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

Title of the Project: THE DETERMINANTS OF ELECTRICITY ACCESS IN RWANDA.

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A thesis submitted, in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE IN ENERGY ECONOMICS.

In college of Science and technology

African Center of Excellence in Energy for Sustainable Development (ACE-ESD)

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January, 2023

Kigali-Rwanda

Abstract

Low access to electricity consumption distorts economic development, Rwanda is among the Sub-Saharan African countries with limited access to electricity, whereby 25.5% of the population is without access to electricity (REG, 2022). Accordingly, the determinants of electricity access in Rwanda were the focus of this thesis. The secondary data, spanning from 1990 to 2020, was used on the ARDL model variables, which were collected from the World Bank database. (WDI, 2020). On the one side, the empirical findings suggest that in the short run; GDP growth positively influence access to electricity. On the other side, the empirical findings reveal that in the long run; GDP positively influence access to electricity whereas population density negatively influence access to electricity. Since the Government of Rwanda has the target of achieving a 100% electrification rate by 2024, this thesis' recommendations suggest the Government of Rwanda keep on increasing the growth of GDP and keep on controlling both the increase of the population density and price of electricity. Additionally, the population (consumers) are recommended to use methods such as load shifting to avoid high tariff charges in peak hours and use electric efficiency technologies to overcome power shortages.

Key words: Electricity access, electricity price, GDP, Rwanda and ARDL model

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I declare that this thesis contains my own work except where specifically acknowledged, and it has been passed through the anti-plagiarism system and found to be compliant and this is the approved final version of the Thesis:

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Student Number: **221004974**

Program of study: **MASTER OF SCIENCE IN ENERGY ECONOMICS**

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16th of December, 2022

Acknowledgements

I would like to express my special thanks to my supervisor, Dr. Yvonne UMULISA for valuable guidance and advice that enabled me to complete this thesis.

I extend my heartfelt appreciation to my colleagues' sisters and brothers for valuable advice and assistance given during the period of study.

I am indebted to my family, who supported me morally and endured the long period of my absence in pursuit of my studies.

May God bless you all!

Table of contents

Abstract i

Declaration ii

Acknowledgements ii

List of figures vi

List of tables vii

List of appendices viii

Acronyms..ix

1. INTRODUCTION 1

1.1Background..1

1.2 Statement of the Problem 2

1.3 Objectives 3

1.3.1 Main Objectives..3

1.3.2 The Specific Objectives..3

1.3.3 Research question 3

1.4 Scope of the study..4

1.5 Expected Outcomes and Significance of the Study..4

1.5.1 Expected Outcome of the Study 4

2. LITERATURE REVIEW 5

2.1 Description of key terms..5

2.1.1 Electricity..5

2.1.2 Electricity access 5

2.2 Theoretical review 6

2.2.1 Influence of labor force participation to electricity access 6

2.2.2 Power of gross domestic product to electricity access 6

2.2.3 Effect of population density to electricity access 8

2.3 Empirical review 8

3. METHODOLOGY 12

3.1 Econometric model specification 12

3.2 Data variable description 13

3.2.1 Measurement of explained variable 13

3.2.2 Measurement of explanatory variables 14

3.2.2.1 Measurement of price of electricity 14

3.2.2.2 Measurement of labor force participation 14

3.2.2.3 Measurement of Gross domestic product 14

3.2.2.4 Measurement of population density 15

3.3 Data analysis 15

3.3.1 Stationarity test 15

3.3.2 Normality test 15

3.3.3 Correlation test 16

4. RESULTS AND DISCUSSIONS 17

4.1 Descriptive statistics 17

4.2 Normality test 17

4.3 Unit roots test 18

4.4 Correlation matrix 18

4. 5 Estimation result 19

4.6 Stability test 23

5. CONCLUSION AND RECOMMENDATION 24

5.1 Summary of findings 24

5.2 Recommendations 24

5.2.1 Recommendations to government 24

5.2.2 Recommendations to the population 24

5.3 Conclusion 24

References 26

APPENDICES 32

List of figures

Figure 1.1: Electricity access rate……………………………………………………………11

Figure 4.1: Electricity access rate……………………………………………………………26

List of tables

Table 4.1: Short run result……………………………………………………………………20

Table 4.2: Long run result……………………………………………………………………21

Table 4.3: Bound test result…………………………………………………………………..22

Table4.4: Error correction result...……………………………………...………………....23

List of appendices

Appendix 4.a: Descriptive result……………………………………………………...…………..…33

Appendix 4.b: Augmented-Dickey-Fuller unit root test………………...……………………...……33

Appendix 4.c: Kwiatkowski-phillip-schmidt-shin unit root test……………………..………………34

Appendix 4.d: Comparison of results of three-unit root test methods……………………………..…34

Appendix 4.e: Correlation matrix results……………………………………………………..……35

Appendix 4.f: Lag order selection criteria Bound ………………………………………...………35

Appendix 4.g: Model stability …………………………………………………………………35

Acronyms

AEI	: Africa Electrification Initiative
FDI	: Foreign Direct Investment
GDP	: Gross Domestic Product
IEA	: International Energy Agency
LV	: Low Voltage
MV	: Medium Voltage
OBA	: Out-Based Aid
REG	: Rwanda Energy Group
SSA	: Sub-Saharan Africa
WSSD	: World Summit on Sustainable Development

1. INTRODUCTION

1.1Background

The journey to achieve 2030 global electrification still lengthy compared with the 940 million of people in the world without access to electricity (IEA, 2021). To provide energy access, the International Energy Agency (IEA) suggested that worldwide $15 billion must be invested in energy sector by the period between 2010 and 2030. Electricity access is the most challenge in developing countries mainly in Africa specifically in sub Saharan Africa (SSA) countries to achieve sustainable development because 46 % of SSA population have only access to electricity (IEA, 2021). This situation still limits Africa not only to meet social obligation demand but also for universal development competition.

World Summit on Sustainable Development (WSSD) held in New Delhi, India in February 2022agreed that, there is a need in improving in energy services, which are affordable, reliable, and adequate electricity specifically for poor who are very much deprived on access to electricity. The sub-Saharan region of African has a lot of source of electricity, according to IEA (2019) there is a strong relationship between access to electricity and electricity prices, labor force participation, gross domestic product, and the number of people per square kilometer.

Muceka (2017) argued that if there are no major policies adopted to reduce increment in extreme poverty in some part of SSA, electricity access will still a dream to the Africans. Electricity access is determined by numbers of ender-users connected mainly numbers of households. A case of Rwanda, as of September 2022, the aggregate household's electricity access was 74.5% includes 50.9% connected to national grid and 23.6% connected to off-grid systems (REG, 2022). Off-grid is headed by solar connectivity. Relief and price are the most constraint for electricity access in land locked countries as Rwanda. So, there is a use of Mini grids and off grids such as solar photovoltaic connections to enhance the population with access to electricity.

All of that done to attain the target of 2024 electrification target where to achieve this; by the end of this year of 2022 all productive end-users must be connected and Rwanda Energy Group (REG) must increase 500,000 new connections including 200,000 on-grid and 300,000 off-grid each year (AEI, 2020).

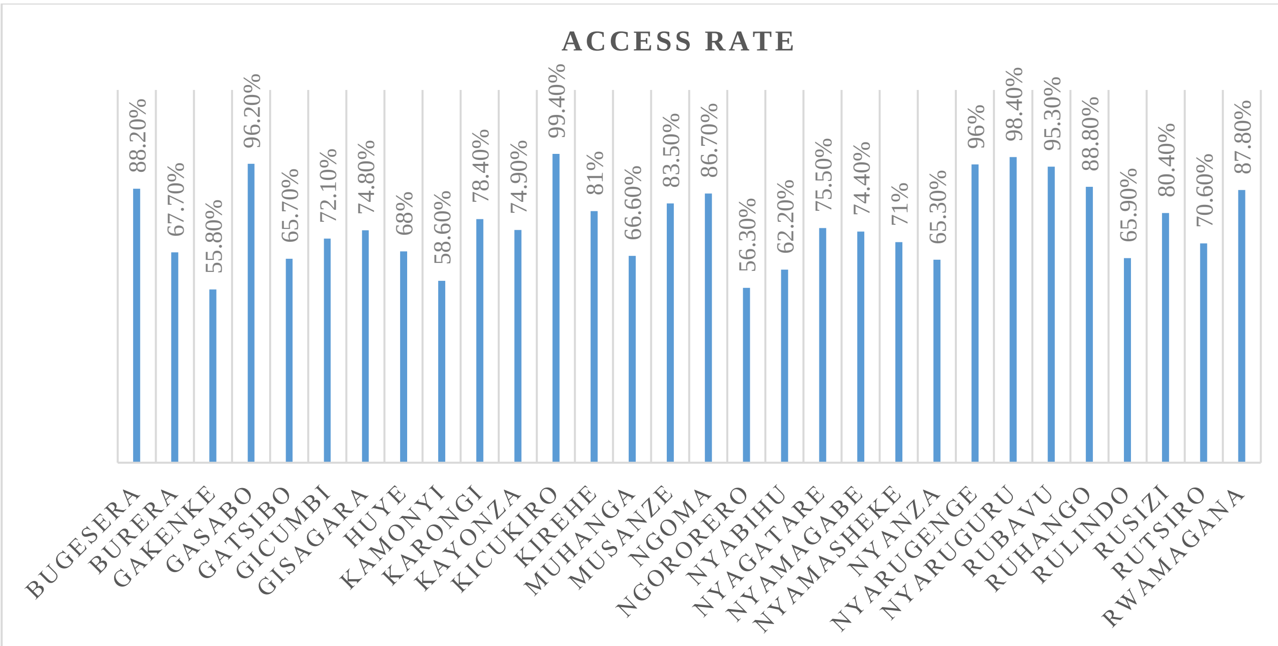

Figure 1.1: Electricity access rate

Source: REG 2022 statistics available for download at https://www.reg.rw/what-we-do/access/

According to the fourth population and housing census of 2012, about 83% of Rwandan population living below $ 2 per day among them 38% living in rural areas with the population density of 525 per square kilometer as a density. Sarkodie and Adams (2020) claimed that low rate of labor force participation negatively influences the level of electricity access. Given this background, the current thesis examines the determinants of electricity access in Rwanda with the purpose of understanding why the remaining 25.5% of population are without access to electricity (REG, 2022).

1.2 Statement of the Problem

Apergis, Polemis and Soursou (2022) pointed that there is great relationship between electricity access and poverty. Henderson *et al.*, (2018) localized Rwanda as a country located approximately the equator which affect it lighting time, this means that Rwanda has a long time of darkness than illumination which pressure electricity access. Shaqsi, Sopian and Al-Hinai (2020) explained that the effect caused by dirty energy resources rapid the transition from traditional forms of energy to modern form of energy mainly electricity.

Scarlat *et al.* (2015) mentioned that the population in urban areas has more option on energy sources than the population in rural areas, which leads rural household to used dirty energy resources, the reason why the population in rural areas still faces lack of electricity. The aggregate of Rwandan household's electricity access was at 74.5% includes 50.9% connected to national grid and 23.6% connected to off-grid systems (REG, 2022). The paper of Onyeji, Bazilian and Nussbaumer (2012) titled Contextualizing electricity access in sub-Saharan Africa, presented that electricity access in SSA influenced by the marginal change in GDP, poverty, rural population and population density. The difference in economic and geographical character of SSA countries imposed to conduct the study on the determinants of electricity access in Rwanda rather than in SSA as a whole.

1.3 Objectives

1.3.1 Main Objectives

The aim of thesis is to examine the determinants of the electricity access in Rwanda.

1.3.2 The Specific Objectives

i. Identify the influence of labor force participation to electricity access.
ii. Detect the power of gross domestic product to electricity access.
iii. Establish the effect of population density and price of electricity to electricity access.

1.3.3 Research question

This thesis intends to examine why 25.5% of Rwandan population still do not have access to electricity. This is examined through the below questions.

i. What is the influence of labor force participation to electricity access?

ii. What is the relationship between gross domestic product and electricity access?

iii. What effects do the population density and price of electricity have on electricity access?

1.4 Scope of the study

Electricity is a driver of economic development in all economic sectors. This study is undertaken due to the existing variation in the population having access to electricity. It examines the determinants of electricity access in Rwanda for the period from 1990 to 2020, using world development indicator statistics released in 2021.

1.5 Expected Outcomes and Significance of the Study

1.5.1 Expected Outcome of the Study

The thesis's findings will help policymakers how to improve the effectiveness and efficiency of the determinants of electricity access in order to achieve a suitable rate of the population having access to electricity. In addition, it will be a reference for future researchers interested in the domain of electricity access.

1.5.2 Significance of the Study

This thesis emphasizes on how the determinants of electricity access such as, price of electricity, labor force participation, gross domestic product, and the number of populations per square kilometer affect the rate of people with access to electricity.

2. LITERATURE REVIEW

2.1 Description of key terms

2.1.1 Electricity

Theoretical understanding; Electricity is the phenomenon associated with stationary or moving of electric charges. Electric charge can be either positive or negative which produces an electric field is a fundamental property of mater which borne by elementary particles (He *et al.*, 2016). In electricity, the particle involved is the electron, which carries a charge designated, by convention, as negative. Thus, the various manifestations of electricity are the result of the accumulation or motion of numbers of electrons. Electricity can also be defined as a fundamental form of energy observable in positive and negative forms that occurs naturally as lighting or is produced as in generator and that is expressed in terms of the movement and interaction of electrons (Neugebauer &Webb, 1962).

The rapid expansion in electricity technology in now day transformed industry and society, becoming a driving force for modern industrial revolution. Electric extra ordinary adaptability mean it can be put to an almost limitless set of applications which include transport, heating, lighting, communications, and computation (Marx, 2010). Therefore, electricity is now a backbone of modern industrial society and modern technologies through electric power where electric current used to energize equipment and through electronics, which deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes and integrated circuits and associated passive interconnection technologies.

2.1.2 Electricity access

Broadly speaking, electricity access commonly known as electrification, which means the process of powering, by electricity (Rad *et al.*, 2020). Electrification was the build-out of the electricity generation and electric power distribution systems. The electrification of particular sectors of the economy named by terms such as industrial electrification, household electrification, and rural electrification. The difference in nationals' technological advancement made higher electrification in developed countries and lower in developing countries.

The supreme benefit of electrification is that electric lighting is highly desirable. The light is much brighter than oil or gas lamps, and there is no soot. Although early electricity was very expensive compared to today, it was far cheaper and more convenient than oil or gas lighting (Guarnieri, 2018). Electric lighting was so much safer than oil or gas that some companies were able to pay for the electricity with the insurance saving. Therefore, Electrification and economic growth are highly correlated. Economically, the efficiency of electrification has shown to correlate with technological progress.

2.2 Theoretical review

2.2.1 Influence of labor force participation to electricity access

Economically, in Rwanda as well as in global economy, labor force participation rate is the sum of employed and unemployed persons who are in working age varying between sixteen and sixty-four years old. World Bank (2020) argued that, the fourth Rwanda Population and Housing Census figured out that Rwanda labor force participation rate is averaged 54.57 percent from 2019 until 2022.The higher the labor force participation rate is the healthiest the economy. Whereas the lower the labor force participation rate the weaker the economy.

The higher the labor force participation rate means that; in the economy there is existence of higher number who is in working group and vice versa. Electrification sector as argued by Rad *et al.*, (2020) includes industrial electrification, household electrification, and rural electrification. Hand in hand in all highlighted economic sector involves labor force participation. The revenue obtained from economic sector raise the rate of electrification in generation, transmission and distribution. In long run the higher labor force participation rate rises the rate of electrification.

2.2.2 Power of gross domestic product to electricity access

Gross domestic product comprises savings of household sector, Private Corporation sector and public sector. The public sector contains government companies and statutory corporations. The private sector involves non-governmental and non-financial corporate enterprise. The remaining economic subdivision classified in household sector as the host of economic agents that is more engaged in production and consumption activities. Gross domestic product commonly obtained by adding up all of the money received by all participants including public and private in the economy (Kulshreshtha, 2016).

Relating to the purpose of the study; deterioration in the overall tax to GDP ratio and losses made by public sector utilities such as REG are some of the factors that are responsible to the trend of gross domestic product (Ahmed, Abbas & Ahmed, 2013).The private corporate product is predictable by massive increase in the use of loan, significant position of the unincorporated private sector which is reflected in the household savings and the taxation policy which depresses the accumulation of undistributed profit in the Private Corporation.

Since the independency of Rwanda, a low saving rate has observed as a result in a low economic growth rate over the time. The low saving rate reflects the consumption preference of economic agents. The low level of saving and lack of saving culture causes the shift of investors' preference towards physical assets compared to financial assets, which attributes a rise in inflationary pressure (Vines & Wills, 2018). Rwanda has a target to reach 24 percent by 2024 as domestic savings. The vision of Rwanda is to be a self-investment reliance and a self-economic resilience. The more the country sure domestic saving the more it attracts financial investment, which reduces the cost of capital.

To reach the target of 2035 Rwanda as the middle income and 2050 Rwanda as the high income; in the projected policies to be implemented there are investment in education and innovation, high level of savings and investment, technological innovations towards competitiveness, political and social consensus on reforms, attracting FDI and growing exports (Mukeshimana, Zhao & Nshimiyimana, 2021). Kolin, Sedlar and Kurevija (2021) argued that there is a great relationship between gross domestic product and electrification. Scholars also said that gross domestic product is significant for rural electrification and decreasing electrification inequalities. High gross domestic product should increase electrification. Sparsely population low rate of electrification, thus the existence of gross domestic product to raise infrastructure access to the population.

2.2.3 Effect of population density to electricity access

Geographically, Putri, Wibirama and Giyarshi (2018) express Population density, as the number of people per square kilometer of land area. This number presents us how many people can live within one square kilometer if a given country may distributed population across its land area. Economically, (Wang et al., 2018) describe population density as the concentration of individuals within a class in a specific geographical location. Population density used as a variable to assess the relationships with ecosystem, human health and infrastructure.

Rwanda is the most populated country in the region and in the SSA countries with an area of 26,338 km^2. The current population of Rwanda as it estimated by united nation data is 13,595,154, which projected to be 13,600,464 in July 2022. Guneralp *et al*. (2017) projected the population of Rwanda which was12.95 million of people in 2020 will be 20 million of people in 2042. The highly population density put pressure on government on increased demand commonly food and infrastructure. What important is that high population density reduces losses in electricity distribution.

Growing in population density multiplicatively with rising in per capital income led to high demand of electricity consumption (Anser *et al*., 2020). Government faces with pressure of extension and densification of the medium voltage (MV) and low voltage (LV) distribution to meet electricity demand. Population density influences not only urban electrification but also rural electrification through reduction of electrification inequality in SSA (De la Croix & Gobbi, 2017). Trotter and Philipp (2016) confirms that there is a great negative relationship between population density and electrification in developing countries specifically SSA countries.

2.3 Empirical review

The theory of Peters and Sievert (2016), suggested that electrification in SSA countries is practicable when it covers evaluation of rural electrification projects and its valuation. The assessment of the association between electrification project and poverty reduction with economic development and finally the assessment of energy demand modeling in order to select which models attempt to answer electricity consumption and socio-economic factors. De-Assis Cabral, Legey and De-Freitas Cabral (2017) proposed that in analysis of electrification project, it is important to use econometric approach.

By using macro-economic approaches to stick the determinants of electricity access, package of economic and demographic factors careful verified and distinguished (Belaid & Garcia, 2016). Generally, energy project is highly costlier due to generation, transmission and distribution activities. That is because most of energy project are highly capital intensive. Ayodele *et al.* (2021) highlight that most of the investment sources for electrification project derived from gross domestic product. This defended by Nagawa, Wasswa and Bbaale (2020) as an increase in economic productive activities there is an increase in income and their rest of it saved.

The theory supported by Keynes (1936) described that consumption is an important factor of national income. This demonstrated by Keynesian consumption function $C = a + bY$ where C is consumption expenditure, Y stand for current disposable income a is independent income or autonomous consumption and b is the marginal propensity to consume. Demographically, IEA (2019) criticized that almost of 85% of the population in developing countries living in rural areas; where there is low access to general infrastructure. This is the top factor that rural households face low access to electricity.

Burgess *et al.* (2020) noted that low energy infrastructure in rural areas leads to low commercial energy consumption of rural households as the consequences of poor capacity in transmission and distribution of the utilities. This is the fact that in rural areas there is low population densities as well as low demand of electricity, combination of this leads high line losses. Mekonnen and Sarwat (2017) mentioned that low rates of electrification in SSA located in rural areas and this comes on the top of obstacles in African development.

This is because the low rate of electricity access results in less job creation, health, social and economic development as whole. Apergis, Polemis and Soursou (2022) emphasis on how electricity access influenced by the development of human capital, the fact that electricity access influences school attendance. Whenever, Alstone, Gershenson and Kammen (2015) suggested that the effort to enlarge the rate of access to electricity must be oriented in utilities financing. Unfortunately, rural household' financial capacity and settlement missed in the study of the cited.

Yang and Yang (2018) come up with the analyzes of how low rate of population with electricity access influenced by the cost of connection charges where the SSA is the highest region with costlier connection charges around $100 per customer which lower the rate of population with electricity access. This highlight the gap between access to electricity and the rate of population living below the labor force participation. Mentioned continue by showing that the causal influence of high charge to small consumers caused by weak commitment of the utilities and the end users, lack of incentive to motivate the poor population to have access to electricity and the distance from power plant up to the households.

Alasseri, Rao and Sreekanth (2018) proposed the new program titled as out-based aid (OBA), which plays the great role of offering subsidies to the connection of the households and on the billing amount of low- income households. The cited gives an example of Senegal, where this method was applicable. As results where these subsidies made a change from $725 to the fall of $ 286, the difference is a subsidy in order to generate new connection of households with access to electricity. The literature gap is from that Senegal financial, social and geographical factors are very different as that of Rwanda.

To expand the rate of population with electricity access, the government of Botswana; conclude to finance 90 % of the project which lighting the rural household over the period of two years. This decision is from the statistics results shown that the low rate of electricity access is from high connection charges. Therefore, the implemented policies such as offering the long-term loans for to the households and lowering the connection cost increases the rate of population with access to electricity (Kizilcec & Parikh, 2020).

Adusah-Poku and Takeuchi (2019) present Ghana as a good example for rural electrification, this reachable by exercising the voluntary labor to erect poles which aided in lowering the cost of providing electricity to the rural household. As a result, the methodology used faster the rate of population with access to electricity in Ghana. The influence of education policy in Rwanda is not the same as of Ghana reason why the shown methods is not yet applicable in the country of the case study.

In addition, the differences in countries differences is another factor to the differences in electrification for instance, in 1989, the government of Ghana present the new project of rural electrification, this is why in SSA countries Ghana is at the top of other countries with having high rural households with access to electricity. Korkovelos *et al.* (2020) described that; Rwanda emphasis on the procurement policies practices to low the cost for sustainable electrification technologies. Rwanda energy group (REG) has been able to low the cost specifically on the hardware installation materials such as low-voltage cable, distribution transformers, poles, prepayment meters, brackets and other important connection materials including the cost of paying technicians.

Nonetheless, the view of World Bank shown what is need for the country for as a new policy for electrification but did not show what determines electrification, that what the study called determinant of electricity access. Opportunely, the study of Son and Yoon (2020) positioning the determinants of electricity access with a view of Government of Vietnam. Cited said that electricity access influenced by Location either local or regional and by governmental financing. Also, Son and Yoon (2020) described that multiple funding resources raise government budget for electrification project as a result it rises the number of rural households with access to electricity. The missing of population density and contribution of gross domestic product as other determinants of electricity access remains as the cause of conducting the study titled determinants of electricity access in Rwanda.

3. METHODOLOGY

3.1 Econometric model specification

The aim of thesis is to examine the determinants of electricity access in Rwanda, which can lead to the achievement of Rwanda 2024 electrification rather than 2030. Referring to Mijiyawa (2017) few factors have shown to be the factors that may encourage or discourage higher or lower rate of electricity access in Guinea. Poor governance and low access to finance are at the top of the most challenges facing the low rate of access to electricity. Despite to Rwanda; good governance and incentives for access to finance motivate to use variables includes price of electricity (price), labor force participation rate (labor), gross domestic product (GDP) and the number of populations per square kilometer (density). Therefore, model function specification is as follows;

$$log\ EA_t = \beta_0 + \beta_1 \log price_t + \beta_2 \log labor_t + \beta_3 \log gdp_t + \beta_4 \log density_t + \varepsilon_t \quad \text{(Equation 1)}$$

Ulsrud (2015) explained that the main reason that the population in rural areas has less access to electricity is that almost of them are living in dispersed settlement meaning that there is a long distance from one household to another, this settlement affects the density on square kilometer; yet the less population density the less electricity access and vice versa, that is due to the long distance in electricity distribution causes energy losses and discourage the utilities. Nagawa, Wasswa and Bbaale (2020) report that the total amount for financing of energy projects is from the ratio of gross domestic product. However, it varies depends on the economic situation of the region. Son and Yoon (2020) highlights that; electricity access is strongly correlated with the number of populations belongs the labor force participation. Accordingly, this study was conducted with the aim of presenting the determinants of electricity access in Rwanda. Hence, it uses electricity access as explained variable, while price of electricity, labor force participation, gross domestic product, and the number of populations per square kilometer are taken as explanatory variables.

The information from thesis is useful to evaluate and inform policy decision makers in the electricity sector. Thesis proxies the electricity access as the percentage of population with access to electricity in Rwanda for the period 1990 to 2020. Access to electricity is a crucial component for poverty reduction through job creation and extending working hours. An evidence of Rwanda; working hours of electrified region is 24 hours per a day while in non-electrified region working hours is less than 10 hours per day.

The more the population density per square kilometer, the more it easy to have access to electricity Hence, the sign for the estimated coefficient for density is expected to be positive. (Arderne *et al.*, 2020). Moreover, there is a positive relationship between labor force participation, gross domestic product and electricity access. Conversely, the researcher expected that there is a negative relationship between price of electricity and electricity access

3.2 Data variable description

Thesis uses time series data of 30-year period to examine the determinants of electricity access in Rwanda. The secondary data was collected from the World Bank development indicators (2022)[1] available online and REG online database[2].

3.2.1 Measurement of explained variable

Thesis uses electricity access as explained variable. World Bank (2020) pointed that access to electricity measured in tiers. It mentioned that there are five tiers used when measuring access to electricity, whereas in Rwanda electricity access is generally at third tiers. The tiers started from tiers zero that means that there is no household, which has access to electricity. In the first tier, the households can afford 22 kilowatt-hours with basic appliance capacity includes lighting, phones and radio charging. In this tier the available hours of electricity per day is at least four hours.

In the second tiers, the consumption of electricity per consumer per year is 224kilowatt-hours with first tier appliances plus general lighting, air conditioning and television. The third tiers allow the consumer to have access to 696 kilowatt-hours with the second tiers appliances plus refrigerator and washing machine. The available electricity per day is eight hours. The fourth tiers, the consumer of electricity has to afford 1800 kilowatt-hours with the third-tier appliances plus a microwave, space

[1] https://data.worldbank.org/country/rwanda
[2] https://www.reg.rw

heating and iron as well as available hours of electricity per day sixteen hours. The fifth tier, consumer has to afford 2195 kilowatt-hours with fourth tiers appliances plus heavy energy- intensive appliances with at least 23hours of available hours of electricity per day.

3.2.2 Measurement of explanatory variables

3.2.2.1 Measurement of price of electricity

Countries use three main pricing models to calculate wholesale electricity prices (Arderne *et al*., 2020). Each option differs in terms of locational granularity, or how a country divides its pricing regions. While some countries have a single national wholesale electricity price, others divide their markets into zones or nodes, each with its own wholesale electricity price. National pricing is available at the highest level. This is where the price of electricity is the same across the country at any given time. The transmission system divided into several pre-determined zones, or geographical regions, in zonal pricing. Nodal pricing is also known as locational marginal pricing (LMP), divides the national network into hundreds or even thousands of nodes, each with its own wholesale electricity price.

3.2.2.2 Measurement of labor force participation

In common understanding, labor force participation known as the measurement of active workforce or working age population (either employed or actively looking for job). The global working age varying between sixteen and sixty-four years old who is not institutionalized. What is important is that the higher the labor force participation rate is the healthiest the economy. Whereas the lower the labor force participation rate the weaker the economy. The higher the labor force participation rate means that; in the economy there is existence of higher number who is in working group and vice versa. By calculation labor force participation rate is obtained by dividing the total number of persons available for work by the total population.

3.2.2.3 Measurement of Gross domestic product

Gross domestic product is the measurement used by nations to gather the information about the size of the economy and how an economy is performing. For the reason that the increase in real GDP shows the well doing of any economy, this thesis took GDP as one of the used variables. The calculation of

GDP depend on the type of it where is real or nominal. Hence, the thesis uses the real GDP values adjusted for inflation.

3.2.2.4 Measurement of population density

Population density expressed as the number of people per square kilometer of land area. This number presents us how many people can live within one square kilometer if a given country may distributed population across it land area. Even if it cannot possible to distribute the population on each square kilometer of a country. Population density obtained by dividing the number of total populations by the area of a country in square kilometer.

3.3 Data analysis

Thesis data analyzed by using E-views 10. Data analysis method guided a researcher as a technique applied in processing of collected data, with a view of arriving at a valid conclusion. With the help of data analysis method, different statistical test were tested includes stationarity test for verifying the stationarity of data, normality test for testing whether residuals are normal distributed or not, correlation test for verifying the correlation between variables and regression analysis made to estimate the coefficient of variables.

3.3.1 Stationarity test

The study conducted with use of time series data. Therefore, stationarity tested to see the influence on how data perceived and predicted (Fuglstad *et al*., 2015). Some properties of stationarity like constant variance, constant autocorrelation and non-periodic fluctuation over the time analyzed. The stationarity of thesis data tested by comparing Augmented Dickey-Fuller and t-statistics with critical value at each level (1%, 5% and 10%).

3.3.2 Normality test

The normality test used to test whether a set of time series data distributed in a way that is consistent with a normal distribution. In addition, it used to check whether there is a goodness of model fit. For any conducted study, it is important to test normality in other to decide the measurement of central tendency and statistical methods for data analysis (Walesiak, Dehnel & Dudek, 2022). With the assessment of general assumption of normal distribution, which state that normal distribution must applied only on the residuals not to the independent variables, the normality of residuals tested and presented via histogram.

3.3.3 Correlation test

Correlation matrix used to measure and quantify the degree and direction of the linear relationship between study variables. The purpose of correlation test in the study is to present out which variables correlated or connected. Through the correlation analysis, correlation coefficients tell how much one variable changes when the other one does (Fisher, 1915). Therefore, positive correlation presents the relationship between two variables in which both variables move in the same direction while negative correlation presents the relationship between two variables in which one variable increases as the other decreases.

4. RESULTS AND DISCUSSIONS

4.1 Descriptive statistics

Appendix 4.a shows that, mean and standard values comparison for log labor, log gdp and log density present that there is a low variation between data variables, which shows the accuracy of data variables.

4.2 Normality test

Statistically, normality test in data analysis tested by setting hypothesis assumption. The aim for normality test is to determine if data set specifically residuals are well normally distributed. Thesis uses histogram to present normality test result.

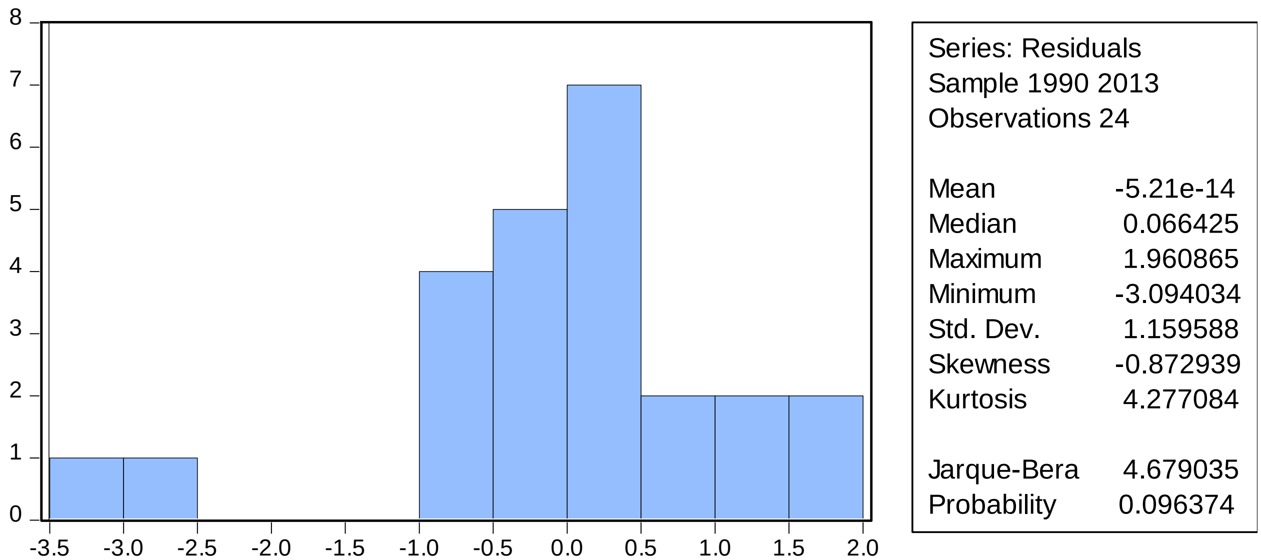

Figure 4.1: Normality of the residuals

Normality test hypothesis assumption presented as follows:

H_0: Residuals are normally distributed.

H_1: Residuals are not normally distributed.

Respect to the stated assumptions, the figure results from figure 4.1 shows that, the residuals are normally distributed. This proved by the P-value of Jarque-Bera, which is 0.096 and is greater than the level of significance of 5%, this confirms that residuals follows normal distribution. Moreover, if the value of skewness is less than zero and the value of kurtosis is greater than three; the residuals follow normal distribution. This is proved by the value of skewness which is -0.8729 less than zero and the value of Kurtosis, which is 4.2770 greater than three; all the statement proves that residuals follow a normal distribution. Walesiak, Dehnel and Dudek (2022) argued that normal distribution must be applied only to the residuals, not to the independent variables. See the presentation of the normality test via histogram

4.3 Unit roots test

In general, for time series data, the known methods used for testing stationarity is Augmented Dickey Fuller (ADF). But depending on the character of data set there are other methods used including Phillips-Perron (PP) which is specifically used for large dataset, Kwiatkowski-Phillip-Schmidt-Shin, Elliot-Rothenberg-Stock Point-Optimal and Ng-Perron (Fuglstad *et al*., 2015). The clarification for the ADF results is that when the ADF statistics greater than all critical values (1%, 5% and 10%) the presence of stationarity exist.

Moreover, the null hypothesis for both ADF and PP is that there is presence of unit root (non-stationarity) and alternative hypothesis is that there is no presence of unit root (stationarity). Therefore, to have series, which is stationary, we have to reject the null and accept alternative hypothesis (see Appendix 4.b). While for KPSS, null hypothesis is stationary and alternative hypothesis is non-stationary. Thus, to have stationary series by KPSS we have to accept null hypothesis and reject alternative hypothesis. In addition, for accepting null hypothesis, the variable to be stationary, LM-Statistics should be smaller than the critical values and vice versa (appendix 4.c). Appendix 4.d presents the summary results.

4.4 Correlation matrix

Test for correlation is for the resolution of identifying whether the changes from one variable is associated with the change in another variable. The followed principle assumption for testing correlation is that the value in correlation results must be between positive one and negative one. Appendix 4.e presents that; there is a negative correlation between electricity access and price of electricity, the results show that there is a positive correlation between labor force, gross domestic product and electricity access. The low correlation coefficient for Gross domestic product and labor force proves that there is no multicollinearity between both variables. The results also show that there is negative correlation between electricity access and price of electricity; since all results varies between positive and negative one. The robust check for potential endogeneity between electricity access and Gross domestic product by extracting gross domestic product in the model proves that there is no existence of endogeneity between the two variables since the model without GDP is not stable (Appendix 4.h). Fisher (1915) argued that; positive correlation presents the relationship between two variables in which both variables move in the same direction while negative correlation presents the relationship between two variables in which one variable increases as the other decreases.

4. 5 Estimation result

The ADF and KPSS test results show that there is a mixture of stationarity and non-stationarity variables (appendix 4.d). An autoregressive distributed lag (ARDL) model is preferable for variables that has mixed order of integration. An error correction model (ECM) commonly used for data where the underlying variables have a long-run common stochastic trend, also known as co-integration. Equation 2 presents ARDL general model combining both short run and long run. The first part with β represents short run dynamic of the model and the second part with λ represents the long run dynamic with the model, p is the lag of dependent and q is the lag of independent variables. The model was estimated by ARDL (2, 1, 2, 1, 2) and was selected by Akaike information criterion (AIC). Appendix 4.f presents lag order selection criteria. AIC is commonly preferable for time series analysis, the lower the AIC value score the better model is fit.

$$\triangle\, log\,(EA_t) = \beta_0 + \sum_{i=1}^{p} \beta_1 \triangle \log(EA_{t-i}) + \sum_{i=1}^{q} \beta_2 \triangle \log(price_{t-i}) + \sum_{i=1}^{q} \beta_3 \triangle \log(labor_{t-i}) + \sum_{i=1}^{q} \beta_4 \triangle \log(gdp_{t-i}) + \sum_{i=1}^{q} \beta_5 \triangle \log(density_{t-i}) + \lambda_1 \log(EA_{t-i}) + \lambda_2 \log(price_{t-i}) + \lambda_3 \log(labor_{t-i}) + \lambda_4 \log(gdp_{t-i}) + \lambda_5 \log(density_{t-i}) + \varepsilon_t \quad \text{(Equation 2)}$$

Table 4. 1: Short run results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGEA(-1)	-0.5884	0.2629	-2.2379	0.0520***
LOGEA(-2)	-0.6421	0.2587	-2.4814	0.0349**
LOGPRICE	-1.8541	1.4828	-1.2503	0.2427
LOGPRICE(-1)	-1.3430	0.9434	-1.4234	0.1883
LOGLABOR	2.6027	1.7193	1.5137	0.0000*
LOGLABOR(-1)	-2.2455	1.7988	-1.2483	0.0208**
LOGLABOR(-2)	-2.2742	1.7409	-1.3063	0.0077*
LOGGDP	0.3787	6.4299	0.0589	0.9543
LOGGDP(-1)	10.8480	3.0799	3.5221	0.0065*
LOGDENSITY	-10.0486	5.8363	-1.7217	0.1192
LOGDENSITY(-1)	25.5000	5.0229	5.0766	0.0007*
LOGDENSITY(-2)	7.7501	4.1934	1.8481	0.0976***
C	-2.5452	1.9359	-1.3147	0.0028*
R-squared	0.9937	Mean dependent var		0.9594
Adjusted R-squared	0.9853	S.D. dependent var		2.2065
F-statistic	49.4232	Durbin-Watson stat		2.5171
Prob(F-statistic)	0.0000			

*significant at 1%, **significant at 5%, ***significant at 10% level of significance

Table 4.1 shows that in the short run, if in previous two year there is an increase of one percent in electricity access, the current electricity access will be decreased by 0.64 percent. If in previous two year there is an increase of one percent in labor force, the current electricity access will be decreased by 2.27 percent. If in previous one year there is an increase of one percent of gdp, the current electricity access will be increased by 10.84 percent. If in the previous two year there is an increase of one percent of population density, the current electricity access will be increased by 7.75 percent. The ARDL estimates of the data show robust results with high adjusted R^2 value of 0.98 and significant- prob (F-statistic).

ARDL - Long run model

$$log\ (EA_t) = \beta_0 + \lambda_1 \log (EA_{t-i}) + \lambda_2 \log (price_{t-i}) + \lambda_3 \log(labor_{t-i}) + \lambda_4 \log(gdp_{t-i}) + \lambda_5 \log(density_{t-i}) + \varepsilon_t \quad \text{(Equation 3)}$$

Table 4. 2: Long run result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGEA(-1)	-2.2305	0.4415	-5.0519	0.0007*
LOGPRICE(-1)	-3.1971	1.1187	-2.8578	0.0188**
LOGLABOR(-1)	36.6130	12.3823	2.9568	0.0160**
LOGGDP(-1)	11.2267	6.4447	1.7419	0.1155
LOGDENSITY(-1)	23.2015	10.9453	2.1197	0.0631***
C	-57.3454	14.6190	-4.6802	0.0012*

*significant at 1%, **significant at 5%, ***significant at 10% level of significance

Table 4.2 shows that in long run; if in previous one year there is an increase of one percent of electricity access, the current electricity access will be decreased by 2.23 percent. If the price of electricity increases by one percent in previous one year; the rate of electricity access will be decreased by 3.19 percent. If labor force participation rate increases by one percent in previous one year; the rate of electricity access will be increased by 36.61 percent. If population density increases by one percent in previous one year; the rate of electricity access will be increased by 23.20 percent in the long run.

Table 4. 3: Bound test result

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	48.54309	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

By 5% level of significance, table 4.3 presents that the value of F-statistic (48.54) is above upper bound I (1) value (3.49) which show that there is a long run relationship of the model variables. Also, the value of F-statistic (48.54) is above lower bound I (0) value (2.56) which shows that there is a long run relationship of the model. Bound test hypothesis assumptions are as follows:

H_o: $\lambda_{1i} = \lambda_{2i} = \lambda_{3i} = \lambda_{4i} = \lambda_{5i} = 0$ (where i = 1,2,3,4,5)

H_1: $\lambda_{1i} \neq \lambda_{2i} \neq \lambda_{3i} \neq \lambda_{4i} \neq \lambda_{5i} \neq 0$

The null hypothesis (H_o) state that, the coefficients of long run equation are all equal to zero, this implies that there is no co-integration, thus we have to consider ARDL short model. The alternative (H_1) state that, the coefficients of long run equation are different from zero, this implies that there is co-integration, therefore ECM must be considered (equation 4).

$$\triangle\, log\,(EA_t) = \beta_0 + \sum_{i=1}^{p} \beta_1 \triangle \log(EA_{t-i}) + \sum_{i=1}^{q} \beta_2 \triangle \log(price_{t-i}) + \sum_{i=1}^{q} \beta_3 \triangle \log\,(labor_{t-i}) + \sum_{i=1}^{q} \beta_4 \triangle \log(gdp_{t-i}) + \sum_{i=1}^{q} \beta_5 \triangle \log(density_{t-i}) + \lambda \mathrm{ECT}_{t-i} + \varepsilon_t$$

(Equation 4).

Table 4.4: Error correction result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.3852	1.0354	-0.3720	0.7147
D(LOGEA(-1))	0.0576	0.2192	0.2630	0.7959
D(LOGPRICE(-1))	-1.7881	1.8196	-0.9826	0.3404
D(LOGLABOR(-1))	-2.3947	76.2710	-0.0313	0.9753
D(LOGGDP(-1))	26.7624	5.0050	5.3471	0.0001*
D(LOGDENSITY(-1))	-11.7246	6.5439	-1.7916	0.0921***
ECT(-1)	-2.3307	0.4152	-5.7964	0.0043*

*significant at 1%, **significant at 5%, ***significant at 10% level of significance

The error correction term represents the long-run relationship. A negative and significant coefficient of the error correction term indicates the presence of long-run causal relationship (Table 4.4).

4.6 Stability test

Appendix 4.g presents the model stability result. The model stability verified on the basis of the following hypothesis assumptions:

H_0: There is no auto-correlation

H_1: There is autocorrelation

Breusch-Godfrey serial correlation test assumption stated that; if the probability value of chi-square is greater than five percent level of significance; data is free from serial correlation so that the model is stable (fit). It indicates that we fail to reject the null hypothesis against alternative hypothesis. To evaluate whether all variables are free from serial correlation we have also to compare it P-values with level of significance. Here, if the P-value of variables is greater than level of significance, the results in the appendix 4.g, also show that the data are free from serial correlation.

5. CONCLUSION AND RECOMMENDATION

5.1 Summary of findings

The thesis examines the determinants of electricity access in Rwanda. The empirical findings show that in the short run; labor force positively influence access to electricity. Moreover, the empirical findings reveal that in the long run; price of electricity negatively influence access to electricity whereas labor force and population density positively influence access to electricity. The thesis model is significant since it prob (F-statistic) is 0.00 and is robust since adjusted R^2 is 0.98. The bound test result shows that series are co-integrated. Finally, after error correction; model becomes stable, since the prob of chi-square is greater than five percent level of significance.

5.2 Recommendations

5.2.1 Recommendations to government

Since government of Rwanda has the target of achieving total electrification rate by 2024, the thesis findings stimulate some suggestion to government including revising policies of rising employment rate in labor force participation to keep the positive relationship between electricity access and labor force participation. Moreover, government of Rwanda must keep the policies, which can raise gross domestic product and keep measures to control price of electricity and population density.

5.2.2 Recommendations to the population

Population (consumers) are recommended to use some methods including load shifting in order to avoid high tariff charged in peak hours and keep using electric efficiency technologies to meet power shortage.

5.3 Conclusion

Thesis titled "The determinants of electricity access in Rwanda". This is examined by imposing three specific objectives including identifying the influence of labor force participation to electricity access, detecting the power of gross domestic product to electricity access and establishing the effect of population density and price of electricity to electricity access. This thesis's empirical findings enabled to conclude that, it is important to put in place the policies, which raise labor force participation rate, and gross domestic products as the foremost variables quick raise the rate of electricity access. The findings also revealed that there is a need of adjustment in price of electricity and put in place policies that controls the population density in order to achieving the total Rwanda electrification.

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APPENDICES

Appendix 4.a: Descriptive result

	LOGEA	LOGPRICE	LOGLABOR	LOGGDP	LOGDENSITY
Mean	0.9489	-0.8178	4.3232	5.8318	5.7716
Median	1.7555	-0.7809	4.3239	5.7731	5.7527
Maximum	2.8622	-0.3369	4.4596	6.2128	6.0437
Minimum	-4.6052	-1.1777	4.1931	5.5411	5.3748
Std. Dev.	2.1087	0.2017	0.0761	0.2138	0.1664
Skewness	-1.6854	0.0375	0.1146	0.3106	-0.2783
Kurtosis	4.8567	2.8169	2.1749	1.9370	2.7344
Jarque-Bera	14.8101	0.0391	0.7333	1.5160	0.3803
Probability	0.6080	0.9806	0.6931	0.4686	0.8268

Appendix 4. b: Augmented-Dickey-Fuller unit root test

Variable	Trend and intercept			
	Level		First difference	
	t-stat	P-value	t-stat	P-value
Log (EA)	-5.5139	0.0007	-3.5950	0.0008
Log(PRICE)	-1.1984	0.8921	-3.0574	0.0021
Log(LABOR)	-4.1463	0.0145	-3.5742	0.0111
Log(GDP)	-3.4512	0.0691	-3.6328	0.0173
Log(DENSITY)	-3.5745	0.0548	-3.6328	0.0042

Appendix 4. 1: Kwiatkowski-phillip-schmidt-shin unit root test

Variable	LM Statistics KPSS tests	
	Trend and intercept Critical value@5%=0.146	
	Level	First difference
Log (EA)	0.1064	0.0939
Log(PRICE)	0.1014	0.1345
Log(LABOR)	0.0751	0.0690
Log(GDP)	0.1601	0.0996
Log(DENSITY)	0.1064	0.6947

Appendix. d: Comparison of results of three-unit root test methods

Variables	ADF	KPSS
Log (EA)	Stationarity at level	Non-stationarity at level
Log(PRICE)	Non-stationarity at level	Stationarity at level
Log(LABOR)	Non-stationarity at level	Non-stationarity at level
Log(GDP)	Non-stationarity at level	Non-stationarity at level
Log(DENSITY)	Non-stationarity at level	Non-stationarity at level

Appendix4. 2: Correlation matrix results

	LOGEA	LOGPRICE	LOGLABOR	LOGGDP	LOGDENSITY
LOGEA	1.0000	-0.3049	0.2083	0.4993	-0.2885
LOGPRICE	-0.3049	1.0000	0.4187	-0.2330	-0.2521
LOGLABOR	0.2083	0.4187	1.0000	-0.2912	-0.3597
LOGGDP	0.4993	-0.2330	-0.2912	1.0000	0.3160
LOGDENSITY	-0.2885	-0.2521	-0.3597	0.3160	1.0000

Appendix 4.f: Lag order selection criteria Bound

	La	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
Endogenous variables: LOGEA	0	-34.005	NA	2.046618	3.545988	3.793952	3.604400
	1	-28.164	8.4973*	1.3259*	3.1058*	3.4033*	3.1759*
Exogenous variables: C LOGPRICE LOGLABOR LOGGDP LOGDENSITY	2	-28.147	0.0222	1.462638	3.195237	3.542387	3.277015

*indicates lag order selected by the criterion, **LR**: sequential modified LR test statistic (each test at 5% level), **FPE**: Final prediction error, **AIC**: Akaike information criterion, **SC**: Schwarz information criterion, **HQ**: Hannan-Quinn information criterion.

Appendix 3.g: Model stability

d(LOGEA)	F-statistic	5.85E-05	Prob. F(1,15)	0.9940*
	Obs*R-squared	8.97E-05	Prob. Chi-Square(1)	0.9924*

* Model fit at 5%

Appendix 4.h: Robust stability test

d(LOGEA)	F-statistic	14.02166	Prob. F(1,22)	0.0011
	Obs*R-squared	10.89918	Prob. Chi-Square(1)	0.0010