UNIVERSITY OF GHANA

COLLEGE OF HUMANITIES

ECONOMIC GROWTH AND ENERGY INTENSITY IN SUB-SAHARAN AFRICA

BY

MADLEEN MADINA FRAZER

(10638627)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER
OF PHILOSOPHY IN ECONOMICS DEGREE

July 2019

DECLARATION

I Madleen Madina Frazer declare that this thesis submitted by me to the Department of Economics, University of Ghana in partial fulfilment of the requirement for the award of the Master of Philosophy (MPhil) Degree in Economics is entirely my work under the guidance of my supervisors. I also declare that to the best of my knowledge, no part of this thesis has been submitted to this or any other University for the award of a degree. All sources of knowledge used have been duly acknowledged.

…………………………………………...
MADLEEN MADINA FRAZER

STUDENT

(10638627)

July 2019

SUPERVISORS

………………………………..

DR. IDDISAH SULEMANA

DEPARTMENT OF ECONOMICS

UNIVERSITY OF GHANA

July 2019

………………………………..

DR. AMIN KARIMU

DEPARTMENT OF FINANCE AND

DEPARTMENT OF OPERATIONS AND

MANAGEMENT INFORMATION SYSTEM

UNIVERSITY OF GHANA BUSINESS SCHOOL

July 2019

ABSTRACT

Energy use is the primary source of greenhouse gas (GHG) emission from the industrial sector with carbon dioxide (CO_2) accounting for more than 90 per cent of CO_2 equivalent of GHG, globally and in most countries. The fact that the Sub-Saharan African countries only contribute 4% of global greenhouse gas emissions does not in any way diminish the dangers that climate change poses to the region. Reduction in energy intensity has been advocated as a means of mitigating climate change and energy insecurity.

Using a panel data spanning 1990-2015, this study investigates the energy intensity and economic growth relationship, causality, and convergence patterns in Sub-Saharan Africa. The Generalised Methods of Moments model estimation shows a strong negative relationship between energy intensity and economic growth. The Granger-causality test revealed a unidirectional causality from economic growth to energy intensity. The study uses conditional beta and sigma convergence criterion to test for convergence in the region, and the results revealed that it is converging to a lower rate of energy intensity. The study, therefore, recommends that policies that will increase growth are implemented.

DEDICATION

This thesis is dedicated to my father, Mr Allieu Sesay, for his constant love and support.

ACKNOWLEDGEMENT

First and foremost, I am grateful to the Almighty Allah from whom we seek knowledge for his countless blessings in my life. I would like to express my profound gratitude to my parents, Mr and Mrs Allieu Sesay, for their love, support, guidance and patience throughout my academic career and to ensure the success of this work.

I am grateful to the African Economic Research Consortium for awarding me a full scholarship to pursue this MPhil Economics degree. I would like to express my sincere gratitude to my supervisors, Dr Iddisah Sulemana and Dr Amin Karimu, for being available at all times to give direction and support.

My sincere thanks and gratitude to the lecturers and staff of the Department of Economics for their inspiration and encouragement.

Thanks to my friends for their constant love and moral support through this journey, especially Edwin Atitsogbui, Matilda Tsekpokumah, Mark Senanu, Jephthah Osei Owusu, and Dictus Azor.

TABLE OF CONTENTS

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

ADF	Augmented Dickey-Fuller
Bcm	Billion cubic metres
CFT	Clean Fuels and Technologies
CHP	Combined Heat and Power
CPIA	Country Policy and Institutional Assessment
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
EEPC	Engineering Exports Promotion Council
EKC	Environmental Kuznets Curve
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEMS	Global Environmental Monitoring System
GHG	Green House Gas
GMM	Generalised Methods of Movement
GNI	Gross National Income
GW	Gigawatt
IEA	International Energy Agency
IPS	Im-Pesaran-shin
K-B	Khazzoom-Brookes
NAFTA	North American Free Trade Agreement
NOx	Nitrogen Oxides

OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PCAF	Pollution Control and Abatement Fund
PP	Phillips-Perron
PPP	Purchasing Power Parity
RISE	Regulatory Indicators for Sustainable Energy
SEforALL	Sustainable Energy for All
SDG	Sustainable Development Goal
SME	Small & Medium Enterprise
SO_2	Sulfur Dioxide
SPM	Suspended Particles Matter
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
TOE	Ton Per Oil Equivalent
UNEP	United Nations Environment Programme
UN	United Nations
WDI	Word Development Indicators

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Energy is an essential factor in all sector of any country's economy (Oyedepo, 2012). The importance of energy in an economy cannot be overemphasised. It greatly influences the socio-economic and environmental aspects of an economy because its demand is crucial to economic growth and environmental quality (Recalde and Ramos-Martin, 2012). Since Georgescu-Roegen (1976) first shed light on the critical role of energy in production, both physical theory and causal observation have convinced investigators that in the real World, one can only understand production when the role of energy and materials are accounted for. Yet, it was not until the 'productivity slowdown' of the 1970s caused by the oil crisis that mainstream economists recognised its significance to economic growth (Stern and Cleveland, 2004). The 1970s to 1980s oil shocks brought with them a wave of research on the energy and growth relationship (Kaufmann, 1992).

Following four decades of research, there does not seem to be any consensus among the various schools of thought on the strength of this relation (Kaufmann, 1992). The interpretation of this relationship is filled with a lot of controversies. One reason for this, according to the neoclassicals and energy experts is the weak relationship that exists between energy use and economic activity. Neoclassicals believe that energy can be decoupled from economic growth through technological change and substitution, resulting from technological progress and rising energy price. (Kaufmann, 1992). Biophysical economists, on the other hand, claim that the neoclassical theory is flawed (Kaufmann, 1992) because of their assumption that any capital goods can be produced without the use of energy (Dalgaard and Strulik, 2008). Their assumption that energy intensity can be reduced through technical change and substitution is as a result of the system boundaries[1] the neoclassicals set (Kaufmann, 1992). Biophysical economists re-draw their system boundaries to factor the laws of thermodynamics and portray energy and matter as the primary input in the economy where economic production is powered by a unidirectional throughput of low heat (Hall et al., 1986).

Closely linked to energy intensity is energy efficiency (Adom, 2015a). Energy intensity measures the energy per unit of output (Voigt et al., 2014). With statistics on energy intensity, energy efficiency levels can be compared across countries (Mahmood and Ahmad, 2018). Energy efficiency improves when energy intensity falls. Hence, energy intensity has been widely used in the energy literature as a proxy for energy efficiency (Adom, 2015a). A country's energy efficiency level may depend amongst others on its energy policy, level of industrialisation, foreign direct investment, and energy mix (Mahmood and Ahmad, 2018). Energy efficiency has been recognised as a significant element for sustainable growth, that would address climate change concerns and at the same time, tackle energy security and poverty (Voigt et al., 2014). To this effect, the World has pledged to the Sustainable Development Goal (SDG) 7, which binds signatories to "ensure access to affordable, reliable, sustainable, and modern energy for all by 2030" (UN General Assembly, 2015). The targets of this goal are to: "(i) ensure universal access to affordable, reliable and modern energy services; (ii) increase substantially the share of renewable energy in the global energy mix; (iii) double the global rate of improvement in energy efficiency; (iv) enhance international cooperation to facilitate access to clean energy research and technology; and (v) expand infrastructure and upgrade technology for supplying modern and sustainable services for all in developing countries." (UN General Assembly, 2015).

---

[1] This sets capital, labour and energy as independents inputs.

Several studies (e.g., Thiam, 2011; Chavez et al., 2005; and Hussein and Filho, 2012) have shown that an increase in energy access can help end extreme poverty and boost shared prosperity. Thus, understanding the true value of energy efficiency is important now more than ever. Research has drawn scholarly attention to the fact that energy efficiency goes beyond just a reduction in energy demand and lower greenhouse gas emission (IEA[2] report, 2014a). The report, "capturing the multiple benefits of energy efficiency", states that energy efficiency in emerging economies improves energy access, which allows more people to get electric power, thereby reducing inequality and poverty. It improves the health of women and children who are more exposed to pollution and unclean energy. It also improves the economic growth of countries through industrial productivity. According to Adom (2015a), the benefits gained from achieving energy efficiency has a spillover effect. He noted that the energy insecurity in Nigeria has a significant impact on the supply of gas to the West African gas pipeline[3]. Ghana, for instance, experienced periods of gas shortages and blackouts as a result of the irregular gas supply from Nigeria.

Access to energy increases the level of education and encourages women empowerment because of the time saved from gathering woods for cooking (Thiam, 2011). According to Chavez et al., (2005), energy access can promote sustainable livelihood and increase productivity, among others, for poor people, especially subsistence farmers in developing countries. They argued that energy access could also increase productivity in income-generating activities that can contribute to poverty reduction and rural development. Hussein and Filho (2012) argued that access to good

---

[2] International Energy Agency.

[3] The first regional natural gas transmission channel in Sub-Saharan Africa that runs from Nigeria to Niger Delta area, Benin, Ghana and Togo (Accessed https://en.wikipedia.org/wiki/West_African_Gas_Pipeline).

healthcare, educational opportunities and the basic amenities of life would improve only if modern energy becomes accessible to all.

1.2 Problem Statement

The strong correlation between energy consumption and economic growth poses a challenge to SSA. Can economic growth be accelerated without an increase in energy intensity? These last few years have seen a growing urgency to mitigate climate change around the World. This is more critical in Sub-Saharan Africa, where the low-income countries have the highest energy intensity in the World at 10.3 megajoules per 2011 Purchasing Power Parity (US$). This is as a result of their high dependence on inefficient, traditional biomass (World Bank Report, 2018).

Africa is home to 17% (1.3 billion) of the World's population and 1.3 billion more people –representing 26% of the projected 2050 world population would be added by 2050(United Nations Report, 2017). To date, roughly one billion people lack access to electricity, of which the majority are in SSA (United Nation, 2017). The "Key World Energy Statistics" 2018 report, by the IEA, shows that coal and oil make up more than half (59%) of the total primary energy supply[4]. The private and public sectors have paid little attention to energy efficiency investments which is one of the main hindrances to achieving energy-efficient economies (IEA Report, 2014b). If policies do not change, by 2035, about two-thirds of energy efficiency potential will remain untapped (IEA Report, 2014b). The Sub-Saharan Africa economy is also fragile and susceptible to domestic and international shock. The region is set for a modest increase in growth.

---

[4] Natural gas makes up 22.1 %, Biofuels and waste 9.8%, Nuclear 4.9% Hydro 2.5 % and others which includes a mix of geothermal, solar, wind, tide/wave/ocean/ heat and others 1.7%.

With about two-thirds of the countries in the region experiencing accelerated growth, growth is expected to rise by 21 per cent to 3.4 per cent in 2018. (Regional Economic Outlook, 2018).

A large and growing number of energy intensity and economic growth nexus literature in SAA has been published. Some have explored the possibility of an Environmental Kuznets curve (EKC[5]) relationship; convergence trends of energy intensity and; the determinants of the energy intensity levels. Yet, researchers have failed to investigate how economic growth affects energy intensity adequately in the region. The vast majority of work in this area has focused on developing countries, and the number of African countries that have been studied does not give a proper representation of the situation in SSA as the pooled results were masked mainly by development in other regions of the World. This research, therefore, extends this area of study by attempting to investigate whether SSA can benefit from the twin goals of increased economic growth and energy efficiency.

1.3 Research Questions

This thesis seeks to answer the following questions for Sub-Saharan Africa:

- Does economic growth negatively affect energy intensity?
- Is the economic growth and energy intensity relationship non-linear?
- What is the nature of causality between energy intensity and economic growth?
- Is there energy convergence in the region?

---

[5] The EKC hypothesizes that in the early stage of industrialization growth rises with environmental degradation until a given income level is achieved then environmental degradation decreases (Accessed online from https://www.economicshelp.org/blog/14337/environment/environmental-kuznets-curve/).

1.4 Objectives of the Study

The objectives of this thesis include the following:

- To test the effect of economic growth on energy intensity;
- To test for a non-linear relationship between economic growth and energy intensity
- To explore the nature of causality between energy intensity and economic growth; and
- To provide evidence or lack thereof of convergence in energy intensity in Sub-Saharan Africa.

1.5 Scope of the study

The scope of the study is limited to Sub-Saharan Africa because of the lack of literature exclusive to this region in the growing energy intensity and economic growth nexus literature. There are forty-eight countries in SSA, and they are all included in our study. The period of the study is limited to 1990 to 2015 due to the constraints with the availability of data on SSA.

1.6 Justification

Should we focus on growth at the expense of the environment? To a large extent, it is a widely accepted fact that economic growth and energy intensity have an inverse relationship (Mahmood and Ahmad, 2018). Access to the basic needs (food, health, services, shelter, clean water) is what billions of people desire for a better life. However, these basic needs cannot be provided without energy. (Hussein and Filho, 2012). Income generation is the solution to poverty reduction, but for it to be sustainable, efficient energy is needed. High levels of energy intensity result in additional cost in terms of damage to the environment (Mahmood and Ahmad, 2018). Increased population and economic growth are projected to triple energy consumption in SSA by

2060 (World Energy Scenarios, 2017). With such projections, understanding the energy intensity and economic growth nexus is crucial now more than ever. It is only when the relationship is known that the right policies would be implemented so that this projected increase in energy consumption would be met with sustainable economic growth outcomes. Only then can we avoid the problems of high carbon dioxide (CO_2) emissions. Rising CO_2 emissions would increase atmospheric temperature, which could result in crop failure, rising sea levels and health problems (Adom, 2015b). This would have severe consequences for economies in terms of productivity loss through morbidity and death, higher health costs, increasing poverty and reduction in growth and development.

The focus of this study is the economic growth and energy intensity relationship, the nature of causality between the two and cross-country convergence in energy intensity in SSA. It distinguishes itself from previous work by limiting the investigation exclusively to the SSA countries. Sub-Saharan Africa is the most access-deficit region (World Bank Report, 2018). But to our knowledge, no empirical work has been done exclusively in this region. The insecurity in energy supply possesses a significant threat to the countries in SSA. These threats include high production cost, increased unemployment in the industrial sector, increased demand of unclean fuel, environmental degradation because of the dependence on contaminated fuel, pollution, food insecurity and energy poverty. With the benefits[6] of having low energy intensity, understanding this said relationship is vital to the development of the region.

It is essential to understand the dynamics of energy to prepare for the environmental challenges that come with increased growth. Knowledge of energy transition is essential to inform policymakers of the behaviour of energy demand if the structure of the economy were to

---

[6] Sustainable growth, and low GHG emissions among others.

change (Le Pen, & Sévi, 2010). With current growth projections for SSA and the theory that energy consumption increases output, knowledge on energy transition is much more important for policymakers in developing countries (Inglesi-Lotz and Pouris, 2012). This study is motivated by the fact that findings on the economic growth and energy intensity relationship could inform public policy. For instance, if energy intensity granger causes economic growth, then conservation policies would have an adverse effect on economic growth, but if economic growth granger causes energy intensity, then conservation policies will not hinder economic growth (Narayan and Popp, 2012).

1.7 Organisation of the Study

The study is organised into five chapters. Chapter two outlines the current energy intensity levels and growth status of SSA compared to other regions. Chapter three presents the empirical and theoretical literature on the energy intensity and economic growth relationship. The methodology employed and the estimation analysis are covered in chapter four. Chapter five discusses the results. And chapter six concludes and recommends policies in line with the research findings.

CHAPTER TWO

ECONOMIC GROWTH AND ENERGY INTENSITY TRENDS IN SUB-SAHARAN AFRICA

2.0 Introduction

An overview of the growth and energy intensity trends in Sub-Saharan Africa (SSA) and some of the key factors explaining the dynamics are presented in this chapter. This will provide a clear picture of the growth and energy intensity record in SSA. Energy intensity is used as an indicator of energy efficiency. This is because, at the aggregate level, energy intensity is a proxy for the measurement of the energy needed to meet the energy services demanded and it is to some extent readily available to analyse and compare across countries (IEA Report, 2017). Nevertheless, an important point to note is that low energy intensity does not always mean energy efficiency. A country with a high service-to-GDP ratio and mild climate is more likely to have a low energy intensity than a country with a high industry-to- GDP ratio and harsh climate (IEA Report, 2017).

2.1 Economic Growth in Sub-Saharan Africa

In the 1960s, SSA had a higher growth potential than that of East Asia (Easterly and Levine, 1997). It also had an average GDP per capita higher than in East Asia and South Asia. However, by early 1990s it had fallen behind both regions. (Garner, 2006). From 1990 to 2015, SSA's average GDP growth was 1.2 per cent (Table 2.1). This compares less favourably to the economies of East Asia and Pacific with 3.2 per cent and South Asia with 4.4 per cent.

Table 2.1: GDP Growth Dynamics Across Regions

Region	Average GDP Growth 1990-2015	GDP Per Capita PPP 1990 ($)	GDP Per Capita 2015 ($)
World	1.5	8,925	14,778
East Asia & Pacific	3.2	4,964	15,143
Middle East & North Africa	2	11,859	17,505
South Asia	4.4	1847	5,332
Sub-Saharan Africa	1.2	2,513	3,499
Latin America & Caribbean (LAC)	1.4	9,780	14,568

Source: Author's calculation.

Their performance is most impressive because, 30-years ago, they had an average GDP per capita less than SSA (Garner, 2006) but have now doubled the average growth rate of SSA (Table 2.1). Sachs and Warner (1997), Calamitsis et al. (1999), and Ndambiri et al., (2012) attributed this slow growth in SSA to weak economic policies in the region, lack of openness to the international market, conflicts and weak institutions. Sachs and Warner (1997) also noted that SSA is naturally disadvantaged because many countries in the region are land-locked, in tropical latitudes which makes it prone to disease resulting in a lower life expectancy and have a high dependence on natural resources.

With 42.5 per cent, SSA had the lowest secondary school enrollment of 2015. It also had the highest under-5 mortality rate, almost twice that of the World's, depicting the gap in human capital investment in the region. The Middle East & North Africa and Sub-Saharan Africa in 2015, had the highest total natural resources rent[7]. This over-reliance on natural resources has been cited as one of the reasons for SSA's weak growth. High dependence on natural resources

---

[7] The total natural resource rent measures a country dependence on natural resources.

makes countries invest in that sector at the expenses of other areas, and a fall in the world price of such resources is very likely to pose a risk to the fiscal stability of the country.

Table 2.2 Demographic Statistics Across Regions

Regions	Sec.School (2015)	Resources Rent	CPIA	Mortality Rate (2015)
East Asia & Pacific	88.4	1.1	3.1	17.1
Latin America and Caribbean (LAC)	94.3	3.0	3.4	18.3
The Middle East and North Africa	79.3	14.4	2	24.2
South Asia	69.3	1.6	3	49.3
Sub-Saharan Africa	42.5	7.6	2.7	81.4
World	76.2	1.7	2.8	41.9

Source: Author's calculation.

Note: Sec. School is secondary school enrollment (% of Gross enrollment); Resources Rent is total natural resources rent (% of GDP); CPIA[8] is public sector corruption rating, and Mortality rate is Under-5 mortality rate per 1000.

This was seen in Sierra Leone, Guinea and Liberia when the world price of iron ore fell drastically. Sub-Saharan African countries with vast reserves of minerals and natural resources have also suffered from wars and civil conflicts which also affects their economies. For example, Nigeria, the richest oil resource country in the region, has been at the centre of conflicts, uncertainty and oil theft (in the Niger Delta) which has derailed investment (IEA Report, 2014a).

Foreign direct investment (FDI) has been established in the literature as one of the determinants of energy intensity reduction (Adom, 2015a). But Sub-Saharan Africa, as of 2015 had the second-lowest rating in the CPIA index. The right business environment, coupled with political stability, can serve as an incentive for investors.

---

[8] CPIA is the acronym for Country policy and institutional assessment.

2.2 Status of the Determinants of Growth in Sub-Saharan Africa

Slow growth and the inability to harness new opportunities from technological innovation are as a result of weak institutions, infrastructure and skills (World Economic Forum Report, 2018). The following are some of the most highlighted determinants of slow growth in SSA: poorly developed human capital, poor institutions, weak economic policies and investment, and political instability.

2.2.1 Human Capital

Human capital includes the education, skills, and wellbeing individuals acquire overtime, that enables them to realise their full potential as productive members of society (World Bank Report, 2019). According to the endogenous growth theory, investment in human capital should stimulate innovation, boost modern output production, increase advanced technologies that would consequently stimulate economic growth (Ogundari and Awokuse, 2018). With rising fears of humans losing jobs to robots, investing in human capital is critical (World Bank Report, 2019). In 2016, SSA's human capital capacity was 8.7 per cent (according to tertiary school enrollment data from WDI). Theirs is the lowest compared to other regions such as the Middle East and North Africa with 40 per cent, and Latin America and the Caribbean with 48 per cent. Sub-Saharan Africa has 80 to 90 per cent of its workers in the informal sector[9]. Nevertheless, the rise of secondary school enrollment from 3.2 per cent in 1990 to 8.7 per cent in 2016 in SSA shows that there has been an increasing trend in its human capital formation. It is indicating that the region

---

[9] Accessed online from http://www.ilo.org/global/about-the-ilo/newsroom/features/WCMS_570043/lang--en/index.htm.

is experiencing growth in its human capital capacity, and this will contribute to the development process (Oluwatobi et al., 2016).

2.2.2 Institutions

To attain sustainable growth, ensuring a favourable climate for investors is among the first course of action (World Bank, 2005). As Toulmin (2008) noted, getting formal documentation for lands is one of the biggest challenges to investment. Several surveys have exposed how government inefficiencies, weak institutions, bureaucracies, and poor policies affect potential investors (World Economic Forum, 2004). Many countries in SSA record high corruption index due to the long and robust bureaucratic processes that slow down transactions (De Soto, 2000). The ease of doing business index, which ranks economies from 1 to 190 with 1 meaning the most business-friendly environment, shows that only two countries, Mauritius and Rwanda out of the 48 SSA countries have an index below 50 (25 and 41, respectively). Somalia (190), South Sudan (187), Congo Democratic Republic (182) and Libya (185)[10] are among the highest (WDI). The figures for the largest economies in SSA, namely Angola (175), Nigeria (145) and South Africa (82) are also not encouraging. Not having rights and legal ownership of lands, or having to spend huge sums of money on protecting one's property, discourages investment (World Economic Forum Report, 2018)[11]. Angola, one of the three largest economies in SSA, ranked as one of the worst performers in terms of the quality of institutions, and Nigeria ranked 127 out of 140 (World Economic Forum Report, 2018). This does not paint a good picture of the business environment in SSA.

---

[10] These are countries battling armed conflict and political instability.

[11] An economic compass benchmarking the drivers of long-term competitiveness.

2.2.3 Economic Policy

"Economic policies set the framework within which economic growth takes place" (Barro and Sala-i-Martin, 1995). Economic policies affect various sectors of the economy. Reduction in political and economic uncertainty may boost growth. (Ndambiri et al., 2012). Economic policies that can increase private investment, decrease public debt, stabilise the exchange rate and stimulate human capital development, results in real GDP growth. But high inflation discourages investment because it increases the cost of borrowing and the difficulty of firms to forecast accurate trends of profit. (Calamitsis et al., 1999). The average public debt-to-GDP ratio in SSA surged to 45.9 per cent in 2018 from 32.4 per cent in 2014. In 2015 the public debt-to-GDP ratio in Zambia was more than two times that of 2011. By 2018, it was 65.5 per cent. (World Economic Forum Report, 2018). Similarly, it more than doubled in Malawi from 23.4 per cent in 2011 to 55.2 per cent in 2016 and was 48.7 per cent in 2017 (WDI). However, Botswana with a public debt of 15.2 per cent of GDP in 2016 (WDI) is proof that countries in SSA can cut down on their debt-to-GDP ratio if they implement the right policies (World Economic Forum Report, 2018).

2.2.4 Investment

It is widely believed that foreign direct investment (FDI) has a beneficial effect on host countries because a more significant share of it is concentrated in developed countries (Bermejo et al., 2018). Investment is a central determinant of economic growth, especially private investment, because of its efficiency due to low levels of corruption (Hernandez-Cata, 2000). However, high taxes, macroeconomic instability, armed conflicts and weak institutions have put a dent in the level of investment in SSA (Hernandez-Cata, 2000). Data from WDI shows that at 1.5 per cent in 2017, SSA's FDI rate grew by only 1.2 per cent from 0.3 per cent in 1990. Increased investment flow was one of the main drivers of the 5.8 per cent GDP growth in South Africa in 2012 (Global Economic Prospects, 2013). FDI declined in Africa in 2017 by 21 per cent to $42 billion and $28.5 billion in SSA due to oil and commodity prices volatility. Of the three largest economies in the region, Angola was the most severely hit with -$2.3 billion. (United Nations Report, 2018a). With steady commodity price recovery and strong interregional economic co-operations, FDI in Africa was projected to increase by 20 per cent to $50 billion in 2018 (United Nations Report, 2018a) but increased by 11 per cent to $46 billion (United Nations Report, 2019a).

2.3 Recent Growth Records in Sub-Saharan Africa

In 2018, there was a steady increase of 3.1 per cent of growth in the global economy. (United Nations, 2019b). Due to rising exports and private consumption (demand side) and rebound in agricultural, mining and service sectors (supply side) in some countries, the 2019 and 2020 growth projections are 3.4 and 3.7 respectively (United Nation Report, 2019). East Africa[12] is the fastest-growing region in Africa, led by increased government spending on infrastructure and domestic demand (United Nations Report, 2019). West Africa growth of 3.2 per cent was driven mainly by growth in Nigeria's oil sector. North Africa's improvement in tourism revenue and rising agricultural production increased its growth to 3.7 per cent. Central Africa exited a -0.2 per cent recession to 2.2 per cent growth in 2018. However, the Southern Africa regions suffered a fall in growth from 1.5 per cent in 2017 to 1.2 per cent in 2018 due to poor economic performance in South Africa[13]. (United Nation Report, 2019).

---

[12] Djibouti is the only country in East Africa not in the group of SSA countries.

[13] Northern region is the only region with no country classify as an SSA country. All countries in the West, Central Africa and Southern regions are SSA countries.

Notwithstanding the above, cross-country differences in growth persisted (World Bank Report, 2019). Growth picked up in the resource-intensive countries of Congo, Dem. Rep; Guinea; and Nigeria, driven by increased global metal price and recovery made in agricultural production, and government spending on infrastructure (World Bank Report, 2019). The 2.4 per cent growth in Nigeria in 2018 was led by the service and agriculture sectors (World Bank Report, 2019). South Africa exited recession by the third quarter of 2018, but growth decelerated due to a sharp fall in fixed investment (World Bank Report, 2019). However, Angola remained in recession with a sharp fall in growth from weak oil production due to maturing oil fields (World Bank Report, 2019). Non-resource-intensive economies of Ghana, Kenya, Rwanda, Uganda, Tanzania, Benin, and Cote d'Ivoire recorded solid economic growth in the third quarter of 2018 (World Bank Report, 2019).

Africa's 2018 decline in inflation is projected to continue to 2019 as a result of stable exchange rate and improved agricultural and food production (United Nations, 2019b). The fall in the number of drought-affected countries in 2018 played a crucial part in the increased agriculture production of the region. Mozambique, Malawi and Zimbabwe were hit by a tropical cyclone (Cyclone Idai) which in addition to the high death toll, greatly damaged infrastructure, disrupting economic and trade activities in the sub-region (World Bank Report, 2019). These natural disasters would have a significant impact on social wellbeing through food security, poverty and inequality.

A 1.4 per cent fall of the public debt-to-GDP ratio is projected in 2019, mainly driven by a decline in the debt-to- GDP ratio among oil exporters, a rise among metal exporters and stability among non-resource-intensive countries (World Bank Report, 2019). In the first quarter of 2019, the average crude oil price was US$ 61 per barrel following cuts in production by the Organisation of Petroleum Exporting Countries (OPEC) and non-OPEC partners. But the stability of this production cuts is clouded with uncertainty. Metal price increased slightly and is projected to remain stable in 2019. (World Bank Report, 2019).

2.4 Risks Facing the Region

Economic growth in SSA in 2018 was 0.4 percentage point below the 2018 projected figure. For the fourth time in a row, economic growth fell below the population growth rate. (World Bank Report, 2019). This poor performance was driven by weaker oil exports in Nigeria and Angola[14], occasioned by low oil production in response to high but unstable international crude oil price (World Bank Prospect, 2019). The contraction of the Sudanese economic activities and non-resource-intensive countries also played a part (World Bank Report, 2019). The global slowdown in growth presents a challenging external environment for SSA countries (World Bank Report, 2019). An unprecedented downturn in the USA, Eurozone and China- Africa's leading trade partner- could have a ripple effect on the region's economic activities (World Bank Report, 2019). An unexpected decline in commodity prices could put pressure on investment and more likely affect efforts to rebuild fiscal and external sustainability, especially in resource-intensive countries (World Bank Report, 2019).

Protectionist trade policies and increased trade tension could undermine exports which would stifle exports growth- an essential aspect of the region's economic rebound (World Bank Report, 2019). Political considerations in countries holding elections this year (e.g. Nigeria, Malawi and South Africa) with a need for significant fiscal adjustments may jeopardise commitment to tighten fiscal policies (World Bank Report, 2019). Security is also fragile in the

---

[14] Nigeria and Angola are the largest oil exporters in the region.

region (World Bank Report, 2019). Political instability discourages investment because of the fear of capital loss that comes with uncertainty (Fosu, 1992). Unstable domestic security situations remain in many countries, and poor economic and social conditions could worsen matters because governments' spending would be directed towards security reforms rather than economic. (World Bank Report, 2019). Public debt vulnerabilities remain elevated. Out of the 48 countries in SSA, 16[15] are classified as high-risk debt distress or already being debt distressed. (International Monetary Fund Report, 2019).

As Sachs and Warner (1997) put it, SSA is naturally disadvantaged and prone to natural disasters. The occurrence of natural disaster remains high and is a significant risk to the region as was seen in Mozambique, Malawi and Zimbabwe (World Bank Report, 2019). El Niño[16] is also expected to cause droughts in Southern Africa[17] as well as above-average rainfall in East Africa[18] (Regional Economic Outlook, 2019).

2.5 Energy Use in Sub-Saharan Africa

Africa is richly endowed in natural resources (UNEP, 2017). SSA has high potential generation capacity with diverse and large quantities (though unevenly distributed) of solar potential (10GW), hydro (350GW), natural gas (400GW), wind (109GW), and geothermal 15 (GW) (Avila et al., 2017). Even with these unlimited possibilities from renewable energy resource endowment, biomass energy makes up about a quarter of the energy consumed in Africa but quite

---

[15] Burundi, Cameroon, Cape Verde, Central Africa Republic, Chad, Ethiopia, Ghana, Sierra Leone, Zambia, Congo Rep, Eritrea, the Gambia, Mozambique, Sao Tome and Principe, South Sudan, and Zimbabwe.

[16] An irregularly recurring flow of unusually warm surface water from the Pacific Ocean.

[17] Botswana, Lesotho, Malawi, Mozambique, South Africa, Zambia, and Zimbabwe.

[18] Ethiopia, Kenya, Tanzania, and White Nile Basin.

encouragingly makes up 80 per cent of that consumed in Sub-Saharan African countries (UNEP, 2017). Notwithstanding, there is still hope of a better energy system in SSA, with barrels of oil and natural gas estimated at 115.34 billion barrels (UNEP, 2017) and 11.225 bcm, respectively, and a lot of undiscovered opportunities[19]. Nigeria, the leading producer and consumer of natural gas in SSA, consumed 5.2 bcm in 2015, followed by South Africa with 2.3 bcm (et al., 2018). However, discoveries have been made in Mozambique and Tanzania, and their potential is estimated at 2.8 and 1.3 bcm, respectively (IEA Report, 2014a).

Improvement in the power sector reforms and gas infrastructure project is expected to increase the incentive to use gas. A significant hindrance to this is the amount of gas lost through flaring. Over the years, over one trillion cubic metres of gas has been lost to flaring. If this were used to generate power, it would for the next decade meet the electricity needs of Sub-Saharan Africa. In 2012, natural gas used was 27 bcm, and approximately, the same volume was exported and lost to flaring. (IEA Report, 2014a). Nigeria accounts for 60 per cent of SSA's gas flaring, followed by Angola, Congo and Gabon (Hafner et al., 2018).

Fuelwood and charcoal demand in SSA outweigh that for all other forms of energy combined. Even when income increases, the fall in demand for fuelwood and charcoal is gradual. Four out of five people in Sub-Saharan Africa rely on solid biomass, especially fuelwood for cooking. A 40 per cent rise in the demand for energy by 2040 is predicted, and this will result in high rates of deforestation. The fact that most of those largely dependent on solid biomass is in the informal sector puts a dent in efforts to promote more sustainable wood production. (IEA Report, 2014a). From figure 2.1, over the 25 years period from 1990 to 2015, electricity

---

[19] Sourced online from https://www.standardbank.com/standimg/cib/Sector%20Expertise/Static%20files/2018/Oil%20and%20Gas%20Sector%20Potential%2013%20Mar%202018%20v3.pdf

generation from coal sources only fell by approximately 12 per cent, natural gas sources increase by less than 10 per cent, and oil by less than 5 per cent.

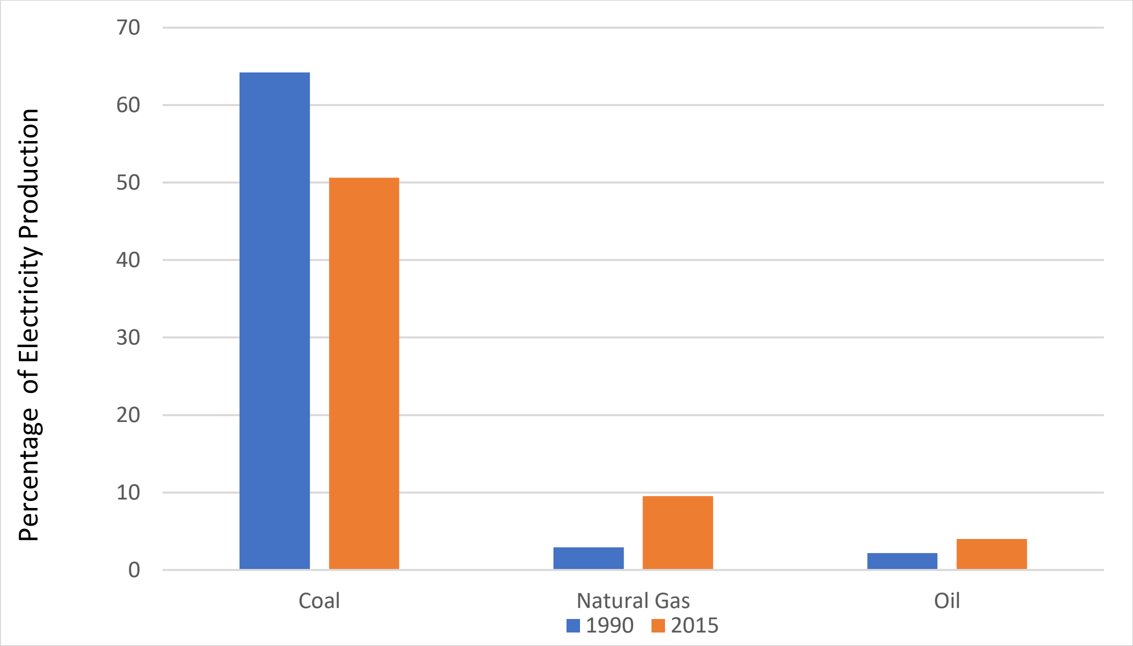

Figure 2.1: Electricity Production from Solid Biomass in Sub-Saharan Africa

Source: Author's compilation.

South Africa is the dominant agent in coal production and consumption in the region[20]. Production of coal in SSA has been hindered mostly by the remoteness and poor railway and port infrastructure (Hafner et al., 2018). New energy diversification policy in South Africa has also limited the prospect for coal supply. South Africa plans to reduce the share of coal in the power supply to less than two-thirds by 2040. (IEA Report, 2014a).

---

[20] Sourced online from https://www.miningafrica.net/natural-resources-africa/coal-mining-in-africa/

2.6 Energy Consumption in Sub-Saharan Africa

Data from World Development Indicators show that energy consumption has been rising in the region. From 1990 to 2017, Uganda's total energy consumption increased by 99 per cent while it's per capita GDP increased by 121 per cent.

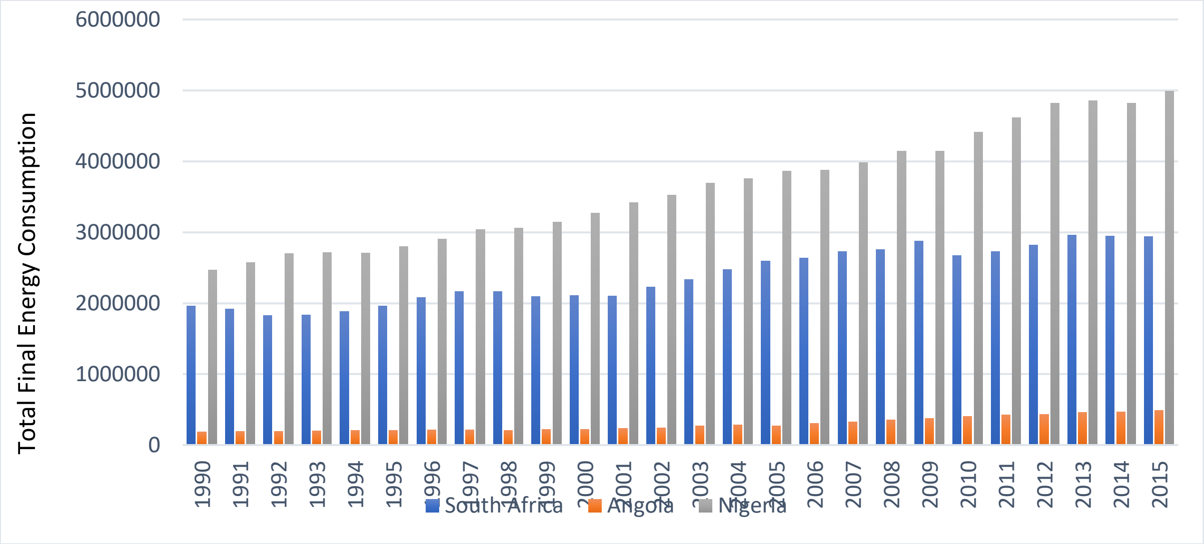

Figure 2.2: Energy Consumption in SSA's three Largest Economies

Source: Author's Compilation.

Similarly, Tanzania's total energy consumption increased by 157 and its GDP 82 per cent. Nigeria's total energy consumption increased by 102 per cent, while its GDP per capita rose by 76 per cent. The current figures (Figure 2.2) of the largest economies in the region show that there has not been much improvement in this area. Energy consumption from Nigeria and South Africa does not give much encouragement about the threat of energy security and climate change the region faces.

2.7 Energy Intensity in Sub-Saharan Africa

To meet our daily needs, industries use about 40 per cent of total world energy and in the process release about 37 per cent of greenhouse gas (GHG) emission. Energy use is the primary source of GHG emission from the industrial sector with CO_2 accounting for more than 90 per cent of CO_2-eq GHG, globally, and in most countries (Worrell, 2011). The fact that the SSA countries only contribute 4 per cent of global greenhouse gas emissions does not in any way diminish the dangers that climate change poses to the region (World Energy Council, 2017[21]). The direction of change in energy intensity can be as a result of three effects: (i) the scale effect, that is environmental degradation caused by an increase in energy consumption; (ii) structural effect, that is a change from energy-intensive to the non-energy intensive sector; and (iii) the technological effect, that is an increase in energy efficiency resulting from technological development (Inglesi-Lotz and Pauris, 2012).

Figure 2.3 depicts trends in energy intensity and economic growth in SSA from 1990 to 2015. From 1990 to 1998, there were some mild fluctuations in GDP per capita. During the same period, energy intensity was relatively high but constant. After 2000, GDP per capita peaked and maintained a steady increase till 2015. This steady increase was matched with a steady decline in energy intensity over the period under review.

---

[21] This information is reported with the permission of the World Energy Council.

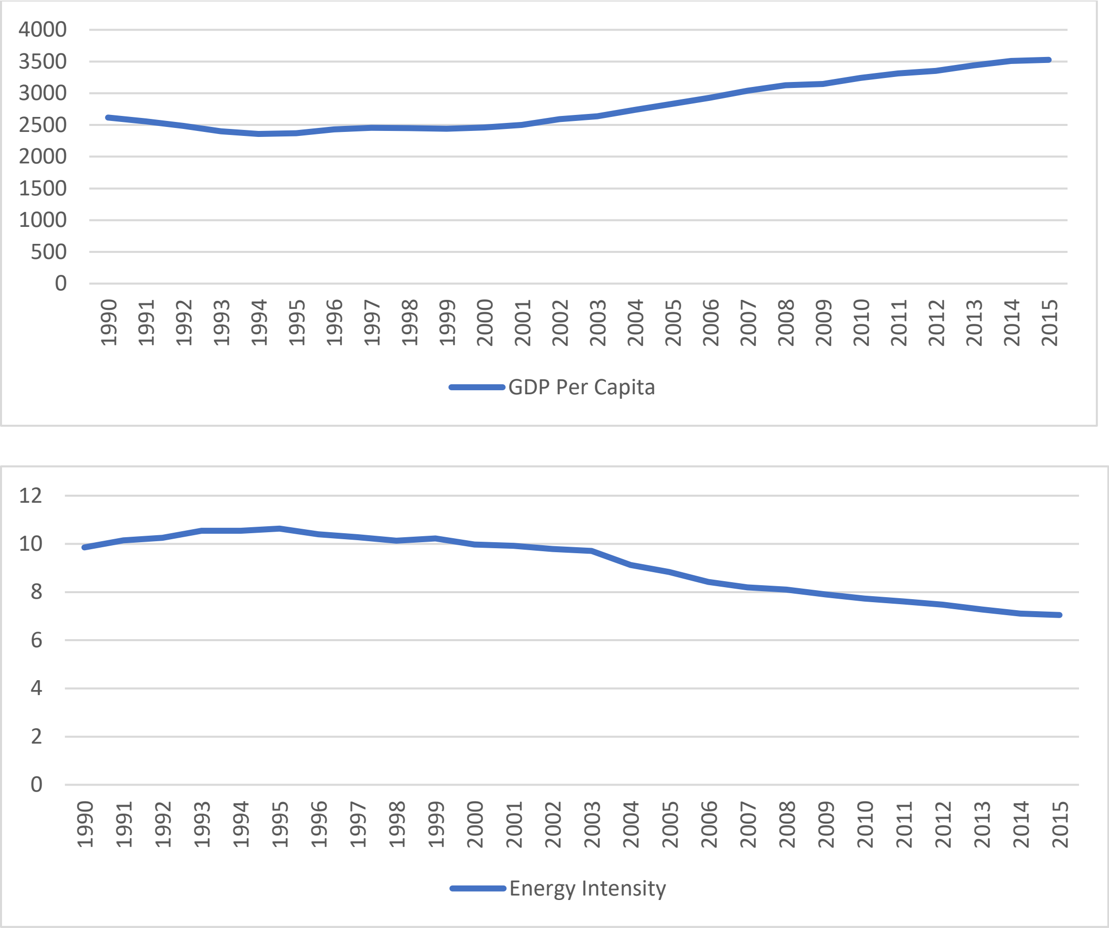

Figure 2.3: **Energy Intensity and GDP Per Capita Trends In SSA**

Source: Author's compilation.

2.8 Barriers to Energy Efficiency

Barriers to energy efficiency are factors that inhibit energy and efficient economic investment (Worrell, 2011). Several studies, including Worrell (2011), Luken and Rompaey (2008), Sorrell et al. (2011), Schleich (2009) and O'Malley et al. (2003) have investigated the barriers of energy efficiency. Some examined it from the manufacturing and industrial sector (Sorrell et al., 2011, Hassan et al., 2017); the commercial and service sector (Schleich, 2009; Reddy, 2013); the end-use sector (Reddy, 2013); industrialised countries (O'Malley et al., 2003); and developing countries (Mallet et al., 2011). The following have been highlighted as some of the most common barriers to energy saving: inadequate information; capital insufficiency; institutional cost; and institutions, regulatory and legal policies.

2.8.1 Inadequate Information

Inadequate information about the level of energy consumption or the performance of energy-efficient technology would cause firms and individuals to under-invest in energy-efficient technologies (Schleich, 2009). Having access to information on energy consumption levels and patterns is particularly important in developing countries (Mallet et al., 2011). Luken and Rompaey (2008), surveyed firms and informants in nine developing countries, discovered from both groups that high cost of production was one of the reasons for the adoption of new technologies. Absence of information may be as a result of organisations having not done their research or producers not provided with adequate information on certain energy-saving technologies (Schleich, 2009). Hence, the more information available about new and improved technology, the higher the chances of industries investing in them (Mallet et al., 2011).

2.8.2 Capital Inadequacy

Limited access to capital could be from external policies (e.g. limited access to capital for the organisation) or internal (e.g. strict policies on capital access for energy-efficient investment) (O'Malley et al., 2003). Lack of access to capital is particularly prominent in small and medium enterprises (SMEs[22]) in developing countries, which are surprisingly energy-intensive (Sorrell et al., 2011). The unavailability of high collaterals requested (especially from SME) by lenders and the high-interest rate charged may prevent energy-efficient investment even when the price of

---

[22] This is because SMEs are considered high economic risk (Sutherland, 1996).

returns is high (Schleich, 2009). Industries with limited capital may also go in for used equipment which requires more energy and leads to an increase in energy intensity because they cannot afford state-of-the-art equipment (Worrell, 2011). Financing difficulties have prevented the vast majority of countries in Africa from fully exploiting their energy potential (Chirambo, 2016). Lack of access to capital in the region is partially a result of inadequate domestic investments, foreign direct investment (FDI), and often unregulated or unpredictable banking system which often results in banking crisis (e.g. Ghana) (Knott, 2018). Such a banking crisis hampers small- to medium-scale projects (especially off-grid), which local entrepreneurs may develop were they to have an accessible line of credit (Bilotta and Colantoni, 2018). In Sri Lanka, for example, in 1995, when the government wanted to encourage industries to be energy-efficient, it implemented the Pollution Control and Abatement Fund (PCAF). This scheme was to provide technical assistance and loan of US$128,000 per industry at no interest rate to be paid over seven years. By 2003, 75 firms were involved in the programme. (Thiruchelvam et al., 2003). Thus, access to capital encourages energy-efficient investment.

2.8.3 Institution, Regulatory and Legal Policies

The importance of the government's involvement through policies (e.g. removal of energy subsidies) and regulations cannot be over-emphasised in achieving energy efficiency (Sorrell, 2011). Regulations that create a level playing field for both innovations of clean but expensive technologies and innovation of cheap but unsafe technologies must be put in place by policymakers and regulators and legally implemented by the local government (Fischer et al., 2011) to serve as an incentive for clean energy innovation. But the public and legal institutions in developing countries usually do not have laws that may serve as incentives, especially for innovation in renewable energy policies (Fischer et al., 2011). The Chinese motor system energy conservation programme is an example of how government policies can help eradicate barriers to energy efficiency. The programme offered minimum efficiency standards for motors, technical assistance, training and financing for investment in new motor systems (EEPC India, 2006). From 1988 to 2011, Mauritius also tripled its industrial cogeneration power generation (combined heat and power) by implementing policies[23] to remove barriers to the development of its industrial power generation and export to grid (Worrell, 2011).

2.8.4 High Transaction Costs

Transaction costs are expenditures incurred through running a business operation (Ganda and Ngwakwe, 2014). There are high transaction costs in renewable energy technologies, but these costs become exacerbated by local circumstances, especially in SSA countries (Fischer et al., 2011). Electricity cost has been cited as one of the challenges that companies in SSA face which has a negative impact on growth. In Ghana, for example, the cost of electricity can be as high as 38-euro per kWh. (Baart, 2018). A significant financing gap exists in the power sector due to the high existing operating cost, which leaves insufficient funds for long-term investment in the power supply (Fischer et al., 2011). If these unfavourable trends continue, half of SSA's population will lack access to electricity by 2030. It will be the region with the highest reliance on traditional fuels in households. (UN-Energy/Africa, 2011).

---

[23] Such as abolishing export duties, tax cuts, etc.

2.9 Energy Access in Sub-Saharan Africa

In 2016, the electrification rate in SSA averaged at 42 per cent. The lowest in the World (World Bank Report, 2018). In 2015 (Figure 2.4), coal, at 50 per cent was the highest source of electricity production and renewables the lowest (excluding hydroelectric) at 1.7 per cent.

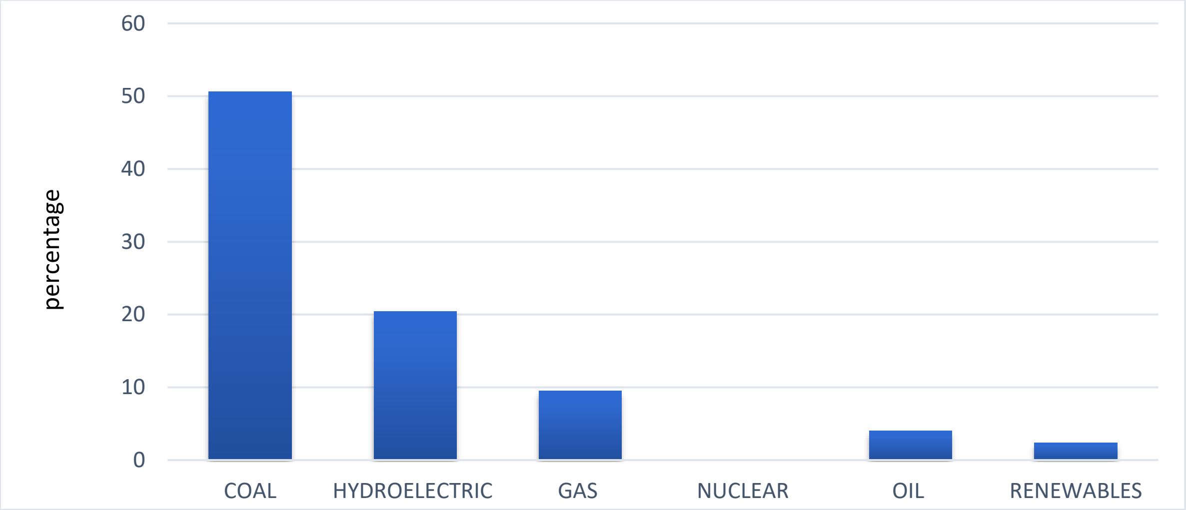

Figure 2.1: Sources of Electricity Generation in SSA

Source: Author's compilation.

Electricity generation capacity in Sub-Saharan Africa in 2011 was 68 gigawatts when South Africa was included, and 28 gigawatts when it is not (Prasad, 2011). In 2015, it was about 96 gigawatts with South Africa accounting for nearly half of it and Nigeria with the highest population in the region accounting for just about one-fourth of South Africa's total installation. This compares less favourably with 325 gigawatts in India and 1,519 gigawatts in China (IEA Report, 2017).

The electrification rate in Africa increased by 12.9 per cent from 1990 to 2010, that is from 186 million people to 444 million people over the 20 years. Total population growth, however, outpaced the rate of electrification, increasing on average by 20.7 million people every year. By 2012, the electrification rate increased by just 2.1 to 45.1 per cent but by 2016 it had gotten to 50 per cent. Though the rate of electrification has outpaced the growth rate of population, Africa is still lagging because of population growth. (United Nations, 2018b). In 2016, household's access to electricity fell to 590 million from 640 million in 2013. In SSA, a wide access gap still exists between the urban (77 per cent) and rural (32 per cent) areas (United Nations, 2018b).

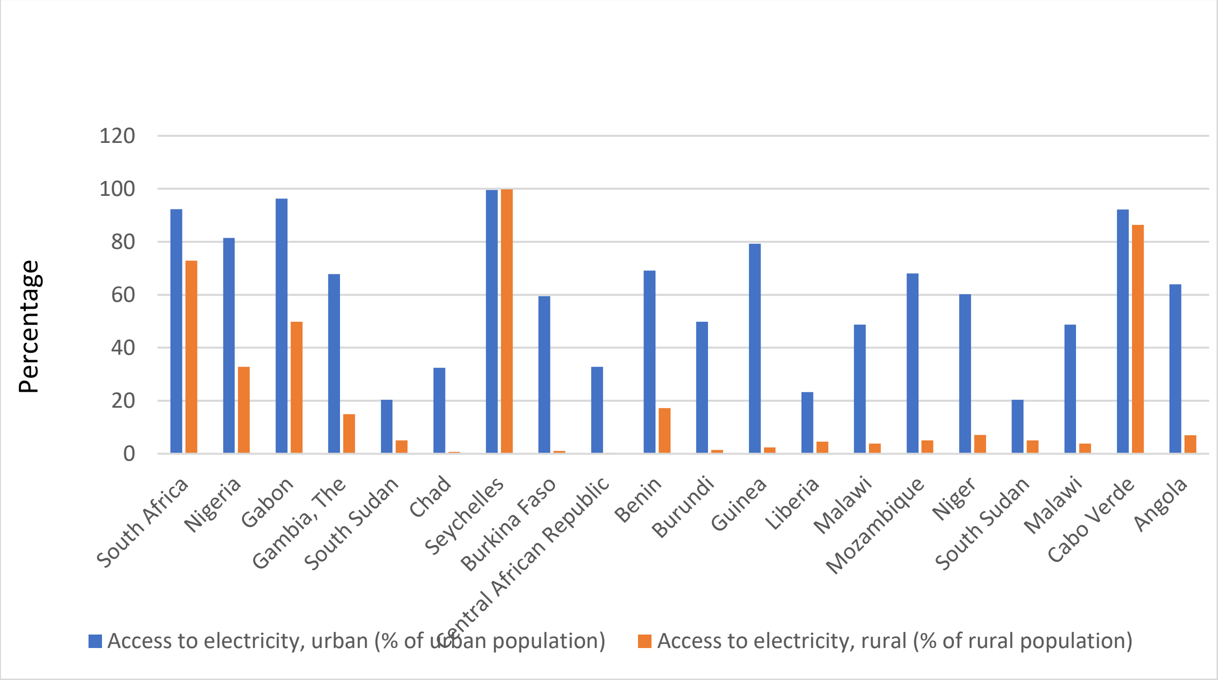

Figure 2.2: Access to Electricity in Selected Countries.

Source: Author's compilation.

From figure 2.5, the striking inequality in electricity access between rural and urban communities can be seen clearly in the Central African Republic with 0.3 per cent in rural as opposed to 32 per cent in urban. Burkina Faso, Burundi, Mozambique, Angola, Guinea and Chad follow a similar trend with high inequality in electricity access between the Urban and Rural population. Nevertheless, significant progress has been made in Seychelles with 99 per cent in both urban and rural, and Cabo Verde with 86 per cent in rural

Africa also has the worst performance in terms of percentage of the population with access to clean fuels and technologies (CFTs). From 2010 to 2015, the total number of people without access to CFTs increased from 610 million to 846 million. (United Nations, 2018b). With 783 million people depending on solid biomass for cooking, there has been an increase in under-5 mortality on the continent resulting in 500,000 premature deaths per year from poor indoor air pollution (IEA Report, 2017).

In this chapter, we have looked at current demographic characteristics, growth levels, risks and energy challenges facing SSA relative to other regions. The data has shown that SSA is lagging behind the other regions in all sectors covered in this chapter, albeit steady progress made in some areas.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

The energy use and economic growth nexus have been investigated by both neoclassical and ecological economists with both presenting conflicting accounts of the various theories. These theories and the empirical literature surrounding the energy intensity and economic growth relationship are reviewed in this section. But we would focus on the literature related to our objectives.

3.1 Theoretical Review

3.1.1 Mainstream Theory of Growth

The neoclassical theory of growth is divided into three mainstream categories (Stern and Cleveland, 2004): i) Growth without natural resources, ii) Growth with natural resources, and iii) Growth with natural resources and technological change.

3.1.1.1 Growth Models Without Natural Resources

Of these, there are two schools of thoughts, Aghion and Howitt (1998) and Solow (1956). These theories state that growth can only be increased at the equilibrium level through technology (Stern and Cleveland, 2004). That is when the steady-state is reached, and growth is constant, it is only through technological change that growth can be increased (Ockwell, 2008).

A. Neoclassical Growth Model

(i.) *The Solow Model*

Almost all growth discussions are centred around the Solow Model (Romer, 2001). Known as the neoclassical growth model or the Solow-Swan model, this model was developed by Robert Solow (Solow, 1956) and T.W. Swan (Swan, 1956). The neoclassical growth theory is grounded on capital accumulation and its relation to savings decisions. The model assumes diminishing returns to capital and labour. The economy is assumed to be a closed one that employs labour (L) and capital (K) to produces one good. Labour and knowledge grow at a constant exogenous rate, and the saving rate is exogenously determined.

All saving is invested, that is S =I = sY; There is no government and only a given number of firms in the economy. Each firm has the same production technology. Output price is constant, and factor prices adjust to ensure full utilisation. Output is a function of labour and capital; the production function exhibits constant returns to scale and diminishing returns to variable factors (Labour & Capital), and the elasticity of substitution between factors is unitary. Output is expressed as a function of capital and labour, and growth is determined by an exogenous factor, technology.

The Solow model can be explained in figure 3.1. y and k are output per effective labour (Y\L), and capital per effective labour (K\L), respectively. Sf(k) is the actual investment per unit of effective labour, f(k) is output per unit of effective labour, s is the marginal propensity to save, and (n+g+ d) is the breakeven investment. d represents depreciation of capital and n and g are the rates at which capital stock is growing. k* and y* are the equilibrium capital per effective labour and output per effective labour, respectively. When the actual investment curve is above the break-even investment curve, k will rise until it gets to a point k*.

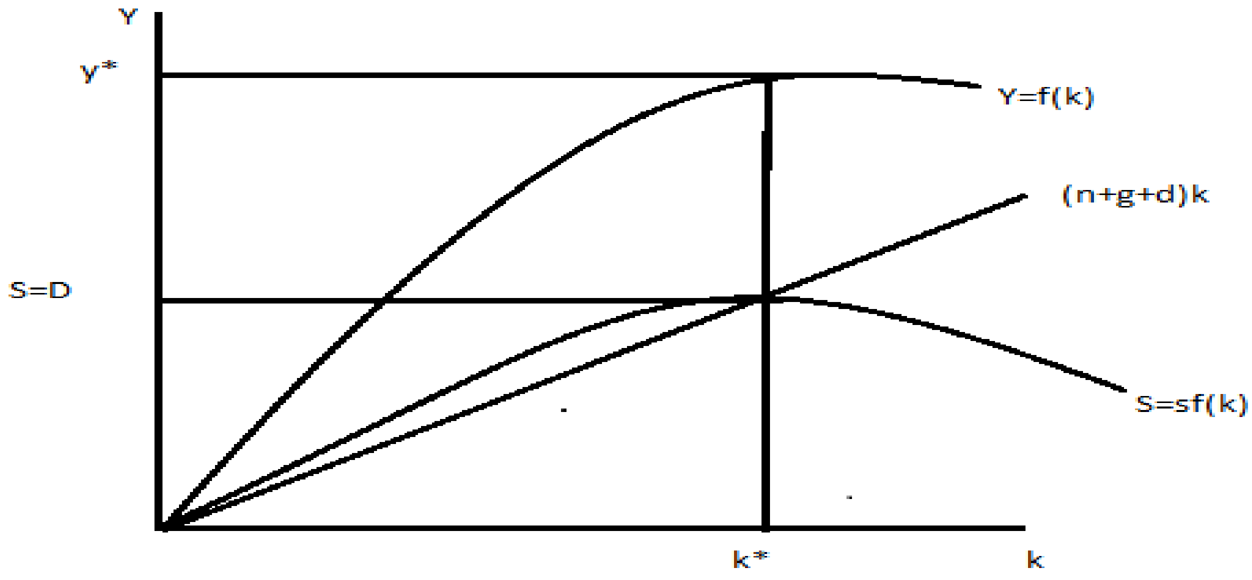

Figure 3.1: The Solow Model

Source: Romer (2001)

On the other hand, when the actual investment is below the break-even investment, k will fall until it gets to k*. This point is called the Steady-state. When an economy gets to this stage, capital and output per effective labour are constant, and hence growth is constant. The economy is then said to be on a balanced growth path.

According to Solow (1956), when an economy gets to this stage, growth of output per worker is only determined by the rate of technological improvement which would offset the effect of the diminishing returns assumption. This assumption that capital and labour are the only input necessary for economic growth was questioned and empirically tested by economists, including Solow. The result showed that the model could not account for the actual income of the US from 1909 to 1949 being several times greater than the expected income based on the conventional model. This difference was dubbed the Solow-residual, and Solow ascribed it to 'Technological growth,' now total factor productivity. (Ayres, 2008). Mainly, the Solow model concludes that physical capital accumulation fails to account for both high growth in output per capita over time and the difference in income across countries.

Several economists have overly criticised this theory because of its inability to account for the international difference in income (Mankiw et al., 1992). These criticisms gave rise to the endogenous growth theory in an attempt to answer the questions the neoclassical theory could not seem to answer (Ayres, 2008).

(ii.) The Ramsey-Cass- Koopmans Model

Developed by Ramsey (1928), Cass (1965), and Koopmans (1965). This model deals with the microeconomic dynamics of economic aggregates. It assumes that growth rate and knowledge are exogenous, but the growth of consumption and savings are determined by demand and supply in the competitive markets. Hence the savings rate is no longer exogenous. The saving rate is therefore constant and a function of per capita capital stock. This distinguishes the Ramsey-Cass-Koopmans model from the Solow-Swan model (Hernandez, 2003).

B. Endogenous Growth Model

The term "endogenous growth" covers a set of theoretical and empirical work of the 1980s. Unlike the neoclassical growth theory, here, economic growth is an endogenous outcome. Therefore, exogenous technological change is not factored in explaining the rapid increase in income per capita since the industrial revolution. The empirical work also tries to find the private and public sector decisions responsible for the variance in the growth of the residual across countries rather than measure the differences in the rate of the growth residual across countries.

In this model, the principal assumption of the Solow model- diminishing returns to capital- is relaxed. The model shows that the assumption of convergence in per capita income across countries cannot hold with constant or increasing returns. Generally, it has been thought that convergence is one of the factors that differentiate the Neo-classical growth theory from the new growth theories and for that reason, it was believed that convergence could be used to test the viability of different growth theories (Islam, 2003). However, Islam (2003) refuted this claim and showed in his work on the convergence debate that both convergence and non-convergence can be explained with appropriate models of growth theory from both varieties. The endogenous models include i) The AK model of Increasing Returns and Long-run Growth (Romer, 1986) and ii) The Model of Endogenous Technological Change (Romer, 1990).

3.1.1.2 Growth Models with Natural Resources

The second theory looks at the natural capital[24] as a determinant for maintaining steady economic growth. It assumes with the right institutions; the equivalent value of physical capital can be substituted for natural capital when natural capital is used up. Though some natural resources like sunlight are available in large quantities, it assumes that all natural resources exist in fixed quantities. Environmental resources can either be renewable or non-renewable with the potential of being depleted. The limit to the availability and depletion of natural resources renders the idea of indefinite economic growth and non-declining sustainable development implausible. With both capital and natural resources as inputs, economic growth can take many alternative paths and the path taken depends on the institutional arrangement of the economy. According to

---

[24] According to the neoclassical theory, this includes both renewable and non-renewable natural resources.

this theory, growth and sustainable development are determined by technical and institutional conditions.

3.1.1.3 Growth Model with Natural Resources and Technological Change

The third model considers both technology and natural capital as factors of sustained growth (Stern and Cleveland, 2004). That is, substituting between physical and natural capital as well as improvement in growth are both considered as determinants of sustained economic growth (Ockwell, 2008). According to this theory, technological change and capital substitution for resources might make growth or non-declining consumption feasible, even when faced with limited resources. The resulting growing total factor productivity makes sustainability technically, easily achievable even when the elasticity of substitution is less than one. However, technical feasibility does not guarantee sustainability. Technology improvement only implies that in the future output per unit of resources will be higher.

In all three growth models, energy is only relevant relative to its cost in the production process and considered an intermediate input in the production process used up through the process of employing the primary inputs of labour and capital which do not get used up but only depreciate in case of capital. In others, words decoupling economic growth from energy use is feasible under the neo-classical model. (Ockwell, 2008).

3.1.2 Ecological View of Economic Growth

Land, labour, capital and energy vectors are reproducible products, but energy is not (Stern, 1999). Because of this, natural scientist and ecological economists have stressed on the role energy plays in the production process and hence growth (Stern, 2003). This has led to the criticism of the neoclassical theory by ecological economists. One of the highlights of the criticism by ecological economists was by Daly (1997):

"since the production function is often explained as a technical recipe, we might say that Solow's recipe calls for making a cake with only the cook and his kitchen. We do not need flour, eggs, sugar, etc., or electricity or natural gas, or even firewood. If we want a bigger cake, a cook simply stirs faster in a bigger bowl and cooks the empty bowl in a bigger oven that somehow heats itself. Nor does the cook have any cleaning up to do, because the production recipe produces no wastes. There are no rinds, peelings, husks, shells, or residues, nor is there any waste heat from the oven to be vented. Furthermore, we can make not only bake a cake, but any kind of dish without worrying about the qualitatively different ingredients, or even about the quantity of any ingredient at all." (Daly, 1997).

Figure 3.2: Neoclassical Circular Flow Model of Economic Production

Source: Hall et al. (1986)

The Neoclassical model was also criticised by Georgescu and Roegen (1971) for violating the second law of thermodynamics. According to him, even money, after being circulated between household and firms, gets worn out and needs to be restocked. Therefore, the economic process should not be considered as a secluded self-supporting process, where the circulation within this closed system is not expected to affect the environment or the process being altered in return. Assuming that the economy can flow smoothly without energy is the first myth of perpetual motion, and the second is the assumption that the same energy can be reused several times. It would still be available in different indirect forms (Georgescu-Roegen, 1975). Hartwick (1978) stated that the services provided by energy and other natural resources could not be substituted in principle or otherwise for man-made capital or human labour. Hence energy should be considered as a primary input to economic growth.

Ecological economists have proposed that assuming that the economy is a subsystem within the global ecosystem is a more realistic view (Sorrell and Dimitropoulos, 2007). Here, energy and materials flow through the system from the environment and return to the environment as waste and low heat temperature (Cleveland and Ruth, 1997), supported by the constant flow of solar energy (Cleveland et al., 1984). Ecological economists present their theory from a thermodynamic point of view that emphasises the production of goods and not the exchange of goods based on individual inclination as the neoclassicals assume (Cleveland et al., 1984). The "Mass balance principle", the first law of thermodynamics, maintains that energy cannot be created or destroyed. And, in the sub-ecosystem, the only source of energy is solar energy, which can either be used directly or indirectly as fossil fuels.

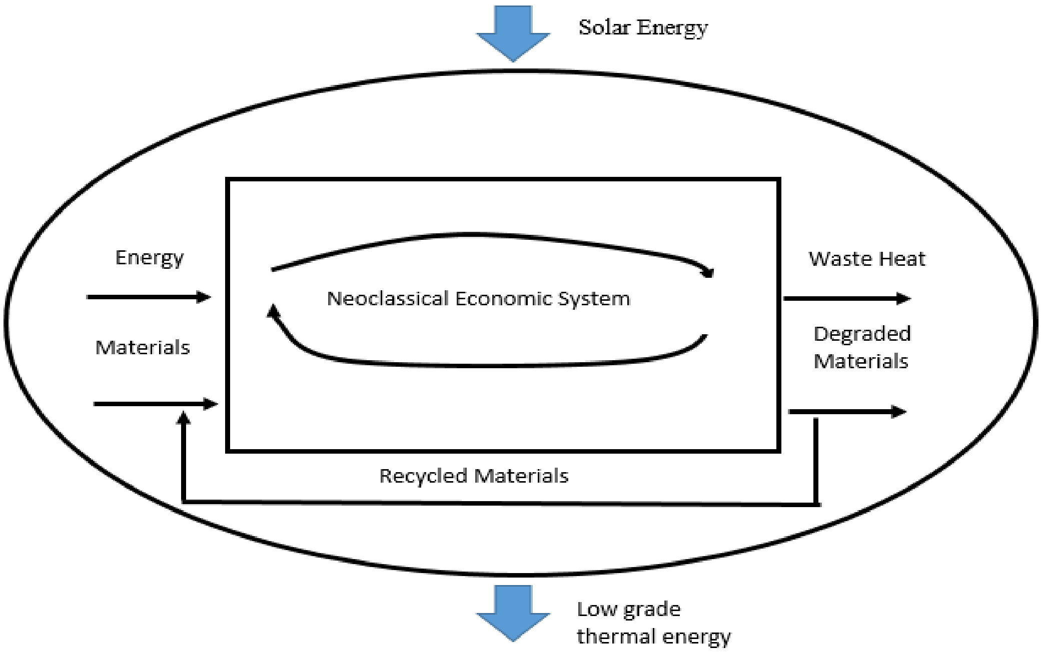

Figure 3.3: Ecological/Biophysical Model

Source: Hall et al. (1986)

It also maintains that the by-product (e.g. carbon dioxide emissions) of using fossil fuel is absorbed by the environment as waste. "Entropy law", the second law of thermodynamics states that although energy and materials are re-useable, they will, to an increasing extent, get to a less productive stage. It also implies that there is a limit to the rate at which energy can be substituted for other factors of production. Even without reliance on natural capital, energy and labour (which also consumes energy) are required for the manufacturing process. (Ockwell, 2008). From these laws, they presented the following theories of the growth process:

(i) Feedback Cycle Theory, and (ii) Power Feedback Cycle Theory.

(i) Feedback Cycle Theory

Under this theory, households sell energy and other factors of production to firms who use them as input in the production process to produce outputs which households purchase.

Therefore, the relationship between energy use and economic growth strengthens as the level of technology ingenuity rises and/or price of energy falls relative to other inputs. But this theory has also been criticised on the argument that energy is an essential input in the economic systems that causes the cycle feedback between firms and households and as such the relationship between energy and economic growth will still be strong irrespective of the level of technology ingenuity or the price of energy relative to other inputs.

(ii) Power Feedback Cycle Theory

This theory states that innovations, economies of scale and technical progress result in low cost of production and in a competitive market, the lower cost will result in lower prices and increase demand. This increase causes a rise in output which corresponds to an increase in factor payment, a more significant share of which is wages and salaries. The increase in wages causes a further increase in the substitution of fossil fuels for human labour, resulting in increased benefits from economies of scale and even lower cost of production.

3.1.3 Energy Intensity and Economic Growth

The energy intensity and economic growth relationship have not been extensively documented in the theoretical literature. In his 2004 study Stern acknowledge that the production function can be used to explain the energy intensity and economic growth theory. This function is represented as follows

$$(Q_{1 \ldots\ldots} Q_m)^1 = f\left(A_{1,}\ X_{1 \ldots\ldots} X_{m,}\ E_{1 \ldots\ldots} E_p\right) \qquad (1)$$

Where Q represent various outputs; A is technology; X represents various inputs and E energy inputs. From this production function, the energy intensity and economic growth relationship can be affected through technological advancement, the substitution of energy and other inputs, and a change in output composition.

As countries develop, they adopt cleaner energy input in the production process. Hence, energy intensity falls. Economic growth also paves the way for technological advancement, which result in energy-efficient production process. However, the effect of growth may depend on a lot of factors, including the composition of the sectors in the economy. According to the Khazzoom-Brookes postulate, innovations from economic growth can have a rebound effect on energy intensity as savings made through energy innovations maybe diverted to others good and services that require more energy for their production.

3.2 Empirical Literature Review

Empirical studies on energy intensity and economic growth nexus continue to flood the literature. But there is still no unanimous conclusion on the relationship between them. This could be attributed to the fact that different studies have employed different methodologies, data set and scope.

3.2.1 Energy Intensity and Economic Growth Nexus

The empirical literature has produced varying results on this relationship. Some studies have found a positive correlation (e.g. Jones, 1989; York, 2007; Parikh and Shurkla, 1995), others a negative relationship (e.g. Su-yun and Zhen-yu, 2010; Mahmood and Ahmad, 2018; Cole, 2006; and Sadorsky, 2013). Jones (1989) used income as one of his explanatory variables to study the impact of urbanization on energy intensity, for 59 developing countries in 1980. He observed a positive relationship between income and energy intensity. Similarly, York (2007) investigated the determinants of energy consumption in the European Union from 1960 to 2005 using panel data techniques and found a positive relationship between income and energy consumption. This is consistent with findings by Parikh and Shurkla (1995), who used a cross-group regression of developed and developing countries in 1992.

On the contrary, Sadorsky (2013) used a dynamic estimation technique for 76 developing countries from1980 to 2010. He found a negative relationship between income and energy intensity, positive for industrialization, and mixed for Urbanization. Mahmood and Ahmad (2018) also observed a negative correlation between energy intensity and economic growth in a panel dataset of European countries, even after detrending energy intensity. Jimenez and Mercado (2014), based their analysis of 75 countries from 1971 to 2010 and found that energy intensity falls as income increases. This is also consistent with findings by Wu (2012) for China regional economies, Galli (1998) for 10 developing Asian countries from 1973 to 1990, and Medlock and Soligo for a 28-country sample of OECD[25] and developing countries from 1979 to 1995.

3.2.2 Causality

The empirical literature on causality, have concluded on one of four results: (i) unidirectional causality from economic growth to energy use; (ii) unidirectional causality from energy use to economic growth; (iii) bidirectional causality between energy and economic growth and (iv) no causality between the two (Kwakwa, 2012). This may be as a result of the structural changes in the country, the country's consumption pattern, and energy sources (Soytas and Sari, 2007). The

---

[25] Organization for Economic Co-operation and Development.

nature of causality between economic growth and energy use have been explored to great length (Stern, 1993). Kraft and Kraft (1978) used Sims (1972) methodology to investigate the nature of causality between gross national product and energy use in the United States and observed that causality runs from GNP to energy use but not from energy use to GNP. They concluded that economic growth could not be negatively affected by environmental protection policies. Akarca and Long (1980) criticized these results, on the grounds that, Kraft and Kraft (1978) only got to that conclusion because they extended their data sample by two years, 1973-1974 and those years were years of the oil crisis as a result of the oil embargo. Hence, they may be spurious.

Adopting the Sims (1972) methodology, Ammah-Tagoe (1990) observed that causality ran from GDP to total energy use in Ghana. Robert and Nord (1985), in their work on "causality test and the functional form sensitivity," argued that the sensitivity of both the Granger causality and Sims methodologies were affected by the functional form of the time series. To overcome this limitation in the methodology, Stern (1993) adopted a multivariate approach of the vector autoregression (VAR) to investigate the energy consumption and economic growth relationship in the US. He reported a unidirectional causality from economic growth to change in gross energy use.

3.2.3 Convergence

Although quite a number of studies in the empirical literature have covered the area of convergence, there is a significant difference in the theoretical background and methodology employed and the way cross-sectional heterogeneity is treated, and there is no consensus among researchers on the results. A large and growing number of literature has been published on the convergence of economic indicators among countries. The most common being income convergence. That is, countries converging as a result of a decline in inter-country income inequality. (Markandya et al., 2006). Baumol (1986), using Maddison's 1982 data, observed productivity convergence among 16 industrialised economies since 1870. He found that 18 per cent of the variations in the labour productivity growth could be accounted for by convergence. Dowrick and Tho-Nyugen (1989) and De Long (1988) among others have criticized Baumol (1986) for being convergence biased because he used Madison (1982) data set of countries that were already rich and developed.

In investigating convergence in the energy field, researchers have concentrated on these three strands: i) convergence in energy intensity and energy productivity (for example Markandya et al., (2006); Ezcurra (2007a); Le Pen and Savi (2010); ii) convergence in carbon-dioxide emissions (Aldy (2006) and Ezcurra, (2007b)) and iii) convergence in electricity variables (Maza and Villaverde (2008) and Liddle (2010)). Strazicich and List (2003) carried out both panel unit root tests and cross-section regression to test for stochastic and conditional convergence to examine the time paths of carbon dioxide emission in 21 industrialised countries from 1960-1997. Both tests rejected the null of divergence. However, the methodology used has faced several criticisms by Quah (1993, and 1996) for its inability to capture several inherent characteristics of the progress of the distribution patterns in the economic growth literature context (Ezcurra, 2007b). In addition, Ezcurra (2007b), argues that the approach adopted is grounded on a single ‘representative’ economy model. Therefore, such analysis does not provide a broad view of the observed distribution and thus completely overlooks the possibility of intra-distribution mobility.

To overcome this problem and the shortfalls in the methodology of standard convergence analysis, Ezcurra (2007b) adopted the non-parametric approach recommended by Quah (1993, and 1996) to analyse the distribution dynamics of per capita CO_2 emissions in 87 countries from

1960 to 1999. Ezcurra (2007a) also used a non-parametric approach to investigate the spatial distribution of energy intensities in 98 countries from 1971-2001. The analysis revealed that the sample countries are converging. This result mirrors the findings of previous studies (Nilsson (1993); Goldemberg (1996); and Mielnik and Goldemberg (2000), who used different methodologies and smaller sample size. Though Van (2005) used the same methodology for a sample of 100 countries from 1966-1996, he observed that only countries with high CO_2 emissions per capita, relative to the sample average observed a decrease in their relative emissions. However, relative emissions of low-income countries remained unchanged throughout the study period.

The energy intensity convergence literature has mostly investigated the possibility that variation in energy intensity across countries is getting smaller and whether a decline in energy intensity of less efficient countries is faster than more efficient ones (Deichmann et al., 2018). Herrerias (2012) analysis of 83 countries over the period 1971-2008, using the dynamic distribution approach and weighing the distribution of the population by country,

noted that developing countries were converging at a higher energy intensity ratio. However, convergence among developed countries was in two-fold - one in the lowest level of energy intensity, and another in the higher level of energy intensity. Liddle (2010), in a study, using a data set of 111 countries from 1971-2006, and 134 countries from 1990-2006 including the former Soviet Union Republic and Balkan countries, indicated a significant level of continued convergence from 1971-2006. Investigating further, using geographical disparities, the study revealed that the OECD and Eurasian countries had observed a significant level of continued convergence at a rate faster than Sub-Saharan African countries that have been converging among themselves. However, Latin America and the Caribbean and the Middle East and North Africa countries have shown divergence in energy intensity. Also, Kiran (2013), in a study on convergence for OECD countries, found evidence of convergence for nine (9) countries. Nilsson (1993) used a purchasing power parity GDP measure to investigate the energy intensity trends for 31 countries from 1950 to 1988. After adding non-commercial energy in the model, he concluded that there is not much difference between the energy intensity levels of low income and high-income countries. He also found that countries are converging to a common rate between 0.25 and 0.5 toe (ton per oil equivalent) per 1000 international dollars. Mielnik and Goldemberg (2000), using the same methodology and a dataset for 41 countries from 1971 to 1992, confirm this finding.

3.2.4 Environmental Kuznets Curve

In the 1980s, income growth and environmental protection were seen as two conflicting goals. The 1980s was the start of sustainable development discussions that shifted the mainstream perspective to "too poor to be green". That is, underdeveloped countries lack the resources needed to achieve a clean environment, and environmental protection could only be achieved through growth and development. This idea gave birth to the Environmental Kuznets curve (EKC) empirical model. (Stern, 2003). The first EKC models were estimated by Grossman and Krueger (1991) as part of a study responding to the concerns of environmentalist on the "Environmental impacts of the North American Free Trade Agreement (NAFTA)" (Stern, 2015). They used the Global Environmental Monitoring System (GEMS) dataset, to estimate EKCs for Sulphur, dark matter (fine smoke), and suspended particles matter (SPM). To estimate the model, each regression had a cubic function in levels of GDP per capita adjusted for purchasing power parity (PPP), a time trend, a trade intensity variable and various site-related variables. They argued that at low levels of national income, SO_2 and dark matter increase in tandem with income per capita. However, the opposite holds at high levels of national income.

Galli (1998) found an inverted U-shaped relationship between the energy intensity and income levels for 10 Asian emerging countries from 1973 – 1990. Aslanidis and Iranzo (2006) applied a smooth transition regression model that accounts for regime-switching on a dataset of 77 developing countries, and failed to reject the null of no EKC for carbon dioxide emissions, but found that the rate of environmental degradation declines as low-income countries develops. These findings are consistent with findings by Galeotti et al. (2006). They employed a Weibull functional form, contrary to studies based on quadratic models (for example, Shafik (1999) and, Holtz-Eakin and Selden, 1995).

Shafik (1994), among others, have shown from empirical studies that not all environmental impact can fall with an increase in income level (Stern, 2015). This has led to a wide debate on its validity, especially for developing countries (Aslanidis and Iranzo, 2006). Data used in the EKC hypothesis have also been criticized for being insufficient and/or not credible for such analysis, parameter estimation and making recommendations (Stern et al., 1996). Stern (2004) has criticized the EKC literature for being econometrically weak with conclusions based on findings of statistically significant coefficient and the expected signs. Perman and Stern (2003) went as far as to say the EKC does not exist when diagnostic statistics and specification test are accounted for, and appropriate techniques are adopted. Hence the decomposition approach has been used instead in other fields to study climate change (Stern, 2015).

In this chapter, the contrasting theories of the neoclassicals and the ecological economists on energy’s role in productivity and hence growth have been reviewed. Also, evidence from the ecological economist as to what makes the neoclassical theory flawed has been presented in addition to empirical literature to back the ecological theory.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

In this chapter, we present the theoretical and empirical framework that informed our model, methodology, and econometric analysis.

4.1 Theoretical Framework

The famous steady-state condition of the neoclassical growth model by Solow (1956) is the most straightforward approach to modelling the energy intensity and economic growth relationship (Mahmood and Ahmad, 2018). Solow (1956) specified the production function as:

$$Y(t) = AF\big(K(t), L(t)\big) \qquad (2)$$

$$Y(\cdot),\ Y'(\cdot) > 0$$

where Y is the output produced, K is capital, L is labour, t denotes time, and A captures total factor productivity (TFP).

Solow (1956) assumed that the production function must satisfy a series of technical conditions:

1. Increasing marginal returns to each factor

$$f'(K) > 0 \; and \; f'(L) > 0 \qquad (3)$$

2. Decreasing marginal returns to each factor

$$f''(K) < 0 \; and \; f''(L) < 0 \qquad (4)$$

3. It exhibits constant returns to scale

$$\rho Y = AF(\rho K, \rho L) = \rho \, AF(K, L) \qquad \rho \; for \; all \; \rho \;\; \geq 0. \quad (5)$$

4. It satisfies the Inada condition

$$\lim_{K \to 0} f'(K) = \lim_{L \to 0} f'(L) = \infty \qquad (6)$$

An example of a production function that exhibits the above-listed conditions is the Cobb-Douglas production function (Romer, 2001) and it is of the form

$$Y = AK^{\alpha} L^{1-\propto} \qquad (7)$$

where, $0 < \alpha < 1$

Given the savings-investment function in the Keynesian economy, savings is assumed to be a constant fraction of income (Y) (Keynes, 1936).

$$I = S = sY \qquad (8)$$

where I is investment, S represent savings, s is a fraction of output (Y).

Also, given the law of motion of capital stock as

$$I = \Delta K + \delta K \qquad (9)$$

where K is capital, Δ represent change and δ represent depreciation.

The new equation for the law of motion for capital stock is:

$$\Delta K = I - \delta K \tag{10}$$

In the continuous form equation (10) becomes:

$$\dot{K} = I - \delta K \tag{11}$$

Solow (1956) again assumed that population grows at a constant rate (n). That is, to find the growth rate:

$$L_t = L_o e^{nt} \tag{12}$$

By taking the natural log of both sides and differentiating yields the growth rate of population (n):

$$\frac{\dot{L}}{L} = n \tag{13}$$

In growth theory, income can be expressed in per capita to measure welfare (Solow, 1956). Hence, the variables of interest in the production function will be expressed in per capita terms.

From equation (2), given $Y = AF(K, L)$, in per capita terms, it can be written as

$\frac{Y}{L} = \frac{AF(K,L)}{L}$. Therefore, the production function in per capita terms is

$$y = A\,F(k) \tag{14}$$

where $y = \frac{Y}{L}$ and $k = \frac{K}{L}$. Taking the natural log of the expression $k = \frac{K}{L}$ yields:

$$Ink = In\,K - InL \tag{15}$$

Differentiating equation (15) gives:

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{L}}{L} \tag{16}$$

Substituting equation (11) into (16) transforms the Solow growth equation into

$$\dot{k} = sy - (n + \delta)k \tag{17}$$

But $y = A\,F(k)$. This implies that:

$$\dot{k} = sAf(k) - (n + \delta)k \tag{18}$$

At steady-state, growth is equal to zero (Solow, 1956). This implies that:

$$sAf(k) = (n + \delta)k \tag{19}$$

Equation (19), the steady-state condition, becomes the starting point in modelling the energy intensity and economic growth relationship. Therefore, equation (19) is formulated as:

$$\frac{k_t}{f(k_t)} = \frac{sA}{n + \delta} \tag{20}$$

That is, the capita-output ratio is inversely proportional to the steady-state growth rate of output. This is because a higher level of steady-state growth rate is only sustainable at a lower level of capital-output ratio (Mahmood and Ahmad, 2018). Following the work of Mahmood and Ahmad (2018), we assume that energy enters the production function through capital to operate capital primarily. Capital intensity (ratio of a unit of capital over output) is directly related to energy intensity (ratio of a unit of energy over output). That is, an increase in capital intensity by 1 per cent will also increase energy intensity by the same amount, holding all other things equal.

Therefore:

$$\frac{E_t}{f(k_t)} = Q\left(\frac{k_t}{f(k_t)}\right) \tag{21}$$

Thus, energy intensity is also equal to the steady-state capital-output ratio which is also a function of technology

$$\frac{E_t}{f(k_t)} = Q\left(\frac{sA}{n + \delta}\right) \tag{22}$$

where the instantaneous conditions

$$y^* = \frac{Y}{L} \tag{23}$$

$\partial(E_t/f(k_t)/\partial(k_t/f(k_t)) > 0 \qquad \partial E_t/f(k_t)/\partial A < 0,$ holds (Mahmood and Ahmad, 2018).

Following Mahmood and Ahmad (2018), the following assumption will be carried on to the empirical framework):

In the long run, an increase in the steady-state GDP growth rate will cause energy intensity to fall.

In the long run, the steady-state GDP grows at a rate of n. Thus,

$$Y = (y^*)(L) \tag{24}$$

By taking the natural log and then differentiating, the growth rate is n (note: at steady-state y^*=0)

Therefore;

$$g_Y = n \tag{25}$$

From equation (22),

$$\frac{E_t}{f(k_t)} = Q[sA(n+\delta)^{-1})] \tag{26}$$

By differentiating the energy intensity function with respect to the GDP growth rate $(g_Y = n)$

$$\frac{\partial \frac{E_t}{f(k_t)}}{\partial n} = \left(\frac{\partial \frac{E_t}{f(k_t)}}{\partial \frac{k_t}{f(k_t)}}\right)\left(\frac{\partial \frac{k_t}{f(k_t)}}{\partial n}\right) \tag{27}$$

The final result is;

$$\frac{\partial \frac{E_t}{f(k_t)}}{\partial n} = -\left(\frac{\partial \frac{E_t}{f(k_t)}}{\partial \frac{k_t}{f(k_t)}}\right)\{sA(n+\delta)^{-2}\} < 0 \tag{28}$$

Thus, in the long run, growth is negatively related to capital-output ratio and hence energy intensity.

4.2. Empirical Model

4.2.1 Regression Analysis

From the theoretical model specified above and consistent with prior studies (Mahmood and Ahmad, 2018; Deichmann et al., 2018), the empirical model is specified as follows and forms the basis for our empirical model:

$$lnEI_{it} = \beta_0 + \beta_1 lnEI_{it-1} + \beta_2 GDPPCG_{it} + \beta_3 GDPPCG_{it}^2 + \varepsilon_{it} \quad (29)$$

where ln represents natural log, EI_{it} is the energy intensity of primary energy level in country i at time t, $GDPPCG_{it}$ is the growth in GDP per capita of country i at time t and ε_{it} is the error term. $lnEI_{it-1}$ is the first lag of the natural log of energy intensity. The lag of energy intensity is introduced to control for the inertia in energy intensity resulting from the use of machines that are not changed yearly because of sunk cost. (Mahmood and Ahmad, 2018). We also include a squared term of GDP per capita in equation (29) to test for the non-linearity, as suggested in the empirical literature. Prior studies have emphasized the importance of controlling for the composition of the sectors in the economy (Burke and Cserelkyei, 2016; Medlock and Soligo; 2001 and Deichmann et al., 2018), and also to account for factors that affect energy intensity levels (Mahmood and Ahmad, 2018). Therefore, on the right-hand side of equation (29), we also include a set of control variables.

Hence;

$$lnEI_{it} = \beta_0 + \beta_1 lnEI_{it-1} + \beta_2 GDPPCG_{it} + \beta_3 GDPPCG_{it}^2 + \gamma_1 X_{it} + \mu_i + \varepsilon_{it} \quad (30)$$

where, X_{it} represent the control variables (trade (% total GDP); regulatory quality; value-added in services, industry, and agriculture; and population density[26]) and μ_i is a country fixed effect controlling for time-invariant country-specific characteristics.

---

[26] a demographic variable that can affect energy consumption patterns.

4.2.2 Causality

Given two stationary variables x and y, x is said to granger cause y if previous values of x can significantly predict current value of y even when past values of y are included in the model (Lopez and Weber, 2017). To test for the direction of causality, we employed the Dumitrescu and Hurlin (2012) Granger-causality. This test accommodates the panel structure of the data. We specify the empirical model as follow:

$$EI_{i,t} = \varpi_i + \sum_{k=1}^{k} \emptyset_{i,k} EI_{i,t-k} + \sum_{k=1}^{k} \partial_{i,k} GDPPCG_{i,t-k} + \mu_{i,t} \quad (31)$$

$$GDPPCG_{i,t} = \varphi_i + \sum_{k=1}^{k} \theta_{i,k} GDPPCG_{i,t-k} + \sum_{k=1}^{k} \gamma_{i,k} EI_{i,t-k} + \upsilon_{i,t} \quad (32)$$

where ϖ and φ are intercepts, $\emptyset$, ∂, θ, and γ are slope parameters, EI_{t-k} and $GDPPCG_{t-k}$ are the lagged values of energy intensity and GDP per capita growth. The null hypothesis assumes there is an absence of causality in all unit of the panel against the alternative of the presence of causality in all unit of the panel.

4.2.3 Convergence

Beta (β), and sigma (σ) convergence are the two necessary conditions in testing convergence. To test for β-convergence, the mean growth rate of energy intensity and the initial level of energy intensity are studied overtime by regressing the average growth rate on the initial level of energy intensity. If the coefficient of the initial level of energy intensity (β) is negative and statistically significant, then we can conclude that there is beta convergence. (Mohammadi and Ram, 2012).

However, Quah (1993), among others have challenged β-convergence for not being a sufficient condition for convergence because convergence deals with the dispersion in cross-sectional income and growth distribution, and as such a negative beta may not be sufficient to capture such dispersion. They were of the view that looking at convergence through the negative sign of β is an indirect approach that may give erroneous results. They then proposed the concept of σ-convergence. Where σ represents the standard deviation of the cross-sectional distribution of either income level or growth rate. In the energy literature, σ-convergence talks about increasing cross-country differences in energy intensity (Mulder et al., 2014).

σ-convergence is confirmed when there is a decline in the dispersion of the variables over time, and it is usually calculated by the coefficient of variation (Mohammadi and Ram, 2012). Hence, following the work of Mohammadi and Ram (2012), we specify the following model to test for β convergence.

$$\ln(\frac{E_{i1}}{E_{io}}) = \beta \ln EI_{i0} + \varepsilon_i \tag{33}$$

where, EI_{i1} represent the energy intensity in the last year in country i and EI_{i0} is the energy intensity of the initial year in country i in the period under review, ln indicates natural logarithm, i represents country, and ε_i is the error term. The variable on the left-hand side represents increase over the period and not the annual rate. Equation (33) can be referred to as a model of unconditional convergence (Mohammadi and Ram, 2012). That is convergence to a common level of energy intensity. However, it has been shown in the literature that this may not be the case as depending on country-specific characteristics, countries may converge at different levels of energy intensity (Mohammadi and Ram, 2012). This is a condition referred to as "conditional" convergence (Islam, 2003). Hence, equation (33) is transformed to represent a model of conditional convergence by including on the right-hand side urbanisation and GDP per capita as "conditioning" variables that are likely to affect convergence in energy intensity. Equation (33) is, therefore, re-specified as:

$$\ln\left(\frac{E_i}{E_{io}}\right) = \beta \log \mathrm{EI}_{\mathrm{i0}} + \gamma_1 \pi_i + \gamma_2 \delta_i + \varepsilon_{\mathrm{i}} \quad (34)$$

where π_i represents urbanization, proxy by the percentage of the population living in urban areas, and δ_i is GDP per capita in country i.

4.3 Data Source

This study employed a secondary macro-level annual data on Sub Saharan Africa for the period 1990 – 2015, from World Development Indicators. It covered all the 48 countries in Sub-Saharan Africa. SSA is chosen because of the dearth in the energy intensity and economic growth literature on the region. The study period was restricted due to lack of data. The data utilized are GDP; GDP per capita; energy intensity level of primary energy; Industry value-added as a percentage of GDP; agriculture value-added as a percentage of GDP; service value-added as a percentage of GDP; trade; urbanization; population density; and regulatory quality. Description of the variables can be found in Appendix B.

4.4 Econometric Analysis

In examining the possible relationship between energy intensity and economic growth, we first conducted a set of diagnostic tests. These diagnostic tests include a test for the stability of the regressions overtime, Breusch-Pagan test for individual country heterogeneity, Hausman test to test whether the differences in coefficient are systematic, a summary statistics, and a linear and quadratic fit graph for the principal variables - energy intensity and GDP per capita growth to give an overview of the data. Following the work of Mahmood and Ahmad, (2018), Deichmann et al. (2018), Markandya et al. (2006), and Galli (1998), this study employs a panel data estimation technique to investigate the energy intensity and economic growth relationship in the first stage; and energy intensity convergence in the second stage. A panel data gives more information, more degrees of freedom, and less collinearity among variables and is more efficient than cross-sectional and time-series (Hsiao, 2007). It accounts for individual heterogeneity and is ideal in the study of dynamics or change (which is what our work is about) because it follows the same individual unit through time. It can also better detect and measure effects that are unobservable under cross-section or time-series data. (Hsiao, 2007).

Equation (30) is estimated using the fixed effect (FE) model, and the standard errors are corrected for autocorrelation and heteroskedasticity. We then test for the non-linearity in the model by introducing the squared term of the GDP per capita growth, and re-estimating equation (30) using the FE model with the standard errors corrected for autocorrelation and heteroskedasticity.

However, because of the possible endogeneity from the lag of the dependent variable in the model, the FE model may result in inconsistent estimates (Grohmann, 2015). To address the possible endogeneity in the model, we adopt the Generalised Methods of Moment (GMM) estimation. The GMM is appropriate for dynamic models and in situations with small T and large N (Grohmann, 2015). In situations where the model suffers from endogeneity and multicollinearity, the GMM estimation technique produces more efficient parameter estimates than most of the primary panel estimation techniques such as ordinary least squares (OLS), random effects and fixed effects (Arellano and Bover, 1995). According to Grohmann (2015), if the dependent variable has a unit root, then its lagged levels are weak instruments because there exists a weak correlation between the lagged levels with the subsequent first difference of the series.

Furthermore, according to Bond et al. (2004), the system GMM (Arellano and Bover, 1995; Blundell and Bond, 1998) controls for unobserved country heterogeneity, omitted variable bias, measurement error and endogeneity problems that are prevalent in growth estimation. Hence, the system GMM (SYS-GMM) is preferred over the difference GMM. Therefore, we tested for the unit root of the dependent variable (lnEI) to determine which estimation technique is more appropriate to estimate equation (30).

In testing for causality, it is important to note that the variables must be of the same order of integration (Foresti, 2006). Thus, we test for unit root to ensure that the variables are of the same order. Several methods (e.g. Levin and Lin (1992) and Im et al. (1995)) have been advanced in the econometric literature to test for unit root in panel. This study employs the IPS tests because it is ideal for unbalanced panels and in situations of small T and large N (Hall and Mairesse, 2002). The IPS test is performed as Fisher-Augmented Dickey-Fuller (ADF) or Phillips-Perron (PP) tests. We then test for causality using the Granger causality extension by Dumitrescu and Hurlin (2012) because it caters for the panel nature of the data.

Finally, to test for convergence, equation (34) is estimated using the FE technique to test for β-convergence. The standard errors are corrected for autocorrelation and heteroscedasticity. The standard deviation and correlation coefficient of energy intensity are also calculated to test for evidence of σ-convergence.

Table 4.1: Variable Labels

Variables	**Variable Labels**
EI	Energy Intensity Levels of primary energy
GDPPC	GDP per capita
GDPPCG	GDP per capita growth
GDPPCG2	GDP per capita growth squared
AVA	Agriculture, Forestry, and Fishing Value-Added (% of GDP)
IVA	Industry Value-Added (% of GDP)
SVA	Service Value-Added (% of GDP)
PopD	Population Density
RegQ	Regulatory Quality

Source: Author’s compilation.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.0 Introduction

In this chapter, we present findings and discuss the results of our diagnostic tests and regression analysis. The ordering of the presentation of the results is influenced by the fact that the validity of the results and the model to estimate and present are preconditioned on the findings obtained from the diagnostic tests.

5.1 Diagnostic Tests

5.1.1 Time - Effect

We included time dummies to the pooled regression model to test for the stability of the regression function overtime. The pooled model is estimated using OLS. Then we tested whether the time dummies are jointly equal to zero. Since the p-value in table 5.1 is less than 0.05, so we reject the null of no time effect and conclude that the pooled model is inappropriate.

Table 5.1: Test for Time-Effect

_IYearCode_n= 0
F(24, 477) = 1.70 Prob > F = 0.0217
Where n = 2,3,…..,25

Source: Author’s estimation.

5.1.2 Test for Country Heterogeneity

The p-value of the Breusch-Pagan test (table 5.2) is higher than 0.05, so we failed to reject the null hypothesis of no heterogeneity in the data. This suggests that the effect of economic growth on energy intensity is homogeneous across the SSA countries.

Table 5.2: Breusch and Pagan Lagrangian Multiplier Results

Variable	Var	sd = sqrt (Var)
lnEI	0.580	0.761
E	0.008	0.089
U	0	0

Test: Var(u) = 0
chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Source: Author's estimation.

5.1.3 Hausman Test

Table 5.3 reports a p-value less than 0.05. Hence, the null that the differences in the coefficient are not systemic is rejected, and we conclude that the fixed effect model is appropriate.

Table 5.3: Hausman Test

Variable	Coefficients			
	(b)	(B)	(b-B)	Sqrt(diag(V_b-V_B)
	Fixed	Random	Difference	S.E.
Lag_LEI	0.910	0.992	-0.082	0.018
GDPPCG	0.000	0.000	0.000	0.000
RegQ	0.004	0.002	0.002	0.001
PopD	1.33e	3.42e	-4.752	
AVA	0.001	0.001	-9.04e	0.001
IVA	0.002	0.002	0.000	0.001
SVA	0.001	0.001	0.000	0.001

b = consistent under H_0 and H_1; obtained from xtreg
B = inconsistent under H_0, efficient under H_1; obtained from xtreg
Test: H_0: difference in coefficient not systematic
Chi2 (8) = (b-B) ‘ [(V_b-V_B)^(-1)] (b-B)
= 42.22
Prob>chi2 = 0.000

Source: Author's estimation.

5.1.4 Summary Statistics

The summary statistics result on table 5.4 shows that GDP per capita growth is the most volatile variable within each country and between countries with a coefficient of variation of 410.9 per cent and 190.2 per cent, respectively. This means that the variable most susceptible to change within each country and from one country to another is GDP per capita.

Table 5.4: Summary Statistics

Variable		Obs	Mean	Std. Dev.	CV	Min	Max
EI	Overall	1222	9.622	8.349	86.770	1.086	57.988
	Between			7.87	81.792	1.086	39.079
	Within			3.141	32.644	-5.889	37.274
GDPPCG	Overall	1171	1.694	7.494	442.385	-54.052	140.501
	Between			3.222	190.201	-9.706	16.337
	Within			6.961	410.921	-49.664	125.858
Reg.Quality	Overall	611	-0.718	0.656	-91.362	-2.668	0.893
	Between			0.627	-87.309	-2.440	0.606
	Within			0.212	-29.565	-1.510	0.404
Pop.Dens	Overall	1218	81.003	110.072	135.886	1.718	621.973
	Between			109.099	134.685	2.351	585.839
	Within			20.624	25.461	-24.539	206.571
Trade	Overall	1092	70.310	35.838	50.971	11.087	311.354
	Between			31.700	45.086	27.067	153.977
	Within			19.173	27.269	-19.682	227.687
AVA	Overall	1143	24.757	15.145	61.173	0.893	79.042
	Between			15.601	63.016	1.239	62.745
	Within			5.165	20.862	1.449	51.129
IVA	Overall	1134	24.341	13.089	53.775	2.073	84.349
	Between			13.611	55.917	8.263	75.575
	Within			5.005	20.561	-0.896	56.008
SVA	Overall	1103	44.604	11.085	24.853	12.435	82.586
	Between			10.042	22.515	23.736	72.860
	Within			5.923	13.280	21.353	67.925

Source: Author’s calculation.

Note: Obs, Std. Dev, CV, Min and Max mean observation, standard deviation, coefficient of variation, minimum and maximum, respectively.

This is followed, at a distance, by energy intensity with a coefficient of variation of 32.6 per cent within countries and population density with 134.7 per cent between countries. Service value-added as a percentage of GDP (SVA) is the least volatile within and between countries. With a mean of 70, trade contributes the most to GDP. The maximum and minimum values show the extent to which energy intensity levels in the region have fluctuated over the study period.

5.1.5 Scatterplot

The linear fit (a) and quadratic fit, (b) graphs in figure 5.1 both show a negative downward-sloping (inverse) relationship. This implies that energy intensity and GDP per capita growth have a negative linear relationship for the data sample.

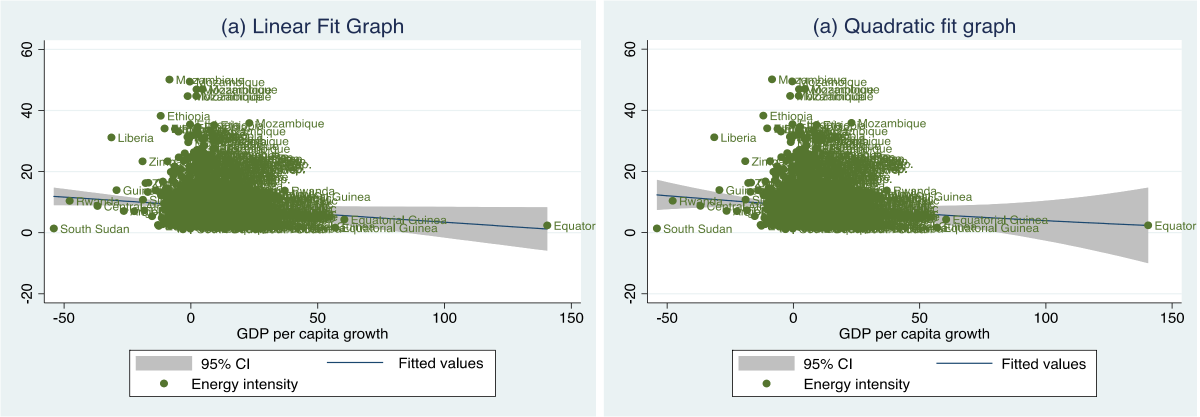

Figure 5.1: Scatterplot of Energy Intensity and Economic Growth
Source: Author’s compilation.

5.2 Regression Results

From the unit root test for the lnEI, we failed to reject the null of no unit root in the panel (see Appendix B). This suggests the presence of a random walk in the model, and as such, the difference GMM will yield biased and inconsistent estimators. Therefore, we adopt the one-step and two-step system GMM to estimate equation (30). Only the GMM result is discussed in this analysis because as stated earlier it is more appropriate for dynamic models and in situations with small T and large N, it produces more efficient parameter estimates than most of the primary panel estimation techniques. The estimation results show a positive and statistically significant relationship between the lag of the natural log of energy intensity and the natural log of energy intensity. This implies that a 1 per cent increase in the previous year's energy intensity levels will result in a 0.994 per cent and 1 per cent increase in the current year's energy intensity for the one-step, and two-step estimation respectively.

In line with our first objective, and consistent with equation (30), a negative and highly statistically significant result is observed between energy intensity and economic growth. This negative relationship means that a 1 per cent growth increase will result in a 0.009 per cent fall in energy intensity. This coefficient implies that the fall in energy intensity as a result of an increase in growth will be minimal. Thus, economic growth alone cannot reduce energy intensity. It must be complemented with energy efficiency reforms. There are three plausible explanations for this negative relationship: i) structural change; ii) efficiency improvement; and iii) fuel substitution (Sadorsky, 2013). Structural change occurs as countries move from the early stages of industrialisation where the agricultural sector is the major player, and it is less energy-intensive, so energy intensity levels are low, to post industrialisation stage where the manufacturing sector gives way to the service sector which is less energy-intensive. In the early stage of industrialization, energy intensity may rise until it gets to a saturation point where material consumption is geared towards a replacement of durables rather than creation, so intensity level will fall. (Sadorsky, 2013). Efficiency improvements and fuel substitution result from technological advancement that comes with economic growth that results in increased opportunities for more efficient production processes which therefore reduces energy intensity (Deichmann et al., 2018).

Table 5.5: Regression Results[27]

			SYS-GMM	
	FE	**FE**	**One-Step**	**Two-Step**
Lag_lnEI	0.912***	0.912***	0.994***	1.000***
	(-0.024)	(-0.024)	(-0.037)	(-0.025)
GDPPCG	-0.008***	-0.008***	-0.009***	-0.009***
	(-0.001)	(-0.001)	(-0.001)	(-0.001)
GDPPCG^2		0.000	0.000	0.000
		(-0.000)	(-0.000)	(-0.000)
PopD	0.000	0.000	0.000	0.000
	(-0.000)	(-0.000)	(-0.000)	(-0.000)
RegQ	-0.025*	-0.024	0.001	0.005
	(-0.025)	(-0.014)	(-0.016)	(-0.010)
Trade	-0.001	-0.001	-0.000	0.000
	(-0.000)	(-0.000)	(-0.000)	(-0.000)
AVA	0.000	-0.000	0.001	0.001
	(-0.001)	(-0.001)	(-0.001)	(-0.001)
IVA	0.000	0.000	0.002	0.002
	(-0.002)	(-0.002)	(-0.002)	(-0.001)
SVA	-0.001	-0.001	0.002	0.001
	(-0.001)	(-0.001)	(-0.00)	(-0.001)
Constant	0.206	0.207	-0.114	-0.119
	(-0.143)	(-0.143)	(-0.19)	(-0.171)
Observations	530	530	530	530
Instruments			72	72
R-squared	0.986	0.986		
AR(1)			0.002	0.002
AR(2)			0.336	0.336
Sargan			0.480	0.480
Hansen-J			0.999	0.999

Source: Author's estimation.

Note: Standard errors are in parentheses. *, **, and *** signifies significance at the 10%, 5% and 1% levels respectively level. The dependent variable is lnEI.

---

[27] The second lag of the natural log of energy intensity enters the GMM model as an endogenous variable.

Higher levels of income enable investment in advanced technology and substitution between energy inputs which increases efficiency. At high levels of income, the cost of input substitution and energy-efficient investment relative to income is low. (Adom, 2015b).

The squared term, introduced to test for the non-linearity of the energy intensity and economic growth relationship, the second objective of this study is positive but statistically insignificant. This suggests that energy intensity and economic growth have a linear relationship in the case of SSA. This observation is consistent with our scatterplots in figure 5.1, and findings by Luzzati and Orsini (2009). All the control variables are statistically insignificant. This suggests that these variables have no statistically significant impact on the energy intensity levels in SSA. The Hansen-J's statistic is statistically insignificant. This suggests that there is no evidence of misspecification in the model (Hansen, 1982). The Sargan test is statistically insignificant meaning that the overidentifying restrictions are valid (Sargan, 1958). Similarly, the AR (2) for both tests are statistically insignificant and thus indicates that the error terms are not serially correlated (Arellano and Bond, 1991).

5.3 Causality Result

5.3.1 IPS Test

From results presented in Table 5.6, both GDP per capita and energy intensity are stationary at levels at the 1%, 5% and 10% significant level. Suggesting the variables have a long-run relationship. From the causality test results in Table 5.7, the Z-bar wilde result is presented because according to Lopez and Weber (2017) in situations with large N and small T the Z-bar wilde test result should be favoured.

Table 5. 6: IPS Unit Root Test

	ADF	**PP**
Variables	Levels	Levels
EI	-1.424*	-1.556**
GDPPCG	-24.310***	-24.310***

Source: Author's compilation
Note: *, **, and *** signifies significance at the 10%, 5% and 1% levels respectively.

The results show a unidirectional causality from economic growth to energy intensity. That is, we reject the null of no causality from economic growth to energy intensity at the 1% significant level. This means that past values of economic growth can be used to predict present values of energy intensity, but past values of energy intensity cannot be used to predict present values of economic growth.

Table 5. 7: DH Panel Causality Test

Ho: Y does not Granger-cause X					
Energy Intensity to Economic Growth			**Economic Growth to Energy Intensity**		
Tests	**Z-bar Stats.**	**P-value**	**Tests**	**Z-bar Stats.**	**P-value**
EI→ GDPPCG	0.947	0.344	GDPPCG→EI	3.721	0.000***

Source: Author's estimation.
Note: *** signifies significance at the 1% level.

5.4 Convergence Result

Investigating convergence among countries is very important and crucial. The evidence of convergence provides information that will enable the establishment of fair global environmental constraints on countries. (Liddle, 2010). This is more beneficial to developing countries because it ensures that they can either maintain or increase their growth (Kiran, 2013). The results for the test for β-convergence are reported in Table 5.8, and reveal a statistically significant negative β. That is, β-convergence is confirmed. This means that the countries with initially high levels of energy intensity are observing a faster decline in energy intensity levels than countries with initially low levels of energy intensity (Liddle, 2010). A plausible explanation for convergence is that developing countries are benefitting from advanced technology and the knowledge used by industrialized countries. Hence, they would converge to a lower level of energy intensity within a shorter time frame as compared to the time taken by developed countries. A process referred to as leapfrogging. (Mielnik and Goldemberg 2000). The result is consistent with the findings of Mielnik and Goldemberg (2000), and Markandya et al., (2006).

According to Quah (1993), β-Convergence is not a sufficient condition to make a conclusion about convergence because it does not capture a number of potentially interesting features of the evolution of the distribution. Hence, the standard deviation and coefficient of variation for energy intensity are calculated to test for σ-Convergence among SSA countries.

Table 5. 8: Test for β-Convergence

Variable	**Coefficients**
Initial EI levels	-0.005***
	(0.002)
GDP per capita	-0.000
	(0.000)
Urbanisation	0.000
	(0.000)
R^2	0.055
Observations	212

Source: Author's estimation.

Note: Standard errors are in parenthesis. ***, **,** and ******* signifies significance at the 10%, 5% and 1% levels respectively. The dependent variable is the change in energy intensity.

Table 5.9 presents the evolution of cross-country energy intensity differences. Even though there were periods of increase in energy intensity levels, by 2015, it has declined. Therefore, the decline in the coefficient of variation from 1990 to 2015 confirms the presence of σ-Convergence.

Table 5.9: Test for σ-Convergence

Energy Intensity	Obs	Mean	SD	CV
1990	45	10.25	8.492	82.849
1995	47	11.476	11.157	97.220
2000	47	9.798	8.03	81.956
2005	47	9.627	8.157	84.730
2010	47	8.799	7.642	86.851
2015	47	7.157	5.074	70.896

Source: Author's calculation.

Note: Obs, SD and CV are observations, standard deviation and coefficient of variation, respectively.

Since beta is negative and significant at the 1% significance level, and the standard deviation declined from 1990 to 2015, we can argue that SSA is converging to a common level of energy use and as such energy inequality across the region is falling. This could be as a result of the successful diffusion of energy-related technology among the countries (Herrerias, 2012).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

There have been growing concerns on the risks energy intensity possess for the world, and especially to developing countries. This study investigates, whether economic growth drives energy intensity in SSA, the region that houses more than half of the world's extreme poor.

6.1 Summary

While there has been research done on how growth affects energy intensity, little is known about how growth affects energy intensity in SSA. Understanding this relationship is a step toward mitigating the risks that come with climate change. This study presents various theoretical and empirical analysis of the energy intensity and economic growth nexus with a focus on SSA. Drawing from the works of Deichmann et al. (2018), and Mahmood and Ahmad (2018) this research reports a dynamic panel model estimation and a set of diagnostic tests to achieve its objectives. The estimated coefficient of the growth variable is negative and statistically significant. This result is vital in proving that an increase in growth reduces energy intensity.

6.2 Conclusion

The GMM estimation technique, and fixed-effect model, are adopted to address the empirical questions of this study. An unbalanced panel dataset from 1990 to 2015 of the 48 countries in SSA is used. From the diagnostic tests and regression results, a strong negative and statistically significant relationship is observed between energy intensity and economic growth for SSA during the review. This result is consistent with findings from earlier studies by Mahmood and Ahmad (2018); Deichmann et al. (2018); and Su-yun and Zhen-yu (2010), but is in contrast with findings by Aboagye and Alagidede (2016). From the result of this study, we also conclude that there is a non-linear relationship energy intensity and economic growth in SSA for the referenced period. That is, the theory of the EKC in energy intensity does not hold for our analysis. This supports findings by Luzzati and Orsini (2009).

There is also a unidirectional causality from economic growth to energy intensity. Finally, concerning the fourth objective (convergence in energy intensity), our results confirmed both the presence of a negative and statistically significant beta and a decline in the standard deviation, sigma convergence, supporting findings by Nilsson (1993) and Mielnik and Goldemberg (2000). We can, therefore, conclude that economic growth does not drive energy intensity in SSA, and the region is converging to a lower level of energy intensity.

6.3 Recommendations

A decline in energy intensity can partially ease climate change impacts and energy security risks (Sadorsky, 2013). Our results show that energy intensity declines with economic growth in SSA. This implies that economic policy that increases income in SSA will likely reduce energy intensity. Therefore, policymakers should implement strategies that would boost growth in the region and hence a fall in energy intensity levels. Countries can invest in human capital development which could improve efficiency (Penner, 2015). They can create an enabling environment to encourage Foreign Direct Investment which would provide a source of long-term finance, technology transfer and access to the global market (Lewis, 2001). They can also promote privatization through the establishment of property rights, fosters specialization and increases productivity (Filipovic, 2005).

Because the causality is unidirectional from economic growth to energy intensity and the relationship is negative energy conservation policies can be implemented without worries of it affecting growth. Therefore, in order to reduce energy intensity conservation policies such as the removal of fuel subsidy should be introduced by the Government and managed by the Ministry of Finance and National Petroleum Agencies. The Government can also provide financial incentives and make them flagships of Local/Municipal Councils. Energy Tax could also be implemented by the Environmental Protection and Revenue Agencies.

Convergence is usually associated with rapid economic changes made by developing countries (Maza and Villaverde, 2008). These economic changes most often result in the reduction of technological inequality across countries (Herrerias, 2012), leading to convergence. Therefore, more of those policies that encourage technological innovations such as copyrights law, good governance and the rule of law should be implemented to promote changes and further promote efficiency savings and reduce carbon dioxide emissions.

6.4 Area for Further Study

A possible area of study includes a decomposition analysis of energy intensity in SSA. This will inform policymakers of the sectors that are more energy-efficient and those that contribute more to energy intensity. Evidence of convergence as a group does not mean convergence for individual countries (Anoruo and DiPietro, 2014). Hence, a further study can be undertaken to test for convergence for the different countries and the rate at which they are converging with respect to energy intensity.

REFERENCES

Aboagye, S., & Alagidede, P. (2016). Energy consumption efficiency in Sub-Saharan Africa: Evidence and policies. *Ghanaian Journal of Economics*, 4(1), 116–138.

Adom, P. K. (2015a). Asymmetric impacts of the determinants of energy intensity in Nigeria. *Energy Economics*, 49, 570–580.

Adom, P. K. (2015b). Business cycle and economic-wide energy intensity: The implications for energy conservation policy in Algeria. *Energy*, 88, 334–350.

Aghion, P., & Howitt, P. W. (1998). *Endogenous growth theory*. London: MIT Press.

Akarca, A. T., & Long, T. V. (1980). On the relationship between energy and GNP: a reexamination. *The Journal of Energy and Development*, 326–331.

Aldy, J.E., (2006). Per Capita Carbon Dioxide Emissions: Convergence or Divergence? *Environ Resource Econ* **33,** 533–555

Ammah-Tagoe, F. A. (1990). On Woodfuel, Total Energy Consumption and GDP in Ghana: A Study of Trends and Causal Relations. Center for Energy and Environmental Studies, Boston University, Boston, MA.

Anoruo, E., & DiPietro, W. R. (2014). Convergence in per capita energy consumption among African countries: Evidence from sequential panel selection method. *International Journal of Energy Economics and Policy*, 4(4), 568–577.

Arellano, M and Bond, S (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies*, 58(2), 277-297

Arellano, M. & O. Bover (1995). Another Look at the Instrumental Variable Estimation of Error-Components Models. *Journal of Econometrics* 68, 29-51.

Aslanidis, N., & Iranzo, S. (2009). Environment and development: Is there a Kuznets curve for CO2 emissions? *Applied Economics*, 41(6), 803–810.

Avila, N., et al. (2017). The energy challenge in Sub-Saharan Africa: A guide for advocates and policymakers. Technical report, OXFAM.

Ayres, R. U. (2008). *Energy and economic growth, in Sustainable Energy Production and Consumption: Benefits, Strategies and Environmental Costing*. Springer.

Barro, R. J., & Sala-i-Martin, X. (1995). Economic Growth. *Journal of Economic Dynamics and Control*, 21, 895-898

Baart, M (2018). The missing middle: supplying sub-Saharan Africa's commercial and industrial sector with solar energy. https://cleantechnica.com/2018/08/02/the-missing-middle-supplying-sub-saharan-africas-commercial-industrial-sector-with-solar-energy/.

Baumol, W. J. (1986). Productivity growth, convergence, and welfare: what the long-run data show. *The American Economic Review*, 1072–1085.

Bermejo C. J., & Werner, R. A. (2018). Does foreign direct investment generate economic growth? A new empirical approach applied to Spain. *Economic Geography*, 94(4), 425–456.

Bilotta, N., & Colantoni, L. (2018). Financing Energy Access in Sub-Saharan Africa. *Istituto Affari Internazionali*, 1-21.

Blundell, R. & S. Bond, (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics* 87, 115-143.

Bond, S. R., et al. (2004). GMM Estimation of Empirical Growth Models, London: *Centre for Economic Policy Research*. Discussion Paper.

Bretschger, L. (2015). Energy prices, growth, and the channels in between: theory and evidence. *Resource and Energy Economics*, 39, 29–52.

Burke, P. J., & Csereklyei, Z. (2016). Understanding the energy-GDP elasticity: A sectoral approach. *Energy Economics*, 58, 199–210.

Calamitsis, E. et al. (1999). Adjustment and Growth in Sub-Saharan Africa (April 1999). *IMF Working Paper No.* 99/51

Cass, David (1965): "Optimum growth in an aggregative model of capital accumulation," *Review of Economic Studies*, 32, 233–240.

Chirambo, D. (2016). Addressing the renewable energy financing gap in Africa to promote universal energy access: Integrated renewable energy financing in Malawi. *Renewable and Sustainable Energy Reviews*, 62, 793–803.

Cleveland, C. J., et al. (1984). Energy and the US economy: a biophysical perspective. *Science*, 225(4665), 890–897.

Cleveland, C. J. & Ruth, M (1997).When, where, and by how much do biophysical limits constrain the economic process?: A survey of Nicholas Georgescu-Roegen's contribution to ecological economics. *Ecological Economics*, 22, (3), 203-223

Cole, M. A. (2006). Does trade liberalization increase national energy use*? Economics Letters*, 92(1), 108–112.

Dalgaard, C.-J. & H. Strulik (2011). Energy distribution and economic growth. *Resource and Energy Economics*, 33(4), 782–797.

Daly, H. E., (1997), 'Georgescu-Roegen versus Solow/Stiglitz', *Ecological Economics*, 22(3), 261-66.

De Soto, H. 2000: The Mystery of Capital. London: Black Swan

De Long, J. B. (1988). Productivity growth, convergence, and welfare: comment. *The American Economic Review*, 78(5), 1138–1154.

Deichmann, U. et al. (2018). Relationship between energy intensity and economic growth: new evidence from a multi-country multi-sector data set. Policy Research working paper; no. WPS 8322.

Dowrick, S., & Nguyen, D.T. *(1989).* OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence. *The American Economic Review*, 79(5), 1010.

Dumitrescu, E.-I., & C. Hurlin. 2012. Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29, 1450–1460.

Easterly, W., & Levine, R. (1997). *Afric*a's growth tragedy: policies and ethnic divisions. *The Quarterly Journal of Economics*, 112(4), 1203–1250.

Economics.Help. (2018). Environmental Kuznets Curve Retrieved on December 5, 2018, from https://www.economicshelp.org/blog/14337/environment/environmental-kuznets-curve/.

Engineering Export Promotion Council retrieved on December 5, 2018, from http://www.eepcindia.org/download/IB20052015112435-1.pdf

Ezcurra, R. (2007a). Distribution dynamics of energy intensities: a cross-country analysis. *Energy Policy*, 35(10), 5254–5259.

Ezcurra, R. (2007b). Is there cross-country convergence in carbon dioxide emissions? *Energy Policy*, 35(2), 1363–1372.

Filipovic Adnan (2005). The Impact of Privatization on Economic Growth. *Issues in Political Economy*, 14, 1-22.

Fischer, R., et al. (2011). Barriers and drivers to renewable energy investment in sub-Saharan Africa. *Journal of Environmental Investing*, 2, 54–80.

Foresti, P. (2006). Testing for Granger Causality between Stock Prices and Economic Growth. MPRA Paper No. 2692, online at https://mpra.ub.uni-muenchen.de/2962/. (Accessed May 20, 2018).

Fosu, A. K. 1992. Political Instability and Economic Growth: Evidence from Sub -Saharan Africa. *Economic Development and Cultural Change* 40(4), 829-39.

Galeotti, M. et al. (2006). Reassessing the environmental Kuznets curve for CO2 emissions: A robustness exercise. *Ecological Economics, 57(1), 152–163*

Galli, R. (1998). The relationship between energy intensity and income levels: forecasting long term energy demand in Asian emerging countries. *The Energy Journal*, 85–105.

Ganda, F., & Ngwakwe, C. (2014). Problems of sustainable energy in Sub-Saharan Africa and possible solutions. *Mediterranean Journal of Social Sciences*, 5(6), 453.

Garner, P. (2006). Economic Growth in Sub-Saharan Africa. In *Southern Agricultural Economics Association (SAEA)*. Africa: Southern Agricultural Economics Association (SAEA).

Georgescu-Roegen, N. (1971). The Entropy Law and the Economic Process. Harvard University Press, Cambridge.

Georgescu-Roegen, N. (1975). Energy and economic myths. *Southern Economic Journal*, 347–381.

Georgescu-Roegen, N. (1993). *The entropy law and the economic problem. Valuing the Earth: Economics, Ecology, Ethics*. London: MIT Press.

Goldemberg, J. (1996). A note on the energy intensity of developing countries. *Energy Policy*, 24(8), 759–761.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37, 424–438.

Grohmann, T (2015). Difference GMM vs System GMM. The Econometrics of Economic Consultancy Interpreting Regression Estimates for Policy Makers Seminar, 1-23

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free-trade agreement. *National Bureau of Economic Research, 1-39.*

Hafner, M., et al. (2018). Energy in Africa: Challenges and Opportunities. *SpringerBriefs in Energy*, 1-98

Hall, C. A. S., et al. (1986). Energy and Resource Quality: The Ecology of the Economic Process. *Wiley Interscience, New York.*

Hall, B., & Mairesse, J. (2002). Testing for unit roots in panel data: An exploration using real and simulated data. Identification and Inference for Econometric Models. Essays in Honor of Thomas Rothenberg, 451–475.

Hartwick, J. M (1978).Substitution Among Exhaustible Resources and Intergenerational Equity. *Review of Economic Studies*, 45, (2), 347-354

Hassan, M. T., et al. (2017). Barriers to industrial energy efficiency improvement–manufacturing SMEs of Pakistan. *Energy Procedia*, 113, 135–142.

Hernandez-Cata, E. (2000). Raising Growth and Development in Sub-Saharan Africa: What can be done? IMF Policy Discussion Paper, 1-24.

Hernandez, R. A. (2003). Neoclassical and Endogenous Growth Models: Theory and Practice. Working Paper, 1-55.

Herrerias, M. J. (2012). World energy intensity convergence revisited: A weighted distribution dynamics approach. *Energy Policy*, 49, 383–399.

Hansen, L.P., 1982. Large sample properties of generalized method of moments estimators. *Econometrica* 50, 1029 – 1054

Holtz-Eakin, D and Selden, T (1995). Stoking the fires? CO2 emissions and economic growth. *Journal of Public Economics*, 57, (1), 85-101

Hsiao, C. (2007). Panel data analysis—advantages and challenges. Test, 16(1), 1–22.

Hussein, M. A., & Leal F. W. (2012). Analysis of energy as a precondition for improvement of living conditions and poverty reduction in sub-Saharan Africa. *Scientific Research and Essays*, 7(30), 2656–2666.

R Inglesi-Lotz & A Pouris (2012). Energy efficiency in South Africa: A decomposition exercise *Energy* 42 (1), 113-120.

Im K.P., & Shin H.Y., (1995). Testing for unit roots in heterogeneous panels. DAE Working Papers Amalgamated Series No.9526, University of Cambridge

International Energy Agency. (2014a). Capturing the Multiple Benefits of Energy Efficiency. France: OECD/IEA

International Energy Agency. (2014b). *World Energy Outlook*. France: OECD/IEA

International Energy Agency. (2017). *World Energy Outlook*. France: OECD/IEA

International Labour Organisation (2018). Creating decent jobs for a rapidly expanding young African labour force. Retrieved on November 8, 2018, from http://www.ilo.org/global/about-the-ilo/newsroom/features/WCMS_570043/lang--en/index.htm.

International Monetary Fund. (2019). Regional Economic Outlook: Sub-Saharan Africa Recovery Amid Elevated Uncertainty. Washington, DC: International Monetary Fund.

Islam, N. (2003). What have we learnt from the convergence debate? *Journal of Economic Surveys*, 17(3), 309–362.

Jimenez, R., & Mercado, J. (2014). Energy intensity: A decomposition and counterfactual exercise for Latin American countries. *Energy Economics*, 42, 161–171.

Jones, D. W. (1989). Urbanization and energy use in economic development. *The Energy Journal*, 29–44.

Im, K.S. et al. (2003). "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, (115), 53-74.

Kaufmann, R. K. (1992). A biophysical analysis of the energy/real GDP ratio: implications for substitution and technical change. *Ecological Economics*, 6(1), 35–56.

Keynes, J. M. (1936). The general theory of employment, interest, and money. London: Macmillan.

Kiran, B. (2013). Energy intensity convergence in OECD countries. *Energy Exploration & Exploitation*, 31(2), 237–247.

Knott, S (2018). Ghana backpedalling out of banking crisis Retrieved online on November 8, from https://mg.co.za/article/2018-08-19-ghana-backpedalling-out-of-banking-crisis/.

Koopmans, T.C., (1965). On the concept of optimal economic growth, in The econometric approach to development planning. *Pontificiae Academiae Scientiarvm Scripvm Varia*.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, 401–403.

Kwakwa, P. (2012). Disaggregated energy consumption and economic growth in Ghana. *International Journal of Energy Economics and Policy*, 2(1), 34–40.

Le Pen, Y., & Sévi, B. (2010). On the non-convergence of energy intensities: Evidence from a pair-wise econometric approach. *Ecological Economics*, 69(3), 641–650.

Levin, A. et al. (2002). “Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties.” *Journal of Econometrics*, 108, 1-24.

Levin, A. and C.F. Lin (1992). “Unit Root Test in Panel Data: Asymptotic and Finite Sample Properties”. Discussion Paper, 92-93, Department of Economics, University of California at San Diego.

Lewis, J.D. (2001). “Policies to Promote Growth and Employment in South Africa” *The World Bank Southern Africa Department. Discussion Paper*, 1-86.

Lopez, L and Weber, S (2017). Testing for Granger causality in Panel Data. *The stata journal* 17(4) 972-984

Liddle, B. (2010). *Revisiting world energy intensity convergence for regional differences.* Applied Energy, 87(10), 3218–3225.

Lucas, R.E. (1988). “On the Mechanics of Economic Development,” *Journal of Monetary Economics*, 22, 3–42.

Luken, R. & Van, Rompaey, F. (2008). Drivers for and barriers to environmentally sound technology adoption by manufacturing plants in nine developing countries. *Journal of Cleaner Production* 16, S67-S77.

Luzzati, T., & Orsini, M. (2009). Investigating the energy-environmental Kuznets curve. *Energy*, 34(3), 291–300.

Mahmood, T., & Ahmad, E. (2018). The relationship of energy intensity with economic growth: Evidence for European economies. *Energy Strategy Reviews*, 20, 90–98.

Mankiw, N. G., et al. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 107(2), 407–437.

Markandya, A. et al. (2006). Energy intensity in transition economies: is there convergence towards the EU average? *Energy Economics*, 28(1), 121–145.

Maza, A., & Villaverde, J. (2008). The world per capita electricity consumption distribution: Signs of convergence? *Energy Policy*, 36(11), 4255–4261.

Medlock III, K. B., & Soligo, R. (2001). Economic development and end-use energy demand. *The Energy Journal*, 77–105.

Mielnik, O., & Goldemberg, J. (2000). Converging to a common pattern of energy use in developing and industrialized countries. *Energy Policy*, 28(8), 503–508.

Mining Africa (2018). Coal Mining in Africa Retrieved on December 10, 2018, from https://www.miningafrica.net/natural-resources-africa/coal-mining-in-africa/.

Maddison A. (1982), Phases of Capitalist Development, Oxford, Oxford University Press

Mohammadi, H., & Ram, R. (2012). Cross-country convergence in energy and electricity consumption, *1971–2007. Energy Economics*, 34(6), 1882–1887.

Mulder, P., et al. (2014). Dynamics and determinants of energy intensity in the service sector: A cross-country analysis, 1980–2005. *Ecological Economics*, 100, 1–15.

Narayan, P. K., & Popp, S. (2012). The energy consumption-real GDP nexus revisited: Empirical evidence from 93 countries. *Economic Modelling*, 29(2), 303–308.

Ndambiri, H. K., et al. (2012). Determinants of economic growth in Sub-Saharan Africa*:* A panel data approach. *International Journal of Economics and Management Sciences*, 2 (2) 2012 18-24.

Nilsson, L. J. (1993). Energy intensity trends in 31 industrial and developing countries 1950–1988. *Energy*, 18(4), 309–322.

Ockwell, D. G. (2008). Energy and economic growth: Grounding our understanding in physical reality. *Energy Policy*, 36(12), 4600–4604.

Ogundari, K. & Awokuse, T. (2018). Human capital contribution to economic growth in Sub-Saharan Africa: Does health status matter more than education? *Economic Analysis and Policy,* 58(C), 131-140

Oluwatobi, S., et al. (2016). Human capital, institutions and innovation in Sub-Saharan Africa. *International Journal of Economics and Financial Issues,* 6(4), 1507–1514.

O'Malley, E et al. (2003). Barriers to Energy Efficiency: Evidence from Selected Sectors. *Policy Research Series*, 47

Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, 2(1), 15.

Parikh, J., & Shukla, V. (1995). Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries. *Global Environmental Change,* 5(2), 87–103.

Penner, R.G. (2015). Economic Growth. *Budgeting for National Priorities Project at Brookings*, 1-6.

Perman, R., & Stern, D. (2003). Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist. *Australian Journal of Agricultural and Resource Economics*, **47**, (3), 325-347.

Quah, D. T. (1996). Empirics for economic growth and convergence. *European Economic Review, 40(6), 1353–1375.*

Quah, D. T. (1993). Galton's Fallacy and Tests of the Convergence Hypothesis. *The Scandinavian Journal of Economics* Vol. 95(4), 427-443

Quah, D. T. (1990). Galton's fallacy and tests of the convergence hypothesis. *The Scandinavian Journal of Economics*, 95 (4) 427-443.

Ramsey, F (1928). "A Mathematical Theory of Saving," *Economic Journal*, 38(152), 543–559.

Recalde, M., & Ramos-Martin, J. (2012). Going beyond energy intensity to understand the energy metabolism of nations: The case of Argentina. *Energy*, 37(1), 122–132.

Reddy, B.S., (2013). Barriers and drivers to energy efficiency – A new taxonomical approach. *Energy Convers. Management*. 74, 403–416.

Roberts, D. L. & Nord, S. (1985). "Causality Tests and Functional Form Sensitivity". *Applied Economics* 17(1): 135- 141.

Romer, D. (2001). Advanced Macroeconomics. 2nd Edition, McGraw-Hill, New York.

Romer, P.M. (1986). "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94, 1002–37.

Romer, P.M (1990). Endogenous Technological Change. *The Journal of Political Economy*, 98, S71-S102.

Sachs, J. D., & Warner, A. M. (1997). Sources of slow growth in African economies. *Journal of African Economies*, 6(3), 335–376.

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics*, 37, 52–59.

Sargan, J. (1958). The Estimation of Economic Relationships Using Instrumental Variables. *Econometrica* 26, 393-415.

Saunders, H. D. (1992). The Khazzoom-Brookes postulate and neoclassical growth. *The Energy Journal*, 131–148.

Shafik, N (1994). Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*. 46, 757-73

Schleich, J. (2009). Barriers to energy efficiency: A comparison across the German commercial and services sector. *Ecological Economics*, 68(7), 2150–2159.

Sims, C. (1972). Money, Income, and Causality. *The American Economic Review*, *62*(4), 540-552. Retrieved from http://www.jstor.org/stable/1806097.

Solow M. R (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70 (1), 65-94.

Sorrell, S. et al. (2011). Barriers to Industrial Energy Efficiency: A literature review. Vienna. United Nations Ind. Dev. Organ. Working Paper

Sorrell, S., & Dimitropoulos, J. (2007). UKERC review of evidence for the rebound effect: Technical Report 5*: UK Energy Research Centre* Working Paper EF UKERC/WP/TPA/2007/013

Soytas, U., & Sari, R (2007). The growth of income and energy consumption in six developing countries. *Energy Policy* 35 (2), 889-898

Standard Bank (2018). Africa's oil and gas potential. Retrieved on November 4, 2018, from https://corporateandinvestment.standardbank.com/standimg/cib/Sector%20Expertise/Static%20files/2019/Standard%20Bank_Africas%20Oil%20and%20Gas%20Potential_24%20April%202019.pdf

Stern, D. I. (1993). Energy and economic growth in the USA: a multivariate approach. *Energy Economics*, 15(2), 137–150.

Stern, D. I. (1997). The capital theory approach to sustainability: a critical appraisal. *Journal of Economic Issues*, 31(1), 145–174.

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics*, 22(2), 267–283.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development*, 32(8), 1419–1439.

Stern, D. I. (2017). The environmental Kuznets curve after 25 years. *Journal of Bioeconomics*, 19(1), 7–28.

Stern, D.I. (2004) and Cleveland, C.J Energy and Economic Growth. Rensselaer Polytechnic Institute Working Papers in Economics.

Stern, D. I., & Cleveland, C. J. (2004). Energy and economic growth. *Encyclopedia of Energy*, 2, 35–51.

Stern, D. I., et al. (1996). Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. *World Development*, 24(7), 1151–1160.

Stern, D (1993). Energy and economic growth in the USA: A multivariate approach *Energy Economics*, **15**, (2), 137-150

Strazicich, M. C., & List, J. A. (2003). Are CO 2 emission levels converging among industrial countries? *Environmental and Resource Economics*, 24(3), 263–271.

Su-yun, Y. & Zhen-yu, Y. (2010). Empirical Study on the Impact of FDI on Regional Energy Intensity in China. *Journal of International Trade*.

Thiruchelvam, M. et al. (2003). Policy options to promote energy-efficient and environmentally sound technologies in small- and. *Energy Policy*. 31. 977-987.

Thiam, D. R. (2011). Renewable energy, poverty alleviation and developing nations: Evidence from Senegal. *Journal of Energy in Southern Africa*, 22(3), 23–34.

Toulmin, C. (2009). Securing Land and Property Rights in Sub-Saharan Africa: The Role of Local Institutions. *Land Use Policy*, 26, 10-19.

Swan, T. W (1956). Economic Growth and Capital Accumulation. *Economic Record*, 32, 334

Uzawa, H., 1965. "Optimum Technical Change in an Aggregative Model of Economic Growth." *International Economic Review* 6: 18–31.

United Nations (2018a). World Investment Report: Investment and New Industrial Policies. New York: United Nations.

United Nations (2018b). Accelerating SDG7 Achievement. New York: United Nations.

United Nations (2019a). World Investment Report: Special Economic Zones. New York: United Nations.

United Nation (2019b), World Economic Situation and Prospects 2019, UN, New York, https://doi.org/10.18356/a97d12e3-en

UN General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, 21October,2015, A/RES/70/1, availableat:https://www.refworld.org/docid/57b6e3e44.ml

UN-Energy/Africa. 2011. Energy for Sustainable Development: Policy Options for Africa.

UNEP (2017), *Atlas of Africa Energy Resources* United Nations Environment Programme. PO Box 30552, Nairobi 00100, Kenya

Van, P. N. (2005). Distribution dynamics of CO 2 emissions. *Environmental and Resource Economics*, 32(4), 495–508.

Voigt, S. et al. (2014). Energy intensity developments in 40 major economies: Structural change or technology improvement? *Energy Economics*, 41, 47–62.

Wikipedia (2018). West African Gas Pipeline. Retrieved online on November 8, 2018, from https://en.wikipedia.org/wiki/West_African_Gas_Pipeline.

World Bank. (2013). *Global Economic Prospects*. Washington, DC: World Bank.

World Bank. (2018). Tracking SDG7: The energy progress report. Washington, DC: World Bank.

World Bank. (January 2019). Global Economic Prospects: Darkening Skies. Washington, DC: World Bank.

World Bank Group. (2018). Africa's Pulse, No. 17. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/29667 License: CC BY 3.0 IGO.

World Bank (2019) Africa's Pulse, Spring 2018*: Analysis of Issues Shaping Africa's Economic Future (April),* World Bank, Washington, DC. Doi: 10.1596/978-1-4648-1291-0.

World Bank. (2018). *World Development Report 2018: Learning to Realize Education's Promise.* Washington, DC: World Bank. DOI:10.1596/978-1-4648-1096-1.

World Bank (2019). Retrieved March 6, 2019, from https://www.worldbank.org/.

World Economic Forum. (2004). Global Competitiveness Index. Geneva: World Economic Forum.

World Economic Forum. (2018). Global Competitiveness Index. Geneva: World Economic Forum.

Worrell, E. (2011). Barriers to energy efficiency: International case studies on successful barrier removal. *Development Policy, Statistics and Research Branch, Working Paper* 14/2011, 1–19.

Wu, Y. (2012). Energy intensity and its determinants in China's regional economies. *Energy Policy*, 41, 703–711.

York, R. (2007). Demographic trends and energy consumption in European Union Nations*, 1960–2025. Social Science Research*, 36(3), 855–872.

Yu, E. S. H., & Choi, J.-Y. (1985). The causal relationship between energy and GNP: an international comparison. *The Journal of Energy and Development*, 10(2), 249–272.

APPENDIX

Appendix A: Unit Root test for the Lag of the Natural Log of Energy Intensity

```
Fisher-type unit-root test for Lag_LEI
Based on augmented Dickey-Fuller tests
--------------------------------------

Ho: All panels contain unit roots           Number of panels       =     48
Ha: At least one panel is stationary        Avg. number of periods =  24.46

AR parameter: Panel-specific                Asymptotics: T -> Infinity
Panel means:  Included
Time trend:   Included                   Cross-sectional means removed
Drift term:   Not included                ADF regressions: 0 lags
------------------------------------------------------------------------------
                                            Statistic           p-value
------------------------------------------------------------------------------
 Inverse chi-squared(94)          P        97.0348             0.3945
 Inverse normal                   Z         -0.2433              0.4039
 Inverse logit t(239)             L*        -0.3300             0.3709
 Modified inv. chi-squared        Pm        0.2213             0.4124
------------------------------------------------------------------------------

 P statistic requires a number of panels to be finite.
 Other statistics are suitable for a finite or infinite number of panels.
------------------------------------------------------------------------------
```

Appendix B: Description of Variables

No	Variable	Description	Expected Sign
1	**Energy Intensity**	Energy intensity level of primary energy is the ratio of energy supplied and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used in producing one unit of economic output. A lower ratio indicates that less energy is used in producing one unit of economic output. Primary energy is energy in its natural form, which has not been transformed. These include coal, natural gas and crude oil (OECD/IEA, 2014).	+/-
2	**GDP Per Capita**	GDP per capita is gross domestic product divided by the mid-year population. GDP per capita is used as a proxy for growth because it measures the standard of living in each country which is useful for studies across countries. GDP is the sum of gross values added by all resident producers in the economy plus any product taxes minus subsidies.	+/-
3	**GDP Per Capita Growth**	GDP per capita growth is the annual percentage growth rate of GDP per capita at constant local currency. The aggregates are based on constant 2010 U.S dollars.	
4	**Agriculture Value-Added**	This includes the value-added of forestry, hunting and fishing and cultivation of crops and livestock production. It measures the overall contributions of these sectors to GDP.	-
5	**Industry Value - Added**	This includes the value-added in the mining, manufacturing, construction, electricity, water and gas sector to GDP. It measures the overall contributions of these sectors to GDP.	+
6	**Service Value-Added**	This is the net output of the service sector. It measures the overall contributions of the service sector to GDP	-
7	**Population Density**	this is the mid-year population divided by land area in square kilometres. The population here is based on the de facto definition, which counts all residents regardless of their legal status or citizenship as part of the population of that country except refugees who are not permanent residents in the asylum countries. The land is a country's total land area, excluding areas under inland water bodies, national claims to the continental shelf and exclusive economic zones.	+

8	**Regulatory Quality**	This measures the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Scores are given on the aggregate indicators in standard normal distribution unit ranging from -2.5 to 2.5.	-