++

UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

Rwanda University

College of Science and Technology

Title of the Project: Determinant of Energy consumption in Rwanda

A thesis submitted to the African Center of Excellence in Energy studies for sustainable development (ACE-ESD)

In partial fulfillment of the requirement for the degree of Masters of Science in Energy Economics

By: MINANI Leon Moise

Supervisor: Dr Edward Kadozi

November,2021

Kigali-Rwanda

Declaration

I, the undersigned, declare that this Project proposal is my original work, and has not been presented for a degree in the University of Rwanda or any other university. All sources of materials that will be used for the thesis work will have been fully acknowledged.

Signature

MINANI Leon Moise Date 18/11/2021

Registration Number: 215033833

This research project has been submitted for examination with my approval as University Supervisor

Sign 19/11/2021

Dr. Edward Kadozi Date

DEDICATION

This Thesis is dedicated especially to my Almighty God for His numerous blessings and safety, and special thanks to everyone who helped me during my research their affection, caring and support; everyday encouragement and enthusiasm motivated me to achieve this goal.
May the Almighty God bless you .

ACKNOWLEDGEMENT

This work is the result of efforts and support from many people. Therefore, their support and guidance will always be treasured in my life.

My thanks go to all my lectures mostly those from the University of Rwanda, College of Science and Technology, African Center of Excellence in Energy for Sustainable Development. made me reach this level. I am also grateful to my supervisor Dr. Edward Kadozi for his guidance and time dedicated to this work for his positive critique and guidance. His effort enabled me to produce this research to the quality it deserves.

With all my sincere gratitude and heartfelt, respect and appreciation, I extend my truthful thanks to my family, brothers and sisters for their support, love, sacrifices, moral supports and cares vested to me during my education.

LIST OF Tables

List of figures

Table of contents

Table of Contents

ABSTRACT

Energy has been criticized as the world`s challenge in the next century and Energy consumption increasing rapidly according to the rapid technological growth. However, there is a huge empirical claiming the determinants of energy demand. In Sub-Saharan countries context there is scarce empirical study that provide great insight on the determinants of energy usage. This thesis adds to the existing literature `by studying the determinants of energy demand in Rwanda for the period 1990-2019. An OLS baseline model is employed to examine determinants of energy consumption in Rwanda. Building on the baseline model, causal estimation techniques are employed to study the causal relationship between energy demand (total final energy consumption) and identified control variables. Both short-run and long-run correlation between energy usage and its determinants using granger causality and ARDL model.

The methodological and empirical analysis of this study is embedded in the theoretical framework of the neoclassical growth model and the endogenous growth model. The OLS results imply that 1% rise in GDP per capita increases total energy consumption by 168.9% percentage growth, 1 unit increase in population growth increases total final energy consumption by 0.05 percentage growth, 1% increase on urban population growth, increases energy consumption increase by 19% per annum while foreign direct investment and industrialization adversely affect energy consumption.

ARDL bound test cointegration to confirm the existence of cointegration among variables and ARDL model findings imply that, in short-run urbanization statistically and significantly has a favourable effect on total final energy consumption while GDP per capita, population growth, industrialization and FDI does not have an evidence short-run effect on total final energy consumption. In long run, the total final energy consumption statistically and significantly is positively correlated with industrialization, population growth, urbanization and FDI, and statistically and insignificantly GDP per capita has a long-run impact on total final energy consumption. The causation tests show that there is unidirectional causality runs from GDP per capita to energy demand and bidirectional causality from population growth and urbanization to energy usage and there is no causality between industrialization, FDI and total final energy usage

The findings suggest that to raise economic growth policy makers must ensure that the growth of energy consumption is less than the growth of energy supply and energy efficiency building policy is needful in new and residential buildings to reduce energy consumption in urbanized areas.

Keywords: Energy consumption, ARDL model, Rwanda

CHAPTER ONE

GENERAL INTRODUCTION

1.1Background of the study

Energy will be one of the world's major challenges in the next century, given the increasingly growing demand for energy as a result of fast technological growth through technological growth improves energy efficiency & less energy consumption and countries' reliance on energy in their manufacturing systems and consumption habits. Wu and Chen (2017) show that Energy is crucial to the nation's well-being because energy usage is essential for a country to attain economic growth and development. This brought up new energy-related concerns and challenges, such as the effect of energy usage on the environment, sustainable initiatives, supply capability to meet demand, renewable energy discovery, and the causation between growth and energy usage, among others.

In 2017 global estimates indicate that more than 2 billion were still cooking with solid fuels, which is about 20% of the world’s population. The population without access to electricity has dipped below 1 billion for the first time with 80% of those people living in rural areas more predominantly in sub-Saharan countries (OECD/IEA, 2018). UN-AGECC (2010) argues that up to a billion more have access only to unreliable electricity networks.

In Africa, evidence indicates that the continent is currently experiencing a significant energy deficit, which is hampering its growth and development. According to the Africa energy outlook (2019), most Africans (600 million people) does not have access to electricity, and about 80% of sub-Saharan African businesses experienced regular power outages, resulting in financial losses. Furthermore, approximately 900 million people, or more than 70% of the population, lack access to clean cooking this shows that a high proportion of the African population depends on traditional biomass, mainly wood and charcoal for cooking as a result Traditional biomass uses cause 500 000 early deaths per year because of household poor air quality. Indeed, OECD/IEA (2018) indicates that energy use in Africa as a whole rises by just under 60%.

The development of the energy market would have a massive effect on Africa's future. In 2007, the EAC area generated a total of 12,849 GWh of electricity, hydropower accounted for 65 % of all electricity produced while thermal power accounted for 28 %. The electrification rate in cities is between 30 and 50% (GTZ,2009). Rwanda is currently engrossed in intensively developing its sectors, such as infrastructure, while also strengthening its economy, with a focus on energy as a fundamental driver of economic growth (Minecofin, 2007)

According to studies (Safari B. K., 2010; Minenfra, 2018; business-sweeden, 2016), Rwanda has many energy resources including photovoltaic, biomass, hydropower, methane gas, and geothermal power where currently the electricity supply in Rwanda is sourced mainly from hydropower and thermal sources. Since around July 2018, the ministry of Infrastructure has revealed that Rwanda's installed capacity was 218 MW, interior capacity of 212.5 MW and an importation option of 5.5 MW. this capacity comprises hydropower, which accounts for about 45% of installed capacity. fuel which accounts for 27%, methane gas account for 14%, peat account for 7% and photovoltaic 6%. Rwanda has an abundance of local energy resources. though most of the resources are not being used to their full potential.

As of June 2017, 34.5 % of Rwandans had access to electricity. The main energy balance in Rwanda contained Biomass at 85 % at which 83.3% of households use firewood, electricity 2 % and renewable sources 13% made up of petroleum and petroleum-related products like diesel, kerosene, LPG, and natural gas. (Minifra,2018). Generally, due to inadequate technologies and poverty lead the use of the renewable source to be at a low level.

Energy usage choices made by households and companies have a big impact. Over the last two decades, we see a progressive increase in energy consumption across this field continue to experience hinted and mixed debates about the determinants of energy usage in developing countries, Rwanda in particular, less remain known in Rwanda, to what influence energy consumption.

The mainstream theory of economic growth theory gives minimal consideration to energy's position in economic growth and development, but energy has a mediated effect in the factors of production, as it is promoted by economic growth theories .therefore, to comprehend the significance of energy in economic growth, one must first realise the role of energy in production.

The discussion between the two major theoretical perspectives to the energy-growth effect, the neoclassical growth model and the endogenous growth model frameworks, is embedded in the analytical context of this research. The current research highlights the importance of complementing arguments that indirectly determines economic growth by making electricity available for final use (as inputs) by labour and capital in the production process; As a consequence, increased inputs or their efficiency are the cause of economic growth. Energy inputs are considered intermediate inputs, because of their indirect importance (Stern, 1999; Nela and Saša ,2010). under the assumption of a constant rate of return, the endogenous growth model as advanced by (Harrod, 1939; Romer, 1986; Lucas,1988; Aghion and Howitt,1992) claims that endogenous inputs of total factor productivity (technological progress), physical and human capital, research and development determine national productivity growth in the energy sector, no one technology can be considered the perfect solution to the energy crisis because each technology has its own set of cost and benefits(Chevalier, 2009:264).

Theoretical, empirical, and policy implications of energy consumption determinants are important. The macro factors influencing energy consumption have been the subject of numerous studies. However, the findings so far have been inconsistent and contradictory. The disparity in empirical results could be attributable to the diverse economic structures of the nations under study. (Sari, et al, 2008). A further explanation could be that various countries use different for of energy and have distinct consumption patterns. As a result, Energy consumption from various sources can have a variety of implications on economic growth of a country. (Ozun and Cifter,2007).

Mitra (1992) argues that many developing countries are still employing energy planning strategies developed advanced economies to meet the issues of advanced countries, while based on these fundamentals, the energy consumption and development in this century is projected to undergo significant changes. (Yeager et al, 2012).

Several empirical literatures suggest population, economic activity per capita, and technology performance as the three most basic drivers of energy demand. Fan and Hao (

2019) analyzed the correlation between renewable energy, FDI, and GDP in 31 Chinese provinces in the period from 2000 to 2015. According to empirical findings, GDP per capita, FDI per capita, all have a long-term and steady association with renewable energy usage per capita.

Indeed, rapid population growth leads to urbanization, which likely results in increased energy demand. Industrialization, Alternatively, has a direct and indirect link to energy usage. Industrialization involves the improvement of plants to increase productivity and, as a result, energy use. Industrial growth leads to economic growth by increasing demand for energy through cross-sectoral growth. In addition, industrial production often boosts labour demand, resulting in a rise in their wages. As income rises the consumer demand rises for electrical appliances which boost energy use, then the circle continues.

However, depending on the area, and whether the nation is stable or developing, their position on the development of the energy sector vary from country to country. Energy stability is a top priority for Europeans, while energy equity (accessibility and affordability) is a top priority for African countries especially Sub-Saharan Africa (IEA, 2014). Similarly, country energy consumption, including that of African nations, influences development (IEA, 2014; Minecofin, 2007; Azad et al, 2014).

This study acknowledges that several empirical studies have looked into the determinants of energy consumption in a variety of nations. However, because of the continued mixed empirical debates, the results have been inconsistent, with some claiming elastic and others claiming inelastic effects for certain factors. The various many independent variables their impacts have been investigated, and the variations in the social-economic structure of the countries, the results do not apply to Rwanda. Empirical research on the variables that influence energy consumption has shown mixed results, based on the study, attributed to various factors such as estimation methodology, economic development stage, data usage, and sample size the scale, as emphasized by (Khanna & Rao 2009).

Zhao et al (2012) looked into the long-term factors that determine china's energy imports employing VECM and Johansen-Juselius cointegration techniques. They found that worldwide relative oil price would not be a significant factor in China's energy demand. According to the researchers, The price elasticity of unrefined oil was positive, contradicting classical economic ideas that, if all other things remain constant, rises in the price of energy, the quantity of energy demanded should decrease. This contradicts the findings of kalid and kalid (2010) in Fiji found that real capital per capital affect positively while The effect of real prices and efficiency on energy demand is negative. These results indicate that as income rises, does too energy utilization.

(Ekpo et al,2011) studied the fluctuation of overall electricity usage in Nigeria, using ARDL model and found that in short-run and long-run Industrial sector output, real GDP per capital and population separately and are statistically significant as determinants of electricity consumption in Nigeria. Similarly, (Kraft and Kraft,1978) discovered one-way causality between GNP and energy utilization in the United States from 1947 to 1974,.

Accordingly, this paper recognizes the above theoretical and empirical gaps as well as contextual gaps in the energy economics and seeks to fill the void by examining the determinants of energy utilization in Rwanda at the national level using country time-series data. The study seeks to examine the causal mechanisms between the identified macroeconomic factors and the variable representing energy consumption in Rwanda. Given the centrality of energy in consumption patterns and productive activities, I investigate the most empirically used factors that influence energy demand for the period from 1990 to 2019. This study employs variables such as FDI, GDP, industrial development, and population as suggested by most empirical studies (Tang, 2009; Jumbe, 2004; Narayan and Smyth, 2005; Narayan and Singh, 2007;chor 2008;kalid and kalid,2010).

1.1. Problem statement

Energy naturally is critical in Rwanda's economic growth and development process. Energy influences the path for countrywide capacity to investment and thus to produce, which affects the country's economic growth potential.

In Rwanda, the exponential economic growth and the country's development path over the last two decades have been in line with the increasing energy consumption in the country. However, sparse is empirically known about the factors of energy demand in Rwanda. Empirical review shed light on the determinants of energy utilization at a macro level as; FDI, GDP, industrial development, and population to mention, but a few. Correspondingly, we see that the latter variables have experienced growth trends in Rwanda over the last two decades, despite the recent effects of COVID-19. The underlying question is how these variables influence energy consumption in Rwanda?. Both theoretical and empirical narratives present sparse and mixed discussions about the determinants of energy demand in developing countries. This is compounded by the scarcity of data; less attention to the contextual realities of countries and mixed empirical findings of the direction of causation between different factors and energy consumption. Nations are at different levels of development, and local policy frameworks for energy use and efficiency are different. We know that energy consumption influences economic growth through its arbitrated effect on the factors of production, which finally influence growth. But, we also know that economic growth influences the consumption of energy, but to some extent in an efficient way if the economy is at an advanced level of development. Hence, mixed state of knowledge, with an indication of reverse causality.

Therefore, this study seeks to bridge the above empirical and methodological gap by examining the causal relationship between energy use and different factors influencing energy use. In other words, this study will shade light on macro variables influencing energy consumption in Rwanda. It will determine drivers of energy consumption both in short-run and in the long-run macro level in Rwanda.

1.3.0. General objective of the study

Generally, this study empirically examines factors that influence energy consumption in Rwanda for the period from 1990-2020

3.3.1. Specific objectives

- Determine empirically whether there is either short or long run causal link between energy use and its factors in Rwanda;
- Examine the direction of causality among energy consumption and its identified determinants
- Determine growth trends of energy use against its determinants in Rwanda over time;
- Provide relevant policy implications to the policymakers and other stakeholders.

1.4. Research questions

The above study objectives influence the preceding research questions of the study:

- How the identified macroeconomic variables empirically influence energy consumption in Rwanda?

- What is the short and long run causality anong the specified macroeconomic factors and energy consumption in Rwanda?
- What is the direction of causality between the specified macroeconomic determinants and energy consumption in Rwanda?

1.5. Hypothesis

The study hypothesizes that:

- H0: There is no a causal association of energy demand in Rwanda among proposed determinants.
- H1: There is a causal link of energy consumption in Rwanda among proposed determinants

1.6 .Scope of the study

The study examines the determinants of energy consumption in Rwanda for the period from 1990 to 2020. The study bases its analysis on Rwanda, by using macroeconomic variables time series data for Rwanda from 1990 to 2020. This research is focused on secondary data obtained from the World Bank. The World Bank's Development Indicators (WDI) 2020 database has been issued.

1.7. Significance of the study

The study examines the determinants of energy consumption in Rwanda for the period from 1990 to 2020. The study bases its analysis on Rwanda, by using macroeconomic variables time series data for Rwanda from 1990 to 2020. This research is focused on secondary data found from the World Bank. The World Bank's Development Indicators (WDI) 2020 database has been issued.

1.8. Organization of the study

This research is divided into three main sections, part one is an introduction which includes the background of the study, the problem statement, the study objectives, the research questions, the scope of the study, significance of the study. Chapter two presents the review of the literature.

The third chapter will cover the methodology and estimation techniques. The fourth chapter will cover data and empirical analysis. Lastly, the fifth chapter will present the summary findings, conclusion and policy implication of the study.

1.9. **Expected outcomes**

Based on the objectives and methodology to be used in this research, it is expected that the effects of each selected independent variable will have a statistically significant impact on the energy use among heating, cooling, lighting, electricity, transportation and cooking in Rwanda.

CHAPTER TWO

REVIEW OF THE LITERATURE

Scholars and policymakers disagree about the link between energy consumption and its macro factors. The underlying issue is the macro-determinants of energy consumption growth. Although there is a huge body of literature on the subject, the results are mixed. Scholars are split on the optimal model to describe the energy-growth nexus in a way that accounts for the various mechanisms through which energy consumption influences growth. The problem of data and the methodological difficulty associated to it, the relationship among energy demand and its macro determinant has been impacted by endogeneity that influenced the ongoing empirical arguments on many studies to examine the causal relationship among energy consumption and different determinants either in a single county or multiple countries. The literature review is into five divided portions: definition of key concepts, theoretical frameworks, empirical discussion on drivers of energy consumption, conceptual framework, and energy consumption in Rwanda

2. 1. Definition of Key Concepts

2.1.1 Energy: The meaning of energy differs depending on the context of study, although in this case, the frequently accepted term is chosen. Energy is the ability of a physical system to perform work is defined as energy (UN-DESA 2018).

2.1.2 Energy Consumption: The term "energy consumption " refers to the total quantity of energy necessary to complete a task. Energy consumption according to Collins dictionary is the energy consumed by individuals, businesses, country and other entities

2.2. Theoretical frameworks

The debate about determinants of energy consumption is embedded in the three main theoretical frameworks; the energy-growth effect, the neoclassical growth model, and the endogenous growth model respectively. It is worth noting that, the three theoretical frameworks are based on the Use of energy in production in both industrialized and emerging nations to achieve economic growth.

Based on the theories of production, the Neoclassical Growth Model describes the economy as a closed economy where capital accumulation and how people use it in an economy are essential factors in generating economic growth. It also asserts that the interaction between capital and labour in an economy affects the overall output. As a result increasing inputs or their quality are the cause of economic growth. Indeed, countrywide accounts generally do not differentiate between inputs other than capital and labour; resources are grouped in the intermediate inputs aggregate, which is deducted from gross output to calculate value added. if the value of raw materials used increased, Intermediate inputs value would rise but not always the rise in intermediate inputs indicate a rise in raw material consumption (for instance, it could be due to the shifting of some managerial work (Baptist & Hepburn,2013). The total of the actual values of physical intermediate inputs, energies, and acquired services is defined as intermediate inputs and Some government statistics (such as those of the United States and the European Union) treat energy and secondary inputs separately, while others distinguish services from intermediate inputs at the sectorial level.(Baptist & Hepburn ,2013).Energy is frequently utilized as an intermediate input, the price of goods and services, the quality of produced items, the growth of the nation, and the availability of jobs are all directly affected by the use of energy in the production process of the industry.

The mainstream economists (Stern, 1999; Baptist & Hepburn, 2013; Hulten,1978) have adopted the idea of primary and intermediate inputs of production. Primary elements of production are inputs that occur at the start of the manufacturing process and are not directly working in production because they can be corrupted and modified to, on the other hand, intermediate inputs, are those that are formed throughout the production process in question and are employed altogether in production. The primary factors of production are capital, labour, and land, whereas intermediate inputs include fuels and materials and energy inputs are considered as intermediate inputs, because of their indirect importance. They believe that the amount of energy accessible to the economy is endogenously determined, while it is constrained by biophysical and economic factors (Stern and Cleveland, 2004:5). (Georgescu- Roegen, 1971) was the first to highlight the relevance of energy in the economic system, arguing that the physical character of economic production required additional explicit emphasis in growth theory.

Energy price hikes in the 1970s sparked a lot of study on energy consumption and its relationship to gross output (Schurr, 1984; Berndt, 1982; Tintner et al., 1974; Berndt &Wood, 1979) including work on formulations of input and output (Hannon et al, 1983). This attracted attention in explicitly accounting for intermediate inputs in the production function, such as energy, materials, and services. This attracted attention in the direct measurement of an intermediate factor of production. Many studies have since estimated KLEM (capital, labour, energy, and materials) and KLEMS (capital, labour, energy, materials, and services) production functions, using data dating back to 1947. (Berndt &Khaled, 1979)

In general, the neoclassical production function describes economic growth by increasing labour, capital, and technology, with total factor productivity (TFP) referring to the fraction of output that cannot be described by the sum of inputs utilized in production. The Solow residual is commonly used to measure TFP growth. Although it only precisely estimates TFP growth is feasible if the production function is neoclassical, factor markets are perfect competition and input growth rates are accurately measured (Comin,2006:1). Further, (Solow,1956) also demonstrated that inequalities in the technology of the countries can result in significant changes in income per capita, which was validated in research by Hall and Jones (1999). However the Solow model does not explicate the causes of technological advancement, technological progress is the only reason for continued economic expansion. Understanding the factors that influence technological progress and adoption is crucial to comprehending Total Factor Productivity differences among countries. More modern models, known as endogenous growth theories, link economic choices made by firms and persons to technological advancement.

Industry energy demand is a derived demand that began during the manufacturing process, according to Berndt and Wood (1975). This means that, like another factor of production, industrial energy consumption from a certain sector is influenced by output levels, relative prices, and technical flexibility. As a result, numerous analysts have tried to figure out how to combine energy with other factors of production (e.g., Berndt and Wood, 1979; Griffin and Gregory, 1976; Morrison and Berndt, 1981; Pindych and Rotemberg, 1983; Solow, 1987).

Both technical advancement and energy use have an impact on each other. According to certain prior studies, technological innovation reduces energy consumption which leads to long-term development (Zhou et al, 2017; Tang et al,2017) . on the other hand, Lund(2007) considers that there are three approaches to accomplish sustainable development through technological innovation in energy:demand-side energy savings, increased energy efficiency and the changing from fossil fuels with a diversity of renewable energy sources.

Under the assumption of a constant rate of return, the endogenous growth model as advanced by (Harrod, 1939; Romer, 1986; Lucas ,1988; Romer,1990; Grossman and Helpman (1990, 1991) ; Aghion and Howitt,1992) claim that endogenous inputs of total factor productivity (technological progress), physical& human capital, research and development determine national productivity growth. In the energy sector, no one technology can solve the energy crisis because. Each technology has its own set of advantages and drawbacks. (Chevalier, 2009:264).

The complementarity of capital and energy use in the production process is emphasized by both Putty-Putty Model and Putty-Clay Model as developed by Robert S. Pindyck and Julio J. Rotemberg (1983). The key characteristics of this putty model are that energy is very complementary with capital, and capital has adjustment costs. The stock of capital responds to changes in energy prices slowly over time because of the adjustment. Energy travels slowly because it is extremely complimentary to capital in production. In the long run, both the capital stock and energy use adjust to unavoidable price fluctuation in energy. While The Putty-Clay Model proposes that a great number of capital goods are coupled with energy in various fixed magnitudes. Because current capital utilizes energy in fixed quantities, in the short run, the putty-clay model exhibits low flexibility of energy usage. In the long run, agents spend in a variety of capital goods with varying fixed energy levels, in response to persistent price fluctuation of energy. As a result, energy consumption is sensitive to price fluctuations of energy in the long run.

Despite the fact that, these new growth theories have succeeded in endogenising growth theory by connecting growth to profit motivation, Zon and yetkiner(2003) argue that they have proceeded to overlook the fact that equally endogenous energy efficiency technical change will be implemented to create these development paths feasible. Some recent research has focused on the importance of resources in economic growth models with endogenous technological progress.

Ayres and van den Bergh (2005) argued for a more differentiated approach to growth drivers. They proposed an economic growth framework based on energy sources and dematerialization with three growth drivers: resource use(fossil fuel), scale cumulative learning growth mechanism and value creation(dematerialization). The authors concluded that resources input expands approximately linearly with income at sufficiently high growth rates. Though theoretical findings provide inadequate information on the future growth trend in connection to resource usage, notably energy use efficiency and dematerialization. Apart from a probable decline in energy consumption over time, Smulders and de nooij(2003)believe that the energy consumption is increasing at a positive proportion. Energy use and economic growth are influenced by the availability of investment capital whereas energy use is affected by the level of technology (Dahl,2008:56)

Tahvonen and Salo (2001) create a model that includes all energy resources both non-renewable and renewable energy sources, as well as fossil fuel extraction and renewable energy resource production costs. Their model illustrates the economy's growth process in a very realistic way as it progresses through pre-industrial, industrial, and post-industrial stages of development, as fossil fuel use increases in the beginning.

There has been a significant increase in a study on "good governance" and government institutions' efficiency in recent years. This trend has been sparked by economists' empirical conclusions that such institutions may be used to better explain economic growth in third world nations. (Acemoglu et al., 2002; Acemoglu, 2001; Easterly, t al.2001, Easterly and Levine 2003, Rodrik et al 2004). As a result, neoclassical economic theory has been extended and new concepts have been embraced. In underdeveloped nations, energy accessibility and economic development is primarily reliant on government commitment and assistance. The government must develop a clear institutional structure and to decide what role government firms, private country’s capital, and worldwide investors should play. As a result, the type of political governance in existence has a significant influence on the collaboration among energy supplies, energy policy, and economic growth (Chevalier, 2009:136). The effect of economic, societal, and political structure on energy-efficient usage, institutional economists have made significant contributions to the function of energy in economic development. (Paavola and Adger,2005).

However, Stern and Cleveland (2004) grouped neoclassical economic growth theories into three groups. The first suggests that improved technologies are the most essential determinants of growth in the economy and production function. At first, the economy achieves a level of equilibrium. Then, rather than capital, this technological advancement leads to economic expansion.

The utilization of the natural resource is a factor of stable economic growth in the second category. The third point of view examines changes in technology and natural resources in determining economic growth. As a result, we can achieve economic growth using human and natural capital, as well as enhanced technology. It should be emphasized that in these models, the proportion of energy used for economic activity was measured as a proportion of the cost. In another word, these models viewed energy as an intermediate good rather than a production input.

2.3. Empirical Discussion: Determinants of Energy Consumption

This section discusses empirical narratives about determinants of energy consumption at the macro level to inform the analytical framework of this study. Energy is so important to the growth and development process; scholars have looked into the factors of energy consumption at the national level for many countries. However, empirical studies from both developed and developing countries remain inconclusive.

Several empirical studies on the determinants that influence energy consumption have shown mixed results. This depends on a variety of factors such as estimation methodology, economic stage, data usage, and sample size (Khanna & Rao,2009). But also, empirical findings vary by country and are dependent on selected variables for the study period, this segment presents the findings of empirical research on the factors of energy demand. For instance, the link between energy use and economic variables has been studied since the 1970s oil crises, especially economic growth, has been studied, but the empirical evidence is equivocal as to whether energy consumption induces economic growth or vice versa (Ozturk,2010).

For instance, Ergun et al (2019) investigated the determinants that impact renewable energy use in Africa for a panel of 21 African countries from 1990to 2013, using Fixed-effects (FE) and random effects (RE) techniques the researchers found that nations with a larger Human Development Index and income per capita have a smaller proportion of renewable energy in their grid. on the alternative, Increased renewable energy integration, has been linked to a rise in foreign direct investment. As a result, Foreign direct investment is a factor that influences the use of renewable energy. Direct foreign investment (FDI) can help to the advancement of renewable energy sources in the African continent. Ergun et al (2019) found that Except for Rwanda, where the relationship is positive but small, and all nations have a negative association between GDPpc and renewable energy use. This can be looked at from two perspectives: first, one of the objectives the primary goal of most emerging and underdeveloped nations is to achieve economic development. As energy promotes growth in the economy and fossil fuels are a less expensive choice, their usage will rise to encourage income growth. Second, income growth (GDP) can encourage people to look for more efficient ways of doing things other energy sources and reduce the reliance of established sources of renewable energy. Because of the capital-intensive nature of the change, The use of renewable energy as a proportion of total energy usage is decreasing.

The results of Ergun et al. (2019) contrast those of (Sadorsky, 2009a) in the G7 nations and(Salim and Rafiq,2012) in emerging nations, who found that per capita income is a determinant of green energy use. On other hand (Attiaoui et al.,2017) used the autoregressive distribution lags-pooled mean community to examine the impact of per capita CO_2 emissions, GDP per capita, and per capita non-renewable energy use on renewable energy usage which is calculated using the burnable renewable ratio of total energy in 22 African nations from 1990 to 2011. They found that GDP has little effect on renewable energy consumption,

Poumanyvong and Kaneko (2010) evaluate the effect of income, urbanization, industrialization, and population on energy consumption in a sampling of 99 nations from 1975 to 2005 using panel data methodologies. They discovered that the influence of urbanisation on energy consumption varied by income level, and that urbanization reduces energy consumption in a group of low income. While it raises energy consumption in the high and middle-income category, it decreases it in the lower and intermediate socioeconomic groups. The influence of the portion of industrial output on energy usage in the economy is favorable, but only for middle and low-income classes, it is statistically significant.

(Filippini & Pachauri, 2004), a growing trend in the industry, population expansion, income growth, modernization, and urbanization has increased electricity consumption in the past and will continue to do so in the future. According to on the level and quality of growth and development necessitating high investment to fulfil the ever-increasing demand for electricity in India similarly, Sadorsky(2014) studied The impact of rapid Industrialization and Urbanization on Energy use in a panel of developing nations using Dynamic models, He found that Income boosts energy usage both in short-run and long run, according to the findings. Urbanization reduces energy usage in the long run, whereas industrialization rises it. Similarly,York (2007) analyzed data for fourteen-member of the European Union Nations from 1960 to2000 to evaluate the impact of demographic and social-economic determinants on energy use using The feasible generalized least-squares (FGLS). He found that the size of population size and age composition is highly elastic on energy consumption, variation in energy usage is also influenced by economic development, industrialization, and urbanization. This indicates that as infrastructure is created, increased urbanization enhances the demand for energy-intensive products and materials. If used effectively, green construction initiatives such as LEEDS certification can reduce energy use. Private energy use can be affected by urbanization. Consumption of energy-saving appliances increases as urban inhabitants get wealthy. In conclusion, urbanization can have both favourable and effects on energy consumption, making it impossible to forecast the overall outcome of urbanization. Increased industrial production, such as high-value-added industry, consumes higher energy than agricultural or primary manufacturing. Additionally, (Ivy-Yap and Bekhet, 2014), Income and population increase have a positive effect on Malaysia's electricity usage.

Meanwhile, a handful of studies claim FDI inflows and energy use has a positive association. For instance, Bin Mohammad Mohamed (2016) Using an Autoregressive Distributed Lag Model (ARDL) from 1994 to 2014 analyzed the link between FDI, economic growth, energy demand, and exports in Yemen. He found both short-term and long-term positive impacts among FDI inflows and domestic energy usage In Yemen. A similar study of 22 developing economies, (Sadorsky, 2010) used panel data set on 22 developing countries from 1990-2006 using a generalized method of moment estimator to discover a favourable and statistically relevant link between energy usage and FDI. Furthermore, Foon Tang (2009) tested the causality relationship among electricity usage, income, population, and FDI in Malaysia using ECM and Granger causality analysis in the data of 1970 to 2005. In the short run, he discovered bidirectional causality among electricity use, income, and FDI while unidirectional causality from population growth to electricity usage. While he found that Electricity usage will rise as a result of rising income, FDI, and population expansion. This means that the energy-growth effect is mediated through other macroeconomic variables like urbanization, industrialization, FDI, and population growth.

(Bekhet & Othman, 2014) looked at the short and long-run impact of FDI, exports, and industrial value-added and electricity consumption in Malaysia. The results revealed that FDI, exports, and industrial value-added all boost electricity usage in the long run but in the short run, the effects of FDI and industrial value addition on electricity usage are negative. This indicates that the FDI inflow is increasing electricity usage through the increase of industry and transportation sectors, all of which require electricity to operate. Alternatively, FDI allows enterprises to obtain financial resources at a lower cost and/or with higher efficiency, It could be used to develop existing industries or to construct new industries, which all increase energy demand, which is consistent with this assumption that FDI leads to increased economic growth.

Most previous research has found that FDI encourages energy efficiency in the host country and decreases energy consumption. For instance, Burcak and Nuh(2018) using a dynamic panel data technique, researchers studied the impact of foreign direct investment on renewable and non-renewable energy usage in 85 industrialized and emerging nations from 2002 to 2014. The study found that FDI lowers energy usage in industrialized countries while having little effect in developing countries. Similarly (Mielnik & Goldemberg, 2002) found a negative association between energy intensity and FDI based on research of 20 developing nations. the spreading effect of FDI through the introduction of new technologies has been connected to the reduction in energy intensity.

However, numerous authors found no measurable effects of FDI on domestic energy usage. Lee (2013) uses panel data from 19 G20 countries from 1991to 2009 to analyze the effect of net inflows of FDI on energy demand and economic development Using cointegration test and fixed effect He found that FDI is vital for economic growth, but he couldn't identify any indication of a positive link between FDI and clean energy usage. Similar, Zeeb et al. (2015) used pooled Ordinary Least Square (OLS), Random Effects (RE), and Fixed Effects (FE) models to look at the influence of FDI on energy savings in seven South Asian nationson the period of 1990 to 2013. This study found no evidence of FDI having a major impact on energy usage. The authors found that FDI supports the transmission of new technology to this set of countries; however, the effect of FDI on energy intensity is dependent on national characteristics and energy policy.

The causal link between energy usage and other variables is A well-known topic. For example, Using cointegration and VECM, Soytas and Sari (2003) investigated the causality link among

GDP and energy usage in the top ten developing markets and the G-7 nations. In Argentina, bidirectional causality in Italy and Korea was identified, as well as causality that went from GDP to energy demand, and in Turkey, France, Germany, and Japan from energy demand to GDP. Furthermore, Anwar and Nguyen.(2010) investigate the impact of FDI on energy for a sample of 61 provinces in Vietnam. . Similarly, For the period 1967-2003, Zamani (2006) used the JML technique to look into the causation relationship between Iran's economic activities and energy usage. He found a long-term unidirectional association between GDP and overall energy use from GDP to total energy usage as well as a bi-directional association between GDP and gas use and GDP and petroleum product use. While Using the Error correction model, Jumbe (2004) proposes a bidirectional link between GDP and electricity use in Malawi. From 1996 until 2005, The findings show that FDI and energy usage have a bidirectional causal relationship in all of Vietnam's provinces.

During 1980-2011, Ibrahiem (2015) used an autoregressive lag technique to examine the relationship between economic growth, renewable electricity usage, and FDI in Egypt. The results suggest that there is a unidirectional link from FDI to income. Furthermore, income and renewable energy have a positive link, and Altinay and karagol (2004) empirical Based on the detrended data, findings imply that there is no indication of a causal link between GDP and energy consumption in Turkey On another hand Erol and Yu (1987) examined data from six developed nations and found no proof of a causal association between energy usage, GDP growth, and employment. Yu and Jin (1992) employed the Engle-Granger testing approach to find no long-run correlation between energy use and income in the United States

2.4. Theoretical and Empirical Gaps

The factors influencing energy use at a national level continue to be overlooked in the empirical and policy narratives in developing countries such as SSA countries. More so, some attempts to contribute to the latter, results continue to be inconsistent, with some claiming elastic and others claiming inelastic effects for certain factors.

The direction of causation among studies on energy usage and GDP, the findings on among the variables classified into three categories: unidirectional causality, second bidirectional causality, and finally, no causality (Akinlo, 2009). This inconclusiveness seems to be attributed to the scope and the context of the study

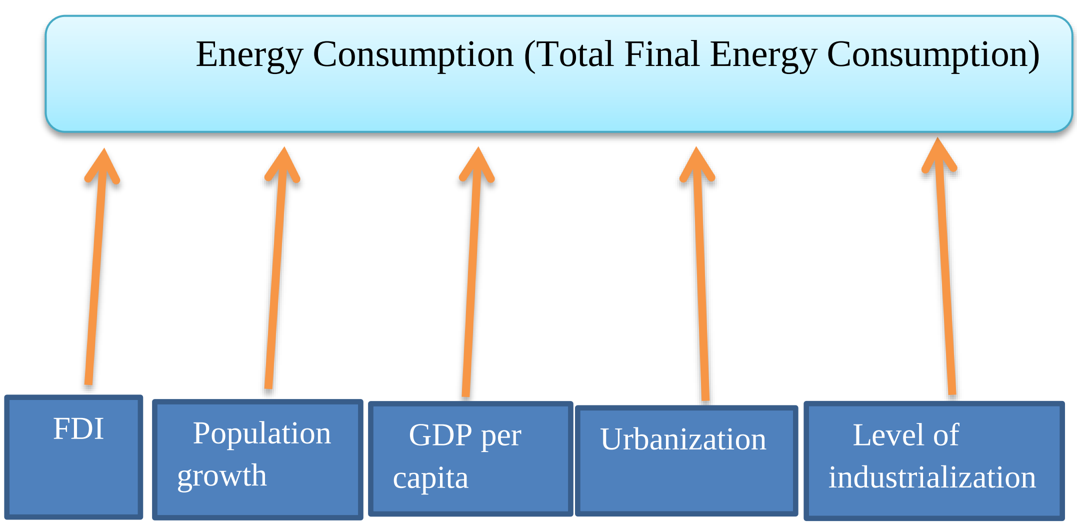
Several studies indicate that GDP per capita, population expansion, urbanization, industrialization, and FDI determine energy demand, however, the empirical findings are mixed. Technological progress, the level and quality of growth and development are among the contributing factors. In Rwanda, sparse is known on how the above factors contribute to the energy demand. For instance, we see from the last two decades, an exponential shift in energy demand and economic growth in Rwanda. Even though Rwanda's energy situation has improved, it appears that little attention has been made to examine the determinants of the country's energy usage. Only a few researchers, particularly in Africa, have looked at the time-varying behaviour of energy determinants. More so, previous studies did not consider variables related to capital formation like Gross capital formation in their analysis as an indicator of public investments- stimulating economic growth and development. This study endeavors to clear this gap by employing the above-mentioned variable in the analysis.

2.5. Conceptual Framework

This section argues the conceptual framework of this study. In this study, the determinants of energy consumption in Rwanda are examined at the macro level. But we well know that energy consumption can be examined at both micro sector, and macro levels respectively through different three layers of energy use: The public sector, Households, and industries (industrialization). The three layers influence energy consumption in their respective sector categories mainly in activities related to lighting, cooking, household appliances at the household level respectively. Energy use in the public sector, involves activities of street lighting, public building, and water pumping, while in the industrial sector where main activities are manufacturing process. The consumption of energy through the three layers is later aggregated at the macro level. The conceptual framework of this study is supported by the theoretical and empirical review, which depict the empirical gaps in the field, to which this study seeks to contribute. We learn from empirical evidence that FDI, Population growth, GDP per capita, level of industrialization, grand urbanization influence energy consumption at the macro level. However, the empirical review shows mixed narratives on how the above variable of interest influences Energy consumption. This seems to be attributed to the varying level of technological progress, quality of growth and development, as well as the country-specific context, as well development path. All of those variables FDI, Population growth, GDP per capita, level of industrialization, growth per capital formation, and urbanization will be employed to empirically examine how the control variables influence energy consumption in Rwanda.

Developing countries receiving capital inflows, experience rapid Population growth, GDP per capita, level of industrialization, and urbanization in the economic growth process, hence increasing their energy demand mostly in developing countries like Rwanda. Furthermore, controls variables are primarily directed to capital-intensive industries in emerging economies. However, emerging economies are likely to create dirty industries, as they increase energy consumption.

This study will employ a baseline model using OLS to examine how the control variables influence energy consumption. Due to the problem of endogeneity and selection bias subjected to the OLS model, the analysis is further customized to the causal estimation techniques to evaluate the short and long-run connection, as well as the direction of causality between dependent variables, and the independent variable of interest. The determinants of energy consumptions in Rwanda are conceptualized here below. This conceptual framework will determine the variables of interest and analytical framework of the study, focusing the macroeconomic variables through the industrial development channel



2.6. Energy consumption in Rwanda

According to studies (Safari B. K., 2010; Minenfra, 2018; business-sweeden, 2016),

Rwanda has many energy resources including photovoltaic, biomass, hydropower, methane gas, and geothermal power however most of the resources are not being used to their full potential. Currently, the electricity supply in Rwanda is sourced mainly from hydropower and thermal sources. As of July 2018, the ministry of infrastructure indicated that the installed capacity was at 218 MW, with a capacity of 212.5 MW sourced within the country, while 5.5 MW was imported as an alternative source. This capacity includes Hydro power that makes around 45% of the total installed capacity, Diesel, 27%, 14% of methane gas, 7% of peat, and 6% solar. This is illustrated in figure 1

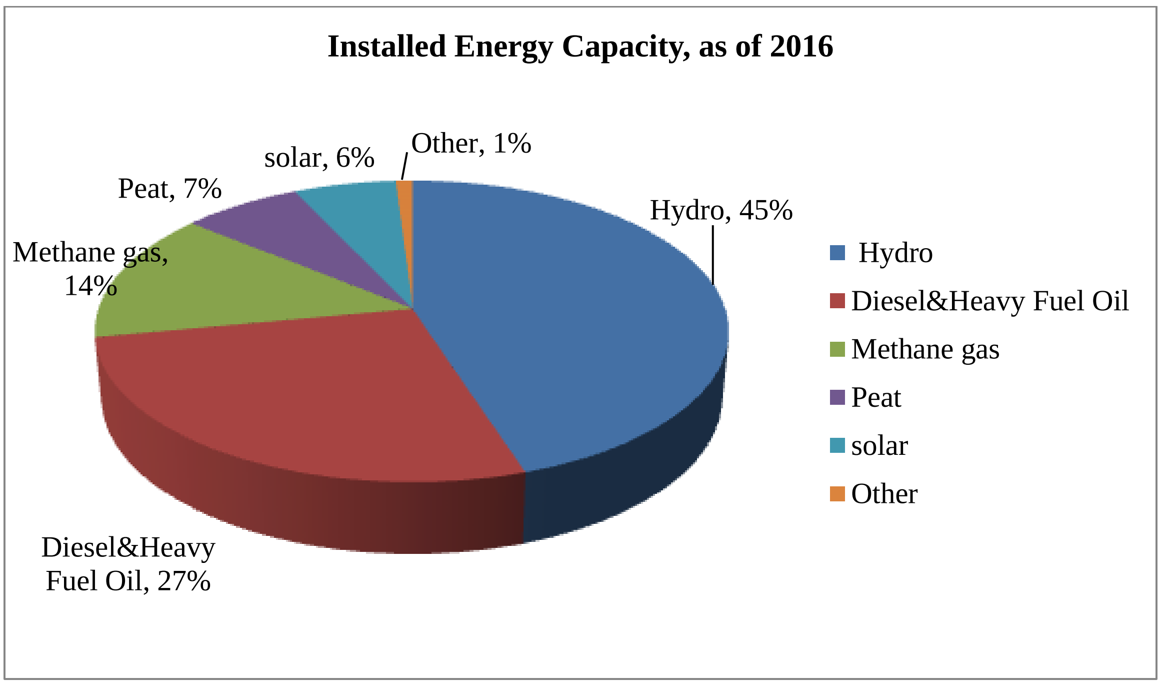


Figure Figure1 Installed capacity by category in Rwanda

The evolution of installed electricity generation capacity is presented in Figure2.

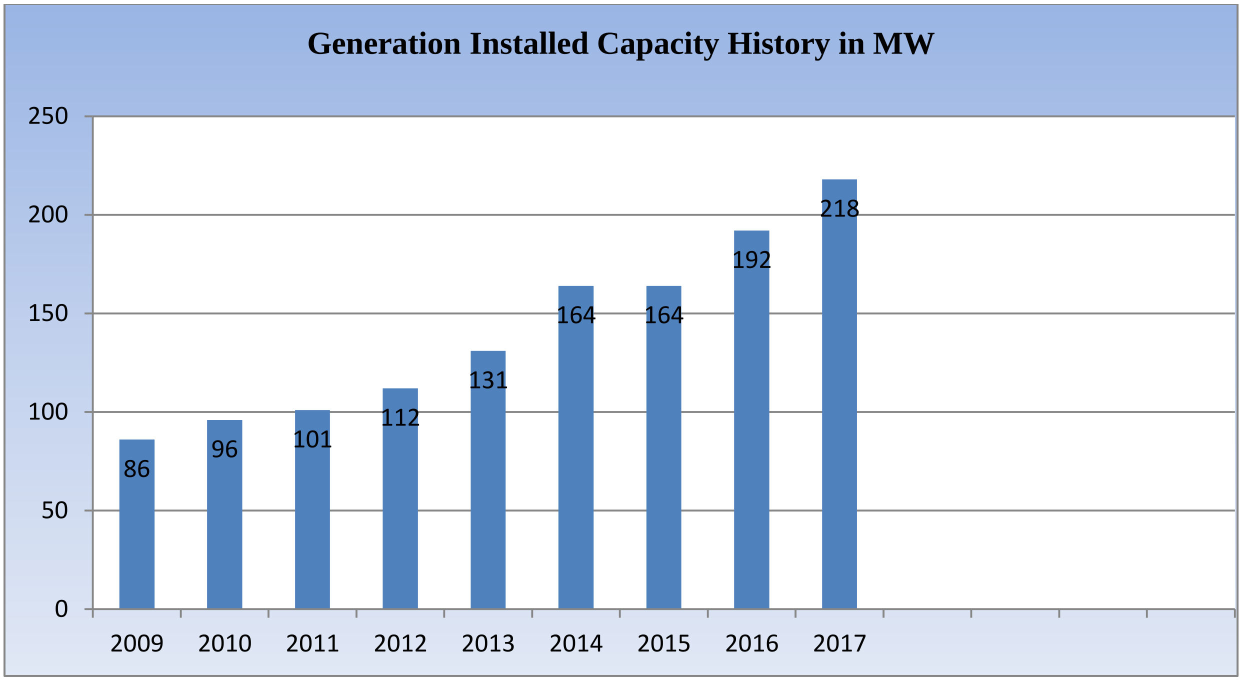


Figure 2. Evolution of installed electricity generation capacity

Source:(MINIFRA, 2018)

Energy production and consumption have witnessed a continuous increase in recent years in Rwanda. Rwanda electricity demand is grouped into two categories which are residential sector comprises the households and the nonresidential sector covers all agricultural, industrial, and service sectors respectively. The electricity demand per house in the base year, as well as the predicted population and GDP, are required inputs in estimating future power demand (Mudaheranwa et al., 2019). As of June 2017, 34.5 % of Rwandans had access to electricity, and by 2024, the 2018 Energy Sector Strategic Plan aimed to provide electricity to all public infrastructure, schools, health facilities, small businesses, and administrative offices, as well as households. Rwanda's primary energy balance consisted of Biomass at 85 % at which 83.3% of households use firewood, electricity at 2 %, and renewable sources 13% made up of petroleum and petroleum-related products like diesel, kerosene, LPG, and natural gas (Minifra, 2018). This is illustrated in figure 3. The growth trends of total final energy consumption are presented in figure four, while the growth trends of the proportion of renewable energy usage to total energy demand from 1990 to 2019 are presented in figure three here below.

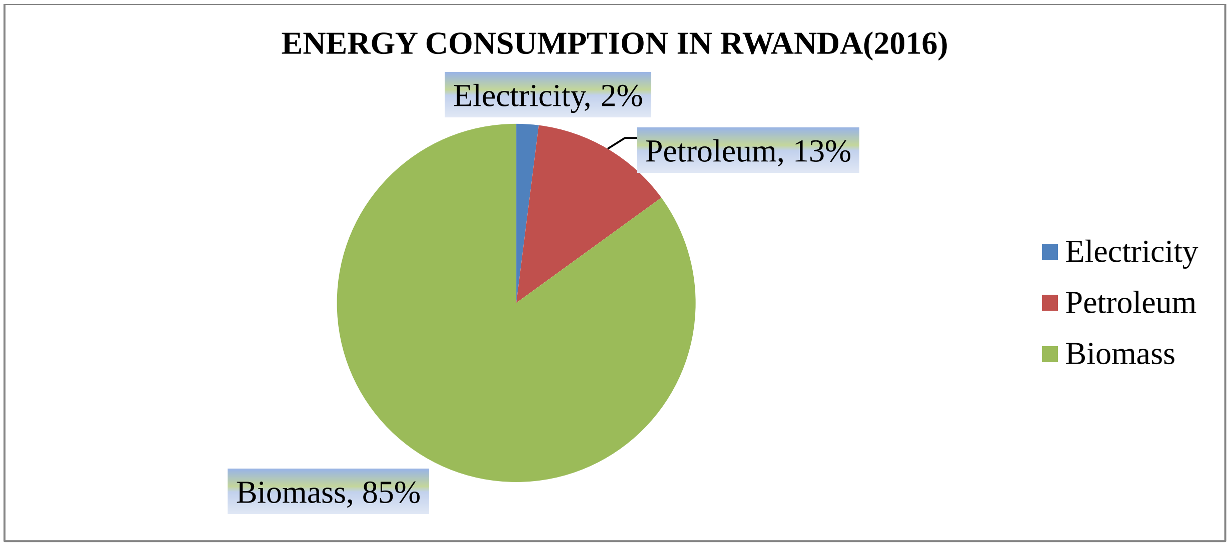


Figure 3.Energy consumption in Rwanda

Source :(MINIFRA , 2018)

Figure 3 above showing that traditional energy consumption is at great extent compare to the other sources of energies

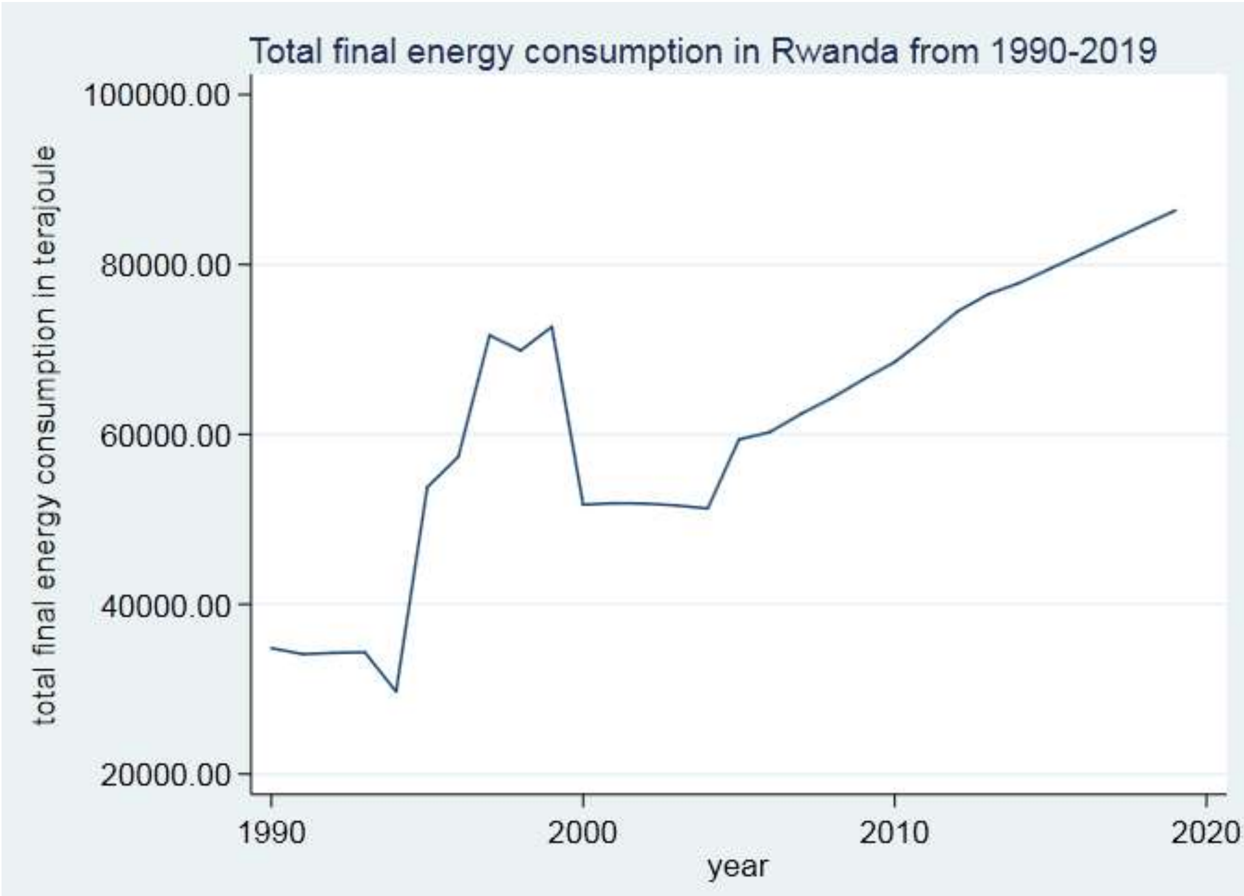


Figure 4. Total final Energy Consumption in Rwanda (1990-2019)

Source: Author's estimation based on (August 2021) time-series data from World Bank.

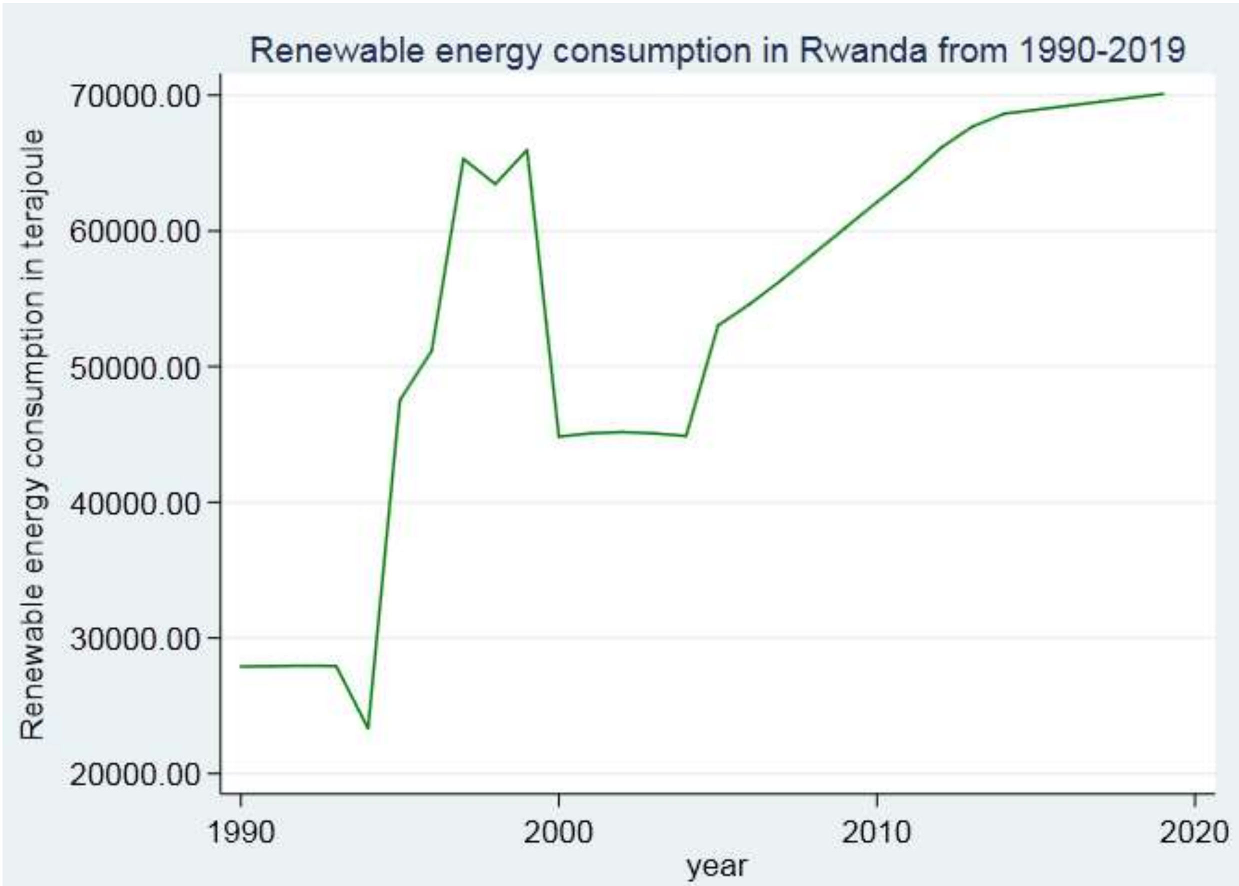


Figure 5. Renewable Energy Consumption in Rwanda (1990-2019)

Source: Author's estimation based on (August 2021) time-series data from World Bank.

Figure 4 above shows that the trend of the last ten years on energy consumption increased progressively this indicates that Rwanda's economic activities for energy consumption are increasing. And figure 5 shows that trend of renewable energy is rising indicate that the government of Rwanda is adopting the use of green energy sources.

According to the national energy strategic plan of 2018 on the energy demand, it was discovered that in 2016 the majority of energy users (82%) are households, who primarily use traditional fuels such as wood. Transportation (8%) is the second energy-intensive sector, after by industry (6%), and finally others (4%). This is illustrated in figure six.

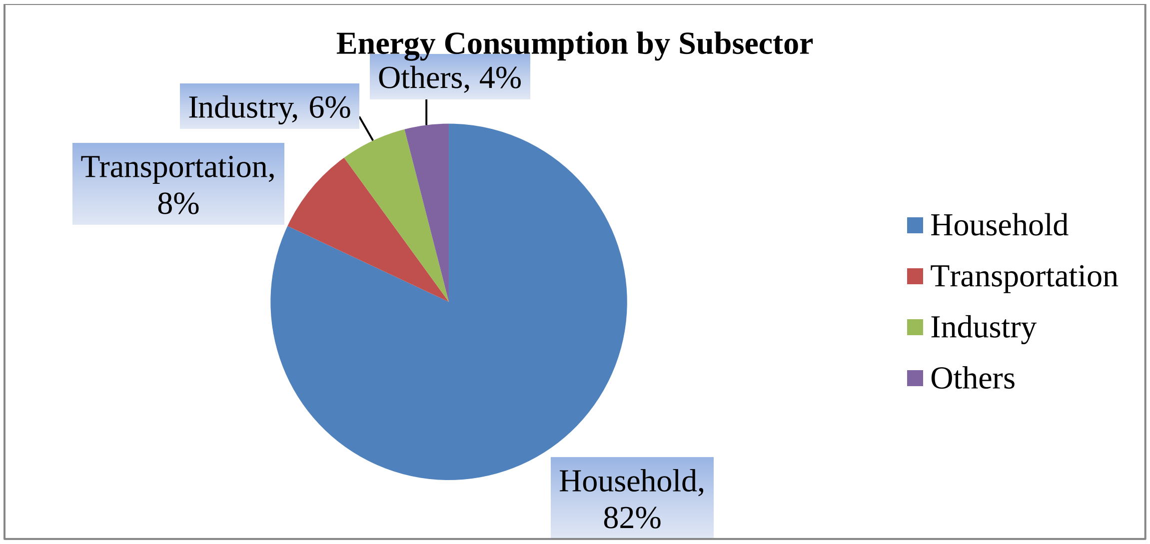


Figure 6: Energy Consumption by subsector

Source :(MINIFRA, 2018)

MINIFRA (2018) show that, besides biomass, consumption of other sources of energy is still low but increases with income levels, households move from traditional energy to new fuels and technologies partially rather than full substitutes (Arnold et al., 2006) and as the term leapfrogging the energy ladder implies, there is a rapid transition from the traditional source of energy to modern source like electricity (Murphy, 2001).

Changing energy sources for households in rural areas depends on various factors, the most factor is the ability to make choices (Pachauri et al., 2004)and Most of such households use electricity only for illumination, the adoption of energy-efficient lights has brought electrical usage to a minimum (Baringanire et al., 2014).one of the main reasons for households in sub-Saharan countries to get access to electricity is the opportunity to use communication equipment such as television and internet. (Chaury & Chandra Kandpal, 2010; Olken,2009; Kemmler 2007) and Rwanda in particular.

In the Electricity Access and Roll-out Programme where most beneficiaries are rural households almost all of them, according to IOB evaluation survey results are considered poor. The distinction on household's payment ability has an effect on not only whether it is able or not it can connect the electricity, but also on how much energy it consumes (IOB, 2014)

This is reinforced by the Rwanda Poverty Profile Report 2016/17 (EICV5) which shows the effect of the poverty level and energy consumption, the report shows that there is a huge gap between poor households where 10% have electricity and rich people where 76% have electricity(NISR, 2018). Table 1 shows Energy sources and remoteness in Rwanda

Table1 Energy Sources and Remoteness in Rwanda

	Electricity from grid or solar panels		Charcoal or better		Road < 20 minutes away	
	EICV4	EICV5	EICV4	EICV5	EICV4	EICV5
	Percentage of individuals					
Rwanda	**21.7**	**35.5**	**13.9**	**16.0**	**87.7**	**93.1**
Provinces						
Kigali City	73.6	79.6	70.3	73.5	97.9	98.7
Southern	11.5	24.8	5.1	5.4	88.9	93.4
Western	19.1	34.6	10.8	11.3	79.0	86.7
Northern	12.7	24.8	4.8	6.6	84.6	88.5
Eastern	16.7	29.7	6.2	5.8	91.9	98.7
Area						
Urban	72.3	75.5	65.8	68.0	98.0	97.7
Rural	11.7	26.8	3.6	4.8	85.6	92.2
Quintile						
Q1: poor	4.0	10.2	1.7	1.3	83.4	91.0
Q2	8.6	19.2	4.1	4.1	84.7	90.6
Q3: middle	12.8	28.8	6.5	7.5	87.3	92.6
Q4	24.0	43.7	14.4	14.4	88.4	94.5
Q5: rich	59.4	75.6	43.1	52.9	94.8	97.1

Sources: NISR: EICV4 and EICV5. Note: Computed using population weights

The table above showing that Kigali city has a great extent on the access at 79.6% while the southern and northern province has the lowest access to electricity at 34.8%. the huge difference also appears in the gap of access to electricity between urban and rural areas where in urban areas access to electricity are at 75.5% and rural areas at 26.8% this indicates that urbanization play a big role in the usage of electricity in Rwanda.

The usage of charcoal is dominant in Kigali city at 87.7 %, urban areas as a whole at 68% and the rich person at 52.9 % on other hand the lowest usage of charcoal are in the southern province at 5.4% and the poor person at 1,3% this indicates that GDP per capita is crucial on the usage of energy in Rwanda

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter presents econometrics and analytical methods for analyzing the determinants of energy consumption in Rwanda. The analytical methods follow three nested stages: first stage, data, and source, second stage econometric techniques/empirical strategies and third stage, empirical results, and discussion

3.2. Data and Source

The econometric model used in this study was derived from time-series data analysis. The models' specifics are given in the following sections, and a brief description follows.

Firstly, to understand the characteristics of the data, descriptive statistics, correlation analysis of the variables examined, and the scatter plot of variables is done to making a well-informed conclusions about data before-processing and estimation method choice as is illustrated in Table 2, Table 3 and figure 5. To find out the most determinants of energy demand in Rwanda, time-series data from 1990 to 2019 are used. The data set of this particular study is based on secondary data which are sourced from the World Bank (2021) World Development Indicators online database.

The selection of both control and dependent variables respectively were informed by theoretical and empirical narratives about energy consumption, while considering the data availability from Rwanda as a major constraint. The data involved in this study include population growth, Industrialization (measured by Industry output value added at constant USD2010), urban population (based on the portion of the population who lives in cities), energy consumption (measured by total final Energy consumption which interpolated to include missing values), and Foreign Direct Investment inflow.

Table2: Sources and Description of Data

Variable	Measurement	Variable Definition	Data source
Total final Energy consumption(TFEC)	Terajoule (1Giggawatt hours = 3.6 Terajoule)	All energy delivered to the final user for all energy uses excluding non-energy use. expressed in Terajoule	WDI(2021)
Industrialization(INDUS)	Industry (including construction), value added (constant 2010 US$)	Mining, manufacturing, construction, energy, water, and gas all create value. Value added is a sector's net output after adding all outputs and subtracting secondary inputs.	WDI(2021)
Urbanization(Ubpop)	the fraction of the population living in urban areas	The inhabitants who live in urban areas, which have a higher population density and are generally more compact than rural areas. Simply, It's the people who live in cities.	WDI(2021)
Population growth(POP)	Population growth rate in percentage	The population growth rate is the percentage change in a country's population during a	

		specific timeframe, usually a year, expressed as a portion of the population at the start of that time period. It depicts the birthrate and deathrate, as well as the number of people migrating to or from a nation, during a period of time.	WDI(2021)
Foreign Direct Investment(FDI)	Foreign direct investment, net inflows (BoP, current US$)	FDI net inflows represents the value of non-resident investors' incoming direct investment in the reporting economy.The data are in current US dollars.	WDI(2021)
Gross Domestic Product per capita(GDP pc)	GDP per capita (constant 2010 US$)	Gross domestic product divided by midterm populations equals GDP per capita.	WDI(2021)

Source: World Bank Development Indicators

Table 3: Descriptive statistics

	Mean	Standard Devation	Minimum	Maximum
total final energy consumption	11.0	0.31	10.3	11.4
GDP per capita	6.19	0.36	5.39	6.80
Industrialization	20.3	0.73	18.7	21.5

Foreign Direct investment	16.8	2.69	6.91	19.8
population growth	1.84	3.41	-6.77	8.12
Urbanization	14.0	0.56	12.9	14.6
Observations	30			

Source: Author's estimation based on (September 2021) time-series data from World Bank.

Notes: All the other variables are converted into logarithm except population growth

This table presents the summary statistics of studied variables. Industrialization presents the highest average among all the variables while population growth presents the lowest mean. All variables present the highest observations of thirty.

Table 4 Pairwise Correlations

Variables	Total final energy consumption	Gdp per capita	industrialization	FDI	Population growth	Urbanization
Total final energy consumption	1.000	-	-	-	-	-
Gdp per capita	0.716***	1.000	-	-	-	-
industrialization	0.695***	0.983***	1.000	-	-	-
FDI	0.719***	0.906***	0.898***	1.000	-	-
Population growth	0.730***	0.197	0.241	0.353*	1.000	-
Urbanization	0.845***	0.760***	0.797***	0.700***	0.565***	1.000

**** p<0.01, ** p<0.05, * p<0.1*

Source: Stata 15

Notes: The correlation matrix of the dependent and key control variables are shown in this table 4. Variables for: Total final energy consumption, GDP per capita, industry value added (as a proxy of industrialization), foreign direct investment, population growth, and urban population (as proxy of urbanization) all are in logarithm form except population growth.

Table 4 shows the extent of correlation and significant level of correlation for each factor in the correlation analysis. It proves that all control variables are correlated with the explanatory variable and that the correlation is statistically significant (total final energy consumption).Based on data from the World Bank's time series

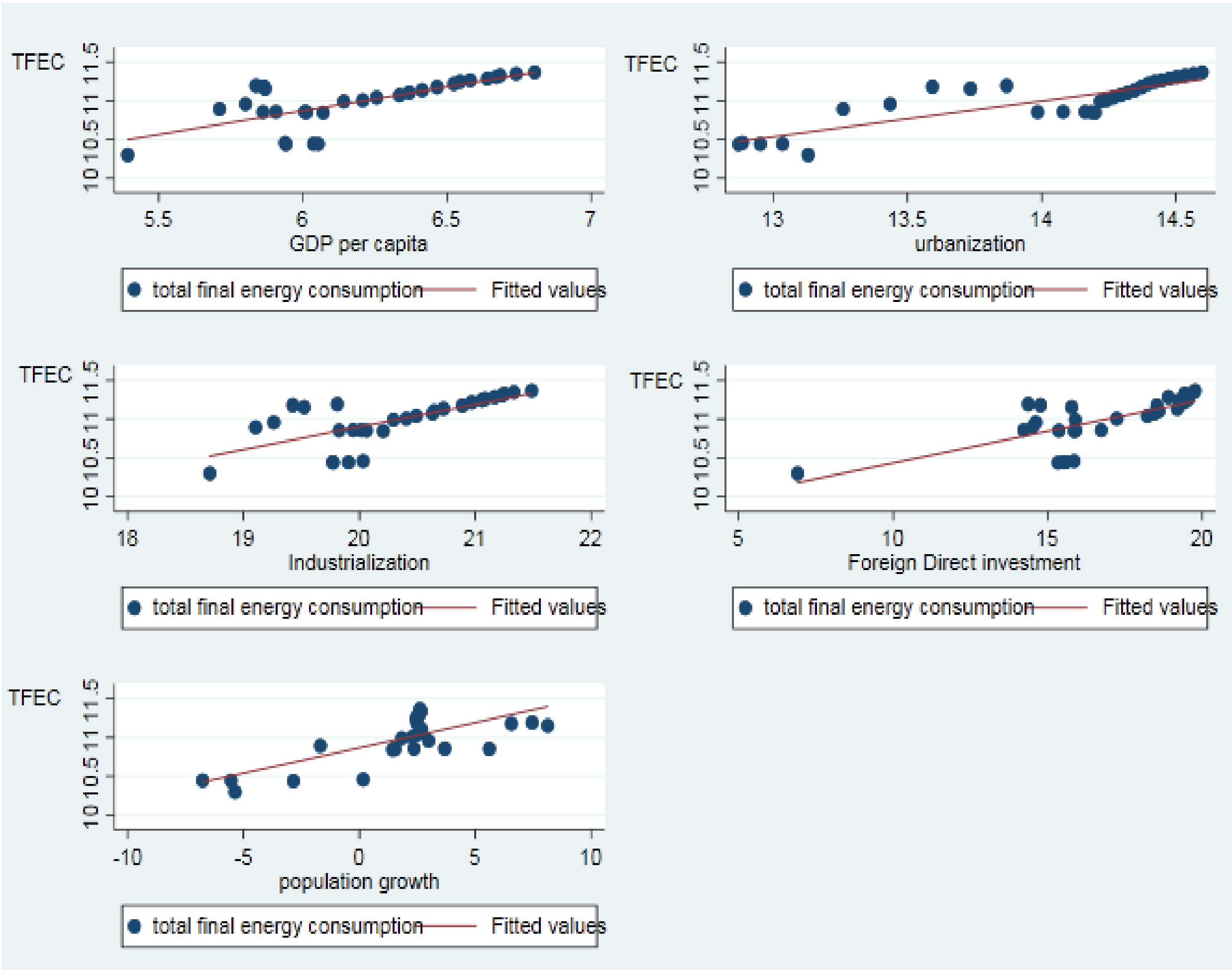


Figure7. Two way scatter displaying the macro determinant variables to total final energy consumption from 1990-2019

Source: Author's estimation based on (September,2021) time-series data from World Bank

This figure shows the two-way scatter plot of studied variables. The figure indicates that all independent variables(GDP per capita, urbanization, industrialization, population growth and foreign direct investment) present positive correlation with total final energy consumption.

3.3. Econometric Techniques

3.3.1. Model Specification

To assess the determinant of energy demand in Rwanda, the study employs time series data. The empirical model (1) suggests that total final energy consumption is determined by foreign direct investment (FDI), industrialization, population growth, GDP per capita and .urbanization. This empirical model's major goal is to identify the nature and relevance of the macro determinant factors as well as the parameter of the related interaction. This study follows the following stages of analysis:

Firstly, the study employs the ordinary least square(OLS) as the baseline model, however, empirically, OLS is criticized for being subjected to the endogeneity bias. For instance, economic growth might explain energy consumption and vice versa. The study considers the existing empirical risk of endogeneity bias and will be addressed by the causal estimation techniques.

Secondly; the study employs causal estimation techniques to study the short and long-run causality among the total final energy usage (being dependent variable) and the control variables. The unit root tests are used to determine whether the data series is stationary. Before attempting to identify whether the variables are cointegrated. Then after cointegration technique is used to determine the long-term connection between the dependent and control variables. Thirdly, In a multivariate regression connection, the granger causality test is employed to assess the direction of causality. The outcomes could be unidirectional, bidirectional, or there could be no causality at all. Lastly, the ECM is employed to study the short and long-run link between total final energy demand and the control variables, the direction of causality, and other associated tests that follow.

However, the above model can be written as:

$$TFEC_t = \int (GDPpc_t\,, Pop_t, Urb_t,, Ind_t, FDI_t) \dots \dots \dots \dots \dots (1)$$

The model is stated as Eq.2 after assuming a relationship among the variables.

$$TFEC_t = \alpha + \beta_1 GDPpc_t + \beta_2 Pop_t + \beta_3 Urb_t + \beta_4 Ind_t + \beta_5 FDI_t + \epsilon_t \dots \dots \dots \quad (2)$$

To capture elasticity, the variables transformed into logarithmic form, turning Eq(2) into the log-linear specification, empirical model as follow

$$lnTFEC_t = \alpha + \beta_1 lnGDPpc_t + \beta_2 Pop_t + \beta_3 lnUrb_t + \beta_4 lnInd_t + \beta_5 lnFDI_t + \epsilon_t \quad (3)$$

Where $TFEC$ is the total final energy consumption expressed in terajoule, α is an intercept, β1, β2, β3, β4, β5and β6 respectively denote the elasticity coefficients of GDP per capita(GDPpc), population growth rate(POP), urban population(Urb), industry value added (Ind) and foreign direct investment inflow(FDI) which are parameters/coefficients of interest. t denotes period and The final element $\mathcal{E}_t$ is an error term. GDP per capita. Model 3 will be employed as the baseline OLS model. Further causal estimation techniques such as Granger causality and VECM will be employed to the direction of causation between energy demand and GDP per capita, population growth, urban population, industry value added at constant 2010$, foreign direct investment net inflow

4.3.1.1. Unit Root Test

If the mean, variance, and autocovariance of time series data stay constant across time, they are said to be stationary.

Most of the macroeconomic factors are not stationary and when the regression of two or more variables is non-stationary, spurious regression occurs. As a result, the properties of the time-series data used for a model estimate will be determined to prevent the problem of spurious regression. As a result, the unit root test is done to identify the stationary (Gujarati, 2004).

The integration analysis is the initial phase in the testing procedure. The goal is to see if the time series variables in the model are stationary. (Engle RF and Granger C, 1987) showed that a linear combination of non-stationary series can be stationary, and the series is deemed cointegrated if this stationarity exists.

This implies the integration of the series in the same order. To evaluate whether the series is stationary or non-stationary, the augmented Dickey-Fuller (ADF) test (Dickey, 1979) was used. Whether the selected research variables' time-series data are stationary at level, first difference, or both.

$$\Delta X_t = \alpha_1 + \alpha_2 + \delta X_{t-1} + \beta_1 \sum_{i=1}^{n} \lambda i \Delta X_{t-i} + \varepsilon_t \quad t = 1, \ldots\ldots, n \quad (4)$$

Where X_t denotes any variable in the model are $GDPpc_t, Pop_t, Urb_t, GCF_t, Ind_t, FDI_t$, t is the trend .Δ is the different operator. α_1,α_2,β_1,…,β_n is a set of parameters. The null hypothesis implies that there is unit root or X_t is non-stationary ($\delta = 0$) against the alternative hypothesis $\delta < 0$).

4.3.1.2. Cointegration

This study uses the autoregressive distributed lag model (ARDL) technique to co-integration proposed by(Pesaran,1997; Pesaran and shin,1998; Pesaran et.al,2001). to identify the long-run correlation between energy use and its variables. It was also used to examine the links between time series data variables i.e, TFEC, GDPpc, Ind, Pop, Urb, and FDI in the long run.

The traditional ARDL cannot evaluate a series integration of order a certain order or difference stationery as a basic postulate. As a result, cointegration, an alternate estimating approach, was developed. (see Engle and Granger (1987), Johansen (1991), Phillips and Hansen (1990). The Error Correction Model (ECM) measures the rate at which a deviation returns to equilibrium, and cointegration is associated with the examination of long-run relations among variables integrated of the same order

Another problem in evaluating and starting long-run correlations is that the cointegration test is ineffective when variables are integrated into different orders. Recent existing literature on re-parameterizing the ARDL model to the Error Correction Model have emerged as a solution for identifying long-term link among series with differing integration orders. The significant impact on the results results in yields the relationship's short-run dynamics (similar to the ARDL) and long-run relationship.

There are five main reasons why limits testing is preferred over standard multivariate cointegration techniques (Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990). First, Once the model lag order has been determined, The ARDL model can be estimated using Ordinary Least Squares (OLS). Second, Both the long-run and short-run parameters of the model can be computed simultaneously. (Pesaran and shin ,1998;pesaran et al.2001). Third, it may be used irrespective of the order in which the underlying variables are integrated (Pesaran and shin,1998). However, to avoid spurious regression or an ARDL procedure crush, make sure that none of the variables is I (2). Fourth, The test's efficiency is improved much more when small (limited) sample sizes are used. (Haug,2002). Furthermore, according to Banerjee et al. (1998), Autoregressive distributed lag does not transform short-run coefficients into residuals.

The ARDL model is expressed as follows Eq,(5)

$$\Delta LnTFEC_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 \Delta LnEC_{t-1} + \sum_{i=1}^{k} \alpha_2 \Delta LnGDPpc_{t-1} + \sum_{i=1}^{k} \alpha_3 \Delta LnPOP_{t-1} + \sum_{i=1}^{k} \alpha_4 \Delta LnUrb_{t-1} + \sum_{i=1}^{k} \alpha_5 \Delta LnFDI_{t-1} + \sum_{i=1}^{k} \alpha_6 \Delta LnInd_{t-1} + \alpha_7 LTFEC_{t-1} + \alpha_9 LnGDPpc_{t-1} + \alpha_{10} LnPOP_{t-1} + \alpha_{11} LnUrb_{t-1} + \alpha_{12} LFDI_{t-1} + \alpha_{13} LInd_{t-1} + \epsilon_t \quad (5)$$

Where ε is the white noise error term and Δ entitles the difference operator. The error correction dynamics are represented by the summation sign. and $\alpha_0$symbolizes constant.

The long-run link is represented by the second part of Eq. (5). The AIC, SC, and HQC were used to determine the appropriate lag of each series and model. Khan et al. 2020c; Koondhar et al. 2020; Liu and Bae 2018; Ohlan 2013; Rehman et al. 2019c) are only a few examples of large researchers that have used this technique with a variety of objectives and factors. Evaluation of the overall relevance of evaluations of the lagged level of the research time-series data using Wald (F statistics). (Pesaran et.al.2001). Furthermore, the long-run coefficient is determined if there is a long-run link between study variables. Equation (6) for the long-run estimation model is as follows:

$$\Delta LnEC_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 \Delta LnEC_{t-1} + \sum_{i=1}^{k} \alpha_2 \Delta LnGDPpc_{t-1} + \sum_{i=1}^{k} \alpha_3 \Delta LnPOP_{t-1} + \sum_{i=1}^{k} \alpha_4 \Delta LnUrb_{t-1} + \sum_{i=1}^{k} \alpha_5 \Delta LnFDI_{t-1} + \sum_{i=1}^{k} \alpha_6 \Delta LnInd_{t-1} + \epsilon_t (6)$$

In addition, if the indication of a long-term link between the research variables is discovered, the short-run model will be predicted .Eq. 7 is the short-run model that is expected to be used.

$$\Delta LnEC_t = S_0 + \sum_{i=1}^{k} S_1 \Delta LnEC_{t-1} + \sum_{i=1}^{k} S_2 \Delta LnGDPpc_{t-1} + \sum_{i=1}^{k} S_3 \Delta LnPOP_{t-1} + \sum_{i=1}^{k} S_4 \Delta LnUrb_{t-1} + \sum_{i=1}^{k} S_5 \Delta LnFDI_{t-1} + \sum_{i=1}^{k} S_6 \Delta LnInd_{t-1} + \eta ECT_{t-1} + \epsilon_t \quad (7)$$

Where the coefficient of the ECT is represented by η in the estimated model.

4.3.1.3. Granger Causality Test

This testing procedure is used to determine the direction of a causal link among two variables using causality analysis. According to the granger(1969) test, if the past values of a valued X make a significant contribution to forecasting the value of another valuable Y, then that X is a granger cause Y, and vice versa.

If the data are not I(1), or even if they are all I(1) but not cointegrated, then there is no long-run link between them, according to the Granger causality theories. However, in this scenario, a short-run causal relationship may exist. If they're cointegrated, it means there's a long-term relationship among them, implying causality in at least one way. The direction of causation can be evaluated in this scenario using a Vector error correction model (VECM).

$$Y_t = Y_0 + \sum_{Z=1}^{p} y_Z Y_{t-z} + \sum_{i=1}^{q} y_z Y_{t-z} + \sum_{i=1}^{q} \lambda_1 X_{t-1} + u_t \quad (8)$$

$$X_t = \varphi_0 + \sum_{z=1}^{p} \delta_z X_{t-z} + \sum_{i=1}^{q} \Psi_i Y_{t-1} + \varepsilon_t \quad (9)$$

Where Y_t and X_t are the variables in our model are $GDPpc_t, Pop_t, Urb_t, GCF_t, Ind_t, FDI_t$, to be tested..$u_t$ and ε_t are respective error term and t denotes period z and i's are a number of lags. The null hypothesis $\lambda_i = \Psi_i = 0$ for all i's versus the alternative hypothesis that $\lambda_i \neq 0 and\ \Psi_i \neq 0$ for at least some i's if the coefficient λ_i are statistically significant but Ψ_i are not then X causes Y and vice versa, but If both coefficients are significant, causation is present in both directions.

CHAPTER FOUR
EMPIRICAL RESULTS AND DISCUSSION

This section shows the results of the econometric analysis and a discussion of the study's main findings from the estimation models discussed here above.

4.4.0. OLS results

The findings and interpretation of the OLS estimation approach which estimates macroeconomic variables on energy consumption are presented in this section. using OLS we estimate the effect of GDP per capita, industrialization, FDI, urbanization, population growth, and energy consumption. Table 5 represents the effect of macroeconomic variables on energy consumption.

Table5 OLS result

VARIABLES	Total final energy consumption
GDP per capita	1.689***
	(0.196)
Industrialization	-0.655***
	(0.173)
FDI	-0.0132
	(0.0180)
Population growth	0.0500***
	(0.00985)
Urbanization	0.191***
	(0.0633)
Constant	11.29***
	(1.495)
Observations	30
R-squared	0.953

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The OLS results from table 5 show that the GDP per capita statistically and significantly influence total energy consumption. Implies that a 1% rise in GDP per capita rises total energy demand by 168.9% percentage growth. The findings were reinforced by a previous study by (Ergun et al, 2019) in the context of Rwanda. That confirms GDP per capita has a favourable effect on renewable energy use in Rwanda.

Population growth statistically and significantly influences total energy consumption. Implies that 1 unit increase in population growth increases total final energy consumption by 0.05 percentage growth. These results are reinforced by previous empirical findings by (Ekpo et al.2011; Khalid,2010; Zaman et al,2012; Chor Foon Tang,2008) who argue that population growth significantly impacts energy use. This confirms up the traditional view of the energy-population nexus, according to which energy consumption is determined by population levels, This implies that the larger the population, the more overall energy is required and that energy consumption is determined exogenously by the population. With increasing population growth, in line with a shift from the traditional source of energy to the modern source of energy is influencing the overall energy consumption.

Urbanization statistically and significantly explains total energy consumption. Evidently, the 1% rises on urban population growth, energy consumption increases by 19% per annum. These results are reinforced by previous empirical findings of Jones (1991), Parikh and Shukla (1995), and York (2007). These studies found any indication that urbanization has a statistically significant favourable impact on energy use, these results are contrary to the study of (sadorsky, 2014), which finds that urbanization decreases energy consumption in emerging economies. Rapid urbanization enhances the demand for energy-efficient products. As infrastructure is created, green construction initiatives such as Leeds lights can minimize energy use. If implemented effectively. However, according to Poumanyvong and Kaneko (2010), varies across socioeconomic levels and is sensitive to the estimating technique used. The contradiction of the findings from most previous studies could be due to the dynamic model, the data collection, context or a mix of both.

Industrializationhas statistically and significantly negative effects on total energy use. Evidently, that 1% rises on the level of industrialization, adversely affect total final energy consumption by 65% per annum. This seems to imply that the industrial sector is at an early stage and consumes an insignificant amount of energy compared to other sectors. This is reinforced by NISR Annual Economic Report, January 2019) which shows that the industrial sector expanded by 8% for the fiscal year 2017/18 compared to 6% in the previous financial year, and the industry sector consume only 6% of energy in Rwanda (MINIFRA,2018).

F DI has a negative effect on total final energy demand but is statistically insignificant. However, the results of the OLS estimation technique are criticized in the empirical analysis for being biased and inconsistent estimates. We address this problem by examining the causal estimation techniques to identify the causal relationship between the energy use (Total final energy consumption) and the control variables. We examine both short and long-run relationships, as well as the direction of causality between the variables using causal estimation techniques (cointegration, granger causality, Error correction model).

4.4.1. Unit root test

The unit root test is used to determine the order of integration in this section. The empirical results of Augmented Dickey-Fuller (ADF) unit root tests were employed to estimate the stationary of the variables of interest. Dickey and Fuller (1979) recognized this test. Table 6 shows the findings of the unit root of linked variables with maximum lags specified.

Table 6 the Summary Results of Unit Root Tests

Variables	Order of integration	P-value	Test-stat	5% Critical value
Total final energy consumption	I(1)	0.0000	-5.776	-3.588
GDP per capita	I(1)	0.0000	-5.430	-3.592
Industrialization	I(1)	0.0050	-4.166	-3.592
Foreign direct investment	I(0)	0.0149	-3.834	-3.592
Population growth	I(0)	0.0000	-9.653	-3.588
Urbanization	I(0)	0.0006	-4.743	-3.596

Source: Stata 15

The results in Table 6 show that FDI, industrialization, population growth, and urbanization are all integrated at the order zero, *I*(0) and their corresponding P values are under critic values at level (at 5% significance level). On either hand, Total final energy consumption, industrialization, and GDP per capita are integrated of the order one, *I*(1). Hence, the data are non-stationary time-series integrated at the order of one I(0) and I(1).

4.4.2. Lag Selection

Table7 The Number of Lags Selected

No of Lags	**LL**	**LR**	**Df**	**P**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	-13.7149		36	0.000	$1.8e^{-07}$	1.51653	1.60014	1.80686
1	198.277	423.98	36	0.000	$2.6e^{-13}$	-12.0213	-11.4361	-9.98903
2	334.172	271.79	36	0.000	$2.0e^{-16}$	-19.7056	-18.6187	-15.9313
3	530.56	392.77*	36	0.000	5.4e-21	-32.0431*	-30.4546*	-26.5268*
4	.	.	36	.	-3.3e-98*	.	.	.

To address the sample's limitation, this study uses the AIC, HQIC, and SBIC criteria to determine the best appropriate lag for the model and the results in table 7 shows that the optimal lag selected is three based on all AIC, HQIC, and SBIC Tests. This indicates that macroeconomics variables and total final energy consumption explained in three lags

4.4.3. Granger Causality Test

Table8: Granger causality Wald tests

	dependent variable					
Independent Variables	Total final energy consumption	Gdp per capita	industrialization	FDI	Population growth	Urbanization
Total final energy consumption	-	0.228	0.074	0.123	0.000	0.000
Gdp per capita	0.029	-	0.023	0.112	0.049	0.012
industrialization	0.108	0.893	-	0.123	0.487	0.000
FDI	0.406	0.967	0.961	-	0.287	0.011
Population growth	0.000	0.055	0.000	0.613	-	0.000
Urbanization	0.000	0.173	0.02	0.169	0.036	-

Source: Stata15

The granger causality test provides estimates for determining if the research variables have a directional causal link. Table 8 shows the findings of the Granger causality test, which show that GDP per capita and energy usage have a unidirectional causal connection. From per capita GDP to energy consumption, implying that GDP per capital granger causes energy consumption in Rwanda

The Wald F-statistics estimate of Granger causality shows that there is a bidirectional correlation from urbanization to energy use. i.e. urbanization granger cause energy consumption and vice versa.

The Wald F-statistics were used to estimate Granger-causality evidence. The results indicate that there is bidirectional causality runs from population growth to energy demand i.e. population growth granger cause energy consumption, not vice versa. This confirms the findings of OLS that Population growth statistically and significantly influences total energy use.

However, the Granger causality evidence estimated with the Wald F-statistics shows that there is no causality between industrialization, FDI and total final energy consumption.

4.4.4. ARDL bound test *Cointegration Results*

The ARDL bound test of cointegration is used to analyze the long-run link among the variables in Equations (6) and (7) after validating the unit root properties of the variables.

The ARDL bounds testing method is used to test series integrated at different order. It must be assured that neither of the variables in the series is I(2), However the F statistics computation method is incorrect if this is the case (see Balaguer and Cantavella, 2018; Churchill et al, 2019; Shahbaz et al., 2017).

This study uses AIC criteria to locate the optimal fitting lag for the ARDL model to solve the sample's limitation and the optimal lag selected is two based on AIC tests. Enders (2004) claims that for yearly data analysis, the system's dynamics can be captured with an optimum lag order of three years. Therefore, the ARDL-bound testing approach is used to describe the cointegration relationship between total final energy consumption and other variables (GDP per capita, industrialization, urbanization, urbanization, and population growth). The values of critical bounds for both small and big samples are recognized by (Pesaran et al,2001).

Table 9 Results of ARDL the bounds test of cointegration

Model	F statistics	Conclusion		
TFEC=∫(GDPPC,INDUS, ,FDI,GR_POP,UBTP)	30.206	Cointegrated		
Optimum lag	[2,3,3,3,3,1]			
Critical Values	1%	2.5%	5%	10%
Lower Bounds *I*(0)	2.26	2.62	2.96	3.41
Upper Bounds *I*(1)	3.35	3.79	4	4.688

Source: Stata 15

According to the Pesaran critical value table, the null hypothesis of no cointegration between research variables is rejected if the estimated result of the F test is greater than the upper critical limit (UCB) value while analyzing the long-run relationship between study variables. If the computed value of the F test lies between the lower and higher critical boundaries, the result is biased. If the computed result of the F test is smaller than the lower critical limit, the null hypothesis of no cointegration among variables is accepted.

Table 10 shows the results of the bounds test based on energy usage and its determinants. As a result, the computed F-statistic of 30.206 in the ARDL bound test is more than the upper critical bound value of 3.35 at the 1% significance level on Narayan (2005). This shows that in Rwanda, final energy consumption, GDP per capita, industrialization, urbanization, and population increase are all cointegrated. The findings are in line with those of earlier empirical studies (Mavikela& Khobai, 2018; Soytas &Sari, 2003; Sadorsky, 2014).

4.4.5. Short Run and Long Run Results

The outcomes of the ARDL short-run and long-run relationship among Total final energy consumption and its determinants study variables are presented in Table 10 and Table 11

Table10: The estimated short run relationship using the ADRL approach

Dependent variable: Log Total final Energy consumption
short-run relationship

Control Variables	Coef.	Std. Err.	t	P>|t|
GDP per capita	-.7445092	.2523337	-2.95	0.026
Industrialization	-.1137391	.1340956	-0.85	0.429
FDI	-.0091835	.0102278	-0.90	0.404
Population growth	-.1834435	.031883	-5.75	0.001
Urbanization	.5456146	.5630858	0.97	0.037
Constant	11.95666	1.651896	7.24	0000

Source: Stata 15

According to table 10, Urbanization statistically and significantly influences total energy consumption. Evidently, implies that a 1% increase in urban population energy consumption increased by 54% in the short run. These results are reinforced by previous empirical findings of Jones (1991), Parikh and Shukla (1995), and York (2007). These studies found no evidence that urbanization has a statistically significant favourable impact on energy use, these results are contrary to the study of (sadorsky, 2014), which finds that urbanization decreases energy consumption in emerging economies. Rapid urbanization enhances the demand for energy-intensive appliances. As infrastructure is created, green construction initiatives such as energy-saving lights can minimize energy use. If implemented effectively. However, according to Poumanyvong and Kaneko (2010), varies across socioeconomic levels and is sensitive to the estimating technique used. The contradiction of the findings from most previous studies could be due to the dynamic model, the data collection, context, or a mix of both.

The results designate that GDP per capita, population growth, industrialization, and FDI does not have an evidence short-run impact on total final energy consumption

Table11: The estimated long-run relationship using the ADRL approach

Dependent variable: Log total final Energy consumption

Long-run relationship

Independent Variables	Coef.	Std. Err.	T	P>|t|
GDP per capita	.0915084	.1600431	0.57	0.588
Industrialization	.3530433	.1000241	3.53	0.012
FDI	.0106808	.0050031	2.13	0.077
Population growth	.0755797	.0136968	5.52	0.001
Urbanization	.2824576	.0942464	-3.00	0.024

The results according to table 11, indicates that in the long run, population growth statistically and significantly influences positively total energy consumption in Rwanda. Evidently, implies that a 1 unit increase in population growth increases totals final energy consumption by 0.75 percentage growth in the long-run. These results are reinforced by previous empirical findings by (Ekpo et al.2011; Khalid Zaman et al,2012; Chor Foon Tang,2008) and the result of OLS

Industrialization statistically and significantly positive long-run impact on total final energy consumption in long run. Evidently, implies that, a 1% increase in the level of industrialization, increases total final energy consumption by 35 % . This result is reinforced by the study of Filippini & Pachauri, 2004; Samouilidis & Mitropoulos,1984; Poumany vong &Kaneko,2010) that revealed a statistically significant link between industrialization and energy demand

FDI statistically and significantly positive long-run effect on total final energy consumption in long run. Evidently, implies that 1% increase on FDI, increases total final energy consumption by 1 %. This result is reinforced by the study of Sadorsky ,2010; Goldemberg ,2002) that revealed a statistically significant and positive link between FDI and energy usage.

GDP per capita statistically and insignificantly has a positive impact in long run on total final energy consumption. Evidently, a 1% increase of income increase total final energy consumption by 91% .these results is consistent with the result of OLS

Several diagnostic tests such as Durbin waston test, Breusch–Godfrey serial correlation LM test and normality test has been definite the robustness of the model. according to all tests. As a result, the reported outcomes are serially uncorrelated, normally distributed, and homoscedastic. As a result, the given results are reliable for interpretation.

Table12: Serial Correlation between Macroeconomic Variable and Energy Consumption

No of Lags	Chi2	Df	Prob>Chi2
1	0.919	1	0.3377

Ho: No autocorrelation at lag order

Table 12 presents the results of serial correlation between foreign direct investment (FDI), population growth, GDP per capita, industrialization, urbanization, GDP per capita, and total final energy consumption. The results of serial correlation on long-run causality show that macroeconomic factors and total final energy consumption have no autocorrelation (the null hypothesis). The null hypothesis is accepted because the p-value is not significant (0.3377). The test of residual normality distribution confirms that the residuals are normally distributed. The p-values for the dependent values and the overall model are significant, as shown in Table 14. As a result, the null hypothesis is rejected, indicating that the model's residuals are normally distributed.

Table13: Results of skewness/Kurtosis Test for Normality

Variable	Obs	Pr(skewness)	Pr(kurtosis)	Adj chi2(2)	Prob>chi2
My residual	27	0.0485	0.0200	7.99	0.0184

Table 13 here presents the results of the normality test for the distribution of residuals test. Accordingly, the results of the normality test for the distribution of residuals show that the p-value is significant. Therefore, The null hypothesis is thus rejected, indicating that the model's residuals are regularly distributed.

The Durbin-Watson statistic is A measurement for first-order serial correlation. The DW statistic, in more technical terms, evaluates the linear relationship between nearby residuals in a regression model. As noticed from table 12 there is no apparent problem with serial correlation, since our Durbin Watson coefficient is (2.3361). Breusch-Godfrey LM test for autocorrelation is 0.2977

CHAPTER 5

SUMMARY, CONCLUSION, AND POLICY IMPLICATIONS

5. 0 Introduction

This chapter presents the major findings of this study, the contribution to the field of energy economics and economic growth, finally the recommendations of the study.

5.1. Main Findings

The study finds that Rwanda is putting more effort into the energy sector at which 34.5 % of Rwandans have access to electricity.(MINIFRA,2018) and expect that all Rwandans will have access to electricity before 2030 (Africa Energy outlook,2019). This indicates that Rwanda is in the best place in Africa as fast-growing in energy accessibility.

The study finds that energy demand in Rwanda is influenced by population growth, urbanization, FDI, Industrialization, and GDP per capita.

The OLS results reveal that 1% rise in GDP per capita rises total energy consumption by 168.9% percentage growth, 1 unit increase in population growth increases total final energy consumption by 0.05 percentage growth, 1% increase on urban population growth, increases energy consumption increase by 19% per annum while FDI and industrialization adversely affect energy usage.

ARDL bound test cointegration to confirm the existence of cointegration among variables Implying that, there is a long-run relationship among macro-economic variables and total final energy consumption. ARDL model in short-run GDP per capita and urbanization statistically and significantly has a positive effect on total final energy consumption. Furth more, GDP per capita population growth, industrialization, and FDI do not have an evidence short-run impact on total final energy consumption.

In long run the total final energy consumption statistically and significantly is positively correlated with industrialization, population growth, urbanization, and FDI, and statistically and insignificantly GDP per capita has a long run effect on total final energy consumption. the findings implies that 1 unit rises in population growth rises total final energy consumption by 0.75 percentage growth, 1% increase on the level of industrialization, increase total final energy consumption by 35 %, 1% increase in FDI, increase total final energy consumption by 1 %, and income statistically and insignificantly has a positive impact in long run on total final energy consumption. Evidently, a 1% increase in economic growth increase total final energy consumption by 91%

The causality tests show that there is unidirectional causality runs from GDP per capita to energy usage and bidirectional causality from population growth and urbanization to energy usage and there is no causality between industrialization, foreign direct investment, and total final energy consumption.

5.2. Conclusion

This study examines the macro determinants of energy consumption in Rwanda for the period from 1990-2019. It employs OLS as a baseline model to examine how selected macroeconomic determinants influence energy consumption. The ARDL model, cointegration test, and granger causality test are employed to the long-run relationship between macroeconomic determinants and total final energy consumption based on data from the World Bank's time series.

Rwanda is undergoing a dramatic economic transformation that is influenced by macroeconomic factors. This study contributes to the ongoing mixed theoretical and empirical narratives on the determinants of energy usage in developing countries. The short-run, long run, and causal relationship of macroeconomic variables, urbanization, industrialization, population growth, FDI on energy usage in Rwanda for the period 1990-2019 are investigated in this study. Specifically, this study examines: To examine empirically whether there is either short or long-run causal relationship among energy demand and its factors in Rwanda; To Examine the direction of causality between energy demand and its identified factors and to Determine growth trends of energy consumption against its determinants in Rwanda over time;

The study considered the methodological issues affecting empirical analysis related to determinants of energy consumption. And employed possible and credible econometric techniques to address the problem of causality; the OLS, cointegration test, error correction model and the granger causality techniques. This study report results from ARDL model for estimating time-series data of energy consumption for Rwanda. ARDL model is useful because it captured both short-run and long-run impacts of variables on energy consumption at the same time and granger causality test employed for the direction of causality.

The methodological and empirical analysis of this study is embedded in the theoretical framework of the energy-growth effect, the neoclassical growth model, and the endogenous growth model. The study finds that the three theories are complementary and mutually exclusive in clarifying the relationship between energy use and economic growth.

They, however, provide frameworks such as endogenous growth theories, both Putty-Putty Model and Putty-Clay Model through which empirical studies examine the energy consumption impact in production and economic growth. They are, however; narrow to explain circumstances (contextual and institutional environment) under which energy influences in economic growth and development. They further remain challenged for their inability to explain the nature and the direction of causation between energy use and economic growth.

The OLS findings found that GDP per capita, urbanization and population growth has statistically and significantly positive impact on total final energy consumption. ARDL bound test cointegration to confirm the existence of cointegration among variables that imply long-run relationship and ARDL model findings implies that, in short-run GDP per capita and urbanization statistically and significantly has positive impact on total final energy consumption while population growth, industrialization, and FDI does not have an evidence short-run impact on total final energy consumption

In long run the total final energy consumption statistically and significantly is positively affected by industrialization, population growth, urbanization, and FDI, and statistically and insignificantly income has a long-run influence on total final energy consumption. The causality tests show that there is unidirectional causality runs from GDP per capita to energy consumption and bidirectional causality from population growth and urbanization to energy consumption and there is no causality between industrialization, foreign direct investment, and total final energy

The causality tests show that there is unidirectional causality runs from GDP per capita to total final energy consumption and bidirectional causality from population growth and urbanization to energy consumption and there is no causality between industrialization, FDI, and total final energy consumption.

The finding suggests that increasing urbanization; population growth and income could boost energy usage in Rwanda. The increase in urbanization and real GDP was considered as a good indicator. Furth more, If there is a lack of energy supply, economic growth and urbanization will be difficult to achieve.

5.3. Policy Implications

The main implication from the finding is as follow:

Firstly, the unidirectional from GDP per capita to energy consumption, is a key challenge to the policymakers to ensure that a sufficient amount of energy is available within a country. Towards economic growth, hence government should carry out strong mechanisms towards improving the energy supply sector and FDI policies are advised to improve energy policies to boost economic growth.

Secondly, Long impact of industrialization on energy consumption, industrial energy efficiency policy are needed to reduce industrial energy consumption this can be implemented by encouraging businesses to use energy efficiency technologies in the manufacturing process.

Third, urbanization increase energy consumption, energy efficiency must be available at a reasonable price for the urban population and businesses. Urban cities attract many populations, businesses, international corporations, and many centres; energy efficiency building policy is needful in new and residential buildings. To limit growing urbanization, the government must also offer energy facilities in rural areas.

Fourth, the Population in Rwanda is growing and expected to be more in the future and are positive associated with energy consumption, tariff and non-tariff barriers needed on the importation of inefficient electronic devices and high-quality standard must be imposed on electronic devices produced locally.

Lastly, the results provide us with confirmation that Rwanda is an energy-reliant country. Thus, the energy policymakers should plan to raise energy generation by making the current energy supply to be sustainable. To raise economic growth policymakers must ensure that the growth of energy consumption is less than the growth of energy supply in order word to support economic growth and development in Rwanda better management of energy growth policy is needed to ensure sufficient energy supply.

It is vital to keep in mind that these recommended recommendations should be implemented when keeping in mind specific political, economic, and social changes.

5.4. Suggestions for Future Research

Future research should examine and investigate the feasibility of energy that is both sustainable and renewable in Rwanda, as a requirement for ensuring the straightforward implementation of development projects and promoting the country's economic growth today and in the future.

REFERENCES

AGECC, U. (2010). Energy for a sustainable future: Summary report and recommendations. *New York, USA.*

Aghion, P., Comin, D., Howitt, P. (2006).When does Domestic Saving Matter for Growth? NBER Working Papers 12275, National Bureau of Economic Research, Inc.

Akinlo, A. E. (2009). Electricity consumption and economic growth in Nigeria: evidence from cointegration and co-feature analysis. *Journal of Policy Modeling*, *31*(5), 681-693

Azad, A.K., Rasul, M.G., Khan, M.M.K., Ahasan, T. and Ahmed, S.F. (2014) Energy Scenario: Production, Consumption and Prospect of Renewable Energy in Australia. Journal of Power and Energy Engineering,2,19-25. http://dx.doi.org/10.4236/jpee.2014.24004

Azam, M., Khan, A. Q., Zaman, K., & Ahmad, M. (2015). Factors determining energy consumption: Evidence from Indonesia, Malaysia and Thailand. *Renewable and Sustainable Energy Reviews*, *42*, 1123-1131.

Baltagi, B. H. (2008). *Econometric analysis of panel data* (Vol. 4). Chichester: John wiley & sons.

Baptist, S., & Hepburn, C. (2013). Intermediate inputs and economic productivity. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *371*(1986), 20110565.

Baringanire, P., Malik, K., & Ghosh Banerjee, S. (2014). Scaling up access to electricity: The case of Rwanda.

Bekhet, H. A., & Othman, N. S. (2014).Long-run elasticities of electricity consumption, FDI, export and GDP in Malaysia. *International Journal of Economics and Finance*, *6*(8), 78-90.

Berndt, E. R. (1980). Energy Price Increases and the Productivity Slowdown in United States Manufacturing (Department of Economics; Resources Paper No. 51). *Vancouver: University of British Columbia*.

business-sweeden.(2016). Opportunities Within the Energy Sector in Rwanda. Nairobi: The Sweden Trade and Invest Council .Business Sweden in Kenya. 1–9.

Chevalier, J. M.(2009).The new energy crisis. In *The New Energy Crisis* (pp. 6-59). Palgrave Macmillan, London.

Cifter, A., & Ozun, A. (2007). Multi-scale causality between energy consumption and GNP in emerging markets: evidence from Turkey.

Çoban, S., & Topcu, M. (2013). The nexus between financial development and energy consumption in the EU: A dynamic panel data analysis. *Energy Economics*, *39*, 81-88.

Domar, E. D. (1946). Capital expansion, rate of growth, and employment. *Econometrica, Journal of the Econometric Society*, 137-147.

Doytch, N., & Narayan, S. (2016). Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. *Energy Economics*, *54*, 291-301.

Ekpo, U. N., Chuku, C. A., & Effiong, E. L. (2011). The dynamics of electricity demand and consumption in Nigeria: application of the bounds testing approach. *Current Research Journal of Economic Theory*, *3*(2), 43-52.

Enders, W. (2004). Applied econometric time series 2nd edition. New York: John Willey & Sons. *Technometrics*, *46*(2), 264-264.

Ergun, S. J.,Owusu, P. A., & Rivas, M. F. (2019).Determinants of renewable energy consumption in Africa. *Environmental Science and Pollution Research*, *26*(15), 15390-15405

Ernst, R., & Mohammed, S. (1979). Parametric Productivity Measurement and Choice Among Flexible Functional Forms. *Journal of Political Economy*, *87*, 1220-1245.

Fan, W., & Hao, Y. (2020). An empirical research on the relationship amongst renewable energy consumption, economic growth and foreign direct investment in China. *Renewable energy*, *146*, 598-609.

Filippini, M., & Pachauri, S. (2004). Elasticities of electricity demand in urban Indian households. *Energy policy*, *32*(3), 429-436.

GIZ.(2020). Partnership ready Rwanda:transport. Eschborn, partnership ready Rwanda.

Hannon, B., Blazeck, T., Kennedy, D.,& Illyes, R. (1983). A comparison of energy intensities: 1963, 1967 and 1972. *Resources and Energy*, *5*(1), 83-102.

Hulten, C. R. (1978). Growth accounting with intermediate inputs. *The Review of Economic Studies*, *45*(3), 511-518.

IEA (International Energy Agency) (2019).Africa Energy Outlook: World Energy Outlook Special Report, IEA, Paris. , retrieved from https://www.iea.org/reports/africa-energy-outlook-2019 on 04th may 2021

IEA. (2014). Africa Energy Outlook a focus on energy prospects in sub-saharan africa. paris: international energy Agency.

Jones, D. W. (1989). Urbanization and energy use in economic development. *The Energy Journal*, *10*(4).

Khalid, I., & Khalid, B. (2010).The Determinant of Demand for electricity. The Case of Jordan (1979-2008).Retrieved on 14/06/2012: www.Caus.org.1b/PDF/EmagazineArticles/economics.

Kraft, J. and Kraft, A.,(1978). On the Relationship between Energy and GNP. Journal of Energy and Development, 3(2), pp. 401-403

Lariviere I, Lafrance G.(1999) Modelling the electricity consumption of cities: effect of urban density. Energy Econ;21:53–66

Lucas Jr, R. E. (1988). On the mechanics of economic development. *Journal of monetary economics*, *22*(1), 3-42.

Ma, H., & Du, J. (2012). Influence of industrialization and urbanization on China's energy consumption. In *Advanced materials research* (Vol. 524, pp. 3122-3128). Trans Tech Publications Ltd.

Mavikela, N., & Khobai, H. (2018). Investigating the Link Between Foreign direct investment, Energy consumption and Economic growth in Argentina.

Mielnik, O., & Goldemberg, J. (2002). Foreign direct investment and decoupling between energy and gross domestic product in developing countries. *Energy policy*, *30*(2), 87-89.

Minecofin. (2007). Economic Development and Poverty Reduction Strategy in Rwanda-EDPRS, 2008–2012. kigali:Rwanda Ministry of Economic and Finance. Retrieved from http://www.minecofin.gov.rw.

Minenfra.(2018).Energy Sector Strategic Plan(2018/19 to 2023/24.Kigali:Rwanda

Mishra, V., Smyth, R., & Sharma, S. (2009). The energy-GDP nexus: evidence from a panel of Pacific Island countries. *Resource and Energy Economics*, *31*(3), 210-220.

OCED/IEA,(2018).Worldenergy outlook 2018. Retrived from https://www.iea.org/reports/world-energy-outlook-2018

Ouédraogo, N. S., & Chevalier, J. M. (2009). Energy Poverty and Economic Development.

Parikh, J., and V. Shukla. (1995). Urbanization, Energy Use and Greenhouse Effects in Economic Development—Results from a Crossnational Study of Developing Countries." *Global Environmental Change* 5(2): 87–103.

Poumanyvong, P., & Kaneko, S. (2010). Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. *Ecological Economics*, *70*(2), 434-444.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of political economy*, *94*(5), 1002-1037.

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy policy*, *37*(10), 4021-4028.

Sadorsky, P. (2014). *The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development. American Journal of Economics and Sociology, 73(2), 392–409.* doi:10.1111/ajes.12072

Sadorsky, P., (2011). Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy 39, 999–1006

SadorskyP(2009a)Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. Energy Econ 31:456–462

Sevestre, P., & Trognon, A. (1985).A note on autoregressive error components models. *Journal of Econometrics*, *28*(2), 231-245

Solow, R. M. (1956). A contribution to the theory of economic growth. *The quarterly journal of economics*,*70*(1), 65-94.

Sondreal, E. A., & Wiltsee, G. A. (1984). Low-rank coal: its present and future role in the United States. *Annual review of energy*, *9*(1), 473-499.

Ting, Y., Yin, L.R., Ying, Z.Y.(2011).Analysis of the FDI effect on energy consumption intensity in Jiangsu Province. Energy Procedia 5, 100–104

UN-DESA.(2018).*International Recommendations for Energy Statistics (IRES)*. Statistical Papers M93, Statistics Division, United Nations. New York: Department of Economic and Social Affairs. Retrieved March 19, 2021, from https://unstats.un.org/unsd/energy/ires/IRES-web.pdf.

Zaman, K., Khan, M. M., Ahmad, M., & Rustam, R. (2012). Determinants of electricity consumption function in Pakistan: Old wine in a new bottle. *Energy Policy*, *50*, 623-634.

Gao, W., Wang, X., Haifeng, L., Zhao, P., Ren, J., & Toshio, O. (2004). Living environment and energy consumption in cities of Yangtze Delta Area. *Energy and buildings*, *36*(12), 1241-1246.

World Bank.(2021)outsourced from world Bank Dataset, Retrieved from :https://databank.worldbank.org/source/world-development-indicators assessed on 08th june2021

Wu, X. F., & Chen, G. Q. (2017). Global primary energy use associated with production, consumption and international trade. *Energy Policy*, *111*, 85-94.

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