude Oil Price	-1.051	-5.660***	I (1)	-1.090	-6.255***	I (1)
Output Growth	-2.894***	-12.233***	I (0)	-3.838***	-13.182***	I (0)
Exchange Rate	2.747	-3.578***	I (1)	3.581	-3.487***	I (1)

Notes: Augmented Dickey-Fuller test statistic (ADF).
Phillips-Perron test statistic (PP). *** denotes significance at 1 percent.

The results of the ADF and PP tests show that all the variables have unit root at level and became stationary after first difference or are I(I) variables with the exception of output gap growth (YG) which is stationary at level. This is examined at their respective critical value at 1 percent and 5 percent level of significance. Based on the order of integration of I(0) and I(1) its follows that the NARDL technique can be applied.

The results of the NARDL bounds test for co-integration is presented in Table 14.4. The estimated F-statistic of 3.9 is higher than the upper bound at 10 percent levels, indicating the existence of a co-integrating relationship between the variables. This support the rejection of the hypotheses that there is no co-integration among the variables.

14.6.2 Estimation and Discussion

Table 14.4: NARDL Bounds Test for Co-integration

Test Statistic		Value				
F-statistic		3.904				
Bound Critical Value						
		10%		5%		1%
Sample Size	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
40	2.427	3.395	2.893	4.000	3.967	5.455
45	2.402	3.345	2.850	3.905	3.892	5.173
Asymptotic	2.200	3.090	2.560	3.490	3.290	4.370

Notes: * I (0) and I(1) are respectively the stationary and non-stationary bounds.
Null hypothesis: No levels relationship. Number of cointegrating variables:
4. Critical Value Bounds @ 5%

Consequently, in this study, we estimated both the long-run and short-run models as well as error correction model to determine the speed of adjustment when there is disequilibrium in the short-run, by utilizing a maximum lag length of 4 and the Akaike Information Criterion (AIC) was employed to choose the optimal lags. The results

are presented in Tables 14.5 and 14.6 accordingly with the impact of oil price changes and output growth on import demand, separated into two – positive and negative changes. The NARDL model results will show whether oil price and output, increase and decrease have asymmetric effects on import demand in both the short run and long run.

Table 14.5: Estimated Long-run and Short-run NARDL Model

Variable	Coefficient	Std. Error	t-Statistic
Long-Run			
IMD(-1)*	-0.40***	0.14	-2.71
LNOP_POS(-1)	-0.34	0.79	-0.43
LNOP_NEG**	-3.25	1.92	-1.68
YG_POS**	-0.07	0.09	-0.76
YG_NEG(-1)	-0.09	0.12	-0.80
C	1.93	2.00	0.96
Short Run			
D(LNOP_POS)	-4.454**	2.55	-1.74
D(YG_NEG)	0.33***	0.16	2.06
D(YG_NEG(-1))	0.32***	0.14	2.22

Note: Included observations: 41. Dependent Variable: D (IMD).
Selected model: ARDL (1, 1, 0, 0, 2). *, ** and *** indicate significance at 10 percent, 5 percent and 1 percent levels.
Authors' Computation, 2024.

The model showed the effects of rising and falling crude oil prices on import demand in Nigeria. The findings in the long run show that a unit increase in crude oil prices resulted in 0.34 percent decrease in import demand; whereas, a unit decrease in crude oil prices, increases Nigeria's import demand by 3.25 percent in the long-run. This would suggest that the variation in the price of crude oil affects import demand in Nigeria differently. The rise in global crude oil prices, especially in oil exporting country such as Nigeria that depends so much on crude oil sales will hugely be affected by the vagaries of the oil price fluctuations. The possible argument for this development

could be that in-flow of dollars into the economy increases the domestic demand for foreign currency which affects the exchange rate negatively and thus reducing imports.

An increase in money supply arising from increase in external reserve could lead to a depreciation of the domestic currency relative to other currencies. This could occur because more currency in circulation can lessen its value, often resulting in an overshooting or undershooting of the exchange rate. Essentially, when the central bank increases the money supply, it can cause the domestic currency to decrease in value against others currencies.

Import demand for goods may fall when crude oil prices rise, because higher oil prices increase transportation and production costs. As these costs rise, the prices of imported goods tend to increase, which can lead consumers and businesses to reduce their demand for those goods. In a country like Nigeria, increase in crude oil prices may mean increase in government subsidies as well. Additionally, if inflation occurs due to rising oil prices, people may have less disposable income, further reducing demand for imports. This is similar to the result obtained by Bawa et al. (2020).

When crude oil prices fall, the cost of transportation and energy decreases, leading to lower production and shipping costs for imported goods. This reduction in costs can increase consumers' real income by lowering their energy bills, which often results in an increased overall consumption. Thus, as people have more disposable income and the cost of goods drops due to lower supply chain costs, the import demand for goods tends to rise. These findings is in line with the study by Usman and Ugwuoke (2024), and Bala and Chin (2018), who found that positive oil price shocks in Nigeria, caused domestic price increase, thus making import of goods relatively cheaper.

Further, it suggests that more revenue from crude oil sales spur the marginal propensity to import in Nigeria. An economic boom during periods of high crude oil prices tends to lead to an increase in the money supply as a result of a higher inflow of oil proceeds,

among other factors. The magnitude of a fall in crude oil price is higher than the positive change. This is contrary to the results obtained by Lacheheb and Sirag (2019) and Choi et al. (2018) who found that positive oil price shocks, had a greater and more substantial impact than negative ones which culminated in inflationary pressures. A similar result was also obtained with output growth.

The short-run result appears to suggest that a positive change in crude oil price is a more influencing factor on import demand; while a fall in output growth has more influence on import demand in the short-run.

The ECM result is presented in Table 14.6. The error correction terms (ECM) is negative and found to be statistically significant at the 1 percent thus providing additional evidence in favour of long-run relationships among the variables in the model.

Table 14.6: Error Correction Model (ECM)

Variable	Coefficient	Std. Error	t-Statistic
D(LNOP_POS)	-4.454***	2.019	-2.205
D(YG_NEG)	0.332***	0.120	2.755
D(YG_NEG(-1))	0.327***	0.130	2.499
COINTEQ*	-0.403***	0.077	-5.204

Note: Included observations: 41. Number of models evaluated: 162.
Selected model: ARDL (1, 1, 0, 0, 2).

14.6.3 Post-estimation Analysis

The results of autocorrelation, heteroskedasticity, and stability tests were conducted to validate the model. We checked for serial correlation using the residual serial correlation LM test and the Jarque-Bera, the results indicated that the residuals are free of autocorrelation. Also, Breusch–Pagan–Godfrey test show that there is no sign of autoregressive conditional heteroscedasticity. The test showed that the residuals from the model are homoscedastic; while

the Ramsey RESET tests indicated that the models are correctly specified since the F-statistics are not statistically significant.

Table 14.7: Diagnostic Tests

	F-statistic	
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.831	Prob. F(8,32) 0.581
Breusch-Godfrey Serial Correlation LM Test:	0.080	Prob. F(2,30) 0.9224
Jarque-Bera	0.167	0.919
Ramsey RESET Test	0.935	0.341

Source: Authors’ computation, 2024

The CUSUM and CUSUMSQ tests were used to test if the models are stable. In a stable model, the recursive residual is expected to be within the two critical bounds. The ARDL based on the ECM proves that our model is stable through CUSUM and CUSUMSQ tests indicated the Figures 14.3 and 14.4, respectively.

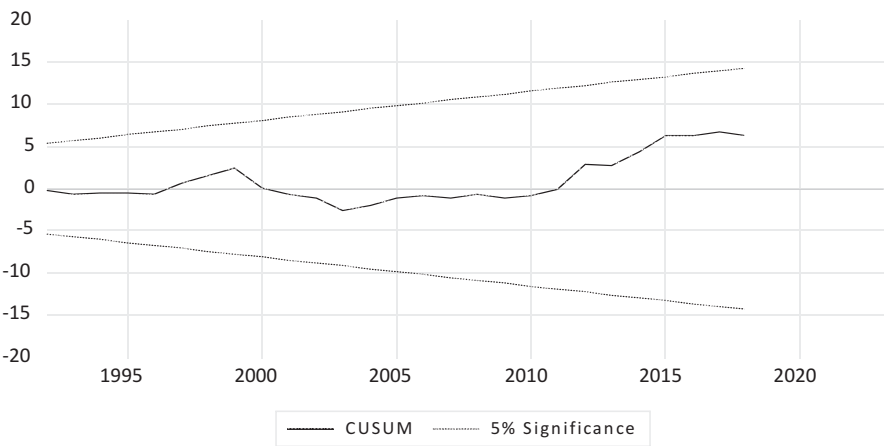


Figure 14.3: CUSUM

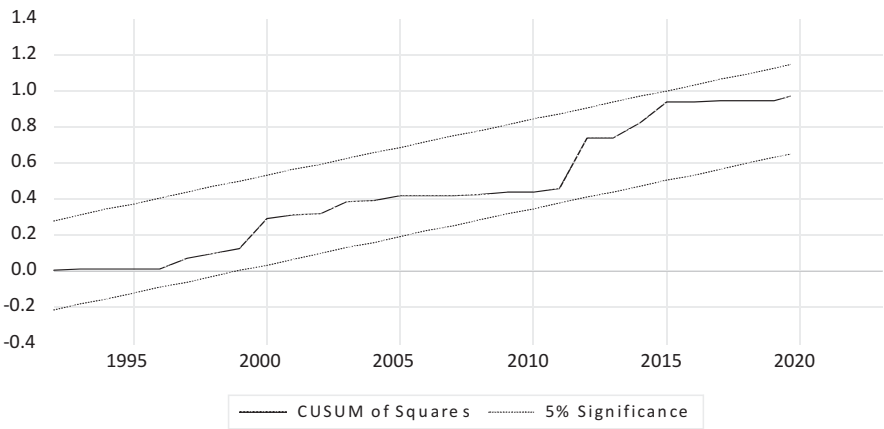


Figure 14.4: CUSUM squares

14.7 Conclusion and Policy Recommendations

The study underscores the asymmetric relationship between oil price changes and import demand in Nigeria. As oil price volatility continues to affect the country's economy, understanding these dynamics is crucial for developing effective trade and fiscal policies. It is more important now than ever for the policy makers to follow through on diversifying the economy and stabilizing its currency to reduce the adverse effects of oil price decreases on import demand.

Fluctuations in oil prices at the international commodities market tend to affect economies across the global. Global oil price shocks often impact domestic inflation through a number of channels.

Given that Nigeria is oil resources dependent for foreign exchange earnings and government revenues, this study investigated the impact of oil price changes on import demand in Nigeria. The study utilized the NARDL approach and annual data for the period 1980 to 2023. Empirical results from the asymmetric analysis indicated that oil price increases significantly impact on import demand in Nigeria.

The study confirm that oil price decreases have a larger impact on Nigeria's import demand than oil price increases, reflecting an asymmetric effect. This is contrary to a prior expectation due to

higher availability of foreign exchange during periods of rising oil prices, which makes imports cheaper and more accessible.

Conversely, during periods of falling oil prices, import demand may decrease as a result of reduced foreign exchange reserves, exchange rate depreciation, and higher import costs.

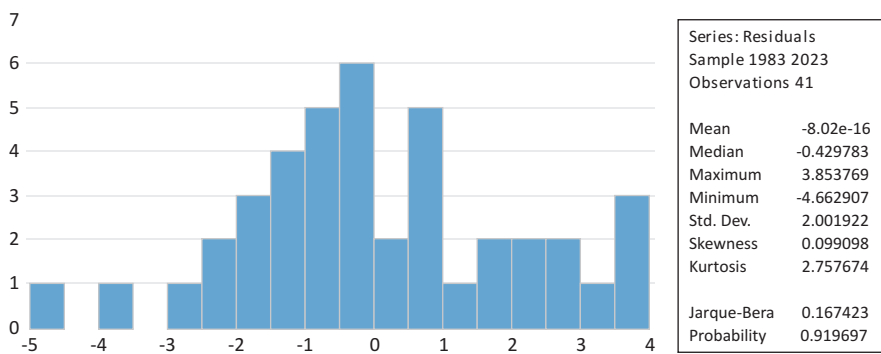
The findings will have significant policy implications. For instance, the government could explore strategies to mitigate the negative impact of oil price declines, such as diversifying the economy, building foreign exchange reserves during periods of high oil prices, and encouraging domestic production to reduce import dependency.

References

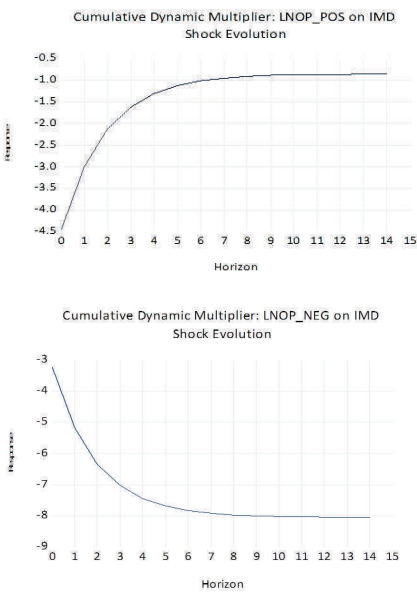
- Abubakar, Attahir B. (2019) "Oil Price and Exchange Rate Nexus in Nigeria: are there asymmetries," CBN Journal of Applied Statistics (JAS): Vol. 10: No. 1, Article 1.
Available at: <https://dc.cbn.gov.ng/jas/vol10/iss1/1>
- Akpan, E.O. (2009). Oil price shocks and Nigeria's macroeconomy. *Journal of Economic Research*, 14(2), 11-25.
- Bala, U., and Chin, L. (2018). Asymmetric impacts of oil price on inflation: An empirical study of African OPEC member countries. *Energies* 2018, 11, 3017, 1-21.
- Bawa, Sani; Abdullahi, Ismaila S.; Tukur, Danladi S.; Barda, Sani I.; and Adams, Yusuf J. (2020) "Asymmetric Impact of Oil Price on Inflation in Nigeria," CBN Journal of Applied Statistics (JAS): Vol. 12: No. 1, Article 5. Available at:
<https://dc.cbn.gov.ng/jas/vol12/iss1/5>
- Choi, S., Furceri, D., Loungani, P., Mishra, S., & Poplawski-Ribeiro, M. (2018). Oil prices and inflation dynamics: Evidence from advanced and developing economies. *Journal of International Money and Finance* 82, 71-96.
- Globaleledge (2021)
<https://globaleledge.msu.edu/countries/nigeria/tradestats> 2021.
10/18/2024.
- Hamilton, J.D. (2003). What is an oil shock? *Journal of Econometrics*, 113(2), 363-398.

- Ibrahim, M.H. (2015). Oil and trade balance in Malaysia: Is there asymmetric adjustment? *Energy Economics*, 50, 308-318.
- Ito, K. (2010). The impact of oil price volatility on macroeconomic activity in oil-exporting and oil-importing countries. *Energy Economics*, 32(2), 402-409.
- Lacheheb, M., & Sirag, A. (2019). Oil price and inflation in Algeria: A non-linear ardl approach. *The Quarterly Review of Economics and Finance* 73, 217-222.
- Mork, K.A. (1989). Oil and the macroeconomy when prices go up and down: An extension of Hamilton's results. *Journal of Political Economy*, 97(3), 740-744.
- Narayan, P.K., and Narayan, S. (2010). Modelling the impact of oil prices on Vietnam's trade balance. *Applied Energy*, 87(1), 356-361.
- Olomola, P.A., and Adejumo, A.V. (2006). Oil price shocks and macroeconomic activity in Nigeria. *International Research Journal of Finance and Economics*, 3(1), 28-34.
- Olawale, F., and Awe, O. (2019). Asymmetric effects of oil price shocks on Nigeria's government revenue and imports. *Economic Modelling*, 82, 110-120.
- Shin, Y., Yu, B., and Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. *Festschrift in Honor of Peter Schmidt*, 281-314.
- Usman, M. J., & Ugwuoke, O. U. (2024). Asymmetric Impact of Crude Oil Price on Domestic Price of Goods in Nigeria. *UNIZIK Journal of Agricultural*.

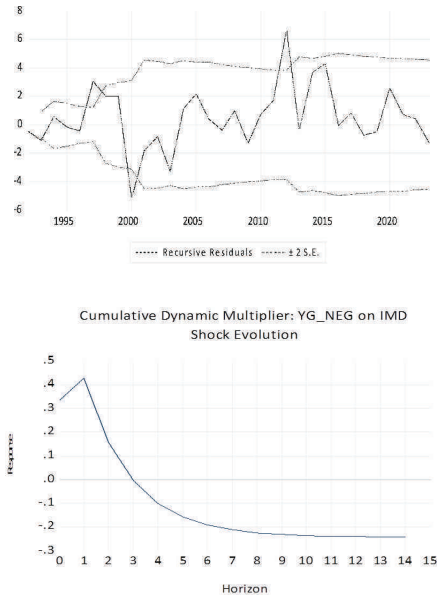
Appendix A.



Appendix B.



Appendix C.



www.naee.org.ng

Index



A

- Abikoye, Michael Oluwafemi, 5, 27, 141
Abuja, 7, 8, 13, 23, 173
Abubakar, R. I., 113
Accountability, 14, 22, 24, 38, 226
Adamu, Ahmed, 27, 201, 261
Adebayo, Aisha Omotolani, 27, 261
Adegbulugbe, Anthony O., 7, 13
 keynote speech by, xiii
Adelekan, O. A., 283-284, 290, 293, 297
Adenikinju, Adeola, xiv, 14, 27, 311
Adewumi, Magaji, Musa, 109
Adeyeye, O. Patrick, 189
ADF (Augmented Dickey-Fuller) test, 46, 98, 248, 324-325
Adom, P. K., 70
Africa

- energy access, 16
- energy poverty, 16-17
- GHG emissions, 17
- renewable energy potential, 20
- African Union Agenda 2063, 8, 69, 234, 236
- Akaike Information Criterion (AIC), 21-22, 99, 153, 325
- Aka, Akan, 198
- Akhbari, M., 282, 294
- Akpan, E. O., 319
- Akpasoh, A., 189-190
- Akram, R., 286, 294
- Akujor, C. E., 167, 170, 174
- Alaje, Paul, 27, 33
- Alamin, Mahmud, 27, 233
- Amakom, C. M., 167
- Aminu, O. R., 113
- Apergis, N., 40
- ARDL (Autoregressive Distributed Lag) model, 42, 89, 95, 99-102, 141, 150-151, 153-154, 321-322, 326, 328-329
- Asongu, S. A., 6
- Asymmetric impact, 311-312, 317-322, 330
- Auriacombe, C., 12, 14
- Awe, O., 318
- Awodumi, O. B., 16, 283-286, 291, 293-294, 297

B

- Babatunde, M. A., 91
- Badiru, Francisca Isibhakhomen, 5, 27
- Baker, L., 283, 286, 291, 293-294
- Bala, U., 327
- Bangladesh, 11, 144, 147-148
- Bawa, Sani, 327
- Belloumi, M., 70
- Bhuiyan, S., 6, 11, 13
- Bima, Fatima Isa, 27, 281
- Biofuels, 171-174, 264, 270-271

Biomass, 16, 18, 35, 90, 111-112, 172, 188, 190, 216, 223, 225, 264, 266
Biose, H., 205-206
Bordoff, J., 287-288, 298
Bound test (Bounds test), 99, 153, 312, 324-325
Brazil, 39-40, 189, 239
Brent, 268
Breusch-Pagan test, 17, 22-23, 27, 102-103, 328-329
Bridge, B. A., 113
Brini, R., 41

C

Carbon capture and storage (CCS), 219, 268-269
Carlsson, F., 12
Casati, P., 286, 289, 292-295, 298, 305-307
CBN (Central Bank of Nigeria), 27, 42, 93, 142, 281, 299, 312
Chakraborty, D., 146-148
Chen, C., 156
China, 40, 70, 114, 181-182, 192, 220-222, 239, 262, 264-265, 276, 315
Chipalkatti, N., 9
Choi, S., 328
Chourmet-Nkolo, J., 113
Clean energy, 17, 19, 34, 42-44, 47-48, 51-52, 110-114, 120, 128, 131, 134-136, 181-182, 190, 211, 224-227, 262, 284-285, 290-291, 294
Climate Change Act (Nigeria, 2021), 173, 223-224
Climate change governance (CCG), 7, 12
Climate change, 83-86
CO₂ emissions, 16, 21, 41-42, 47, 89-94, 103, 170, 192, 218, 236, 238, 244-246, 250-252, 268
Coefficient of determination (R-squared), 21, 25-27, 34, 43, 50-51, 78, 250, 303-304
Compressed Natural Gas (CNG), 171, 173, 201-202, 209-213, 226
Conference of the Parties (COP), 18-20, 166
Congo, Republic of, 233, 235-237, 241-243, 249-250, 255-256
COP26, 19
COP27, 166

Corruption, 16, 21, 28, 36, 38, 146
Côte d'Ivoire, 15, 26
COVID-19 pandemic, 93, 114, 262, 313-314
CUSUM (Cumulative Sum) test, 103, 156-157, 329-330

D

Dagnachew, A. G., 283-284, 286, 291-294, 297, 301-302, 305-307
Das, A., 144, 147-148
Davidson, O., 35
Decarbonization, 165-166, 168, 171, 174-175, 182, 290
Deforestation, 16, 18, 111, 212, 223
Delta State (Nigeria), 109-112, 115, 117-118, 121, 123-125, 127, 130-136
Denmark, 191, 194
Descriptive statistics, 18, 44, 97, 110, 121-122, 149-150, 245, 271, 282, 299-300, 304, 323
Dioha, M. O., 189, 215-216, 283-284, 286, 291-292, 295-296, 298
Dogan, E., 238
Dogo, Bishara Saidu, 5, 27, 141
Dossou, T. A. M., 285-286, 289, 291-293, 296-298, 305-307
Doytch, N., 70
Durbin-Watson statistic, 21-22, 24-27, 47, 51

E

Eco-modernization, 188
Economic Community of West African States (ECOWAS), 172-173
Economic growth, 14-16, 19, 21, 35-42, 48-53, 65-72, 75-79, 84, 88-94, 103-104, 144-145, 147, 182-184, 188, 218-220, 225-227, 233-239, 245-246, 249-251, 264-265, 268-269, 276, 282-283, 290, 297-298, 305-307
nexus between energy, governance, and, 38; nexus among electricity
Infrastructure, foreign direct investment and, 65-80
Economic prosperity, 83-85, 87, 91-92, 95, 101, 103-104, 233, 236, 298
Economy of scale, 183, 195-196
Edeminam, B., 189-190
Edomah, N., 283-285, 289, 291-292, 295-296, 305

- Education, 15-16, 28, 71, 109-110, 113-114, 119-122, 130-131, 133-136, 145, 147, 196, 216
- Effiong, E. L., 90
- Egwakhide, Mercy Ewea, 27, 181
- Egypt, 233, 235-238, 241-244, 249-250, 256, 262-264
- Ehiedu, V. C., 190
- Ekele, J., 184
- Ekpu, M., 205-206
- Electricity access, 16, 34, 47-48, 51, 113, 223, 235, 281-283, 285-287, 291-295, 298-308
- Energy consumption, 16-18, 21, 27-28, 35, 37, 40, 43, 67-70, 84, 89-90, 92, 101, 103, 112-113, 119, 167, 170, 174, 182, 184, 195, 218, 220, 238-239, 242, 245-251, 271, 293, 296, 302, 306
- dependency theory, 295-297
- efficiency, 16, 104, 170-171, 219, 266, 283-284, 291, 294-295, 305-308
- infrastructure, 35-36, 38, 195, 236, 282-286, 290-292, 295
- ladder theory, 112
- mix, 24-25, 167-168, 261-262, 264-269, 283, 285, 289, 296
- poverty, 15-16, 35, 38, 109-112, 215, 223, 234-235, 285, 291
- security, 14, 17-18, 205, 236, 251, 269, 283-289, 291, 305
- system transformation, 281-285, 290; challenges and opportunities of, 291-292; role of government, 292-293
- transition, 18-21, 171, 173, 189, 193, 201, 216-219, 223-227, 261-262, 268, 285, 288, 291-298, 302, 305, 307
- transition plans (ETPs), 19, 169, 171, 173
- Energy Transition Plan (Nigeria), 19, 169, 171, 173
- Entrepreneurship, 188
- Environment, 14-15, 21, 24, 38, 41, 52, 66-67, 79, 84, 109-111, 115, 142, 146-147, 173, 188, 190, 204, 217, 223-224, 293, 313
- Environmental degradation, 14-15, 84, 88-89, 101, 142, 182, 234, 238-239, 250, 252, 284-286, 291, 296-298, 306
- Environmental Kuznets Curve (EKC), 9-10, 88-90, 145, 238-239, 297-298
- Environmental Performance Index (EPI), 191
- Environmental sustainability, 14, 21, 27-28, 39, 84, 94, 104, 135, 183-184, 213, 216-217, 223, 227, 234, 251-252, 290, 295-298, 305-306
- Error Correction Model (ECM), 100, 151, 325, 328-329
- Ethiopia, 66, 233, 235-237, 241-244, 249-250, 258

Etokonza, Abdullahi Muhammad, 27, 201
Euro emission standards, 173-174
EU's Joint Research Centre (JRC), 192
Evans, O., 283, 286, 289, 291-293, 295-296, 298, 301-302, 304-307
Exchange rate, 141, 149, 155, 159, 282, 298, 300-303, 312-315, 317-321, 323-324, 327, 331

F

F-test, 34, 44, 50, 322
Fan, W., 78
Farhani, S., 41
Farzana, N., 145, 147
Feedback hypothesis, 15, 37, 40
Filho, Leal, 6-7, 12, 14
Fixed effects model, 5, 13-17, 22, 24-25, 27, 294
Foreign Direct Investment (FDI), 9, 65-71, 75-79, 83-84, 94-95, 97, 100-103, 237, 281-287, 289, 293-295, 298-307
Fossil fuel, 9, 24, 48, 91, 142, 166-168, 171, 173-175, 193, 203, 211-212, 216-220, 223-224, 227
demand with renewable integration, 261-262, 264-266, 268-269, 271-273, 276-277, 282-286, 291-298, 300-307
Fredriksson, P.G., 16
Frondel, M., 268
Fuelwood, 109-114, 119-120

G

Gas flaring, 90, 170, 225-226, 286
GDP per capita, 5-6, 14-15, 18-19, 21, 26-28, 149, 155
Generalised Method of Moments (GMM), 40, 65, 68, 70, 77
Gennaioli, C., 92
Geopolitical dynamics, 281-282, 284-289, 293, 296-297
Germany, 268
Ghana, 15, 19, 26, 42, 70, 113
Gielen, D., 237
Governance, 5-14, 24, 33, 36-38, 42-43, 66, 69, 111, 147, 186, 219, 223,

- 234, 236, 252, 268, 283, 288-289, 292-293, 296-297
 - energy sector governance, 38;
 - good governance, xxi, 6-11, 14, 33, 38, 42, 52, 268; in addressing climate change, 5-30; on economic growth in Sub-Saharan Africa, 33-57
- Government effectiveness (GEFF), 5, 13-15, 18, 21, 26-28
- Green bonds, 189-190, 194
- Green economy, 165, 181-185, 188, 192, 194-195, 197
 - in eco-modernization, 188-189
- Green Future Index (GFI), 192-193
- Greenhouse gas (GHG) emissions, 17-18, 41, 90, 166-171, 173-175, 216, 218, 220, 222, 227, 238, 266, 284, 292
- Gross Domestic Product (GDP), 17, 43-53, 66-67, 74-75, 88, 91, 93-95, 97, 100-101, 103-104, 149, 155, 170, 220-222, 233, 236, 238, 240-241, 245-247, 249-252, 264, 282, 321
- Gross Fixed Capital Formation (GFCF), 74-75, 77, 84, 94, 97-98, 100, 102-103
- Growth hypothesis, 15, 37, 40
- Gyamfi, B. A., 9

H

- Hafner, M., 238
- Hallegatte, S., 91
- Hamilton, J. D., 318
- Hammami, S., 238
- Hanif, I., 282, 285-286, 290-291, 293, 296-298, 305-307
- Hansen J-test, 78
- Hao, Y., 78
- Harrod-Domar model, 71-72
- Hasanov, A., 237
- Hassan, Mahmud Imam, 27, 65
- Hausman test, 17, 24-25, 27
- Heal, G., 91
- Heteroscedasticity, 102-103, 150, 156, 328-329
- Hochard, J. P., 92
- Holechek, J. L., 262
- Household energy choice, 109-136
- Human capital, 24, 52-53, 66, 71, 104, 205

Hussain, M. S., 237

Hyder, Md, 188-189

I

Ibekwe, K. I., 285, 291-292, 297, 301-302, 304-307

Ibrahim, M. H., 319

Ibrahim, S., 113

Ichedi, Winifred, 27, 233

Iceland, 193-194, 197

Ighosewe, E., 184

Iledare, Prof. Wumi, xiv, 14

Im, Pesaran and Shin (IPS) test, 46, 247

Import demand, 311-331

Inclusive financing, 183

India, 146-148, 220-221, 239, 269

Industrialization, 15-16, 24, 67, 88, 203, 215, 217-222, 225-227

Inflation, 74, 312-313, 318, 321, 327, 330

Infrastructure, 17-18, 20-21, 36, 38, 65-69, 72, 74-75, 77-79, 85, 87, 90-91, 135, 182, 195, 206, 217, 222, 224-225, 227, 235-236, 250, 252, 268, 282-289, 291-292, 294-296, 298-303

 electricity, 65-68, 71, 75-79, 90, 284, 294

 ICT, 75, 77

 road, 75

Innovation, 7, 15, 20, 71, 135, 188, 193, 197, 219, 224-227, 265, 283, 291, 305

Institutional quality, 5, 28, 219

Intended Nationally Determined Contribution (INDC), 170

Intergovernmental Panel on Climate Change (IPCC), 7

International Association for Energy Economics (IAEE), xiii, xxiii, 7, 13, 23

International Energy Agency (IEA), 17, 21, 35-36, 111, 166-167, 171, 236

International Renewable Energy Agency (IRENA), xx, 7, 20, 234, 237-238

Investment, 18-21, 24, 28, 38, 48, 53, 67-69, 72, 90-91, 94, 97, 100, 103-104, 145-147, 159, 182, 185-186, 189-192, 197, 224-227, 234-239, 241-243, 251-252, 268-269, 283-286, 289, 291-298, 302-307

IQAir, 192

Isah, A., 189
Isola, W. A., 27, 165
Ito, K., 319
Iwayemi, Prof. Akin, xiv, xxiii, 14, 23
Iyabo, A. O., 67, 74

J

Jakada, Khaleel, 27, 201
Jamaica, 145, 148
Jarque-Bera test, 18-19, 44, 97, 102-103, 149, 328-329, 333
Just transition, 216, 218

K

Kahia, M., 40
Karimi, S., 7, 11, 13
Karmaker, S. C., 145, 147
Kenya, 5, 15, 19, 27, 33, 42, 49-50
Kerosene, 110-112, 119-120
Khasru, Syed Munir, 183
Khobai, H., 67
Kim, H., 166
Kings, Timipre, 27, 233
Kitole, F. A., 114
Kocak, E., 40
Kolo, Musa Umar, 27, 201
Kumar, A., 283-284, 286, 291-292, 295-296, 298
Kuznets, Simon, 9, 88, 239, 297
Kweyu, R. M., 7-8

L

Labour force, 74, 84, 94, 101, 103
Lacheheb, M., 328
Lagrange Multiplier (LM) test, 20, 22, 103, 328-329
Lawani, D., 155

Le, H. T., 6-7, 11, 13-14
Leitao, N. C., 40
Lin, B., 40
Liquefied Petroleum Gas (LPG), 110-112, 120, 226
Lithium mining, 182, 184, 196
Lundström, S., 12

M

Mabrouk, N. B., 11, 13
Maduechesi, Ifeanyi Polycarp, 27, 109
Magbagbeola, N. O., 90
Mahmud, Dr. Hassan, xiv, xxvi, 7, 13-14, 23, 25
 welcome address by, xxiii
Maina, Y. B., 114
Mainimo, E. N., 114
Mainstream theory of growth, 39-42
Makonese, T., 114
Mamdam, Nanven Haruna, 27, 215
Mamdam, Yaknan Haruna, 27, 215
Marshall-Lerner condition, 320
Martins, T., 293, 296, 298
Mavikela, M., 67
Meadowcroft, J., 7, 12-13
MENA (Middle East and North Africa), 11, 40-41
Methane (CH₄), 201, 218
Migliorelli, M., 186
Millner, A., 91
Mobolaji, D. Akinbomi, 27, 165
Mohammed, Shuaibu, 27, 109
Mork, K. A., 318
Moss, T., 37
Moubarak, M., 40
Mperejekumana, P., 113
Multinomial Logit model, 110, 113, 120, 130, 136

N

- NARDL (Nonlinear ARDL) model, 311-312, 319, 322-326, 330
Narayan, P.K., 317-318, 322
Narayan, S., 70, 317-318
Nasarawa State (Nigeria), 201-204, 206-207, 209, 211-213
Nationally Determined Contributions (NDCs), 175, 283, 292, 295
Natural gas, 17-18, 186, 201-206, 208, 211-213, 223-225, 227, 262, 282, 285
Net-zero emissions, 165, 171, 173, 191
Neutrality hypothesis, 37, 40
New growth theory, 71, 188
Nicolli, F., 16
Nigeria
 energy dilemma, 215-227
 energy transition, 19, 171, 173, 189, 216, 223, 227, 283, 295-297
 transport sector, 168-170, 173-175
Nigerian Association for Energy Economics (NAEE), xiii, xxiii, 7, 13-14, 23, 25
Nigerian National Petroleum Corporation (NNPC), xxiii, 7, 23
Normality test, 51, 156, 158

O

- Obadina, O. B., 205-206
Obasi, Victory K., 27, 281
Obi, C., 282, 286, 292, 296
Odenu, Iruoghene Emohefe, 27, 109, 120
Odhiambo, N. M., 6, 36
OECD countries, 16, 66
Oguntuase, O. J., 190
Oil price, 42, 93, 112, 184, 283, 285-286, 295-296, 311-331
Ojapinwa, V. T., 146-148, 155
Ojonuga, O., 89
Ojukwu, K., 292
Okafor, Ikechukwu, 27, 201
Okeoma, T., 184
Olomola, P. A., 318
Olujobi, O. J., 142, 183, 203

Oluriola, Isaiah O., 28, 311
 Omojolaibi, A. Joseph, 190
 Omojimate, M. O., 291-292, 296, 305-307
 Omri, A., 11, 13, 36
 Omorogbe, Prof. Yinka (SAN), xiv, 14
 Ordinary Least Squares (OLS), 16-17, 21-22, 40, 44, 103, 114, 238-239, 249, 281, 299
 Orimoogunje, I. O., 111
 Osagu, Festus, 27, 311
 O'Sullivan, Meghan L., 287-288, 298
 Osunkwo, F. O., 68
 Oyedepo, S. O., 142
 Ozili, Peterson K., 186-187

P

Panel data, 5-6, 11, 13-16, 20, 22, 24-25, 34, 45-46, 74-75, 145, 233-234, 238, 247-250, 294
 Pao, H. T., 39
 Paramati, S. R., 16
 Paris Agreement, 33, 166, 170-171, 220, 261-262, 284, 292, 305-306
 Payne, J. E., 40
 Petroleum Industry Act (PIA, 2022), xxv, 25, 223
 Physical theory of production, 38-39
 Pinter, L., 91
 Policy recommendations, 5, 14, 28, 37, 90, 183, 195-196, 250-251, 306-307, 330
 Political stability, 24, 34, 42-44, 46-47, 49-53, 146, 283
 Pollution, 16, 88-89, 110, 170, 174, 185, 192, 194, 212, 223, 238, 250, 266
 Popoola, T. O., 113, 121
 Population dynamics, 233-236, 238-239, 245-246, 249-251
 Poverty, 14-17, 25, 35, 38, 91, 109-112, 114, 204, 206, 216, 222-223, 227, 234, 237, 285-286, 291
 Probit model, 110, 113-114, 130, 133-134
 Public-private partnerships (PPPs), 21

R

- Rahut, D. B., 113, 119
- Random effects model, 16-17, 22-25, 27
- Refined oil, 168, 171-172
- Regression analysis, 21, 25-26, 130, 249, 293-294, 299, 301, 304
- Remittances, 141-150, 152-156, 158-159
 - in addressing adoption of renewable energy, 141-159
- Renewable energy adoption, 21, 141-142, 144, 146-148, 155, 158, 233-234, 236-239, 245-246, 250, 276, 294, 305
- Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), 237
- Renewable energy sources
 - factors that can impede full adoption of, 265-266
- Renewable energy, 16-17, 19-21, 28, 34, 39-42, 44, 46-47, 49-51, 70, 84, 91, 103-104, 141-159, 166, 171-172, 183-186, 189-190, 193-197, 219, 225-226, 233-252, 261-262, 265-269, 273, 277, 283-284, 286-291, 293-295, 298, 305, 307
- Renewable integration
 - and energy mix, 266-268
- Resilience, 8, 11-13, 21, 28, 83-85, 87-88, 91-95, 103, 285, 290-293, 296-297
- Resource curse, xxiv, 24
- Road transport, 165-175
 - low-carbon, 172-175
- Romer, Paul, 71
- Rozenberg, J., 91
- Rule of law, 9, 24, 219
- Rural areas, 20, 111, 114, 117, 136, 223, 283

S

- Saidi, K., 238
- Saidu, Dogo Bishara, 5, 27, 141
- Sanusi, Gbenga Peter, 27, 311
- Sarkgunesi, A., 40
- Scott, A., 155
- Seker, F., 238

- Sekoni, Maryam Okikiola, 27, 181
 Seury, S., 145, 147-148
 Shaaban, M., 142
 Shahbaz, M., 9, 36
 Sharma, B., 70
 Shefiu, R., 7
 Shin, Y., 319, 322
 Siddique, M. A. B., 7
 Silva, S., 41
 Sirag, A., 328
 Smith, R. J., 322
 Sokona, Y., 35
 Solar energy, 20, 90, 182, 184-185, 195-196, 235, 238
 Solow growth model, 72-73
 South Africa, 5, 27, 33, 42, 49-50, 91, 233, 235-238, 241-244, 249-250, 268
 Soytas, U., 36
 Stability test, 59, 156, 328
 Stern, D. I., 16, 39
 Subramaniam, Y., 144, 147, 150
 Subsidy removal, 184, 195-196, 202
 Sub-Saharan Africa (SSA), 6-15, 27-28, 33-36, 42, 47-52, 65-69, 71-72, 75-79, 91, 113-114, 142, 167, 215-216, 235, 294
 Sunsuwa, Mercy, 27, 181
 Sustainable Development Goals (SDGs), 14, 19, 85, 144, 148, 190, 202, 204, 211, 213, 234, 236, 252
 Sustainable finance, 185-86
 theory of, 186-187

T

- Taherdoost, H., 118
 Technology, 20-22, 24, 36, 83-84, 94, 101, 103-104, 149, 155, 159, 188, 193, 216-217, 225, 266, 268-269, 293-295, 305-308
 Terrorism, 34, 46-47, 49-50, 53
 Thombs, R. P., 40
 Tinubu, Bola Ahmed, xxiii, 13, 23, 184
 Tractor (agricultural), 202, 206, 208-213

Transparency, 14, 21-22, 24-25, 28, 37-38, 194
Troell, 268
Troster, V., 41
Turkson, J., 35
Twumasi, M. A., 113

U

Udoakah, Y. O. N., 142
Uganda, 114, 192
Ugwuoke, O. U., 327
Umar, Yusuf, 28, 141
Unit root test, 46, 59-61, 98, 152, 247-248, 270, 272-274, 324
United Nations (UN), 18, 21, 68, 85, 166, 185, 188, 204, 212, 216, 234-236, 264
United Nations Environment Programme (UNEP), 173, 185, 188
United States (USA), 23, 220-222, 262, 264, 267, 269
Urbanization, 36, 88, 95, 145-147, 234-235, 252
Usman, M. J., 327

V

Vakulchuk, R., 287-288, 290, 292-293, 296-297, 305-307
Van de Graaf, T., 287, 289, 292, 296, 298, 305-306
Vona, F., 16
Vulnerability (to climate change), 5-6, 8, 11, 13-15



Dr. Mahmud Hassan is an economist, financial sector regulator, and central banker with over 30 years of financial sector regulation, policy research and public service experience. Before his retirement from the Central Bank of Nigeria in 2024, he was one time the Director, Trade and Exchange Department, as well as the Director of Monetary Policy Department during his career at the Bank. Prior to these roles, he was the Group Head, Macro-prudential Analysis in the Financial Policy and Regulation Department at the Bank. He also served at the African Union Commission, Ethiopia, as a technical expert and lead consultant on African trade integration and monetary Union. He currently serves on the Boards of many multilateral corporations, including the African Finance Corporation. He is a visiting scholar and faculty in many Nigeria Universities, including, scholar of Applied Macroeconomics at the Energy Business School of the Federal University of Petroleum Resources, Effurun, Nigeria, and a visiting Professor of Economics at the Baze University, Abuja, Nigeria. He has published many research articles in the fields of applied macroeconomics, Petroleum economics, Energy, Institutions, environment, Sustainability and Growth. He holds a MSc in Energy Economics and Policy and a PhD in Economics from University of Surrey, United Kingdom.



Prof. Yinka Omorogbe, Senior Advocate of Nigeria (SAN), has taught at the universities of Benin, Lagos, and Ibadan, and was previously a Research Professor at the Nigerian Institute of Advanced Legal Studies. She is an internationally recognized expert and consultant, primarily in energy law and policy, with numerous publications within and outside Nigeria. She is the CEO/ Founder, EtnPower Limited, a clean energy company that is focused on providing at least Tier 3 solar electricity to 100% of the people in the totally unserved communities within which it operates; and in promoting the use of modern energy as a catalyst for sustainable development. Prof. Omorogbe is Principal Partner of her specialised legal firm, Terra Cotta Legal Associates. She was Attorney General of Edo State (2017- 2020); Chairperson, Edo State Taskforce Against Human Trafficking., 2017- 2022; Adjunct Professor, Centre for Petroleum Energy Economics and Law (CPEEL) University of Ibadan (2013 -2018), Secretary to the Corporation and Legal Adviser, Nigerian National Petroleum Corporation (NNPC) (2009-2011); and Dean, Faculty of Law, University of Ibadan from 2005 - 2009. She was a member of the two Oil and Gas Sector Implementation Committees established in 2000 and 2008 respectively, by Presidents Obasanjo and Yar'Adua, to develop an optimal framework for the Nigerian petroleum industry. In the 2nd OGIC Committee she was Chairperson of the subcommittee that drafted the first Petroleum Industry Bill, submitted to the National Assembly in November 2008. She is the President, Nigerian Society of International Law, immediate Past President Nigerian Association for Energy Economics. She is Fellow, Institute of Chartered Mediators and Conciliators (FICMC); Fellow, Emerald Energy Institute (FEEL); and Fellow, Nigerian Association for Energy Economics (FNAEE). She is a Harvard Advanced Leadership Initiative Fellow 2021.



Professor Emeritus Wumi Iledare is a distinguished figure in the field of petroleum economics and policy research. He has held various prestigious positions, including the Director of Energy Information and Data Division at the Center for Energy Studies and the Executive Director of the Emmanuel Egbogah Foundation for Petroleum and Energy Industry Economics and Policy Advocacy. His contributions have been recognized with numerous awards, including the Distinguished Fellow of the Nigerian Association for Energy Economics and the USAEE Senior Fellow. Prof. Iledare's expertise spans oil and gas industry structures, exploration and production economics, environmental impacts, taxation, and regulation, and his research has been published in various academic and trade journals. His commitment to mentoring and reforming the petroleum industry has made him a respected and influential figure in Nigeria and beyond.



Professor Adeola Adenikinju holds a PhD Degree in Economics from the University of Ibadan, where he is currently a Professor of Economics. He is also a Research Professor at the Centre for Econometrics and Allied Research. Adeola was a Visiting Scholar to the International Monetary Fund (IMF) in 1996 and 2005. His research interests include Petroleum and Energy Economics, Economic modeling, and Economic Development Issues. He is the former President, Nigerian Association for Energy Economics and Head of Department, Department of Economics, University of Ibadan. He is currently the President, Nigerian Economic Society (NES). Adeola had served in several senior policy positions in his esteemed career. He was a Special Assistant to the Presidential Adviser on Energy Matters, between 2005 and 2007, and Senior Special Assistant to the President, Office of the Chief Economic Adviser to the President between 2010 and 2011. He was Gas Policy Analyst at the World Bank assisted Federal Government Project Gas-to-Power, between 2007 and 2009. In 2010, he served as the Technical Adviser to the Presidential Committee on Deregulation of the Downstream Petroleum Sector. He is a former Director, Centre for Petroleum, Energy Economics and Law (CPEEL), a MacArthur Foundation Regional Centre of Excellence at the University of Ibadan, Ibadan, Nigeria, and a member of the Monetary Policy Committee of the Central Bank of Nigeria. He has consulted widely for many international organisations on energy and economic issues in Africa and Nigeria.



Ben Obi, is a Professor in the Department of Economics, University of Abuja. Over the years he has acquired great knowledge in teaching and research, as well as consultancy. Between 2009 and 2011, he was a Senior Economist to the office of the Chief Economic Adviser to Mr. President. Prof. Obi, while under the Office of the Chief Economic Adviser was part of the team that developed the National M & E Framework under the then National Planning Commission and participated in various committees in the drafting of the Vision 2020: 20 document as well as the fifth National Development plan which happens to be the first implementation plan of the Vision 2020: 20. Prof. Obi was engaged by the then Ministry of Budget and National Planning-National Project Coordinating Unit for State Employment and Expenditure for Results Project (SEEFOR) as Change management consultant to the SEEFOR project covering Bayelsa, Delta, Edo, and Rivers State. Prof. Obi is an author and reviewer of several articles published in both local and international journals. He has reviewed several articles for the CBN's Economic and Financial Review (EFR). Prof. Obi is quantitatively analytical. He is computer literate, and belongs to various academic associations such as the Nigerian Economic Society (NES), Nigerian Association for Energy Economics (NAEE) an affiliate of The International Association for Energy Economics (IAEE) Where he is a fellow of the Nigerian Association for Energy Economics (FNAEE) and the current Vice President, Conferences & Publications. He is on the Network of African Economic Research Consortium (Kenyan), the Global Development Network (GDN, India), and International Development Economics Associates (IDEAS).



Obindah Gershon is an Associate Professor of Energy Economics and Sustainability at Covenant University, Nigeria. He is also a Visiting Professor at Eduardo Mondlane University, Mozambique; the University of Cape Coast, Ghana; and St. Jerome University, Cameroon. Furthermore, he is an Instructor at the African School of Regulation (ASR); the African Economic Research Consortium (AERC) and the FUPRE Energy Business School, Effurun. Previously, he taught Energy Economics at Georgetown University and chairs the Centre for Economic Policy and Development Research (CEPDeR). He obtained his Master's and PhD at the University of Dundee, UK, where he also researched, designed and tutored petroleum and energy courses at the prestigious Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP). He has extensive international experience and serves as the Director of the International Office and Linkages at Covenant University. He founded Global Resources and Clean Energy Limited, an energy and carbon trading consulting firm.

