NON-RENEWABLE NATURAL RESOURCE TRADE ON ENVIRONMENTAL DEGRADATION AND SUSTAINABILITY IN SUB-SAHARAN AFRICA

By

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201801843

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

MASTER OF SCIENCE IN ECONOMICS

Inthe Department of Economics

THE NATIONAL UNIVERSITY OF LESOTHO

2024

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DECLARATION

I declare that the work presented in this thesis is my own and has not been previously submitted for any other degree at the National University of Lesotho or any other institution. Except where acknowledged in the text, tables, figures, and appendices, this thesis is based on my original work. It has never been submitted for consideration for another degree that I pursued. I hereby state that, unless otherwise noted and recognized in the relevant sections, this thesis is entirely my solo effort.

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Date: 14/06/2024

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to the Lord for providing me with the wisdom and strength needed to complete this study. The divine blessings and guidance I received throughout this endeavour have been instrumental in helping me overcome challenges, find clarity in complex concepts, and navigate the intricacies of my research. I am deeply humbled by the divine presence that has illuminated my path, and I attribute my achievements to the providence that has been with me every step of the way.

I would also like to extend my heartfelt thanks to my esteemed supervisors, Mr. Letsie Mohatonyane and Mrs. Mohlori-Khothalo Sepamo. Your exceptional guidance, expertise, and unwavering belief in my abilities have been crucial in shaping the direction of my research and honing my analytical skills. I sincerely appreciate your patience with me, especially during the difficult moments, and your constant reassurance that I could succeed, even when I doubted myself. Your encouragement, understanding, and unwavering commitment to my academic advancement have not only deepened my understanding of economics but also transformed me into a more critical thinker and researcher. Additionally, I am grateful to my colleagues for their unending emotional support throughout this journey. Your camaraderie and encouragement have made this academic journey an extraordinary and transformative experience.

DEDICATION

This work is dedicated to my beloved mother, Mrs. Mapalesa Chesetsi, my sister, Palesa Chesetsi, and my grandmother, Mrs. Malimpho Mapeshoane. Your unwavering support, endless sacrifices, and boundless love have been the bedrock upon which I have built my academic journey. You have gone above and beyond to ensure that I have everything I need to achieve this degree, and for that, I am eternally grateful. Your strength and dedication inspire me every day.

I also dedicate this thesis to my younger brother. Your presence in my life has been a constant source of motivation and encouragement. I hope this achievement serves as an inspiration for you to pursue your dreams with determination and hard work. Know that with perseverance and dedication, you can achieve anything you set your mind to.

LIST OF ABBREVIATIONS

ANS - Adjusted Net Savings

ARDL - Autoregressive Distributed Lag

BEA - Bureau of Economic Analysis

BRI - Belt and Road Initiative

CO_2 - Carbon-dioxide

ED - Environmental Degradation

EKC - Environmental Kuznets Curve

EPI - Environmental Performance Index

ES - Environmental Sustainability

FDI - Foreign Direct Investment

FE- Fixed Effects

GMM- Generalized Methods of Moments

IMF - International Monetary Fund

LMDI - Logarithmic Mean Divisia Index

MIT- Massachusetts Institute of Technology

MRIO - Multi-Regional Input-Output analysis

NNR - Non-renewable natural resources

OEC - Observatory of Economic Complexity

OLS - Ordinary Least Squares

PHH - Pollution Haven Hypothesis

RE- Random Effects

SBI - Sustainable Budget Index

SDGs - Sustainable Development Goals

System GMM - System Generalized Methods of Moments

SSA - Sub Saharan Africa

SWF - Sovereign Wealth Funds

VECM - Vector Error Correction Model

WDI - World Development Indicators

WIOD - World Input-Output Database

WLMC - Wavelet Local Multiple Correlation

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ABSTRACT

The environmental impact of mining is well-documented; however, the specific effects of non-renewable natural resource trade on pollution emissions have received less attention, particularly in Africa. Sub-Saharan Africa heavily relies on exporting primary commodities vital to its economies. Nonetheless, this dependence challenges balancing economic growth with environmental sustainability, as resource extraction often leads to environmental degradation. As a result, little is known about how nations may protect the environment and experience faster economic growth through trade. Therefore, this study aims to investigate the impact of such trade on environmental degradation and sustainability, using carbon dioxide emissions and adjusted net savings as proxies, respectively. Utilizing balanced panel data from 17 resource-rich countries in Sub-Saharan Africa from 2010 to 2020 and employing the System Generalized Methods of Moments, the study finds that a percentage point increase in non-renewable natural resource trade significantly raises carbon dioxide emissions by 0.31 metric tons per capita at 1% level of significance. Additionally, a percentage point increase in trade is associated with 0.77 percentage points decline in environmental sustainability at 10% level of significance. The study recommends reinvesting resource export proceeds into environmental conservation to balance economic development with sustainability.

Keywords:

Adjusted net savings, carbon dioxide emissions, environmental degradation, environmental sustainability, non-renewable natural resource trade, sub-Saharan Africa

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CHAPTER ONE: INTRODUCTION

1.1 Background and Motivation

International trade of environmental goods and environmental sustainability (ES) are two crucial issues interconnected; much as these goods are exchanged between countries, sustainability has to be maintained. Pursuing economic growth through international trade often leads to increased production and resource extraction, contributing to environmental degradation (ED) in both the short and long term (Ssekibaala *et al*., 2021). The extraction of non-renewable natural resources (NNR) can lead to ED because it requires a significant amount of energy and because waste compounds are carelessly disposed of into the air, water, and land (Balcilar *et al*., 2023; Kwakwa *et al*., 2018).

Conversely, Huo *et al*. (2022) stipulated that ES is vital for the long-term viability of trade, as ecosystems provide essential resources and services that underpin economic activities. They further indicated a growing emphasis on incorporating sustainable practices into international trade agreements. Efforts to promote green technologies, enforce environmental standards, and promote appropriate resource management to balance economic growth and environmental protection foster a harmonious relationship between international trade and ES.

Almost every economic activity depends on the environment; natural stock is valuable as it supports social wellbeing and socioeconomic gains. If it could be destroyed or removed, everything would collapse. Recognizing the value of our natural resources is essential for maintaining both social well-being and economic prosperity. The United Kingdom (UK) Natural Capital Committee, according to AfDB (2023), defines natural capital as that aspect of the natural world that directly or indirectly supports human value. Natural Capital encompasses natural processes and functions, ecosystems, animals, oceans, waters, air, oi and gas, minerals and soils. For instance, the goods and services derived from the environment, such as minerals and water resources, are the foundation of many industries and households. These resources are essential inputs for producing goods and meeting the needs of society.

Even though mining, energy, and agricultural products that depend on the environment support global trade, an over-reliance on these sectors can weaken economies and impoverish populations, particularly in developing nations. It is essential to acknowledge that industrial activities often generate byproducts like air emissions and water residuals, containing harmful chemicals that can adversely affect the environment. Studies recognize that not only the consumption of goods and services influences people's well-being but also the quality of their surrounding environment. The environmental damage that is occurring now may harm future production (Heerink *et al*., 1993). Therefore, it is ethically essential to consider future generations when making current decisions. Since they cannot speak for themselves, the current generation must ensure that future generations benefit from the existing environmental and natural resources. The issue of ethics is associated with sustainability.

The main issue evident in Sub-Saharan Africa (SSA) lies in the highly concentrated nature of its exports (trade), principally consisting of a few primary commodities from the past decade; For instance, crude oil alone constituted approximately 45 percent of total exports between 2008 and 2014, while the top 13 products, all commodity-based, represented 71 percent of the region's total exports (Moussa, 2016). This export concentration underscores the excessive dependence of SSA economies on natural resources and reveals the vulnerability of their industrial sectors. What exacerbates the problem is that these primary commodity exports often involve low levels of value-added or processing, limiting the potential for investment in environmental offset projects. Mabey *et al*. (2020) indicated that unsustainable trade practices can lead to ED, deforestation, habitat loss, pollution, and natural resource depletion, directly affecting the region's ecosystems, wildlife, and the overall quality of life for its inhabitants.

Mining activities, particularly in the extraction of minerals, can result in greenhouse gas emissions and water pollution by releasing toxic chemicals and heavy metals. Kwakwa and Aboagye (2024) stated that from 1990 to 2022, the world emitted approximately 1.7 trillion metric tons of CO_2, with Africa contributing just 51 billion metric tons, accounting for less than 3% of cumulative global emissions as of 2020. Still on that, they highlighted that in 2021, Africa's share of CO_2 emissions stood at 4%, totaling 1.45 billion metric tons, and over the past two decades, the continent's contribution fluctuated between 3.4% and 4%, the smallest share among all global regions. Approximately half of the world's greenhouse gas emissions come from resource extraction and production. At the same time, over 90 percent of the effects on water stress and biodiversity loss due to land use are caused by these activities (Oberle *et al*., 2019). A significant portion of the production of copper, gold, iron ore, and zinc, between 30 and 50 percent, occurs in regions with high levels of water stress (Balcilar *et al*., 2023).

In addition to that, small-scale and artisanal gold mining severely impacts nearby water resources. Toxic mine waste contains hazardous substances like arsenic, lead, and mercury. Studies estimated that around 30% of mercury emissions globally come from artisanal gold mining, with SSA being a significant contributor (Savornin *et al*., 2007). On the same issue, small-scale and artisanal gold mining is a significant source of global mercury pollution, responsible for around 37% of anthropogenic emissions, surpassing other sectors like coal burning and non-ferrous metal production (Santana *et al*., 2014; Smits *et al*., 2023). Wang *et al*. (2023) confirmed that CO_2 emissions in SSA, often neglected in the past, have increased by

65.5% from 2000 to 2019; this rapid increase may lead to climate change, posing a substantial threat to the region.

This study examines the impact of NNR trade on ED and ES in SSA nations. The System Generalized Method of Moments (System GMM), a dynamic panel data econometric modelling technique, is used to analyse this impact. The findings underscore a concerning trend: not only does a percentage point increase in international trade (NNR exports) exacerbate ED, as evidenced by a significant increase in carbon dioxide (CO_2) emissions by 0.310 metric tons per capita at the 1% significance level, but it also diminishes ES within SSA. Notably, a percentage point increase in international trade is associated with a noteworthy decrease in ES by 0.77 percentage points . These results emphasize the pressing need for policy interventions that reconcile economic development with environmental preservation in SSA.

1.2 Problem Statement

The main contributing factor to SSA's economic and environmental problems is commodity dependence theory, which describes a nation's heavy reliance on exporting particular primary commodities, like minerals, oil, or agricultural items, for a sizable share of its income. The economic structures of these nations are frequently dominated by the extraction and exportation of these resources, making them highly dependent on the revenues generated from their sale. However, the effects of extracting exported natural resources on pollution emissions have received less attention. As a result, little is known about how nations may protect the environment and experience faster economic growth through trade (Khan *et al*., 2022).

UNCTAD (2023) corroborated that when merchandise export earnings coming from these raw materials are at a rate of 60% or more for specific countries, they are “commodity dependent.” For instance, as SSA’s second-largest oil producer, Angola is overly dependent on oil; in 2022, oil accounted for 26% of GDP, 62% of tax revenues, and 95% of exports (WBG, 2023). Although this kind of reliance is a worldwide issue, emerging SSA nations are heavily affected; the region is extremely susceptible to fluctuations in commodity prices because of its significant reliance on resource-based exports (Christiaensen *et al*., 2013). Most of these developing countries are endowed with natural resources. Still, they face several challenges, such as balancing trade and sustainability, as most rely heavily on extracting and exporting primary resources for revenue generation and neglect the ED that comes with it.

Moreover, most resource-rich nations on SSA do not consider how they use the money they make from NNR to ensure long-term sustainability. They may not be using the income from valuable resources like oil or minerals in the best way to benefit their countries in the future. In addition, developing nations possess weak institutional capabilities and environmental vulnerabilities, which have a detrimental influence on mining output and exports; as a result, the costs of the environment outweigh the advantages (Bimpong *et* *al*., 2022). To guarantee the sustainable exploitation of natural resources, they typically lack the resources or place little emphasis on enacting successful environmental laws.

Apart from that, foreign entities who take a larger share in SSA mining industries prioritize profit and exportation, they often neglect or insufficiently address the ED associated with trade practices (Andriamahery *et al*., 2022; Ssekibaala *et al*., 2021). This shortsighted approach neglects the long-term consequences of unsustainable trade activities on the region's ecosystems, natural resources, and overall environmental well-being. This approach jeopardizes the long-term viability of these ecosystems and the essential resources they offer, such as clean water and air. The focus on immediate profits overlooks the imperative of preserving these resources for future generations. Most importantly, colonization often resulted in the colonizing powers exploiting natural resources in colonized territories.

For international trade, particularly involving NNR, there has been a lot of focus on the economic gains it offers. However, this focus has often led to ED, undermining sustainability. There is a growing shift towards restoring the planet, and the present study aims to contribute to the scanty literature in this area. It is possible to harness the potential of international trade as a spur for environmentally friendly growth in the region while safeguarding its natural resources and ecosystems for future generations. Adopting environmentally friendly trade practices, such as promoting renewable energy and responsible resource extraction, SSA can achieve economic growth while minimising negative environmental impacts. Failure to address these issues risks the environment and undermines the region's population's long-term social and economic well-being.

1.3 Research Gap

To the best of my knowledge, the effects of mining on the environment have been the subject of several studies, for instance, (Emmanuel *et al*., 2018; Helios-Rybicka, 1996; Kříbek *et al*., 2014; Mabey *et al*., 2020). They found that mining operations, particularly those involving rutile, iron ore, and diamond extraction, have resulted in higher rates of crop damage, land degradation, and deforestation. In addition, these mining operations have directly resulted in low air quality, increased noise pollution, and insufficient access to clean water.

Alternative investigations examined the direct link between mining export and the environment, for example, Bimpong *et al*. (2022), but solely used gold exports as a measure for international trade and CO_2 emissions, forest cover, and greenhouse gas emissions are measures of the environment. Results suggested a causal connection between mining exports and environmental factors, with the environmental proxy variables influencing the specific nature of these causal links. Apart from that, studies like that of Khan *et al*. (2022) looked at how trade openness, innovation, and high-quality institutions affect ES, which was proxied by CO_2 emissions. The findings indicated a negative association between ES and trade openness, renewable energy usage, and foreign direct investment. Conversely, Huo *et al*. (2022) demonstrated that financial development, trade openness, and foreign direct investment all positively impact ES, measured by adjusted net savings (ANS).

There is a non-consensus in these results. It might be due to different measurements of both international trade (mining exports and trade openness) and ES (CO_2 and ANS) that may over- or underestimate how international trade affects ES. While both CO_2 and ANS capture aspects of environmental quality, ED, and ES, which are different yet used interchangeably in the literature. Even though CO_2 contributes to both global warming and ED, there is no proof that economic growth has lessened CO_2 emissions. These emissions are a critical factor in climate change; they may not capture the full spectrum of ES. Nevertheless, ANS captures the cost of natural resource deterioration by considering the exhaustion of natural resources and ED; it provides a more holistic view of a country's overall sustainability.

Countries have different contexts. Developed and developing countries export and import different commodities; it all depends on the factor and natural resource endowments, and the country's specialization depends on those endowments. It is crucial to compare the results of those with similar endowment structures. Lastly, the effect of NNR exportation on ED and ES in the context of SSA is understudied. No other study has thoroughly examined this topic, so this is the first to investigate the impact on both.

1.4 Research Objectives

This study will investigate international trade's impact on environmental degradation and sustainability in selected SSA countries using the ES indicator ANS. Specifically, the study aims to:

- Investigate the impact of non-renewable natural resources exports on environmental degradation in selected SSA countries.
- Explore the impact of non-renewable natural resources exports on environmental sustainability in selected SSA countries.

1.5 Research Questions

- What is the impact of non-renewable natural resource exportation on environmental degradation in selected SSA countries?
- What is the impact of non-renewable natural resource exportation on environmental sustainability in selected SSA countries?

1.6 Contribution

The present investigation adds to the prevailing literature by utilizing more comprehensive measures of international trade and ES. Instead of focusing on gold exports and trade openness like most studies for measuring international trade, the current paper uniquely uses diamond, gold, oil, and gas exports as international trade indicators. This is because SSA countries not only export gold but also export other resources they have in abundance; hence, it is crucial to assess their impact. The study focusses on SSA because developing countries that were colonized may still face challenges in internalizing negative environmental costs due to historical factors and limited resources, leading to overproduction or unsustainable extraction of environmental resources, as the focus may be on immediate economic gains rather than long-term ES and cost internalization.

The paper also emphasizes the distinction between ES and ED. At the same time, many researchers have focused on CO_2 emissions as an indicator of both variables and this study recognizes that ES and ED are separate dimensions and that CO_2 emissions alone may not adequately capture the overall sustainability of the environment. This indicates that most researchers have focused on ED rather than ES. This study has the potential to provide solutions to these developing countries, which seem to have low institutional capacity, by providing clear policies in the fields of trade of natural resources and ES. The findings would provide policymakers with evidence-based insights and recommendations. It would, therefore, inform the design of trade policies and agreements that balance economic growth with ES.

1.7 Organisation of the study

Chapter two gives the contextual background. Chapter three analyses the related literature on international trade, environmental degradation, and environmental sustainability. Chapter Four explains the data and methodology. Chapter Five presents results from empirical research, and Chapter Six presents the conclusion and recommendations.

CHAPTER TWO: CONTEXT

2.1 Introduction

This chapter presents an overview of the natural resources found in SSA and identifies the countries known for exporting NNR. It delves into the impact of these resource exports on the region's economy and environment, exploring whether these countries are moving towards a sustainable path or not.

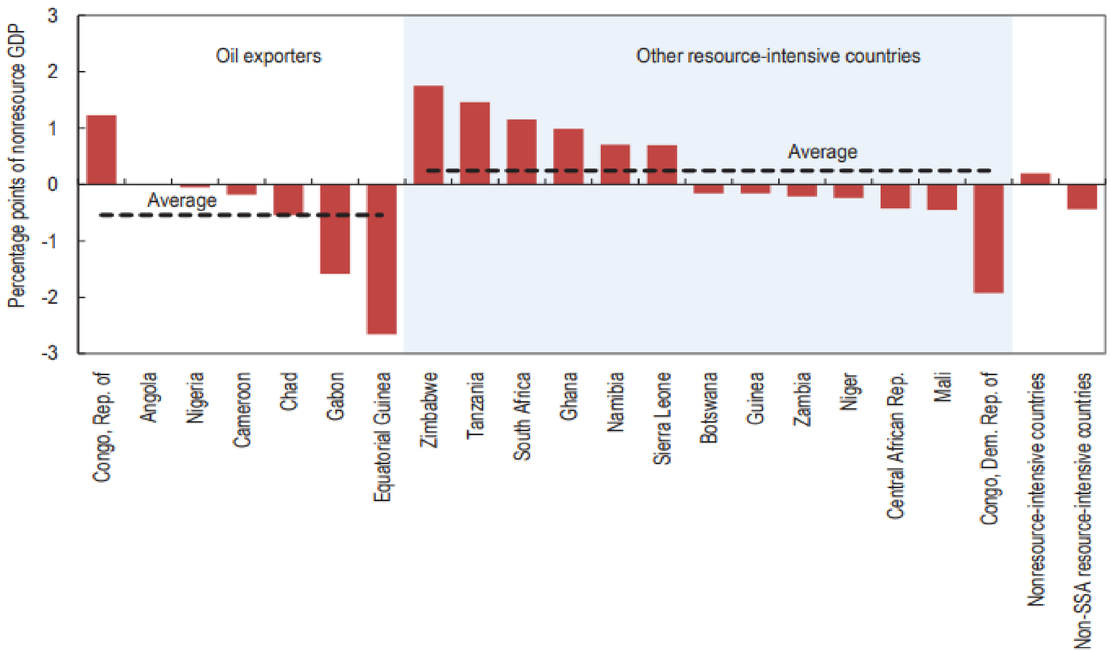
2.2 Contextual Background

Africa possesses abundant non-renewable and renewable natural resources, holding more than 30% of global annual production of several key minerals (diamonds (46%) and gold (22%)), with its natural capital valued at $6.2 trillion in 2018 (Urama, 2024). However, historically, these resources have consistently produced lower-than-potential returns. Two primary factors can lead to these resources yielding less revenue than their maximum potential: first, if the extraction of the resources does not optimize economic rents, and second, if, particularly in cases where foreign capital is engaged in the resource extraction process, the country that owns these resource riches does not receive a reasonable share of the resource rents (AfDB, 2023). If adequately and sustainably exploited, SSA (classification to 46 Africa's 55 countries) has the potential to generate revenue and wealth that can supplement climate finance for both adaptation and mitigation since it has plentiful natural resources.

For the past few decades, most emerging and less-developed countries have aimed to raise and accelerate their economic growth by expanding economic activities, including resource extraction and processing, agriculture, manufacturing, exports, imports, etc. Therefore, trade's impact on the environment, both locally and globally, depends on the countries' natural resource endowment (Soukar, 2019). Natural resources offer the foundation for life on Earth, which allows humans to exist, produce, survive, and make a living. Mineral deposits, forests, oil and gas reserves, and water resources are just a few of SSA's many natural resources. The exploitation of these resources began many years ago. Since the colonial era, there has been extraction and trade of minerals. In the late 19th and early 20th centuries, European powers formed gold and diamond mining operations in several African nations, including the Democratic Republic of Congo and South Africa, for copper and cobalt. In recent years, the discovery and extraction of oil and gas reserves have also become prominent in countries like Nigeria, Angola, and Equatorial Guinea. These resources have contributed to the region's economic growth and have been a significant source of revenue through exports and foreign trade.

International Monetary Fund (IMF) identified twenty SSA countries from 2005- 2010 as having abundant NNR, as shown in Figure 2.1. According to IMF (2010), a nation is "non-renewable resource-rich" if over 25% of its total exports are comprised of NNR, such as metals, minerals, and oil.

Figure 2.1: IMF Classification of non-renewable resource exporters in SSA



Source: IMF, African Department database; and IMF, Strategic, Policy, and Review Department survey data (IMF, 2010).

In SSA, the main exports of NNR are cobalt, copper, oil, gas, gold, diamonds, and other precious stones. The IMF grouping consists of two base metal exporters, two countries that export a mixture of mineral goods, seven oil exporters, and nine nations that export gold, diamonds, and other precious stones. Ten of these 20 resource-exporting nations rely on budgetary revenues from producing natural resources. NNR account for over 80% of the region's GDP, therefore, NNR rich countries form the engine of the SSA economy (IMF, 2010). Oxfam IBIS (IBIS 2014) mentioned that SSA exported US$288 billion worth of NNR in 2012, up from US$56 billion in 2002.

Kalaitzi and Chamberlain (2020), together with Venables (2016), acknowledge that countries with natural resources, such as the ones in the SSA region, have the potential to specialize in their extraction and exportation. Because of its large deposits of fossil fuels, Nigeria continues to be the wealthiest country in SSA regarding NNR (oil and gas); in 2018, the total estimate of these reserves was $582.4 billion (AfDB, 2023). Again, the same author stated that out of the 53 African nations for which data was available, 14 saw a reduction in the value of non-renewable natural capital, suggesting a potential depletion of specific minerals, such as gold and diamonds, as in Botswana.

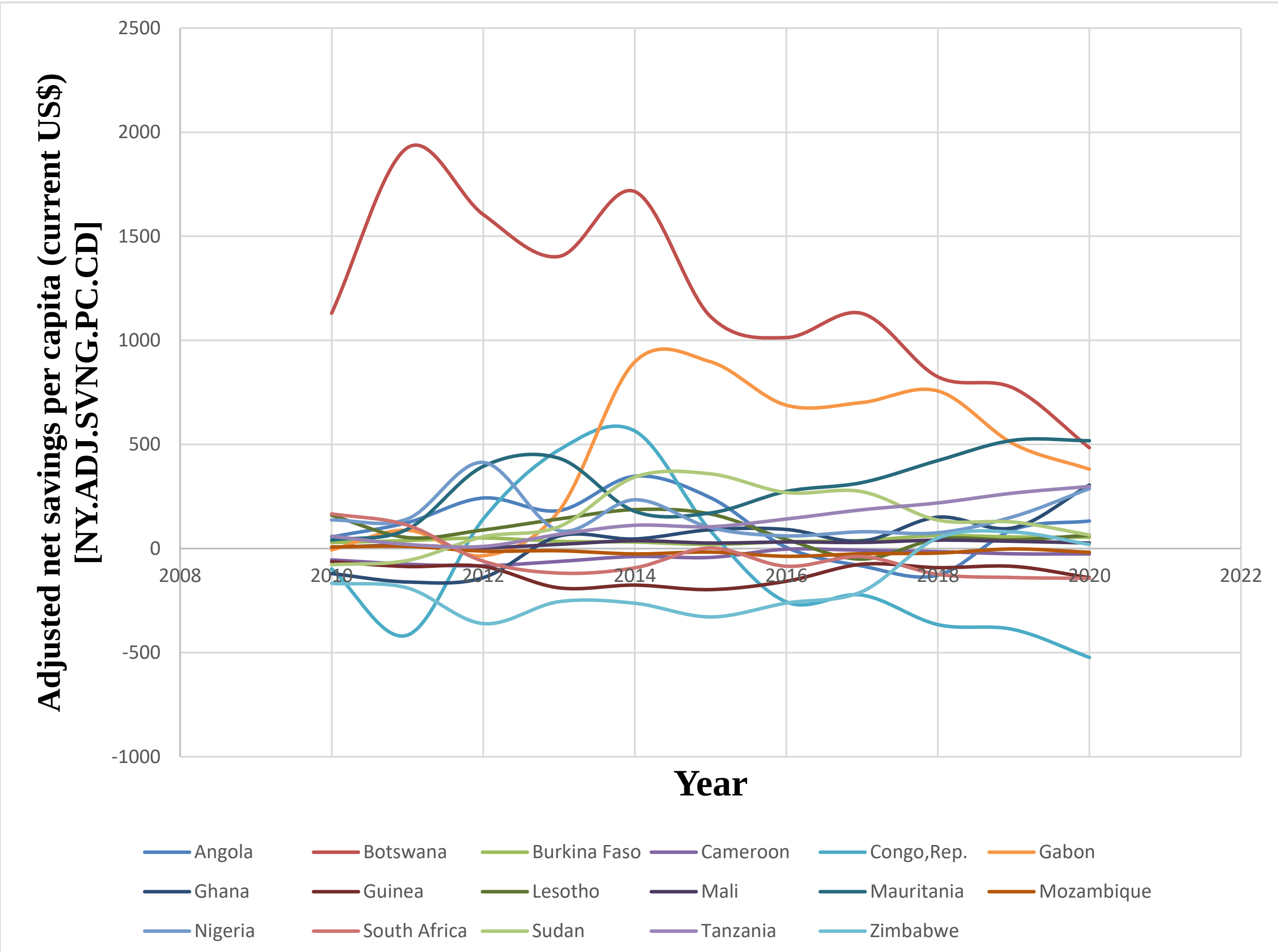
The state can maintain the value of natural capital by employing royalties or taxes based on value to influence techniques for extraction in the direction of optimality. Despite the significant economic benefits of oil and mineral extraction, information asymmetry about production costs, typically overstated, limits corporate tax receipts throughout the SSA region. By 2020, the top four countries that produce oil in SSA exhibited the following ratios of rent to GDP: Nigeria at 4.4 percent, Angola at 24 percent, Congo at 31.9 percent, and Equatorial Guinea at 15.6 percent. Conversely, the ratios of mineral rent to GDP were typically significantly lower, varying from 0.1 percent in Botswana and the Central African Republic to 7.2 percent in Mali (AfDB Group, 2023).

IBIS (2014) analyzed data from 2012 and 2013 and showed that, as of October 2014, seven more nations – Mozambique, South Sudan, Sudan, Burkina Faso, Liberia, Mauritania and the Ivory Coast (Côte d'Ivoire). fall into the resource-rich countries category based on the previously established IMF criterion.In other words, the number of SSA nations designated as resource-rich increased significantly to 27 in 2014, and four more countries are likely to join the group. According to the resource-rich definition, Lesotho can be among the four countries because its diamond exports account for 34.8% of total exports.

Figure 2.2 below shows the ANS or Genuine Savings 11-year trend, frequently suggested as a critical measure for assessing sustainability. A positive value implies that a country saves more than depleting natural resources and capital, signalling sustainable development. Nonetheless, a negative value suggests that the nation is consuming its wealth more quickly than it is investing, indicating potential challenges and unsustainability in economic and environmental practices.

Countries like Guinea, Zimbabwe, Mozambique, and Congo Rep (recent years) registered a negative average ANS from the graph. At the same time, Nigeria had zero ANS from 2015-2010, to be specific, and Botswana and Gabon registered positive values. Botswana introduced a Sustainable Budget Index (SBI) to pursue sustainable development and economic stability. This index measures recurrent (non-investment) spending ratio to non-mineral revenues. An index value of 1 indicates that mineral revenues partially fund recurrent expenditure. In contrast, a value below 1 suggests sustainability, meaning non-recurrent revenues (from minerals) are being saved or invested in public sectors like education. Other African nations can draw lessons from Botswana's careful fiscal management of its mineral wealth.

Figure 2.2: Annual Adjusted Net Savings per capita for selected SSA Resource Exporters



Source: Own computation using World Development Indicators (WDI) data for seventeen SSA natural-resource-rich countries based on non-renewable natural resource exports and data availability. The data used covers ten years (from 2010 to 2020).

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

This section explores a variety of theoretical perspectives, focusing on theories related to the trade of NNR, the nature of these resources, and their connection to trade and economic growth, which leads to environmental degradation and hinders environmental sustainability.

3.2 Theoretical Framework

3.2.1 Theory related to the trade of non-renewable

The movement of money, products, and services across international borders or between nations is referred to as international trade (Grozdanovska *et al*., 2017). It involves importing and exporting various commodities and resources to meet the needs and demands of different nations. One aspect of international trade that is particularly relevant is the exportation of non-renewable natural resources. These resources are often extracted from one country and sold to other nations that require them for their economic activities. Their exportation plays a significant role in global trade. Countries with abundant reserves can capitalize on their resources by supplying them to needy countries. However, it raises concerns about sustainability, environmental impact, and the long-term implications of relying heavily on finite resources.

Traditional trade theory, often associated with the Heckscher-Ohlin (H_O) model, highlights the role of factor endowments in determining comparative advantage and promoting international trade (Cho & Moon, 2000). Based on this theory, nations focus on producing goods and services that use their abundant factors of production, leading to increased efficiency and the maximization of global social welfare. Simply put, WTO (2010) indicates that a nation typically exports goods that rely heavily on its abundant and, therefore, less costly factor of production, while it imports goods that heavily depend on its relatively scarce and hence more expensive factor of production.

According to Davis (2010), production will only occur in nations with substantial resource endowments if export is possible. The theory still holds when considering differences in commodity endowments, particularly in countries endowed with non-renewable natural resources (capital-intensive goods). Countries with abundant natural resources may have a comparative advantage in industries extracting, processing, and exporting those resources. For instance, Davis (2010) further mentioned that Leamer's analysis of trade patterns between 60 countries between 1958 and 1975 indicates that an abundance of oil relative to other commodities leads to net exports of petroleum and petrochemical products, while a surplus of coal and minerals leads to net exports of raw materials. This specialization allows countries to allocate their production factors more efficiently, as they focus on industries where they have a relative abundance of specific resources, such as natural resources or capital.

3.2.2 Theories of non-renewable natural resources

Natural resources exist naturally in the environment, not manufactured, and no technology is needed or used to make them. Natural resources have two main categories: renewable and non-renewable. AERC (2020) stated that renewable resources can replenish over time through biological processes or because they are perpetual in nature, such as flow resources. These resources emanate from living organisms and organic materials, including plants and animals. However, the study primarily focuses on NNRs or stock resources.

NNRs are created through geological processes spanning millions of years. As a result, they exist as finite reserves that, once depleted, cannot be replenished (Perman *et al*., 2003). A key characteristic of NNR lies in their limited availability, with the extraction and consumption processes today causing irreversible changes to the extraction and consumption options for future generations. Since no natural reproduction is needed for them to be there except the geological timescales, all NRRs are critical zone resources, meaning that human action is essential to the availability and persistence of these resources. The amount that one generation consumes now reduces the one that future generations will consume since they cannot grow over time (they are not perpetual).

The conventional trade model mentioned earlier does not explicitly tackle the challenge posed by the exhaustibility of these resources and the trade-offs across different periods. Comprehending the influence of trade on the utilization of non-renewable natural resources requires moving beyond the conventional Heckscher-Ohlin model and embracing a dynamic approach that considers the evolving availability of finite resources over time (WTO, 2010).

Halkos and Papageorgiou (2008) stated, “In the Economics of non-renewable resources arisen by the famous article of Hotelling (1931), every resource mined without the possibility to regenerate, also including the forests, is referred to as exhaustible or depletable resources.” If they continue to be extracted and exported, society will eventually run out of them. Thus, considering intertemporal trade-offs, the hotelling rule forecasts how pricing and extraction pathways would behave (Perman *et al*., 2003). The way countries utilize these resources today directly affects their availability for tomorrow. Therefore, the usage pattern over time is just as significant as the immediate consumption. WTO (2010) explained that according to the rule, the social optimum occurs when the price of a resource, adjusted for extraction costs, increases at a rate that matches the interest rate.

3.2.3 Growth, trade, environmental degradation, and sustainability linkage

All economies need to grow to improve living standards. Regions endowed with abundant natural resources often rely on those resources for economic development, as the availability of rich natural resources typically facilitates economic growth (Li *et al*., 2023). The sustainability of the economy can be maintained even if living standards are low and remain stagnant over time as long as they do not deteriorate further (AERC, 2020). However, economies might destroy the environment as they aim to achieve growth. Copeland (2013) mentioned that a nation possessing a comparative advantage in environmentally sensitive industries might undergo an export boom, exerting a substantial environmental burden and potentially leading to its degradation.

3.2.4 Trade on environmental degradation

3.2.4.1 Environmental Kuznets Curve (EKC)

The EKC hypothesis describes a relationship characterized by an inverted U-shaped curve between ED and per capita income, often considered a measure of economic growth. Initially, the quality of the environment deteriorates as economic growth increases but eventually improves after reaching a certain threshold of economic development (Fang *et al*., 2018). While free trade advocates acknowledge the environmental challenges, especially concerning externalities or weak property rights in the exporting countries, they typically suggest that these problems will resolve themselves over time. In particular, they contend that as trade liberalization boosts incomes, and these higher income levels will lead to increased efforts towards environmental conservation (Tietenberg & Lewis, 2018).

In line with the countries under this study, the rise in per capita incomes correlates with increased trade of natural resources. This boost in the exportation of environmental goods due to free trade can have a positive ripple effect on the economy, improving the current account balance as they are part of merchandized exports; the overall balance of payments improves, contributing to a better economic situation. The theory posits that the environmental issues associated with unrestricted trade will auto-correct over time; environmental protection will be encouraged by rising earnings brought about by freer trade.

Copeland and Taylor (1994) pointed out that the environmental consequences of trade differ significantly from those of economic growth, notwithstanding the strong correlation between trade, income, and economic expansion demonstrated by many theories and data. Without environmental regulations, economic growth will eventually exacerbate pollution levels. However, as prosperity increases, there is a growing desire for higher-quality environmental conditions. The income elasticity of demand for environmental quality dictates the overall impact conveyed by the EKC. If the income elasticity of demand for environmental quality equals 1, governments will enhance environmental policies as pollution worsens.

Consequently, the effects of scale and technique offset each other, resulting in neutral economic growth and no change to environmental quality.

In the context of this research, the scale effect describes how trade affects the degree of economic activity and its potential environmental consequences. When trade liberalizes and economic activity increases, a larger production scale can strain the environment more. This effect is due to the understanding that more trade openness results in greater economic activity, as an economy grows and industrial output expands, there is greater demand for energy, raw materials, and production processes which include increased extraction and processing of resources and overall creation and utilization of goods and services. Considering that these activities involve environmental costs, such as pollution and resource depletion, the scale effect implies that greater economic activity resulting from trade openness can worsen the quality of the environment (Le *et al*., 2016). This effect highlights the role of changes in output levels on emissions. Even if the composition and technique effects (related to the types of goods produced and the technology used) were zero, emissions could still increase in so-called "pollution havens" simply because output levels have increased.

On one hand, the composition effect represents how a change in the mix of industries within an economy can reduce environmental degradation, especially in more advanced stages of economic growth. As economies grow, the structure of production tends to shift. In the early stages of development, economies often rely on resource-intensive and polluting industries such as manufacturing, mining, and heavy industry. However, as income levels rise and economies become more advanced, the composition of production may shift towards less polluting sectors like services, technology, and high-value-added manufacturing. This shift reduces the overall environmental burden because these industries tend to produce fewer emissions per unit of output.

The technique effect captures improvements in technology and production processes that result in more efficient use of resources and less pollution. As income levels rise, societies demand higher environmental standards and are willing to invest in cleaner technologies. Governments may also impose stricter environmental regulations, which force firms to adopt greener production methods, reduce emissions, and improve resource efficiency. As economies advance, the technique effect can outweigh the environmental damage caused by the scale of production, leading to an overall reduction in pollution even as output continues to grow.

Together, the scale, composition, and technique effects explain the inverted U-shape of the EKC. In the initial stages of economic growth, the scale effect dominates, as increased production and consumption lead to higher levels of pollution. However, as economies grow and reach middle-income status, the composition effect starts to take over, with a shift towards less polluting industries. Finally, in the advanced stages of development, the technique effect becomes more pronounced, where cleaner technologies and stricter environmental regulations significantly reduce pollution levels. This combination of effects explains why pollution rises during the early stages of growth but eventually declines as economies transition toward higher-income levels and more sustainable practices.

3.2.4.2 Pollution Haven Hypothesis (PHH)

According to PHH, developing nations with ineffective environmental standards or lax enforcement may attract foreign investment that minimises pollution abatement costs and maximizes economic gains. As a result, foreign direct investment (FDI) could worsen pollution in the host countries (Fang *et al*., 2018).

The theory arises from the interaction between trade costs and environmental regulations. When trade barriers are less, it becomes easier and more profitable for industries to transfer production to nations with weaker environmental regulations. These countries may offer lower labour and production costs, less strict regulations, or limited enforcement of environmental laws. As a result, companies can save money by relocating their operations to these countries, where they can produce pollution-intensive goods more cheaply. Due to international trade and FDI, emerging countries become havens for pollution from advanced countries. The rationale behind this hypothesis is that environmental regulations increase production costs for industries with pollution-intensive processes.

In line with this study, SSA countries attract FDI due to their abundant natural resources, particularly when mining licenses granted to foreign entities. Unfortunately, this symbiotic relationship often results in environmental degradation as foreign firms prioritize extraction and exportation without adequate concern for the local environment. The primary goal for these foreign investors is to exploit the available resources and export them back to their home countries. Consequently, the environmental impact of such activities, including pollution and ecological harm, is often neglected. The consequence is a cycle where these nations, rich in natural resources, endure several environmental damages.

The hypothesis suggests that when trade costs decrease, countries with lower environmental standards draw the production of goods with high pollution levels from nations with stricter environmental regulations. This is because lower environmental standards in certain countries make it more cost-effective for industries to produce goods that generate significant pollution. As a result, industries that produce pollution-intensive goods may move their operations to nations with less stringent environmental regulations to reduce expenses.

3.2.5 Trade on environmental sustainability

3.2.5.1 Sustainability concept

Sustainable development is development that meets the present needs without endangering the ability of future generations to meet their own (WECD, 1987). In resource management, sustainability extends beyond the immediate extraction, exportation, and utilization of resources. It encompasses the responsibility to ensure that the benefits derived from these resources are enduring and contribute to the environment's and society's long-term well-being. The essence of sustainability lies in leaving a positive legacy that persists even after the primary resources are no longer available. Consider mining as an example, it could be argued that while mining and exporting minerals are essential for economic development, sustainability involves envisioning and implementing practices beyond the immediate gains from resource exploitation, focusing on long-term benefits and positive contributions to society and the environment. It is about creating a legacy that future generations can inherit and build upon, ensuring that the impact of resource utilization remains positive and lasting.

South Africa's City of Gold is a notable example of deriving sustainable value from resources. While gold extraction has been a significant part of South Africa's history, the sustainability aspect lies in developing a thriving urban centre, Johannesburg, known as the City of Gold. This city, borne out of the wealth generated from gold mining, represents a lasting and diversified legacy. It is a testament to the notion that even when the gold resources may diminish, sustainable outcomes, such as urban development and economic diversification, continue to endure.

Additionally, Norway has one of the largest Sovereign Wealth Funds (SWFs) globally, holding approximately US$0.5 trillion in total assets, primarily derived from the state's share of oil and gas revenues (Ekeli & Sy, 2010). The Norwegian SWF serves as a model for harnessing volatile petroleum revenues to secure wealth for future generations, emphasizing the need for other natural-resource-rich nations to contemplate establishing an SWF to achieve sustainable growth. Implementing the Hartwick rule emerges as a crucial strategy in this pursuit. Ekeli and Sy (2010) noted that Norway's experience provides a valuable benchmark for SSA's natural-resource-rich countries, where natural wealth constitutes a substantial 50 percent of total wealth, surpassing the 9 percent attributed to oil wealth in Norway. However, these authors mentioned that SSA faces challenges, with intangible wealth accounting for only 35 percent of total wealth, indicative of a lower return on assets than typical developing countries.

Countries can achieve a sustainable wealth distribution by analyzing the changes in the value of natural capital per person over time. While the World Bank's weak sustainability concept demands that the per capita value of all capital be unchanged, the strong sustainability concept requires that the physical stock of natural capital remain unchanged. Despite achieving weak sustainability in all regions in the past quar]ter-century, Africa stands out as the only continent that has not undergone sustainable growth in per capita terms during this timeframe, which means that more needs to be done to achieve sustainability.

As a "rule of thumb," Hartwick in 1977 demonstrated that to achieve sustainability, a portion of the profits, more precisely, all revenues generated from exploiting non-renewable resources, must be reinvested in produced assets (Atkinson, 2001). The rule contends that sustainable growth is possible even when dependent on non-renewable resources. It mandates that any non-renewable resource extraction sector rent be set aside and invested in reproducible capital (AERC, 2020). Simply put, the resource rents from non-renewables (income generated from depleting NNR) should be saved and invested into other forms of capital, such as physical or human capital. The rule suggests that investment in reproducible capital must always be equal to the total rents arising in the resource extraction industry.

3.3 Empirical Review

Numerous studies have examined the linkage between international trade and environmental sustainability in different countries, and according to the relevant empirical literature, the current investigations are conflicting. Between these characteristics, some research found a positive link; others found no effect, while others found an adverse relationship. For instance, Khan *et al*. (2022) examined, using Ordinary Least Squares (OLS) fixed effects and extended technique of moments regressions, the links between innovation, trade openness, and elite institutions in ES in a sample of 176 countries. The results show that trade openness, has a negative relationship with CO_2 emissions, which most studies use as a measure of ES.

3.3.1 Synopsis of studies on trade, economic growth, and environmental sustainability

Shahbaz *et al*. (2013) utilized time series data from 1965 to 2008 to investigate the relationship between financial development, economic growth, coal use, trade openness, and environmental performance in South Africa. The authors used the error correction method (ECM) to look at short-run dynamics and the Autoregressive Distributed Lag (ARDL) bounds testing approach to examine the long-run relationship among the variables. They confirmed that trade openness improved environmental quality by decreasing the growth of energy pollutants. The study also verified the existence of EKC.

While trying to answer the question as to whether economic growth, international trade, and urbanization uphold ES in SSA countries, Iheonu *et al*. (2021) studied the influence of economic growth, international trade, and urbanization on CO_2 emissions based on data from 1990 to 2016 for 34 SSA countries. The methodology used in the research to account for the current amounts of CO_2 emissions in the region were panel quantile regression analysis. The empirical results showed that in nations where CO_2 emissions are now at their lowest and highest points, trade increase ES; however, the effect reverses at the median CO_2 emission level. The study also found a two-way causality between CO_2 emissions and international trade.

In a different research, Nepal *et al*. (2021) looked into the linkages between energy security, economic expansion, and ES in India between 1978 and 2016. Based on the EKC hypothesis, the study used a multivariate framework. Granger causality tests and time series econometric modelling, including the ARDL model and Vector Error Correction Model (VECM), were employed in the methodology. The study's key conclusions demonstrated a significant long-run relationship between trade openness, and CO_2 emissions.

Baajike *et al*. (2022) employed the Generalized Methods of Moments (GMM) approach from 2005 to 2018 to examine the influence of economic growth, trade liberalization, and financial development on ecological health in West Africa. Their findings indicated that while trade liberalization negatively impacts ES (contrary to previous research), it can foster it in the presence of effective institutions and a well-regulated market. In contrast, Ertugrul *et al*. (2016) uncovered that while trade openness positively affects carbon emissions in India, China, Indonesia, and Turkey, its impact on environmental conditions in Korea, Thailand, and Brazil remains inconclusive, highlighting the composite relationship between international trade and environmental outcomes.

Expanding upon existing literature, Adebayo (2022) delved into the interplay among ED, economic growth, coal consumption, and natural resource misuse in China. Using data from 1970/Q1 to 2020/Q4, the study employed the Wavelet Local Multiple Correlation (WLMC) method to investigate the time-frequency nexus. This technique offered insights into the dynamic relationships between these variables across various frequencies. The results confirmed that natural resource utilization and economic growth consistently contributed to CO_2 emissions across all frequencies, highlighting a trade-off between conservational sustainability and economic expansion in China.

Khan *et al*. (2023) examined the interconnectedness among natural resources, renewable energy consumption, economic growth, and CO2 emissions within countries involved in the Belt and Road Initiative (BRI). Focusing on 35 BRI participant nations and applying data from 1985 to 2019, the study employed various regression models, including OLS fixed effects, GMM, and separate regression models. The findings revealed that CO_2emissions and renewable energy consumption acted as catalysts for economic growth, whereas natural resources had an unfavourable effect on economic expansion. Additionally, economic growth and natural resource utilization were positively associated with CO_2 emissions, while renewable energy consumption exhibited a significant reduction in CO_2 emissions.

3.3.2 Synopsis of Studies on international trade and environmental sustainability

Frankel and Rose (2005) investigated the relationship between international trade and ES by focusing on trade's impact on a country's environment for a specified level of GDP. To separate the effect of trade openness, the authors used cross-national data and exogenous trade factors, precisely spatial characteristics from the gravity model. The findings suggested that trade could be advantageous for three sustainability-related air pollution metrics: NO_2 and SO_2, even though particulate matter (PM10) does not statistically significantly affect these measures. The results also support EKC, which suggests that growth damages the environment at low-income levels and helps at high levels. It also indicates that openness to trade hastens the growth process.

When seeking to understand how trade and investment flows impact ES, Chakraborty and Mukherjee (2013) conducted an empirical panel data analysis from 2000 to 2010 in 114 nations with different income levels. The study's primary conclusions indicated that merchandise export orientation and inward FDI movements have an adverse association with ES. Furthermore, the analysis demonstrated that the association between ES and trade and investment flows varies between nations with lower and higher incomes, as does the association between exploitation and environmental performance. Remarkably, the environmental performance index (EPI) variable showed a positive correlation for higher-income nations and a negative coefficient for lower-income ones.

In a distinct investigation, Bernard and Mandal (2016) scrutinized the correlation between trade openness and environmental conditions across 60 emerging and developing economies from 2002 to 2012. Utilizing EPI alongside CO_2 emissions as metrics for environmental quality, the study employed a dynamic panel data model and various econometric methodologies, including fixed effects and GMM. The principal outcomes of the study indicated that trade openness positively affected EPI, signalling an enhancement in environmental quality. Nonetheless, it also resulted in a rise in CO_2 emissions. Upon considering endogeneity, trade openness lacked a significant impact on EPI, while it did contribute to heightened CO_2 emissions. The GMM estimations shed light on the effect of political factors on environmental quality, revealing that income and population had an adverse impact.

Presenting new evidence from a comprehensive panel dataset covering 98 countries worldwide, Le *et al*. (2016) explored the link between trade openness and environmental quality, using PM10 emissions as a key environmental indicator. Their analysis spanned the years 1990 to 2013. The study explored the long-term dynamics between PM10 emissions, trade openness, and economic growth through panel cointegration tests. Results revealed that increased trade openness was associated with environmental degradation across the total sample. Nevertheless, this relationship varied based on the income levels of countries. While trade openness positively impacted the environment in high-income countries, it negatively affected middle- and low-income nations. Moreover, their study found evidence of a feedback loop between trade openness and PM10 emissions. Overall, the study emphasized the nuanced effects of trade openness on environmental quality, influenced by countries' income levels and other contextual factors.

Sajeev and Kaur (2020) conducted research to test the EKC hypothesis and assess the influence of numerous factors, including trade openness, FDI, oil prices, the legal system, and industrialization, on ES in India. Employing the ARDL bounds testing approach for cointegration with structural breaks, with annual time series data from 1980 to 2012, covering FDI, trade openness, CO_2 emissions, economic growth, crude oil prices, economic freedom variables, and industrial development. The study's findings supported the existence of an inverted U-shaped EKC in the short run but not in the long run. Additionally, trade openness decreased emissions when incorporating FDI, while its impact on carbon emissions was adverse in other scenarios. Furthermore, an increase in fuel prices was associated with reduced CO_2 emissions, whereas a smaller government size had a link with ED in the short and long term.

Orhan *et al*. (2021) explored the relationship between CO_2 emissions and economic growth in India since the roles of agriculture, energy consumption, and trade openness. They employed the Bayer and Hanck cointegration and Gradual shift causality tests alongside the wavelet coherence test to differentiate between short-, medium-, and long-run dynamics. The study investigated the connection between economic growth and ES in India using CO_2 emissions as an alternative for environmental impact. The findings revealed strong correlations between CO_2 emissions and all variables (economic growth, energy use, and agriculture), except trade openness.

In a different study, Iorember *et al*. (2021) observed the impact of renewable energy utilization, human capital, and trade on ecological footprint, a more comprehensive gauge of environmental quality utilizing data from South Africa. The research employed multiple structural breaks cointegration tests, a dynamic unrestricted error correction model via ARDL, and VECM Granger causality tests. The findings from the cointegration tests revealed the presence of a long-run affiliation among the variables, with an indication of multiple structural breaks. The ARDL results demonstrated that rising trade enhanced environmental quality by reducing ecological footprint. At the same time, an uptick in income stimulated the environmental footprint.

In examining the relationship between mining exports and the environment in African countries, Bimpong *et al*. (2022) utilized data from 1990 to 2018 from 33 African nations. Employing the bivariate Granger non-causality model, the authors found that mining exports had a unidirectional causality effect on forest cover and CO_2 emissions. Additionally, there was evidence of feedback causality between mining exports and greenhouse gas emissions. These findings underscore the importance for governmental and environmental agencies to bolster environmental protection laws, mining regulations, and monitoring practices to ensure the efficient and effective management of chemicals and gases in African mining operations.

Wang and Song (2022) affirmed the crucial role of international trade in decreasing CO_2 emissions and fostering overall economic development. The primary objective was to quantify the impact of international trade on the carbon intensity of the United States. The study utilized a novel framework and scenario analysis employing Multi-Regional Input-Output analysis (MRIO). Data from the Bureau of Economic Analysis, U.S. Department of Commerce (BEA) website was utilized, with twelve major trading partners of the USA selected for detailed analysis in the World Input-Output Database (WIOD). The methodology combined MRIO with the Logarithmic Mean Divisia Index (LMDI) model to dissect the driving factors behind carbon intensity.

Dingiswayo *et al*. (2023) raised concerns regarding ES and the considerable influence of international trade on environmental outcomes. The study investigates the relationship between trade openness and environmental quality in South Africa from 1994 to 2018. The paper analyzed the data using the ARDL Bounds method and the Granger causality test. The ARDL Bounds approach was selected for its capability to explore both short-run and long-run relationships, while the Granger causality test provided insights into the direction of causality between the variables. The analysis unveiled a significant and positive correlation between trade openness and CO_2 emissions in both the short and long run. Furthermore, the Granger causality test showed a unidirectional causation from trade openness to environmental quality.

Meanwhile, Adebayo *et al*. (2023) used panel data for the countries of the BRICS (Brazil, Russia, India, China, and South Africa) from 1990 to 2018 to examine the relationships between natural resources, trade globalization, energy, and ecological sustainability. The study employed the Common Correlated Effects Mean Group (CCEMG) and Cross-sectional Autoregressive Distributed Lag (CS-ARDL) estimators and found that while trade globalization and renewable energy favour ecological quality in the BRICS countries, economic development and the availability of natural resources have a detrimental effect.

In a paper titled “Dynamics of International Trade, Technology Innovation and Environmental Sustainability,” Ali *et al*. (2021) looked at the nexus between trade openness, technology innovation, and CO_2 emissions in the Asian region. The study covered the period from 1990 to 2015 and used panel data from 22 Asian economies. The objective of the research was to investigate how trade openness and technology innovation impact CO_2 emissions and to analyze the rebound effects of technology change on ES. The study employed Various econometric techniques, including Cross-sectional augmented estimators, the Dumitrescu-Hurlin causality test, and second-generation cross-sectional dependence cointegration and causality approaches. The findings indicated that trade-induced technology innovation contributed to the reduction of CO_2 emissions, while trade-facilitated economic growth led to higher emissions. The positive scale effect of trade outweighed the negative technique effects. Additionally, the study revealed a rebound effect of technology innovation on emissions in Southern and Western Asia.

In their contribution to the continuing discourse on ES, Huo *et al*. (2022) investigated the roles of financial development, trade openness, and FDI in fostering ES in Pakistan. Utilizing ANS as a measure of ES, the study collected time series data from 1996 to 2019. Employing the ARDL methodology, the authors analyzed the impact, revealing positive contributions of financial development, trade openness, and FDI in stimulating ES. Specifically, a 1% rise in trade openness led to a 1.03% increment in ES.

In their endeavour to assess the environmental implications of international trade in 33 Sub-Saharan African (SSA) countries spanning from 1990 to 2020 and to discern the divergent effects of exports and imports on environmental pollution, Duodu and Mpuure (2023) employed the generalized method of moment estimator and Dumitrescu and Hurlin (D-H) causality test. The findings indicated that overall trade reduced environmental pollution by approximately 0.10% and 0.79% in the short and long run. Moreover, exports and imports mitigated environmental pollution by around 0.07% and 0.45% (0.08% and 0.58%) in the short term (long term). The D-H causality test unveiled bidirectional causality between total trade and environmental pollution, whereas exports and imports exhibited a unidirectional causality from CO_2 emissions to exports and imports. The study concluded that international trade reduces pollution in SSA, and exports and imports exert a uniform influence on environmental pollution in the region.

3.4 Summary of the Literature

Theoretical perspectives highlight that trade of NNR can drive economic growth but raise concerns about sustainability due to resource depletion and ED. The EKC suggests that trade-induced growth initially harms the environment but may lead to improvement as economies mature and adopt cleaner technologies. However, PHH posits that lax environmental regulations in developing nations may attract pollution-intensive industries, exacerbating environmental harm. Empirically, there is no consensus on how international trade impacts ED and ES. Some research finds that trade liberalization improves ES through higher income and technological advances, while others highlight negative effects due to weak institutions and unsustainable resource use in developing regions. The divergent results may stem from differences in environmental proxies and country-specific factors like resource endowments. Crucially, the effect of NNR trade on both ED and ES in SSA remains underexplored, presenting a gap in the literature.

My thesis adds value by addressing this gap, providing a comprehensive analysis on the impact of NNR trade on both ED and ES in SSA. This study distinguishes between ED and ES, recognizing that they require different measurements. The study uses System GMM, which is known for its reliable and efficient estimators, to assess this impact. The findings reveal that a percentage point increase in NNR exports leads to a significant rise in CO_2 emissions by 0.31 metric tons per capita and a 0.77 percentage point decline in

ES. This underscores the complex trade-offs between economic gains from NNR exports and environmental costs. Additionally, the study fills a crucial gap by focusing on SSA, where contextual differences in trade and resource endowments are pronounced. The results emphasize that the environmental consequences of NNR exportation in SSA may outweigh the economic benefits, compromising the region's long-term sustainability and the ability of future generations to meet their needs.

CHAPTER FOUR: DATA AND METHODOLOGY

4.1 Introduction

This chapter discusses the data and methodology utilized in this research. The initial section outlines the data sources and variable descriptions. The subsequent sections address the model specifications and estimation methods.

4.2 Variables and data source

The study seeks to empirically examine the influence of NNR trade on ED and ES in selected SSA countries. It utilizes annual panel data from 2010 to 2020 for 17 SSA nations renowned for their natural resource wealth. To be specific, the study is limited to the 2010-2020 period primarily due to data availability. One of the key variables of interest, adjusted net savings, does not have consistent data prior 2010 and post 2020 for nearly all the countries in the dataset. Therefore, including periods outside this range would have resulted in significant data gaps and could compromise the integrity and robustness of the analysis. Regarding the selection of countries, although a total of 27 SSA nations are resource-rich, this study focuses on 17 countries. This limitation arose because 10 of the SSA countries had insufficient data on several critical variables which made their inclusion in the analysis impractical. Hence, the sample was restricted to 17 countries with complete and reliable data to ensure the study's accuracy and adherence to econometric standards. Appendix A shows the countries involved in this study.

In this study, pivotal data was obtained from the World Development Indicators (WDI) and the Observatory of Economic Complexity (OEC) to scrutinize key variables within the context of SSA countries that are prominent resource exporters. WDI is a broad database managed by the World Bank that offers access to a wide array of global economic, social, and environmental data for countries. The World Bank compiles the WDI using data from national statistical offices, international organisations, and other reputable sources. The variables examined include adjusted net savings, population growth, FDI, GDP growth, renewable energy consumption, and NNR rents.

The OEC website is the source of critical data for NNR exports. OEC is a platform that provides visualizations and data related to international trade and economic complexity. Developed by the Macro Connections group at the Massachusetts Institute of Technology (MIT), the OEC uses trade data from various sources, including customs offices and international organisations. It allows users to explore and analyze the export and import relationships between countries, understand the composition of a country's exports, and assess its economic complexity.

Based on the reviewed literature variables included in the study are explained as follows;

Dependent Variables

Carbon-dioxide emissions (CO_2): CO_2 signifies the volume of CO_2 generated from using liquid, solid and gas fuels, including gas flaring. These emissions, stemming notably from the combustion of fossil fuels during mining activities and the subsequent exportation of extracted non-renewable resources, stand as a significant contributor to global environmental degradation. Mining operations, essential for extracting minerals and fossil fuels such as gold, diamond, oil, and natural gas, often entail intensive energy usage, machinery operation, and transportation activities, all of which emit substantial amounts of CO_2. Moreover, transporting extracted resources for exportation to global markets further amplifies carbon emissions. Consequently, the entire process, from extraction to exportation, generates considerable CO_2, exacerbating climate change and environmental ED on both local and global scales.

Adjusted Net Savings (ANS): Perman *et al*. (2003) propose that ANS, also known as the Pearce–Atkinson indicator, is a robust measure of a nation's environmental and economic sustainability. It checks how well a nation is saving and investing to make up for the damage caused by pollution and the loss of natural resources. It assesses intergenerational equity by scrutinizing how net savings, representing the current generation's bequest to future ones, offset today's income from various natural resources and human capital shifts. ANS encompasses net national savings plus education expenditure minus mineral depletion, energy depletion, net forest depletion, CO_2 and particulate emissions damage, offering a holistic evaluation of economic activities' environmental impact. As a result, ANS emerges as a comprehensive indicator of sustainability, reflecting a nation's environmental asset health and capacity for intergenerational equity.

While CO_2 emissions provide insight into a specific environmental impact, ANS offers a more long-term perspective. It reflects whether a country maintains or depletes its wealth over time, considering the interplay between economic development, resource management, and environmental preservation. ANS aligns with sustainable development, which emphasizes balancing economic growth with environmental and social considerations, thereby encouraging a more comprehensive approach to development that considers the well-being of future generations.

Key Variable of Interest

Non-renewable natural resource exports, in the context of this study, are measures of international trade. They encompass mining activities that lead to mineral extraction, processing, and exportation from one country to another.

Other Control Variables

Foreign Direct Investment (FDI): This term denotes the inflow of direct investment equity into the reporting economy, encompassing equity capital, reinvested earnings, and other capital. Direct investment refers to a form of cross-border investment where a resident of one economy exerts control or substantial influence over the management of an enterprise in another economy. This variable reflects the level of international investment in a country's natural resource sector. Understanding the role of foreign investors in resource extraction helps analyze how external influences may affect environmental practices and whether FDI contributes to or mitigates carbon emissions associated with resource exploitation.

GDP growth

GDP quantifies the total economic output of a nation. Essentially, it represents the aggregate gross value added by all resident producers in the economy, including any product taxes and minus any subsidies not accounted for in the product value. It does not consider the depletion and degradation of natural resources. Therefore, assessing the impact of NNR exports on CO_2 requires an understanding of how economic growth, driven by resource exports, may contribute to increased environmental pressures.

GDP Growth: The annual percentage growth rate of GDP at market prices, calculated using constant local currency, is based on aggregates at constant 2015 prices.

Renewable Energy Consumption is critical for understanding the energy requirements of resource extraction, processing, and transportation. A high energy consumption in these processes may indicate a higher likelihood of increased carbon emissions.

Non-renewable natural resource rents depict the share of non-renewable natural resource wealth in GDP.

Institutional Quality: To measure institutional quality, I follow Ahmed, who constructed an index based on six variables: government effectiveness, political stability, voice and accountability, control of corruption, and regulatory quality. The overall index will use principal component analysis (Ahmed *et al*., 2020)

4.3 Estimation Strategy/ Technique

To address the problems of this study's nature, following Jacob Mincer and Arnold Zellner, panel regression analysis, also known as panel data analysis or pooled time-series cross-sectional analysis, was employed in this study. The balanced data on seventeen SSA countries was collected over time (2010 to 2020). The data consists of more than two periods and more than two cross-sectional units (countries). Hence, the study employs panel data models. In this study, the number of countries or cross-sectional units (N) is more than the number of years (T). Therefore, this is considered a micro-panel analysis (Wooldridge, 2012) .

The advantage of having this small T, which is around ten as opposed to N, is that issues surrounding panel unit roots and cointegration do not come into play. Moreover, autocorrelation (where errors are related or dependent on each other) and cross-sectional dependence (observations for different cross-sectional units (in this case, countries) are not independent of each other) are not of major concern in micro panels (Wooldridge, 2012). The assumption is that when these countries face similar shocks, they might react similarly, which is not the case in the real world, so when the period is small, what affects these countries reduces the chances of shocks giving a problem.

The basic framework for the panel regression model could be in the following form:

$$Y_{it} = \beta X'_{it} + \alpha Z'_{it} + \varepsilon_{it} \text{ where } i = 1,2,\ldots,17 \text{ and } t = 1,2,\ldots,11 \ldots\ldots\ldots\ldots\ldots. (1)$$

From the above model, i represents cross-sections (of all 17 SSA countries), while t represents time series. The slope of the variables is indicated by the sign of β, α is the coefficient of a set of extra control variables, and ε_{it} denotes the estimation residual. ε_{it} captures all the variables that could affect the outcome variable (Y_{it}) but are not included in the whole model. The study assumes that while other elements remain constant, one unit rise in explanatory variable increases or decreases the outcome variable Y_{it} by β units. Also, there are K regressors in X_{it}, not including a constant term, the heterogeneity or country effect is captured by $Z_i'\alpha$ where Z_i varies across N, it comprises a constant term and a collection of country-specific variables, which may be observed or unobserved, all assumed to remain constant over time (t). If homogeneity is assumed, the model could not have included the term Z_i. It could have been treated as an ordinary linear model and fit by least squares, which is the basic data model.

4.3.1 Static panel data models

Pooled OLS Model

$$Y_{it} = \beta X'_{it} + \alpha_i + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (2)}$$

The main assumption here is that there are no unobserved group-specific effects, but the model assumes homogeneity, which is not always the case. Panel data relate countries over time; therefore, these units are bound to be heterogeneous. Heterogeneity means there are variations among elements within a group. This study signifies the existence of distinct characteristics or differences among seventeen sampled countries. The techniques of panel data estimation can explicitly address such heterogeneity by incorporating country-specific variables, which are not explicit in this model. The Z_i' that was on the basic model is assumed constant across all cross-section units.

Fixed Effects Model (FE)

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \omega_{it} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

The least-square dummy variable, within the group, first differences

According to Hausman (1978), FE is appropriate when the individual effects correlate with the regressors. This approach controls for unobserved time-invariant heterogeneity by differencing the individual-specific effects, thereby addressing endogeneity concerns. Under this model, Z_i' is unobserved but correlated with X_{it} and omitted variable bias results if ignored. Assume they are fixed over time regardless of how many times you have surveyed the cross-section units.

$$\alpha_i = Z_i'\alpha \quad \text{...} \quad (4)$$

The problem is that the sample size must be sufficiently large.

Random Effects Model (RE)

$$Y_{it} - \lambda\bar{Y}_i = \beta_0(1-\lambda) + \beta_1(X_{1it} - \lambda\bar{X}_{1i}) + \beta_2(X_{2it} - \lambda\bar{X}_{2i}) + (v_{it} - \lambda\bar{v}_i) \quad \text{..................} \quad (5)$$

Hausman (1978) indicated that RE assumes individual effects are uncorrelated with the regressors. This assumption allows for more efficient estimation by pooling the variation across individuals. However, if the assumption of exogeneity of the individual effects is violated, the random effects estimator may be inconsistent.

The choice between FE and RE models depends on the assumptions about the correlation between the individual effects and the regressors. According to Hausman (1978), one can run the Hausman test to choose the appropriate method. However, the econometric model may suffer from these problems: heteroskedasticity, autocorrelation, and endogeneity, if we opt to deal with static models. However, Arellano and Bond (1991) indicated that if we opt for a dynamic model, we are likely to reduce the impact of these problems.

4.3.2 Dynamic panel data model

According to Arellano and Bond (1991), the dynamic panel model effectively addresses endogeneity, heteroskedasticity, and autocorrelation by employing a GMM framework. To tackle endogeneity, the model uses lagged values of the dependent variable and other endogenous regressors as instruments, mitigating bias from correlations between regressors and the error term. It does this by allowing the number of moment conditions, which are instrumental variables in the model, to exceed the number of parameters, making the estimators more efficient. Heteroskedasticity is addressed by applying robust standard errors, ensuring consistent estimation even when the error term variance is not constant across observations. Autocorrelation is managed by including lagged dependent variables as regressors, capturing the persistence over time, and utilizing appropriate instruments to correct autocorrelation in the error terms. This comprehensive approach ensures more reliable and accurate dynamic panel data analysis estimation.

To improve the efficiency and address some of the limitations of the standard Arellano-Bond GMM estimator, particularly in small samples and when the instruments in the difference GMM are weak, Arellano and Bover (1995) proposed System GMM, which Blundell and Bond (1998) further developed.

4.3.2.1 System GMM Estimation Technique

System GMM combines two sets of equations: one in differences (like the original Arellano-Bond GMM) and one in levels. By adding the level equations and using lagged differences of the variables as instruments for the level equations, System GMM increases the number of available instruments and enhances the estimator's efficiency. This dual approach helps to mitigate problems of weak instruments and improve the estimation of parameters in dynamic panel data models. Thus, System GMM provides more reliable and robust estimates, especially in cases where the standard GMM might suffer from weak instrument issues and when the panel data is unbalanced or has a small number of periods (Arellano & Bover, 1995; Blundell & Bond, 1998).

According to Yuni *et al*. (2023), the effectiveness of the System GMM estimator compared to other panel estimators can address endogeneity problems and account for omitted variables, thereby enhancing the precision of parameter estimates. Instead of using within-group estimations or normal panel OLS, which might lead to biased and inconsistent estimates since they don't account for these two issues, this study employs System GMM, whose estimator demonstrates lower bias and higher efficiency than all other estimators.

Several studies have examined the impact of international trade on ED and ES separately by adopting different models. The current research by following (Berk *et al*., 2020; Naseem & Guang Ji, 2020) employs the following form of the generalized functional model to address the first and second objectives, respectively.

$$CO_2 = f(NRX, NR, Growth, FDI, REC, IQ) \ldots\ldots (6)$$

$$ANS = f(NRX, NR, Growth, FDI, REC, IQ) \ldots\ldots (6)$$

Where $CO_2, ANS, NRX, NR, Growth, FDI, REC, and\ IQ$ specified are carbon-dioxide emissions, adjusted net savings, non-renewable resource trade, natural resource rents, foreign direct investment, renewable energy consumption, population growth, and gross domestic product growth, respectively. Both the first and second models show that the outcome variables ($CO_2\ and\ ANS$) are a function of all other variables that are in parentheses.

The System GMM-based econometric model is as follows;

$$CO_{2it} = \varphi CO_{2it-1} + \vartheta NRX_{it} + \beta X'_{it} + Z_i + \gamma_t + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$ANS_{it} = \varphi ANS_{it-1} + \vartheta NRX_{it} + \beta X'_{it} + Z_i + \gamma_t + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Now, ANS_{it} is the outcome variable denoting the adjusted net savings of i^{th}country on t^{th}periods, ANS_{it-1} is the one-period lag of the outcome variable in country i. It is included as a regressor to capture persistence or memory in the dependent variable. Therefore, φ is the autoregressive (persistence) parameter, the AR (1) parameter that captures persistence in the model. ϑ is the coefficient of the main variable of interest (NRX); it explicitly indicates the effect of natural resource trade on environmental sustainability. X'_{it} and β denote the vector of explanatory variables (NR, FDI, Growth, REC, IQ) and their corresponding coefficients, respectively. While Z_i measures country-specific effects, γ_t represents period-specific effects. Lastly ε_{it} is the error term and varies across countries $(i)$and periods (t).

Persistence Effect in the Dynamic Model (φCO_{2it-1} *and* φANS_{it-1})

The lagged value is endogenous by construction, and its coefficient captures persistence in the behaviour of the series. Persistence suggests that history/ past behaviour plays a role in the current behaviour of the outcome variable. The way that CO_{2it} and ANS_{it} respond to the explanatory variable today in part depends on how each responded in the past. Persistence means "history matters." It reflects the entire history of the model (Piper, 2023).

φ: Persistence coefficient is between zero and one, i.e., $0 < \varphi < 1$. After estimation, it should be confirmed that it is positive and significant. A significant one confirms the dynamic character of the model. The higher the value of this coefficient, the more persistent the series. Meaning that it is quicker and easier for ANS_{it} to re-attain normal and optimal levels. It can be referred to as the speed of adjustment to optimal dependent variable levels.

If φ is close to 1, it suggests strong persistence. The case where history weighs heavily on the behaviour of CO_{2it} and ANS_{it}. It implies a less competitive operating environment and quick adjustment to previous normal operating conditions. But, if it is close to 0, there is low persistence. Historical events or activities have very little influence on CO_{2it} and ANS_{it}. Most of what influences the behavior of CO_{2it} and ANS_{it} are current events and conditions. Contemporaneous events largely drive their behaviour. It describes a highly competitive operating environment and slow adjustment to normal levels; history matters but not that much.

The moment conditions, which are instrumental variables (Z) control for endogeneity. These instrumental variables must satisfy the following conditions: they should highly correlate with the regressors: $Cov(X_i, Z_i) \neq 0$ and should be orthogonal to the error term: $Cov(Z_i, \varepsilon_i) = 0$. There are external and internal instruments. External ones should be relevant and greatly influence X_i, they are unseen in the dataset and are greatly guided by theory and logic. The choice of instrument is a bit subjective in as much as it should be backed by sound logic. Lagged regressors that are considered suitable (e.g. Y_{it-2}, X_{it-1}) are included in the model as internal instruments, and the number of instruments in the model should not exceed the number of groups ($Z \leq N$). These instruments are easier to obtain because they are from the dataset, so this study settles for them (internal instruments).

The initial step of the estimation procedure involves removing country-specific effects through a first difference transformation.

$$\Delta CO_{2it} = \varphi \Delta CO_{2it-1} + \vartheta NRX_{it} + \beta \Delta X'_{it} + \Delta \gamma_t + \Delta \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

$$\Delta ANS_{it} = \varphi \Delta ANS_{it-1} + \vartheta NRX_{it} + \beta \Delta X'_{it} + \Delta \gamma_t + \Delta \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

I can now assume that there is no serial correlation among the transitory errors, i.e.:

$$E(\varepsilon_{it}\varepsilon_{is}) = 0 \text{ for } t \neq s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

and that the initial conditions CO_{2i1} and ANS_{i1} are predetermined:

$$E(CO_{2i1}\varepsilon_{it}) = 0 \text{ for } t > 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

$$E(ANS_{i1}\varepsilon_{it}) = 0 \text{ for } t > 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

The two assumptions made, (9) and (10) imply the moment restrictions (11) and (12) proposed by (Arellano & Bond, 1991):

$$E(CO_{2it-s}\Delta\varepsilon_{it}) = 0 \text{ for } t = 3, \ldots, 11 \text{ and } s \geq 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(11)}$$

$$E(ASN_{it-s}\Delta\varepsilon_{it}) = 0 \text{ for } t = 3, \ldots, 11 \text{ and } s \geq 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(11)}$$

$$E(X_{it-s}\Delta\varepsilon_{it}) = 0 \text{ for } t = 3, \ldots, 11 \text{ and } s \geq 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(12)}$$

Nevertheless, Blundell and Bond (1998) demonstrate that when time series exhibit persistence and the time dimension is limited, lagged levels of explanatory variables serve as weak instruments for the first-differenced equation. They propose differencing the instruments instead of the regressors to make them exogenous to the fixed effects. This transition from the difference GMM to the System GMM estimator involves jointly estimating the equation in levels and first differences. Again, Blundell and Bond (1998) introduce specific moment restrictions (13) and (14) to address finite sample bias arising from weak instruments.

$$E[\Delta CO_{2it-1}(Z_i + \varepsilon_{it})] = 0 \text{ for } t = 3, \ldots, 11 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(13)}$$

$$E[\Delta ANS_{it-1}(Z_i + \varepsilon_{it})] = 0 \text{ for } t = 3, \ldots, 11 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(13)}$$

$$E[\Delta X_{it-1}(Z_i + \varepsilon_{it})] = 0 \text{ for } t = 3, \ldots, 11 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(14)}$$

The following diagnostic tests are crucial for maintaining the reliability of System GMM estimations;

Hansen/ Sargan Test: Validity of instruments

H_0: All over-identified restrictions are valid; i.e., instruments are uncorrelated with error terms against H_A: At least one is invalid.

The test statistic has a large sample chi-square distribution with $m - k$ degrees of freedom where m is the number of instruments and k is the number of endogenous variables. Therefore, $m - k$ is the number of over-identifying restrictions. Suppose there are k regressors and $m > k$ instruments. The Sargan-Hansen test checks whether $m - k$ instruments, i.e., the overidentifying restrictions, are valid, assuming that there are already k valid instruments (Kiviet & Kripfganz, 2021). There is support for the validity of the dynamic panel model specification if the null hypothesis is not rejected.

Test for Serial Correlation

The focus here is on the second-order autocorrelation AR (2), not AR (1), as explained by (Roodman, 2009). AR (2) is due to the inclusion of Y_{it-2}, the instrument for Y_{it-1}.

H_0: No second-order Serial Correlation. If not rejected, there is no evidence of second-order serial correlation in the error terms, and this is when the p-value is greater than the significance level.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Introduction

This chapter is about the results and their respective discussions. The first section goes over the summary statistics of the variables employed in the study, and then followed by the correlation analysis. Section 5.4 shows the results, and below them, I display the diagnostic test results. Then, I discuss the results.

5.2 Summary Statistics

Table 5.1: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Environmental Degradation				
Carbo-dioxide emissions (metric tons per capita)	1.156	1.836	0.03	8.218
Environmental Sustainability				
Adjusted Net Savings (excluding particular emission damage, % of GNI)	5.015	12.209	-29.722	31.339
Main Independent variable (Trade)				
Non-renewable natural resource trade (% of GDP)	23.247	35.588	0.366	228.108
Other Control variables				
Non-renewable natural resource rents	7.538	10.35	0	48.666
GDP Growth (annual %)	3.445	4.534	-17.005	21.452
Renewable Energy Consumption (% of total final energy consumption)	61.839	23.224	7.72	90.12
Foreign Direct Investment, net inflows (% of GDP)	94	54.126	1	187
Institutional Quality Index	0	2.3	-3.116	5.49

Source: Author's Computation using data from WDI and OEC; The number of observations is 187 for all variables

Table 5.1 shows that the minimum CO_2 emissions in SSA are 0.03 metric tons per capita, while the maximum reaches 8.218 metric tons per capita, with an average of nearly 1.2 metric tons assuming all other factors remain unchanged. This suggests that the majority of SSA countries emit relatively low levels of CO_2, as the mean is much closer to the minimum than the maximum, indicating high skewness in emissions distribution. Only a few countries, particularly those with extensive resource extraction, contribute significantly to the region's emissions, signaling that some SSA countries with high resource dependence are major polluters. A similar pattern is observed with non-renewable natural resource (NNR) trade, where most countries trade less, while a few trade significantly more. This reveals a direct linkage between NNR trade and emissions: countries that export less tend to emit less. Consequently, if NNR trade were to increase across SSA, a corresponding rise in emissions would likely follow.

SSA countries are not investing as much as expected given their high levels of NNR trade. Despite an average of 23% of NNR being traded, only 5% is reinvested. Many countries are clustered toward the lower end in both trade and ANS. The ANS range, from -29.722 (indicating severe dissaving) to 31.339, reflects significant disparities: while some countries are heavily depleting their natural resources without sufficient reinvestment, others are making considerable efforts to save and reinvest resource revenues. The lower bound of -29.722 signals alarming dissaving, while the upper bound of 31.339 highlights countries actively working towards sustainable development by reinvesting resource revenues.

Remarkably, the average percentage of non-renewable natural resource trade compared to GDP in these countries is 23.247. The range of NNR trade as a percentage of GDP varies widely from 0.366% to 228.108%, with the minimum indicating minimal resource reliance and the maximum revealing extreme dependence on NNR trade. This broad range underscores the disparity in economic structures among these nations. The high standard deviation of 35.588 reflects substantial variability in NNR export reliance, showing that the dependence on NNR trade is much more pronounced and inconsistent among these SSA countries.

In contrast, non-renewable natural resource rents contribute an average of 7.538 percentage points to the GDP in the examined context. Notably, there is substantial variability among countries, with Lesotho consistently registering a minimum contribution of zero over the years, while other nations reach the maximum contribution of 48.666 percentage points to GDP. The instances of zero contribution in countries like Lesotho imply a delicate equilibrium, suggesting that the production value of non-renewable natural resources at global prices equals their total production costs. This underscores the intricate economic balance required when relying heavily on non-renewable resources, with implications for resource extraction costs and market dynamics, yet without factoring in the environmental costs or damages.

Significantly, the average annual increase in GDP growth stands at 7.538, indicating robust economic expansion across these SSA countries. Moreover, renewable energy consumption plays a pivotal role, constituting an average of 61.86% of total energy consumption, reflecting a substantial commitment to sustainable energy sources. Additionally, foreign direct investment (FDI) inflows contribute an average of 4.12 percentage points to GDP, underscoring the importance of external capital in driving economic activities within the region. Meanwhile, the notable average contribution of 23.25 percentage points from non-renewable natural resource trade to GDP highlights the significant economic impact of this trade. However, this reliance raises concerns regarding sustainable development and environmental preservation, particularly in international trade dynamics. As these countries heavily depend on non-renewable natural resource trade, there is a pressing need for careful consideration and long-term strategic planning to guarantee a balance between environmental preservation and economic growth.

5.3 Correlation Analysis

The correlation matrix below indicates a weak overall association among the independent variables, meaning there is multicollinearity but it is no severe enough to pose to pose a problem for the estimation.. However, it highlights a stronger relationship between the independent variables and carbon dioxide emission and adjusted net savings (ANS), the dependent variables in this context.

Table 5.2: Pairwise correlations Matrix of the variables

Variables	CO2	ANS	NRX	NR	Growth	REC	FDI	IQ
CO2	1.000							
ANS	0.017	1.000						
NRX	0.001	0.058	1.000					
NR	-0.081	-0.155	0.053	1.000				
Growth	-0.126	-0.161	-0.146	-0.025	1.000			
REC	-0.630	-0.245	-0.233	0.114	0.166	1.000		
FDI	-0.128	0.001	-0.061	-0.061	0.119	0.258	1.000	
IQ	-0.271	0.432	0.167	-0.280	0.186	0.063	-0.068	1.000

Source: Own Calculations where CO2 is carbon dioxide emissions in metric tons, ANS is adjusted net savings per capita (current US$); GDPG is gross domestic product growth (annual %); PG is population growth (annual %), REC is renewable energy consumption (% total energy consumption), NRR is non-renewable natural resource rents, FDI is the foreign direct investment (share to GDP in current US$) and NRX is non-renewable natural resource trade (share to GDP in current US$)

5.4 Empirical results and discussions

Table 5.3: International Trade's Effect on Environmental Degradation and Sustainability

VARIABLES	Model 1 Environmental Degradation	Model 2 Environmental Sustainability
Environmental Degradation (-1)	0.967068*** (0.002)	
Environmental Sustainability (-1)		0.752328*** (0.075)
Natural Resource Trade	0.00309602*** (0.000)	−0.00770009* (0.004)
Natural Resource Rents	−0.00167994*** (0.000)	−0.0148525 (0.021)
GDP Growth	0.0147779*** (0.001)	−0.126401** (0.054)
Renewable energy Consumption	−0.0016799*** (0.000)	−0.00942745 (0.021)
Foreign Direct Investment	0.00310412 (0.000)	−0.0421597 (0.034)
Institutional Quality	−0.00750172*** (0.003)	0.658446** (0.307)
Constant	0.0829597*** (0.019)	2.65488* (1.454)
Test for AR (1) errors: z	−2.22247** (0.026)	−2.79571*** (0.005)
Test for AR (2) errors: z	−1.17271 (0.241)	1.642 (0.102)
Sargan over-identification test	10.1021 (0.3423)	12.0973 (0.208)
Wald (joint) test	5,150,630*** (0.000)	3559.33*** (0.000)
Number of Observations	170	170
Number of instruments	17	17

Notes: This table shows coefficients and standard errors (in parentheses)
**** p<0.01, ** p<0.05, * p<0.1*

Model 1 is for the ED, where CO2 emissions is a proxy. International trade of environmental goods is proxied by the non-renewable natural resource trade in both models, and it is the primary variable of interest. Model 2 is for ES, where adjusted net savings are a proxy. Both models 1 and 2 constitute the key objectives of the study. In both models, the coefficients for the lagged dependent variable, used as an independent variable, are significant and less than one, signifying that past behaviour influences the current behaviour of the outcome variables (ED and ES). The coefficients, being close to one, indicate strong persistence, suggesting that historical behaviour heavily impacts the outcome variables; prior events and conditions predominantly influence the behaviour of the dependent variables.

The diagnostic tests of both models, indicated by p-values all above 0.05 and thus not significant at the 5.0% significance level, validate the AR (2) tests. Therefore, the models do not show evidence of second-order serial correlation in the error terms. The absence of second-order serial correlation is crucial as it suggests that the error terms are not correlated with their values from two periods prior. This validation strengthens the reliability of the models, as serial correlation in the errors can lead to inefficient and biased estimates, undermining the model's predictive accuracy and the validity of statistical inferences.

The number of instruments for the two models is not more than cross-sectional units-17, which is good because the number of instruments should not exceed the number of degrees of freedom in the model, and each cross-sectional unit (country) contributes one degree of freedom. In addition, the Sargan over-identification test with insignificant p-values validates the instruments employed. Finally, the Wald test is significant at all significance levels since the p-value is 0.000. Therefore, the diagnostic tests confirm that the models are well-specified and robust, providing confidence in the conclusions drawn from the analysis. Thus, the estimators are robust and reliable enough for policy inferences.

Main Findings

The findings from Model 1 reveal a concerning trend regarding the impact of NNR trade on ED. On average and ceteris paribus, the results indicate that a percentage point increase in non-renewable natural resource trade leads to a statistically significant rise in CO_2 emissions by 0.31 metric tons per capita, with significance observed at the 1% level. The positive coefficient observed in this model underscores a crucial point: higher levels of international trade, particularly in NNR exportation, are closely linked with heightened ED, specifically in increased CO_2 emissions. This correlation may be due to the reliance of NNR-rich countries in SSA on extractive industries, such as mining and fossil fuel extraction.

The above outcome is economically plausible because the extraction and processing of NNRs are energy-intensive activities, typically relying on fossil fuels. As trade in NNRs increases, the scale of extraction and production grows, resulting in higher energy consumption and emissions. The PHH further explains that weaker environmental regulations in SSA encourage foreign investors to engage in resource extraction without stringent controls on emissions. While lucrative in generating revenue, these industries often lack investments in cleaner technologies and environmental conservation efforts. Consequently, they contribute significantly to carbon emissions, exacerbating ED.

These findings align with those of earlier studies, Adebayo (2022), Bernard & Mandal (2016), Dingiswayo *et al*. (2023), Khan *et al*. (2023), Le *et al*. (2016), which found that international trade significantly increases CO_2 emissions. This is because these studies primarily focused on emerging and developing nations, where foreign owners often prioritize extraction and exportation to meet external demand over environmental considerations. They bring with them experiences and knowledge of the environmental goods required elsewhere, which enhances the efficiency of resource extraction and exportation but frequently neglects local environmental protection. This combination of heavy reliance on fossil fuels and the prioritization of external demand by foreign owners results in increased carbon dioxide emissions in emerging and developing nations.

Ali *et al*. (2021) in Asian economies; Frankel and Rose (2005); Khan *et al*. (2022) in 178 nations across the world; Wang and Song (2022) in the United States looked at the impact of international trade on environmental quality and found that it can have a beneficial effect on ED. These studies suggest that international trade can be crucial for reducing carbon emissions, which contrasts with the current study's findings. This discrepancy may be due to differences in economic development, regulatory frameworks, and the adoption of cleaner technologies in more developed or diverse economies, which can mitigate the environmental impact of trade.

Meanwhile, the findings from Model 2 shed light on the significant impact of NNR trade on ES, which is hindered by increased ED. According to the results, a percentage point increase in non-renewable natural resource trade corresponds to a 10% statistically significant decline in ES by 0.77 percentage points. The reduction in ANS with increasing NNR trade is sound. ANS is a measure of sustainability that considers natural resource depletion and environmental degradation. When countries export large amounts of NNRs, they deplete their finite resources, leading to a decline in long-term wealth and sustainability. Without reinvesting the proceeds from NNR trade into renewable capital (such as human or physical capital), the reduction in natural capital is not offset, resulting in lower ANS. This finding aligns with the Hartwick rule, which suggests that to maintain sustainability, resource-rich countries need to reinvest resource rents into reproducible assets, something SSA countries fail to do effectively. What is particularly concerning about this result is that the negative environmental consequences might outweigh the benefits; in other words, the economic gains from exporting these resources are being achieved at the expense of the environment, compromising the ability of future generations to meet their needs.

As indicated earlier, I could attribute the divergence in findings regarding the impact of trade on ES to variations in the institutional and governance frameworks across different regions and countries. Baajike *et al*. (2022) found the same results that international trade harms ES while focusing on West Africa, suggesting that in regions with weaker regulatory oversight and governance structures, trade hinders sustainability. Conversely, Huo *et al*. (2022) observed improved ES through international trade in Pakistan, indicating that trade can contribute positively to environmental management in contexts with effective regulation, enforcement, and investment in environmental management.

Chakraborty and Mukherjee (2013) examined 114 countries across different income levels and highlighted the influence of corruption and environmental performance on the relationship between international trade and ES. This suggests that the effectiveness of trade in promoting ES varies depending on factors such as the level of corruption, institutional capacity, and the overall environmental performance of countries. In lower-income countries with higher levels of corruption and weaker environmental governance, international trade may exacerbate environmental degradation. Conversely, in high-income countries with stronger regulatory frameworks and better environmental performance, trade may facilitate sustainable development through technology transfer, resource efficiency, and environmental management practices.

Given the developmental stage of SSA countries, there appears to be a notable emphasis on focusing more on growing their economies and not paying enough attention to the environment using results from both models. These trends reflect the principles outlined in the EKC hypothesis. According to this hypothesis, ED worsens during the early stages of economic growth but then gets better as countries get richer and start caring more about nature. However, things seem different for NNR-rich countries in SSA. This trajectory is disrupted by prioritising resource extraction and exportation over environmental conservation, which seriously threatens ES.

Notably, although the magnitudes of the increase and decrease may seem marginal from Models 1 and 2, the implications are profound. These findings shed light on the unsustainable resource management practices in the region, which pose significant challenges to achieving economic development and ES goals. The failure to prioritize investments in cleaner technologies and sustainable practices perpetuates ED and impedes the region's ability to achieve long-term economic prosperity. The implications of these findings are significant, highlighting the potential trade-offs between economic growth and ES, particularly in resource-rich nations. While resource trade may provide immediate economic benefits, they come at a high environmental cost, jeopardizing the well-being of both current and future generations.

Other Findings

Interestingly, there appears to be a noteworthy impact on reducing environmental degradation by NNR rents and renewable energy consumption, estimated at a 1% significance level in Model 1. This is evident as each unit increases resource rents, and renewable energy consumption corresponds to a decrease of 0.0018 and 0.0017 metric tons per capita in CO_2 emissions, respectively. Renewable energy is directly substituting for fossil fuels, which are the primary sources of CO_2 emissions. Unlike fossil fuels, renewable sources produce little to no direct emissions during energy generation, thereby lowering the carbon footprint. However, the counterintuitive result that renewable energy consumption reduces ANS in model 2 can be explained by considering the costs of transitioning to renewable energy. Investments in renewable energy infrastructure, such as wind or solar power, are capital-intensive and may initially reduce savings.

If countries invest heavily in renewable energy but fail to balance it with sustainable use of natural resources or efficient economic practices, ANS may decrease in the short term, despite long-term environmental benefits. This suggests that renewable energy consumption alone, without broader environmental and economic strategies, might not immediately translate into improved sustainability.

Conversely, economic growth, measured by the GDP growth rate, is linked to heightened CO_2 emissions. Specifically, an annual percentage rise in GDP growth leads to an increase of 0.0148 metric tons per capita in carbon emissions, and this is statistically significant at the 1% level due to a probability value of less than 0.001. However, this same economic growth compromises ES in Model 2. A percentage increase in GDP growth is associated with a decrease of 0.1264 units in ES at a 5% significance level. The effectiveness of institutions reduces not only ED but also ES. The statistically significant coefficients associated with this variable in both models indicate that institutional factors directly influence ED and ES indicators in SSA. On average and under the assumption of all else being equal, higher institutional quality reduces CO_2 emissions by 0.0075 metric tons per capita and enhances ES by 0.6584 units.

However insignificant in both models, a one-unit increase in net foreign direct investment inflows increases carbon emissions by 0.0031 metric tons per capita in Model 1 and reduces ES by 0.0422 units in Model 2. While FDI can bring in capital and expertise that may contribute to economic growth, it can also lead to increased resource extraction and ED if not appropriately managed. The negative coefficient on the ES proxy in Model 2 suggests that FDI may be associated with lower savings, potentially due to capital flight or resource mismanagement. These results align with the dependency theory, which posits that developing countries, mainly those rich in natural resources, often depend on foreign capital and expertise. This leads to a neocolonial relationship where the economic benefits primarily accrue to foreign interests. This dynamic can exacerbate trade imbalances, as a significant portion of the revenue generated from mining activities flows out of these countries rather than circulating within their economies.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Summary

This section summarizes the study's findings and provides inferences made from them. The chapter also offers policy suggestions for how to protect the environment and experience faster growth in light of the findings. It further gives the limitations of this study and suggestions for potential areas of future research.

6.2 Conclusion and Recommendation

The primary issue explored in this study is the environmental impact of NNR trade in SSA, driven by the region's dependence on commodity exports for economic growth. This dependence raises significant concerns regarding ED and ES, as NNR trade often lead to heightened carbon emissions and depletion of natural resources without adequate reinvestment for long-term sustainability. The main objective of this research was to investigate the dual impact of NNR trade on both ED and ES, using CO_2 emissions as a proxy for ED and adjusted net savings (ANS) as a proxy for ES.

This study contributes to the literature by filling a gap where the effect of NNR trade on both ED and ES in SSA has been underexplored. It provides critical insights into the environmental impact of NNR trade in SSA. Using balanced panel data from 17 resource-rich SSA countries from 2010 to 2020 and employing System GMM, the findings indicate that an increase in non-renewable natural resource trade leads to a significant rise in carbon dioxide emissions and a decline in environmental sustainability. There is a direct link between higher levels of international trade of extracted environmental goods and increased environmental degradation, highlighting the detrimental effects on environmental health and sustainability.

The implications of these findings are profound, underscoring the urgent need for a balanced approach to economic growth and environmental preservation in SSA. The prioritization of economic gains from non-renewable resource trade, while providing short-term economic benefits, exacerbates environmental degradation and undermines long-term sustainability. The evidence suggests that current practices in the resource-rich SSA countries contribute significantly to environmental degradation, which in turn hampers efforts to achieve sustainable development. The reliance on extractive industries for economic growth has led to persistent environmental degradation, indicating that economic development does not automatically translate to better environmental outcomes.

Current policies on natural resource extraction and trade in SSA are often suboptimal due to weak enforcement, limited institutional capacity, and insufficient integration of sustainable practices. While many countries have environmental regulations, such as Environmental Impact Assessments (EIAs) and emission limits, enforcement is undermined by inadequate resources and corruption, resulting in noncompliance. Moreover, the lack of coherence between trade and environmental policies causes conflicting priorities that favor economic growth over environmental sustainability.

Nations must secure an equitable portion of resource rents and proficiently oversee generated revenues to leverage natural resource wealth for economic development. The environmental opportunity costs associated with exploiting non-renewable resources are crucial when designing tax laws. In instances of excessive profits resulting from elevated natural resource prices, governments should be able to intervene and capture a portion of these rents. Not only should revenue taxes consider the costs associated with depleting non-renewable natural resources, such as environmental harm, but they should also reinvest the proceeds in productive capital to enhance economic diversification and establish resilient, transparent institutions for governing natural resources. Resource-endowed nations should carefully manage the utilization of rents derived from non-renewable resources to promote long-term sustainability.

Additionally, the absence of robust market-based instruments like environmental taxes or subsidies for cleaner technologies hinders the adoption of sustainable practices. To address these challenges, existing policies should be reinforced through stronger executive oversight, legislative amendments, and the establishment of independent regulatory bodies with enhanced monitoring capabilities. The Hartwick Rule should be emphasized, advocating for reinvestment of resource rents into sustainable assets, as done in countries like Norway. Command-and-control measures, such as stricter emission limits, need to be enforced, while market-based instruments like carbon taxes and green subsidies should be introduced to incentivize cleaner technologies. New policies should focus on regional collaboration to harmonize environmental standards, promote renewable energy investment, and ensure community participation in resource management, ultimately reducing SSA's over-reliance on non-renewable resources.

6.3 Limitations of the Study

The study initially aimed to analyze 27 resource-rich countries in SSA, but due to data unavailability for 10 of these countries, the final analysis focus on only 17 countries. This reduced country coverage may limit the generalizability of the findings and the ability to draw comprehensive conclusions about the entire SSA region. Excluding these countries could mean that certain trends and insights pertinent to the broader region are not captured, potentially skewing the study's results and implications. Furthermore, the data set's time frame, spanning from 2010 to 2020, may not account for recent developments or longer-term trends, thus limiting the temporal applicability of the findings.

6.4 Areas for Further Research

Future research should aim to include a broader range of countries to enhance the generalizability and comprehensiveness of the findings. Expanding the analysis to all 27 initially targeted countries and incorporating additional SSA countries would provide a more complete picture of the region's resource export dynamics and environmental sustainability. Moreover, extending the time frame beyond 2020 and incorporating more recent data would help capture ongoing developments and longer-term trends, offering a more current and relevant analysis.

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APPENDICES

Appendix A: List of 17 non-renewable resource-rich countries in SSA included in this research

Oil and Gas Exporters	**Gold, Diamond and Other Precious Metals Exporters**
Angola, Cameroon, Congo-Republic, Gabon, Nigeria and Mozambique	Botswana, Burkina-Faso, Ghana, Guinea, Lesotho, Mali, South Africa, Tanzania, Zimbabwe, Mauritania and Sudan

Source: Own computations using IMF and IBIS information

Appendix B: Description of variables, source and unit of measurement

Description	Source	Unit of Measurement
Environmental Degradation		
Carbon Emissions	WDI	CO_2 emisssions (metric tons per capita)
Environmental Sustainability		
Adjusted Net Savings	WDI	Adjusted net savings, excluding particulate emission damage (% of GNI)
Main Independent variable		
Non-renewable natural resource exports	OEC	Non-renewable natural resource exports (% of GDP)
Other Control variables		
Natural resource rents	WDI	
GDP Growth	WDI	GDP growth (annual %)
Renewable energy consumption	WDI	Renewable energy consumption (% of total final energy consumption)
Foreign direct investment	WDI	Foreign direct investment, net inflows (% of GDP)
Institutional Quality	WDI	Institutional Quality Index (Percentile rank)

Source: Own Computations. WDI stands for World Development Indicators, and OEC is Observatory of Economic Complexity

Appendix C: Expected Signs of the Variables

Variable	Expected sign (ED Model)	Expected sign (ES Model)	Rational
Environmental Degradation (-1)	+		Environmental degradation in the previous year is expected to positively influence the current year's degradation, assuming other factors remain constant.
Environmental Sustainability (-1)		+	Environmental sustainability in the past year is expected to positively impact the current year's sustainability, assuming other factors remain constant.
Natural Resource Exports	+	-	Heavy reliance on the exportation of extracted resources in SSA increases environmental degradation and harms sustainability.
Natural Resource Rents	-	+	Proceeds from the sale of natural resources can be reinvested in cleaner technologies, reducing emissions and improving sustainability.
GDP Growth	+	–	The focus on economic growth through non-renewable resource trade in SSA increases environmental degradation and harms sustainability due to neglecting environmental costs.
Renewable energy consumption	-	+	Renewable energy is typically more affordable, environmentally friendly, and effective, thus reducing environmental degradation and improving sustainability.
Foreign Direct Investment	+	-	Foreign entities often prioritize economic gains over environmental protection, exacerbating degradation and decreasing sustainability.
Institutional Quality	+	-	Low institutional quality in SSA, characterized by weak environmental laws, is expected to increase emissions and decrease sustainability.

Source: Own computations

Appendix D: Diagnostic test results

Diagnostic test results for the two research model				
	Test	**Null hypothesis**	**P-value**	**Conclusion**
Second-order serial correlation AR (2)	Arellano-Bond test	No second-order serial correlation	>0.05	No autocorrelation in the error
Validity of instruments	Sargan Test	All over identified restrictions are valid	>0.05	All over-identified restrictions are valid; i.e., instruments are uncorrelated with error terms

Source: own computations