

**ELECTRICITY CONSUMPTION AND HEALTH OUTCOMES IN SUB-
SAHARAN AFRICA**

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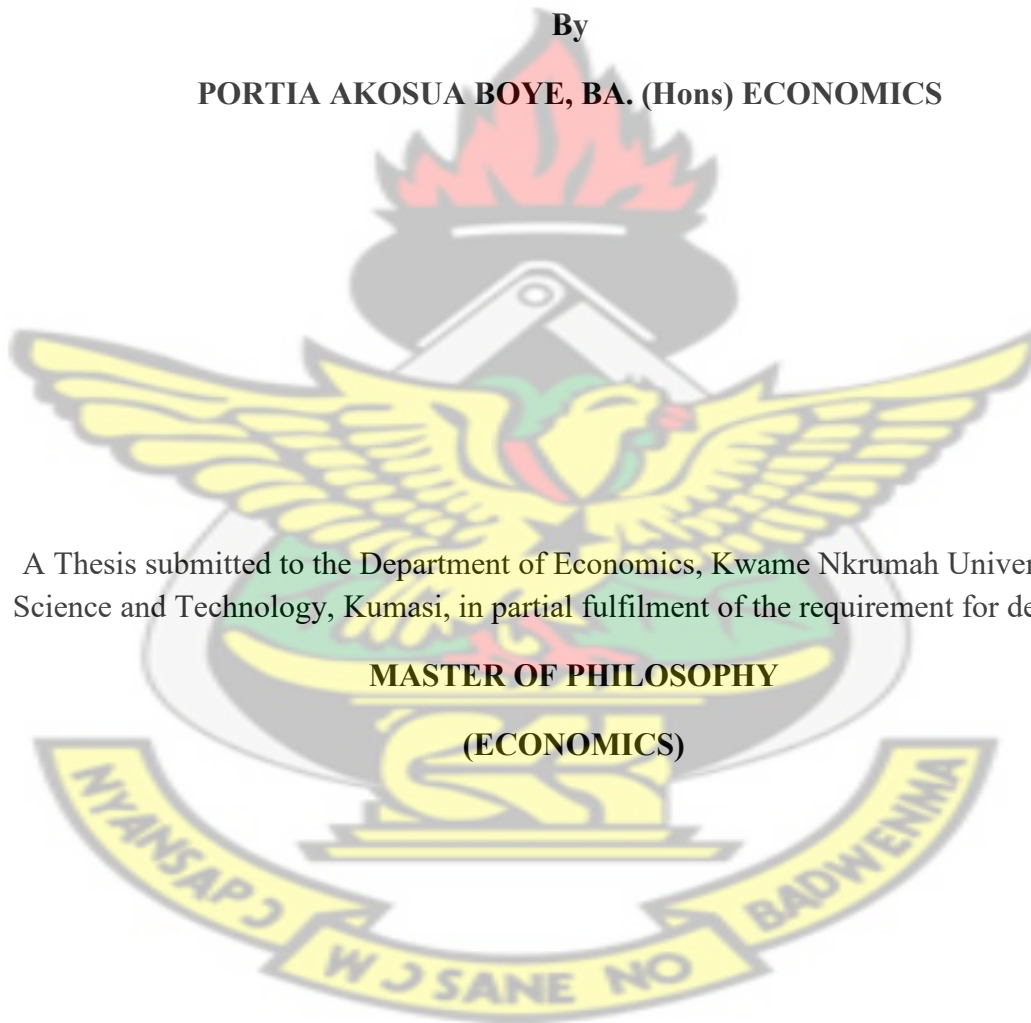
By

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A Thesis submitted to the Department of Economics, Kwame Nkrumah University of
Science and Technology, Kumasi, in partial fulfilment of the requirement for degree of

MASTER OF PHILOSOPHY

(ECONOMICS)



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DECLARATION

This is to certify that this thesis is the result of research undertaken by Portia Akosua Boye towards the award of the degree of Master of Philosophy (MPhil) in Economics at the Department of Economics, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

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ABSTRACT

Inspite of efforts to accelerate increase in access to electricity in SSA, more than half of the populations do not have access to electricity and many more are connected to unreliable sources. Therefore, consumption of electricity by some sections of the population in SSA is accompanied by the use of other unclean fuels like biomass for lighting and cooking among others not considering their health implications. Using the fixed effect model, the results imply that electricity consumption contributes significantly to the reduction in under-five mortality rates, infant mortality rates, and improvement in life expectancy at birth. In addition, the study finds that access to electricity leads to a significant fall in both infant and under-five mortality rates, and increase in life expectancy at birth. The study also found bidirectional causality between electricity consumption and access. Given these results, the study recommends that electricity consumption and access levels should be increased through increased investment into the electricity sector as a requirement to increase the total amount of energy that power stations are able to produce. This increase in investment will as well improve performance within the generation, transmission and distribution chain and increase consumption at the end. Also, measures such as mini grids and renewables should be put in place to strengthen policies directed at increasing electricity access for all in order to help SSA contribute its quota towards the achievement of sustainable Development Goals 3 and 7

DEDICATION

I dedicate this work to God who has been my source of help throughout my academic life.

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I acknowledge the Lord God Almighty for His divine presence that has been with me from day one through to the completion of this thesis. I also appreciate my supervisor Dr. Hadrat Mohammed Yusif for his guidance and commitment to this work. I am very grateful to him for his contributions made. A heartfelt gratitude to my family for their unflinching support throughout my period of study. Thank you to all my friends and course mates for their support and encouragement.

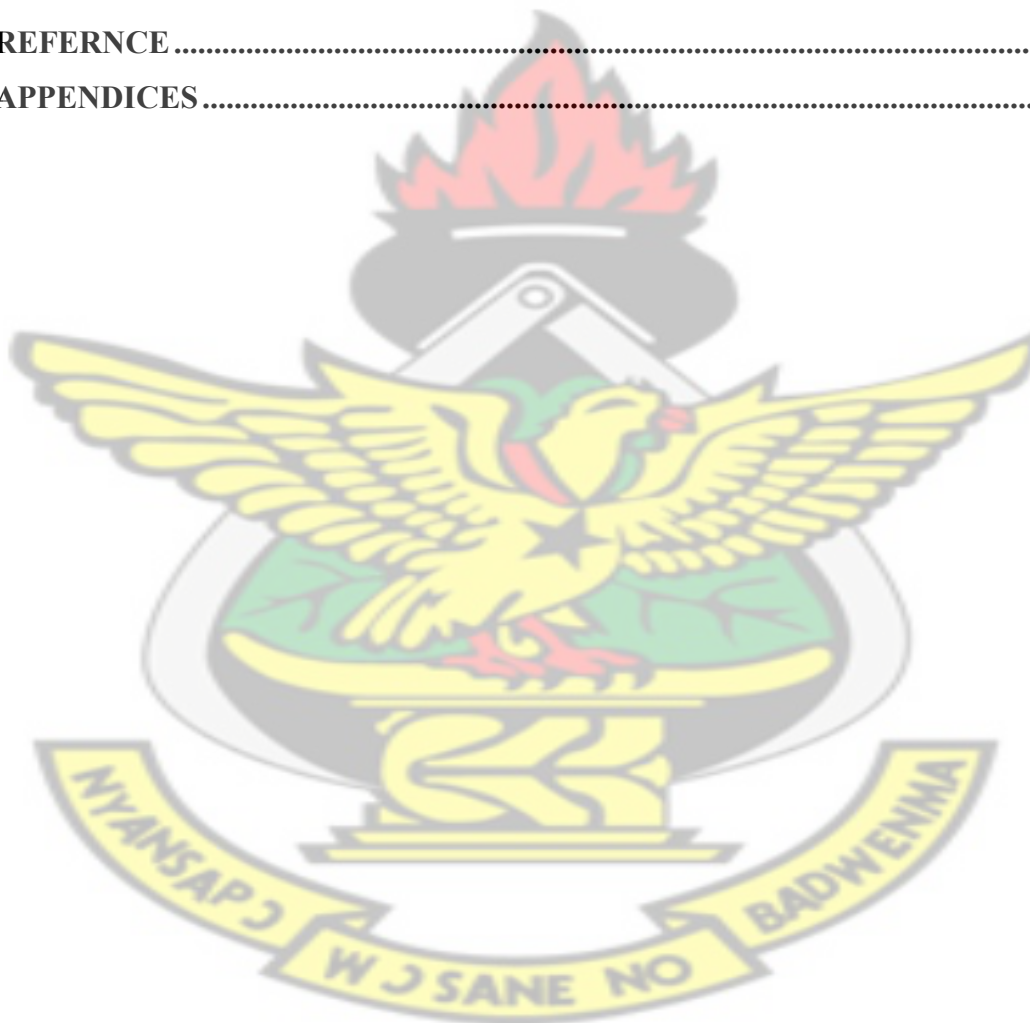


TABLE OF CONTENTS

DECLARATION	i
ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENT	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ACCRONYMS	x
CHAPTER ONE	1
INTRODUCTION	1
1.1 BACKGROUND OF THE STUDY	1
1.2 PROBLEM STATEMENT	4
1.3 RESEARCH QUESTIONS	6
1.5 RESEARCH OBJECTIVES	6
1.6 JUSTIFICATION OF THE STUDY	6
1.7 SCOPE OF THE STUDY	7
1.8 BRIEF METHODOLOGY	7
1.9 ORGANIZATION OF THE STUDY	8
CHAPTER TWO	9
LITERATURE REVIEW	9
2.1 INTRODUCTION	9
2.2 THEORITICAL REVIEW	9
2.3 ELECTRICITY SITUATION IN SSA	12
2.4 THE LINK BETWEEN ELECTRICITY AND HEALTH	13
2.5 TREND OF HEALTH OUTCOME _s AND ELECTRICITY IN SSA.	17
2.6 EMPIRICAL LITERATURE REVIEW	23

CHAPTER THREE	28
METHODOLOGY	28
3.1 INTRODUCTION	28
3.2 THEORITICAL FRAMEWORK	28
3.3 EMPIRICAL MODEL SPECIFICATION	32
3.4 VARIABLE DESCRIPTION AND MEASUREMENT	34
3.4.1 DEPENDENT VARIABLES	34
3.4.2 INDEPENDENT VARIABLES	35
3.5 SOURCE OF DATA	39
3.6 ESTIMATION TECHNIQUE	41
3.6.1 DIAGNOSTIC TEST	42
CHAPTER FOUR	44
EMPIRICAL RESULTS	44
4.1 INTRODUCTION	44
4.2 DESCRIPTIVE STATISTICS	44
4.3 EMPIRICAL RESULTS FROM THE REGRESSION MODELS	49
4.3.1 Electricity Consumption and Health Outcomes	49
4.3.2 Electricity Access and Health Outcomes.	52
4.4 DISCUSSION OF RESULTS OF ELECTRICITY CONSUMPTION, ACCESS AND HEALTH OUTCOMES	54
4.4.1 Electricity Consumption, Access and Life Expectancy at Birth	54
4.4.2 Electricity Consumption, Access and Infant Mortality	56
4.4.3 Electricity Consumption, Access and Under-Five Mortality	57
4.4.4 Other Factors That Affect Health Outcomes Gdp Per Capita and Health Outcomes	59
4.5 RESULTS OF CAUSALITY TEST	62

CHAPTER FIVE	65
SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION	65
5.1 SUMMARY OF FINDINGS	65
5.2 CONCLUSION	66
5.3 RECOMMENDATIONS	68
REFERNCE	70
APPENDICES	75

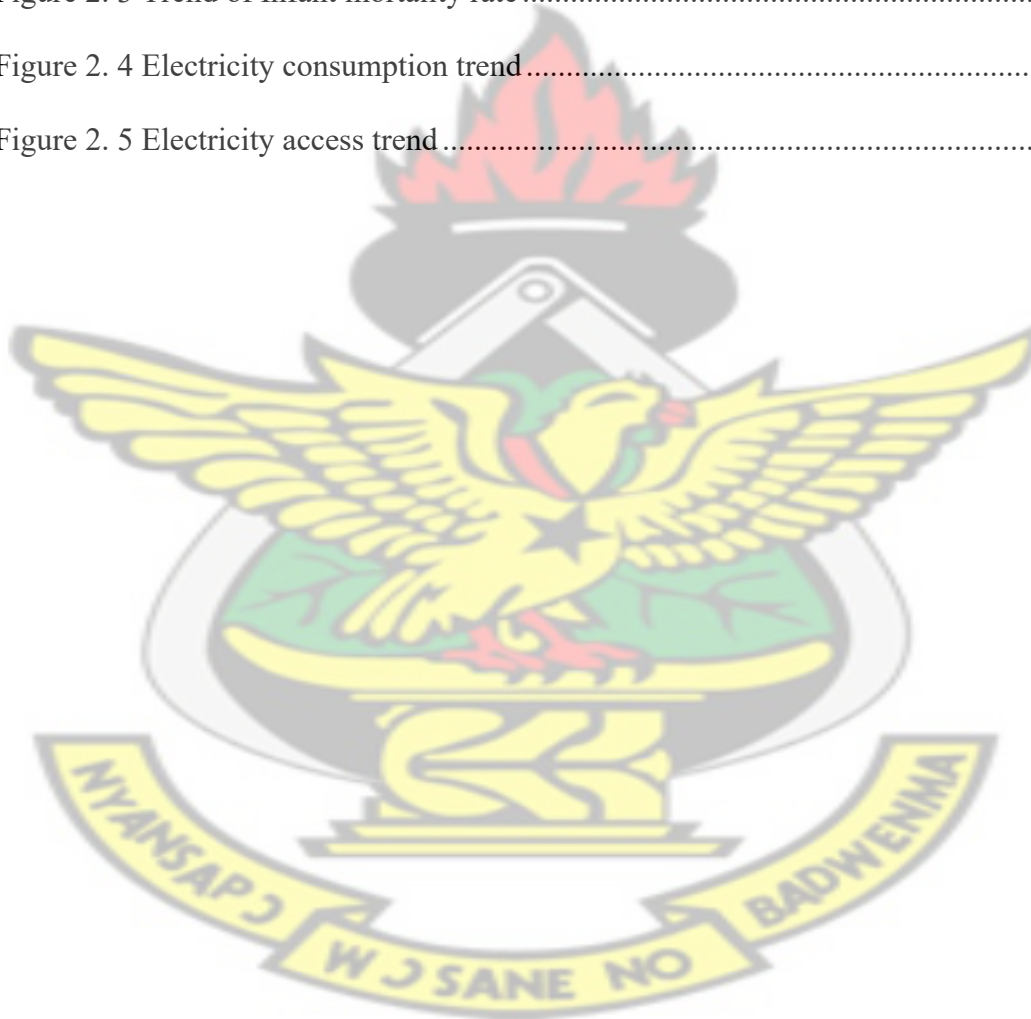


LIST OF TABLES

Table 3.1: Classification of countries into income groups	40
Table 4.1: Descriptive Statistics for Dependent Variables	45
Table 4.2: Descriptive statistics for Independent variables.....	Error! Bookmark not defined.
Table 4.3: Summary statistics for low income countries in SSA	46
Table 4.4 Summary statistics for lower middle income countries in SSA	47
Table 4.5: Summary statistics for upper middle income countries in SSA	48
Table 4.6: Results of electricity consumption and health outcomes	52
Table 4.7: Results of electricity access and health outcomes.....	Error! Bookmark not defined.
Table 4.8: Results of Im-Pesaran-Shin Unit Root Tests	62
Table 4.9: Results of DH panel causality test between electricity consumption and access in SSA.	63

LIST OF FIGURES

Figure 2. 1 Trend of Under-five mortality rate.....	18
Figure 2. 2 Pattern of Life expectancy at birth.....	19
Figure 2. 3 Trend of Infant mortality rate.....	20
Figure 2. 4 Electricity consumption trend.....	21
Figure 2. 5 Electricity access trend.....	22



LIST OF ACCRONYMS

IEA	International Energy Agency
KWh	Kilowatt Hour
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Square
SDG	Sustainable Development Goals
SHEP	Self-Help Electrification Program
SSA	Sub-Saharan Africa
UNEP	United Nations Environment Program
UNFPA	United Nations Population Fund
UNICEF	United Nations International Children's Emergency Fund
WDI	World Development Indicators
WHO	World Health Organization



CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The presence of electricity has numerous benefits to individuals, households and the nation at large as it forms an integral part of daily living. Households mainly depend on electricity as a source of lighting, for recreational and educational purposes among others. Electricity also plays an important role in health care delivery, in storing drugs, for illumination, scanning, running water and proper sanitation amenities among others. Industrial use of electricity for the production of goods and services to be consumed by households improves the health status of the population as well as fostering economic growth and development of the nation. This is because people in the society can go to work and be productive only when they are healthy.

Over the years, economic theory on growth and development has emphasized human capital as one of the engines that drive an economy's growth and development at both micro and macro levels (Wilson & Briscoe, 2004; Becker, 1996). Also, Barro (1996) views health as a capital productive asset which drives economic growth. According to Bloom and Canning (2003) individuals with quality health status have a high tendency of investing in education as they expect to enjoy its benefit over a longer period. As people invest more in education due to good health, the quality of labor force is improved and this drives economic growth. Parents are more likely to choose low levels of fertility in an environment which records a lower number of child deaths and this tends to reduce the rate at which the population grows improving the demographic dividend and drives growth in GDP per capita (Galor, 2005).

In recent years, the number of people gaining access to electricity in Sub-Saharan Africa (SSA) has increased with 9 million people gaining access between 2000 and 2012 and 26 million more between 2012 and 2015. Access rate, however, is higher in some countries than others; for instance countries like Ghana, South Africa, Gabon, Mauritius, Seychelles, Swaziland, Reunion and Cabo Verde had access rate above 80% while some other countries had access rate below 50% and 25% (IEA, 2017). Despite the increase in electrification rate, the reliance on solid biomass is massive in SSA neglecting its health and environmental implication. About 850 million people in SSA lack access to clean cooking fuel; cooking is mostly done using kerosene, fuel wood, charcoal, agricultural residual and dung which cause indoor pollution. Solid biomass accounts for 60% of the total energy demand in SSA most of which is used by households. It is estimated that in 2030, the number of people without access to clean cooking fuel will grow to 910 million if SSA fails to keep pace with population growth.

Due to increasing population growth, electricity consumption per head is low in SSA countries (IEA, 2017). The world health organization forecasts an increase in the demand for energy in SSA due to its anticipation of an increase in the need for cold storage and vaccines. This is because of the growing need to fight diseases, which require complex interventions that will drive the demand for energy. (WHO & World Bank, 2004). However, the basic health indicators such as life expectancy, infant mortality, under-five mortality among others in SSA according to the world health statistics have been decreasing but at a slower pace. These health indicators such as life expectancy and Infant mortality rate are not only concerned with survival, but also measure the attainment of the ultimate goal of an acceptable level of health for all. According to

WHO an infant mortality rate of 50 per 1000 live births and life expectancy of 60 years are indicators that the health status of the population is becoming less of a burden on the individual, family and community's development (WHO, 2000).

Since 1990, significant progress has been made in reducing child deaths worldwide. The total number of under-five deaths has declined from 12.6 million since 1990 to 5.4 million in 2017 out of which 2.5 million are children who die within their first month of birth. This decline is as a result of a significant reduction in the number of children who die every day due to improvement in health care to children under-five years. This has therefore translated in the drop of the global under-five mortality rate from 58 deaths per 1000 live births in 1990 to 39 deaths per 1000 live births in 2017 (WHO, 2017). Although child mortality rate has been improving across the globe, SSA remains the region with the highest rate of under-five mortality in the world. This is because out of every 13 children born 1 dies before his or her fifth birthday (77 deaths per 1000 live births) which is 4times higher than in high income countries (WHO, 2017). Example, United States recorded 6.1 deaths per 1000 live birth, 4.2 deaths per 1000 live births for United Kingdom, 3.6 deaths per 1000 live births for France, 2.3 deaths per 1000 live births for Japan among others (CDDC/NCHS and OECD, 2014).

The role of electricity is as important as the presence of health practitioners in health care delivery. In that, the proper functioning of the health system as well as the wellbeing of the population is attributed to many factors, but electricity cannot be overlooked as it is one of the determining factors affecting the health system (Mohammadi, 2010). Also Adair-Rohani et al., (2013) asserted that, electricity access is essential in health care delivery as well as the world health organization's goal of universal health coverage.

Also electricity will aid in attaining goal 3 of sustainable development goals which is to ensure healthy lives and promote wellbeing for all at all ages. Health centers which serve as the primary source of health care depend on electricity in providing health services. But sadly, the situation in SSA is not desirable; on average about 34% of hospitals and 28% of health facilities in SSA have reliable access to electricity (WHO and World Bank, 2014). The high rate of health facilities without electricity access leads to loss of almost half of vaccines used in African clinics while 70% of clinical medical devices fail (UNEP, 2017). Electricity is an important part of healthcare system infrastructure therefore its sustainable availability is crucial to public health outcomes (Mohammadi, 2010)

1.2 PROBLEM STATEMENT

There exists an electricity deficit in Sub-Saharan Africa (SSA) in that out of a population of 1.033 billion, about 590 million, representing 57% of the total population lack access to electricity as at 2016, and millions more are connected to an unreliable grid that does not meet their daily energy service needs (World Bank & IEA, 2017). As a result, some of the population complements the consumption of electricity with other unclean forms of energy such as biomass, among others, despite the implication of these energy sources on health and the environmental. The use of candles, kerosene and other polluting fuels for lighting in the absence of electricity together with the use of biomass and coal for cooking (often in an enclosed space without proper ventilation) are responsible for an estimated 2.8 million premature deaths per year worldwide (IEA, 2017).

The world health organization stated that in the absence of power supply, poor homes may resort to unclean energy sources like the use of kerosene and fuel wood which can

cause acute lower respiratory infections and children being burned. This increases child mortality and morbidity (WHO, 2006). These premature deaths and energy related illness could be minimized or avoided if people have access to electricity and there were minimal outages, which allow health facilities to store drugs and households to use cleaner fuels for cooking and proper storage of foods. This underscores the importance of electricity for improvement in health and environmental conditions, and hence the importance of national priority in energy distribution and access as part of efforts to improve health outcomes in SSA.

Some studies have documented the impact of unclean fuels on health outcomes. For instance, Owili et al., (2017) have shown that there is a link between the use of charcoal and biomass for cooking and the risk of under-five mortality in SSA. Samuel et al., (2016) found a significant relationship between cooking fuel type such as wood and under-five mortality rate. Similarly, Naz et al., (2006) reported that household air pollution from polluting cooking fuel is associated with under-five mortality rate.

Despite the burgeoning literature on electricity consumption, most researchers fixed their attention on its impact on economic growth. For example, studies such as Al-Mulali & Sab, (2012), Zhang-wei & Xun-gang (2011), Gupta & Sahu (2009); Odhiambo (2009); Akinlo (2008), Wolde-Rufael, (2006), Jumbe (2004) and Ghosh (2002) studied the causality between electricity consumption and economic growth. Although Youssef et al., (2016), Niu et al., (2013) did their studies on electricity consumption and health, their concentration was mainly on causality between electricity consumption and health outcomes, without providing quantitative estimates of the impact. Besides, the focus of these studies on SSA was limited, despite the health and electricity challenges of the

region. Thus, a good understanding of the effect of the consumption of electricity on health outcomes will help in the planning process of electricity in SSA.

1.3 RESEARCH QUESTIONS

This study seeks to provide answer to the following questions;

1. What is the direction of the effect of electricity consumption on health outcomes in SSA?
2. Does access to electricity affect health outcomes in SSA?
3. What is the relationship between access and consumption of electricity in SSA?

1.5 RESEARCH OBJECTIVES

The study seeks to examine the electricity consumption affects health outcomes in Sub-Saharan Africa.

Specifically the study aims at investigating:

1. The effect of electricity access on health outcomes in SSA.
2. The effect of electricity consumption on health outcomes in SSA
3. The relationship between electricity consumption and access in SSA.

1.6 JUSTIFICATION OF THE STUDY

This study examines the effect of electricity consumption on health outcomes in SSA using panel data regression model. Although the role of electricity in people's lives has been continuously mentioned in various literature, most studies have only examined

whether or not there is an association between electricity and health. However, this work goes a step further to finding the magnitude of the impact of electricity consumption on health outcomes, which has been mostly ignored. By including a one time lag of electricity consumption in the model, the study envisages the relationship between electricity consumption, access and health outcomes not to be instantaneous.

1.7 SCOPE OF THE STUDY

The study uses longitudinal data comprising of yearly observations of 20years for 21 sub-Saharan African countries and 3 health outcomes due to data availability. The dependent variable is health outcomes, measured in this study using infant mortality, under-five mortality and life expectancy at birth. The key variable of interest is electricity consumption as the independent variable. Government expenditure on health, age of the population, education, age of population above 65years and GDP per capita are the control variables.

1.8 BRIEF METHODOLOGY

The study uses secondary data consisting of annual observations sourced from the World Banks's World Development Indicators (2017). The study uses data for the period 1998 to 2017 with a sample of 21 sub-Saharan African countries. Sample is selected across sub-Saharan Africa. The study employs panel data regression in achieving the objectives. The study employs both the Fixed and Random effects models to estimate the quantitative impact of electricity consumption and access on health outcomes. Further,

the study uses the granger causality approach to examine the causal relation between electricity consumption and electricity access in SSA.

1.9 ORGANIZATION OF THE STUDY

The remaining sections of this thesis are organized into four chapters. The second chapter elaborates on previous literature on the subject matter. In this chapter, various articles, publications and theories on the link between electricity consumption and health outcomes are discussed. Chapter three is basically data and various research methods and models used in achieving the objectives of this study. Chapter four focuses on discussing and interpreting results to make meaning from them to arrive at the conclusion. Chapter five provides a summary of the entire research findings to make conclusions and recommendations.



CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, related studies are reviewed and theories underpinning this study are used in explaining various ideas. The chapter begins with a chronological review of theories relevant to this study that are used in investigating the link between electricity consumption and health outcomes. And continues with a discussion of both the history and current issues surrounding electricity situation in SSA over the years. It then proceeds to establish the link between electricity and health. Finally, empirical review of related works is conducted.

2.2 THEORITICAL REVIEW

In this section, the study presents a review of relevant theories that can be used to ascertain the relationship between electricity consumption and health in Sub-Saharan Africa. Michael Grossman in 1972 introduced a theoretical model for determining the health status of a population. Grossman developed the human capital model of demand for health, where he viewed good health as a durable commodity that was desirable and hence it was imperative that high levels of it were achieved. According to Grossman, such a model is important for two reasons, with the first reason being that poor health affects the amount of labor productivity supplied in an economy. Also, he postulates that the underlying reason for an individual's demand for medical services is for good health and not for the services in themselves.

Following Gary S. Becker's household production function model in 1967 and his theory of investment in human capital Grossman developed a health production function. In this production function, Grossman assumed individuals inherited an initial stock of health which depreciates over time with age at an increasing rate; this health stock can be increased by investments in the form of inputs. These direct inputs include individuals own time, medical care, diet and other market goods and services. However, Grossman assumed the level of health in the production function to be endogenous being influenced to some extent by the amount of resources allocated to its production. Grossman's health production function also depended on some environmental factors or variables of which the most important according to Grossman is the level of education of the producer, which he argues has the potential effect on the efficiency of production process of good health.

Following the assumption of the downward sloping demand curve in mainstream economics, Grossman's demand for health function is downward sloping with the quantity of health demanded having an inverse relationship with its shadow price. This shadow price is influenced by many factors of which the price of medical care is one of them. He concludes that an increase in the shadow price may reduce the quantity of health demanded and increase the quantity of medical care demanded, under certain conditions.

Based on the assumptions and framework provided by Grossman, Adam Wagstaff in 1986 formulated a conceptual mechanism through which the interaction of the socioeconomic determinants of health could be analyzed. He developed what looked

more like an introduction to the economic theory of the demand for health where he indicated some areas of possible application. Prior to the writing of his paper, there were growing debates and acceptance of the fact that medical care is just one of the determining factors of health. Wagstaff, therefore, introduced a demand for health approach around three basic economic concepts, the indifference curve which he terms as the welfare contour, the health production function and the budget constraint. The welfare map, just as the indifference map, is a means of diagrammatically representing the assumption that individuals value both health and the consumption of other goods and services in life, but do not place an overriding value on their health.

Also, the health production function shows how individuals produce their health by utilizing health inputs such as nutritious foods, health care, exercise among others. While employing more health inputs resulted in improved health, as more and more health inputs are added to the quantity of health inputs employed, smaller and smaller improvements in health are realized due to the law of diminishing marginal returns. The budget constraint here confirms that the individual has limited resources in the form of income to finance his expenditure on health production and other activities and clearly indicates that health production and other activities come at a cost.

In equilibrium, therefore, an individual will choose the highest possible welfare contour subject to his budget constraint which is financial and his health production function constraint that is the technological constraint facing him. Changes in the income of the consumer shift the budget line which in turn changes the position and shape of the welfare production frontier. Finally, an increase in the state of technical knowledge

results in a reduction in the utilization rate of health inputs but an increase in the demand for health. This is due to the fact that advances in medical sciences results in the efficiency of health production.

This study builds on Wagstaff's introduction of technology or technical efficiency into the health production function to model its health production function with electricity as an input to produce good health outcomes. Technical efficiency can be seen as breakthrough in medical sciences and these are powered by electricity. Also the infiltration of modern means of health care delivery requires electricity for proper functioning as much as illumination of health facilities requires electricity. Since electricity is used together with technology in producing desirable health outcomes in modern day health delivery, the importance of incorporating electricity into these health demand theories to assess the effect of electricity consumption and access on health outcomes needed to be emphasized.

2.3 ELECTRICITY SITUATION IN SSA

Electricity access in sub-Saharan Africa over the years have been increasing but the increase is, however, quite slow. Although many are getting access, there are still some proportions of the population without access. The household electrification rate of 42% in SSA according to the World Bank is the lowest in the world. The total installed capacity in china in 2015 was 1,519 gigawatts, and that of India was 325gigawatts while that of SSA was as low as 96gigawatts. Aside low access rate of electricity in SSA, annual per capita consumption of electricity is low and estimated to be just 4% of electricity consumption per capita in the United States from 2010-2014 (World Bank, 2016). On the

other hand, insufficient installed capacity for generation of electricity, coupled with the inadequate transmission and distribution networks, which leads to losses are the major contributing factors to the energy deficit being faced by the region.

Technological change and innovations have propelled the use of electricity over the past few years. These innovations can be seen in the different types and sources of power generation and the influx of energy appliances that use electricity, thus increasing efficiency of use of electricity. This notwithstanding, consumption of electricity on the other hand has been constrained by interruptions which reduce the amount of electric power consumed by the population with access to electricity; hence SSA records low levels of electricity consumption per capita.

2.4 THE LINK BETWEEN ELECTRICITY AND HEALTH

Over the years, determining factors affecting health outcomes across the globe have undergone some changes. At every point in time various discoveries are made of factors affecting health outcomes in sub-Saharan Africa. In times past, the identified factors were mainly medical and the role of electricity in health was underplayed. However, over the past 25 years the public health community's attention has been drawn to other factors aside medical care that affects health through social policies known as the social determinants of health. The World Health Organization's commission on social determinants of health defines social determinants of health as the conditions in which a person is born, lives and works as well the drivers of these conditions. Social determinants are also linked with health-related features of neighborhoods such as

recreational areas among others that can affect health-related behaviors (Braveman and Gottlieb, 2014).

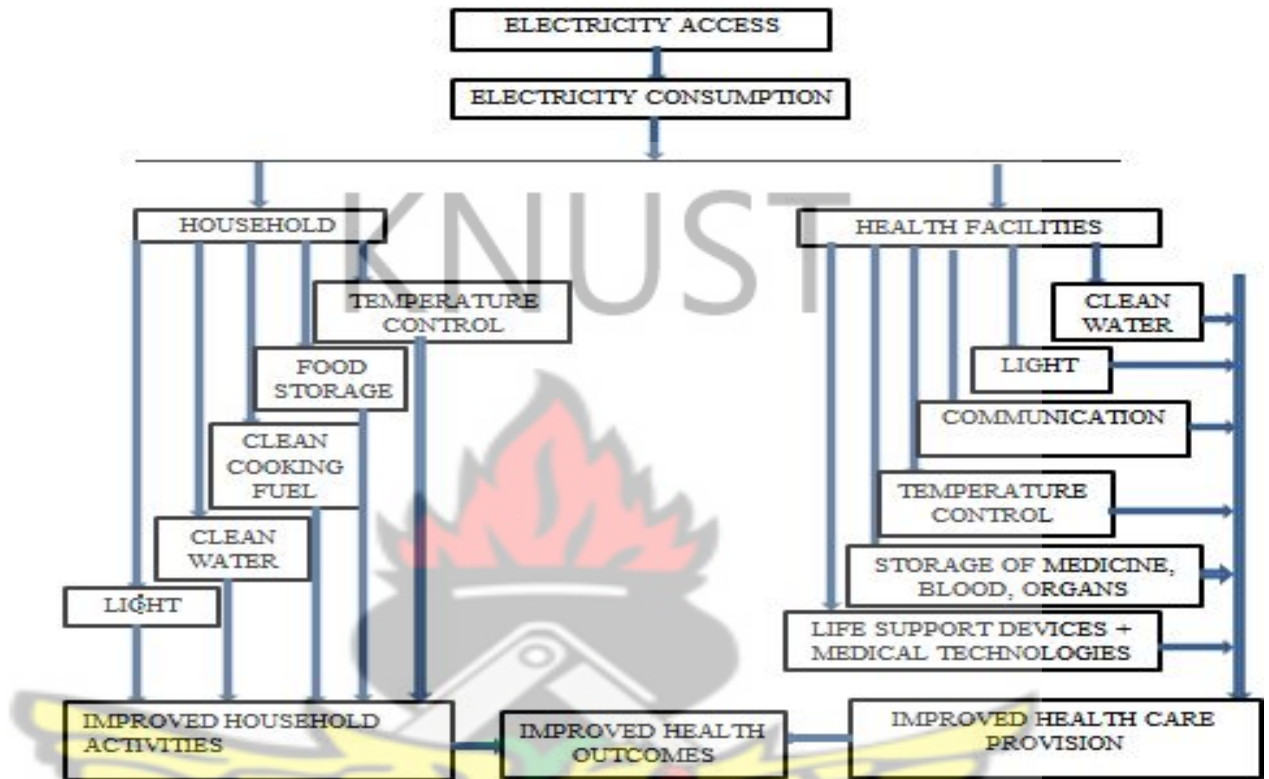
Electricity over the years has been a driver of social determinants of health and determinant of how conditions into which people are born and live affect their health. For instance, electricity in recent times aids in the proper functioning of modern recreation centers, also electricity in the home aids in entertainment and education. This is because after a hard day's work, an individual chooses to watch a favorite program or listen to the news either on television or on radio as a form of relaxation and this is powered by electricity or step out to public places to interact with their social contacts. This helps the individual release stress which is beneficial to health. Burlando (2009) revealed that electricity affects leisure and time use. This is because in the absence of electricity, people returned home earlier than usual and spent fewer hours out in public places, which in turn reduced social interactions in areas with low electricity coverage. Electricity is used to cool most homes in SSA which reduces the risk of contracting heat related diseases.

Also, electricity helps in the informal health education of the public or creation of health awareness through mass communication or other various forms of communication media. This is the fastest way to get information across to a large portion of the population within the shortest possible time to ensure better health outcomes, since individuals have received the knowledge to do so. The rate of return realized from investing in health by increasing in education may outweigh that of investing in health through increased medical care.

Moreover, the introduction of modern technology has become an integral part of everyday lives and in health care delivery, with the introduction of technology in health provision, it has become imperative that the factors affecting health outcomes is revisited and revised to include the role of electricity. Most health facilities and hospitals that assist in the provision of healthcare and have been found to affect health depend on electricity for proper functioning like sanitation, access to safe drinking water, healthy and safe work places, safe houses and communities among others (Constantini and Gracceva, 2004). According to Jorgenson (2004) the inaccessibility of clean water worsens poor sanitation conditions.

A number of experts in development argue that there is much to gain from the spread of electricity. They believe that the benefits of electricity can range from increasing work productivity by using machines powered by electricity, enhancing health services through cold-chain operations for medicines, vaccines and blood, facilitating household investment in education, extending the time students could devote to studying, to improving household health by providing a low pollution alternative to cooking with either charcoal or firewood (World Bank, 2008).

PATHWAYS THROUGH WHICH ELECTRICITY TRANSLATES INTO HEALTH OUTCOMES



The link between electricity and health is not direct therefore, there is the need to have access to electricity first which will in turn lead to consumption of electricity. Consumption on the other hand takes place at both the household level and in health facilities. Electricity improves household activities through its use in the form of lighting to aid movement and household duties at night, for storing of food by use of refrigerators to prevent food spoilage and contamination, providing an alternative and cleaner method of cooking as compared to the use of biomass, for regulating room temperatures by use of heaters, fans, air conditioners among others, by providing a cleaner and source of water for drinking through boreholes and water companies which use electricity for the

processing of water for supply to the population. These help improve the health status of the household.

The use of electricity by health facilities for the cold chain process and refrigerators which helps in the storage of blood, medicine and blood prevents them from going bad. Also life support devices, as well as some medical technologies like scanning, patient monitoring, radiology all use electricity for proper functioning. Information communication technology adopted by health facilities which helps in patient monitoring, keeping of patients records among others depend on electricity for proper functioning. Also electricity helps health facilities access clean water for health care delivery. All these improve the quality of health care provision rendered by health facilities with the presence of electricity and in turn improve health outcomes of the population at large

2.5 TREND OF HEALTH OUTCOMES AND ELECTRICITY IN SSA.

This section presents trends of health outcomes, electricity consumption per capita and electricity access expressed in logarithms for selected Sub-Sahara African countries understudy. The study used data for this study from 1998-2017 to generate the graphs. Here, the behavior of under-five mortality rates, life expectancy at birth, infant mortality, electricity consumption and electricity access for the countries and years under study are examined.

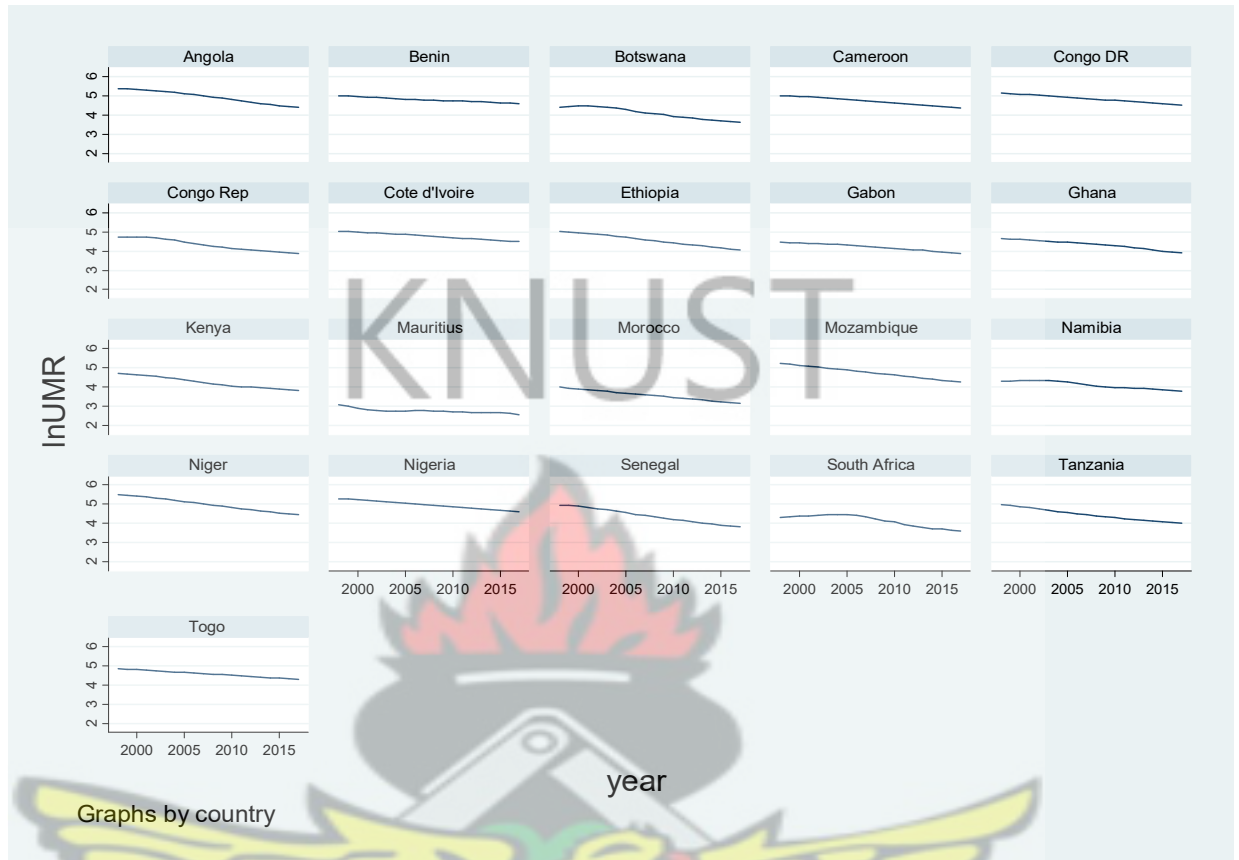


Figure 2. 1 Trend of Under-five mortality rate

Source: Author's computations from STATA

Under-five mortality rates across countries have been falling, because almost all the countries under study started off with high levels of mortality rates for children under five. In recent years most of these countries have seen significant reductions in the levels of under-five mortality although their minimum values are still high compared to global values

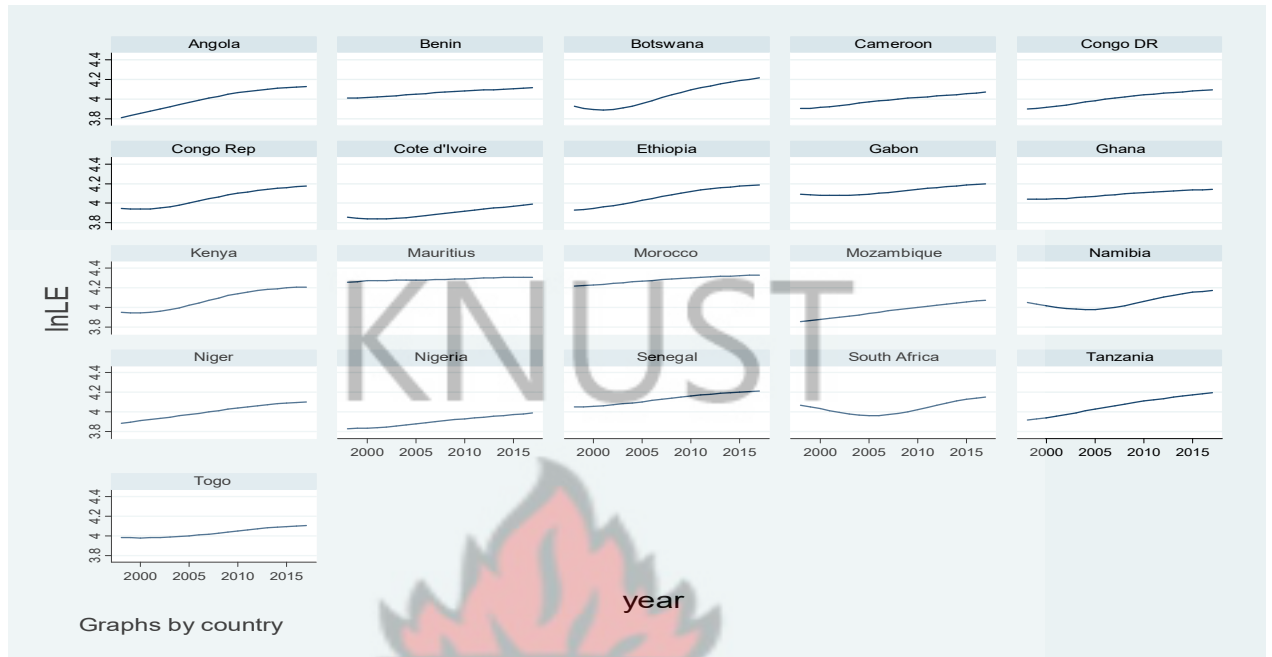


Figure 2. 2 Pattern of Life expectancy at birth

Source: Author's computations from STATA

The patterns of life expectancy at birth have been increasing in recent times. All countries under study except Mauritius and Morocco started with low years of life expectancy at birth but have seen significant increases over the years. South Africa experienced declining years of life expectancy at birth in the early parts of 2000's but increasing years of life expectancy around 2010. Nigeria relatively has lower years of life expectancy at birth.

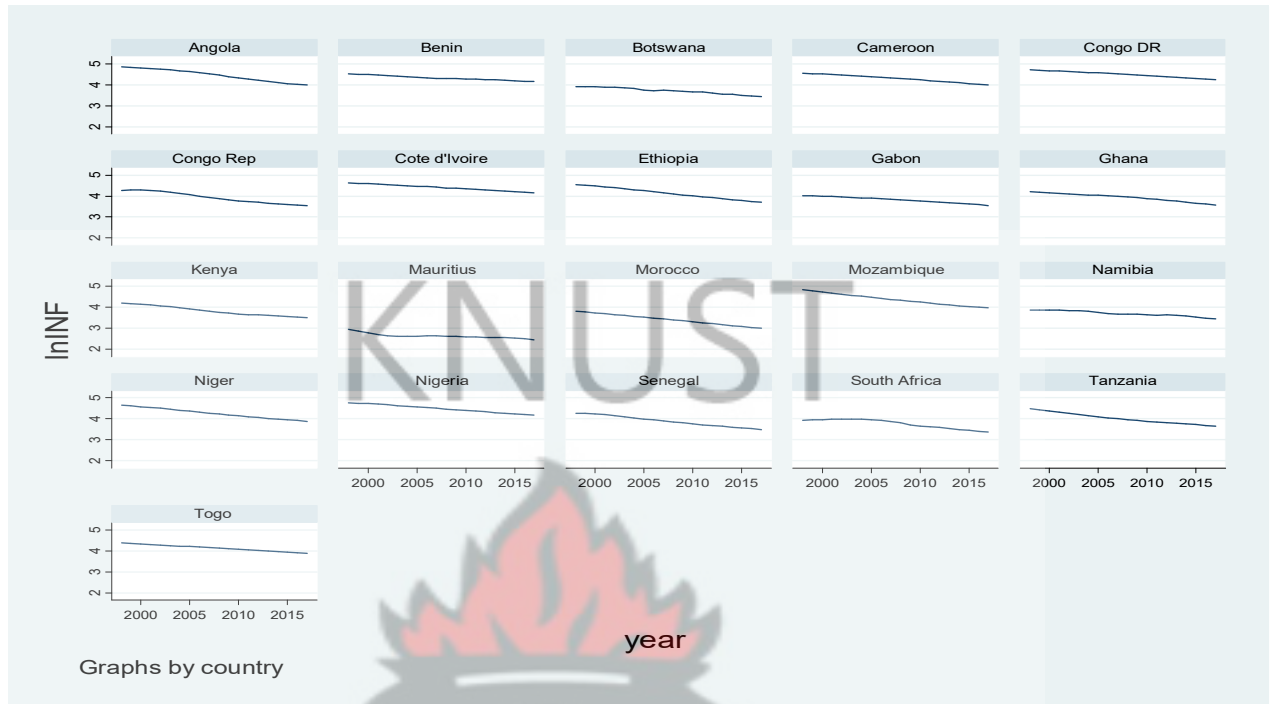


Figure 2.3 *Trend of Infant mortality rate*

Source: Author's computations from STATA

The 21 countries under study in SSA over the years considered for this study have seen general decline in the rates of infant mortality. Despite these declines, the average levels of infant mortality rates for the various countries are still high compared to the global averages even though Mauritius has relatively low infant mortality rates.

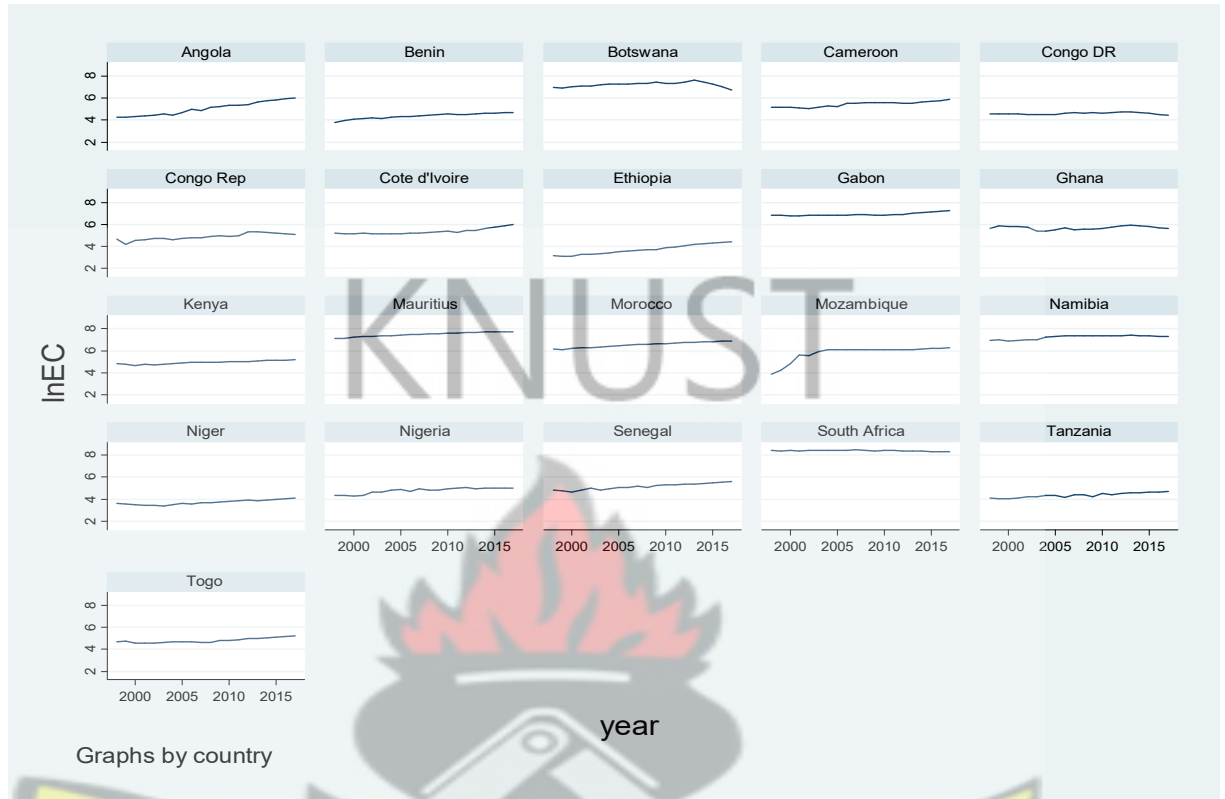


Figure 2. 4 Electricity consumption trend

Source: Author's computations from STATA

Although the path of consumption of electricity in Sub-Saharan Africa has not been smooth over time, countries like Ethiopia, Mauritius and Morocco have had the trend of electricity consumption to be increasing steadily overtime for the period under study. Also Angola, Benin, Cameroon, Cote d'Ivoire, Gabon, Kenya, Mozambique, Niger, Senegal, South Africa and Tanzania electricity consumption pattern although rising seem to see some sharp declines from time to time. However, the consumption trends for the remaining six countries although rising in previous years start to decline in current periods. Some countries have recorded extreme highs characterized by economic boom

and lows as a result of recessions resulting in power outages as well as so many inconsistencies like Ghana, South Africa, Togo and Zambia this has implication on health.

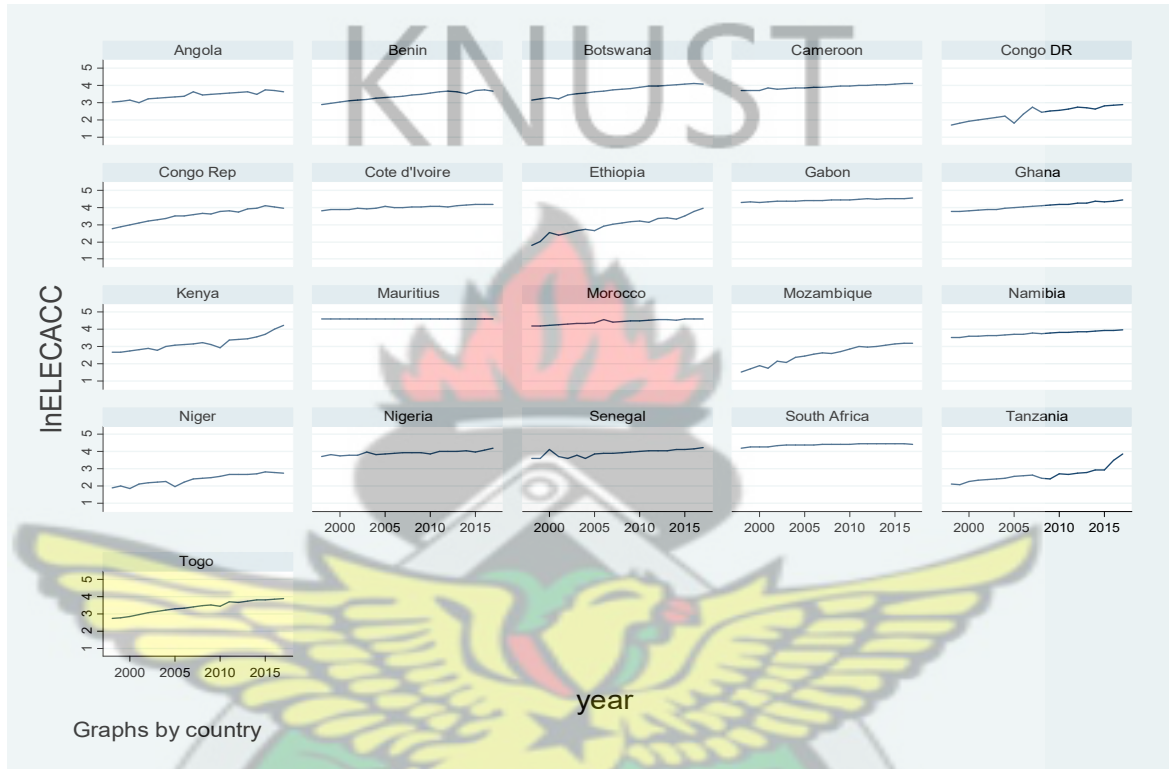


Figure 2. 5 Electricity access trend

Source: Authors computations from STATA.

The trend of electricity access over the study period is generally increasing for all countries in recent times, although almost all countries have had their fair share of ups and downs in past times. Mauritius is one of the countries with the highest proportion of population with access to electricity with an almost constant trend showing access to electricity to be increasing steadily. Democratic republic of Congo has experienced some sharp decline and increase around 2005-2011.

2.6 EMPIRICAL LITERATURE REVIEW

Various empirical studies have found interesting results on electricity and health outcomes over the years using different methods of estimations for instance Novignon and Lawanson (2017) on health expenditure and child health outcomes in SSA over the period 1995-2011 used panel data regression model to estimate the effects of health expenditure on child health outcomes. The study reported the relationship between health expenditure as well as its lags and child health outcomes to be inverse, which has a positive impact. Although both public and private health expenditure were found to be significant, public health expenditure was found to be more significant in explaining this relationship than private health expenditure.

Arthur and Oaikhenan (2017) studied the effects of health expenditure on health outcomes in SSA from 1995-2014. The study employed panel data regression models in assessing this effect. A positive significant but inelastic effect of health expenditure on health outcomes in SSA was reported. The study found public health expenditure to reduce mortality, however, improvement in life expectancy was significantly influenced by private health expenditure.

Owili et al., (2017) analyzed the relationship between cooking fuel and risk of under-five mortality in SSA over the period 2010-2014. Using cox proportional hazard model, the study examined the association between exposure to smoke from cooking fuel and the risk of under-five mortality. The study documented that, children who were exposed to emission from charcoal, biomass and other fuels were at a higher of mortality than those who were exposed to clean cooking fuel. This was only severe for those who had

kitchens in their house than those who had kitchens located outside their homes in separate buildings. The study recorded that, the results were statistically significant before and after controlling for other indicators. Therefore, educating people on health implications of cooking fuel and development of relevant public health policies are likely to have positive impact on child's survival.

Youssef et al., (2016) used bootstrap panel analysis to assess the causal relationship between energy and electricity consumption and health outcomes for 16 African countries over the period 1971-2010. Based on seemingly unrelated regressions and Wald test with country specific bootstrap critical values, the study found unidirectional granger causality from electric power consumption to under-five mortality for seven countries. A positive unidirectional causality between electric power consumption and life expectancy at birth was reported. However, there was no evidence of unidirectional granger causality from health to electric power consumption especially for Benin. Neither was a unidirectional causality from electricity to health reported for Algeria nor a bidirectional for Ethiopia.

Apenteng et al., (2016) in their study on the effect of in-facility mortality in healthcare facilities in Ghana over the period 2007-2011 used a Zero-inflated negative binomial (ZINB) regression model to assess the impact of electricity shortage on mortality. The study revealed that frequent power outage increased the likelihood of reporting at least one in-facility death. Also, frequent power outage was associated with increased risk of mortality. The risk of in-facility mortality increases by 43% for everyday that there is a power shortage for over 2hours. The year variable was also found to be statistically

associated with in-facility mortality. Comparing mortality rates in 2008 and 2007, the study recorded a temporal decline in mortality between these years. This was 20% in 2008, 31% in 2009, 43% in 2010 and 47% in 2011 these were relatively lower compared to 2007.

Alijanzadeh et al., (2016) conducted a study on the correlation between human development index and the rate of infant mortality worldwide across 135 countries over the period of 11 years. They found education and life expectancy in a country to be the leading index of infant mortality rate. The study found Africa to be region with the highest infant mortality rate than any other region in the study with 68 per 1,000 live births.

Adair-Rohani et al., (2013) also conducted a systematic review of data on electricity access, sources and reliability concerning limited electricity access in health facilities in Sub-Saharan Africa from 2001-2012. Using means obtained from summary descriptive statistics, the study reported an average 74% of facilities had access to electricity. 94% of hospital facilities had access to electricity, but 72% of “other” facilities had access to electricity on average across 11 countries in SSA. There is a substantial difference in the extent of electricity access for hospitals compared to other facilities that provide health care.

Kim and Lane (2013) analyzed the effect of government health expenditure and public health outcomes for 17 countries from the Organization for Economic Co-operation and Development within the time frame of 1973-2000. A linear mixed effect model in SPSS was used to measure this effect on a cross-country panel data. The relationship between

government health expenditure and public health outcomes was found to be statistically significant. The study found government health expenditure to have a direct relationship with life expectancy. However, an indirect relationship was identified between government health expenditure and the rate of infant mortality. The study concluded with a suggestion that, if a country seeks measures to improve these two health outcomes, it should consider increasing its public health expenditure as a mechanism to achieve its goals.

Niu et al., (2013) conducted a causality study on electricity consumption and human development as well as the changing trend of electricity consumption for 50 countries from 1990-2009 and found bidirectional causality from electricity consumption to life expectancy at birth in the long-run.

Similarly, Gohlke et al., (2011) in their study on the global public health implications of electricity and coal consumption between 1965 and 2005 for 41 countries worldwide. Used a time series autoregressive model and reported a negative relationship between electricity and health for countries with mid- infant mortality or life expectancy. However, increase in electricity consumption in countries with low infant mortality did not lead to greater health benefits. Electricity consumption leads to a significant reduction in countries with mid infant mortality or low life expectancy.

Burlando (2010) studied on the impact of electricity on work and health following from a month- long black out in Zanzibar an island in Tanzania. The study used ordinary least squares and the instrumental variable approach to assess the impact of electricity outage on work and health. The study recorded a reduction in the income of households in

electricity dependent occupations, and also a reduction in the weight of children who had exposure to the blackout while in their mother's womb was documented which increases the probability of these children having low birth weight.

Fayissa and Gutema (2008) in their study on estimating the health production function for SSA, from 1990-2000 for 31 SSA countries, used the two-way random and fixed effect models and found that, an increase in income per capita, a reduction in illiteracy rate and an increase in food availability have positive and significant association with life expectancy at birth. This was revealed by the two-way random effect model. Wang (2002) on determinants of child mortality in low-income countries employed instrumental variable estimator (IV), fixed effect estimator as it is able to deal with unobservable variables that may affect variables under study and weighted least square estimator, as it helps reduce outliers in data set. Using data for 60 low income countries between 1990 and 1999, the study concluded a significant and robust effect from access to electricity and child health outcomes like infant and under-five mortality.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

The purpose of this study is to unearth the synergy between of electricity and health in Sub-Saharan Africa. The effect of electricity consumption and access to electricity on health outcomes in SSA are examined to assess the magnitude of their impact. This chapter presents a detailed description of the theoretical framework backed by economic theory and goes on to specify the econometric model for estimation. These models aid in achieving the objectives set by this study. Finally, the data used and its source as well as variables used and how they are measured are discussed here.

3.2 THEORITICAL FRAMEWORK

The theoretical framework employed by this study follows a health production function at the macro level developed by Fayissa and Gutema(2008) , based on Grossman (1972) demand for health capital model. The health production function which is specified in equation (1) as;

$$H = F(Y, S, V) \quad (1)$$

Where H measures the health outcomes, Y, S, V are vectors of per capita economic, social and environmental factors which serves as inputs to the health production process. According to Grossman, some of these individual health inputs are in the form of consumption of public goods, nutrients intake, income, education, time devoted to health

related procedures, initial endowments of an individual in the form of genetic makeup, and community endowment such as environment following Fayissa and Gutena(2008).

Equation 1 can be rearranged as;

$$h = f(y_1, y_2, \dots, y_n, s_1, s_2, \dots, s_m, \dots, v_1, v_2, \dots, v_l) \quad (2)$$

Where Y is defined to include $y_1, y_2, \dots, y_n$; S as $s_1, s_2, \dots, s_m$ and V as $v_1, v_2, \dots, v_l$

Subscripts n , m and l are the number of variables in each sub-group in that order.

Equation (2) can be explicitly transformed to equation (3) where

$$h = \Omega \Pi_{yi}^{\alpha_i} \Pi_{si}^{\beta_j} \Pi_{vl}^{\gamma_k} \dots \dots \dots (3)$$

Omega (Ω) in equation 4, estimates the initial stock of health, it measures the health status that would have been observed in the absence of depreciation or improvement in health due to changes in socioeconomic and environmental factors. In a similar manner,

$(\Pi_{yi}^{\alpha_i} \Pi_{si}^{\beta_j} \Pi_{vl}^{\gamma_k} - 1) \times 100\%$ measures the effect of a percentage change in health outcomes due to socioeconomic and environmental factors. Thus in equation (3), $\alpha_i, \beta_j, \gamma_k$ are elasticities. Taking the natural Logarithm of equation (3) yields equation (4)

$$\ln h = \ln \Omega + \sum \alpha_i (\ln y_i) + \sum \beta_j (\ln s_j) + \sum \gamma_k (\ln v_k), \quad (4)$$

Where $i = 1, 2, \dots, n$; $j = 1, 2, \dots, m$; $k = 1, 2, \dots, l$. $\ln(h, y_i, s_j, v_k)$ is the natural logarithm of health outcomes, economic, social and environmental factors respectively as in Fayissa and Gutema (2008)

For the purpose of this empirical analysis, the economic variables here include GDP per capita and general government health expenditure per capita; social factors is represented by education and the total number of population aged 65years and above; variables representing environmental factors are limited to technological factors. The health production function is a function that shows how much health can be obtained from a given quantity of health inputs for a given state of technical knowledge (Wagstaff, 1986). Wagstaff assumed technical knowledge to be variable following breakthroughs in medical science, this technical knowledge he believed resulted from education.

Technical knowledge however is an understanding of modern technology and how it works. Hence changes in the state of technical knowledge, changes the position of the health production function. Improvements in technical knowledge increases health care productivity or efficiency. In the sense that, technology helps in the identification and monitoring of infectious diseases. Clearly wagstaff understood the importance of technology in health production even though the idea was not duly emphasized probably due to the fact that discovery of modern and sophisticated machines for healthcare delivery was still in its infancy at the time. Recently, technical knowledge has increased innovations and developments in health which has resulted in the influx of information technology, computers, and telecommunications into hospitals, gradually changing the phase of the practice of medicine significantly.

The use of technology in healthcare delivery has changed healthcare in enormous ways, it has improved efficiency and quality of care, and made treatment more accessible especially with the replacement of paper records with the electronic health records, where records of vital signs, laboratory results and patients medical history among other

important data are kept in a central digitized system. Technology also improves treatment and diagnosis as well in the area of exploration research through information technology.

Technological progress has changed patients and families experience of health delivery as well as medical processes of health care and practices of health professionals (Banova, 2013). Disease monitoring has been made easy by the rate technological progress as well as formulation of mathematical models for the study of disease dynamics and epidemic prediction (Jones et al., 2008; Weiss and McMichael, 2004; Morse et al., 2012). Up to this time, new mathematical modeling, diagnostic, communication and informatics technologies are able identify and report unknown microbes in other species this can also be used to identify microbes most likely to cause human disease.

Technology is also used in prevention of diseases and research into preventable diseases and outbreaks (Christaki, 2015). Currently the use of information technology or modern technology in medical practice and clinical research has made technology an inextricable part of the health production and hence should be included in the health production function. Therefore, technological advancements have and would decrease mortality rates and increase life expectancy since it aids in finding solution to diseases among others.

However, technology cannot thrive on its own since it is not an end in itself but rather a means to an end. There are factors that drives technology hence mention must be made of energy specifically electricity as an important driver of technology and then health. The use of energy in the production of health has been under rated even though electricity plays an important role in healthcare delivery, as stated by wagstaff (1986) medical care is not usually the major determinant of health care, it is only one of them. Therefore, the

role of electricity in healthcare delivery needs to be emphasized which is what this study seeks to achieve. Electricity is used in radiology and laboratory services for running of tests and scanning and also for Illumination, refrigeration and storage of vaccines, blood among others, sterilization, running water and proper sanitation amenities, patient monitoring among other services. Medical equipment is powered by electricity for proper functioning.

Electricity cannot be used on its own in health care delivery but rather innovations and inventions foster the need and use of electricity in health care delivery it is only by using sophisticated health technology products, equipment and installations, surgical, medical and dental instruments that the importance of electricity can be emphasized. Although the role of technology in the provision of health care have been continuously mentioned by in various literatures, that of electricity has been mostly ignored. Electricity and technology however, work hand in hand in health. For the purpose of this study, technology is represented by the amount of electricity consumed measured by the amount of electric power consumed per capita.

3.3 EMPIRICAL MODEL SPECIFICATION

For the purpose of this research, equations 5, and 6 are specified as a follow up to equation 3. Equations 5 and 6 are models for estimating the effect of electricity consumption and access on health outcomes. In equation 5 and 6 electricity is measured by past levels of electricity consumption and access. The set of controls are kept the same in both equations for the estimations. The equations are models for estimating the effects of explanatory variables on infant mortality, under-5 mortality and life expectancy

respectively. The β coefficients in these models represent elasticities and will be interpreted as, the effect of a percentage (unit) change in the respective predictor variables on health outcomes with the exception of β_{41} and β_{42} . α is the intercept and will be interpreted as the effect of the other explanatory variables on the outcomes variables that have not been explained in these models. The residuals (μ 's) are independently and identically distributed iid's.

$$\ln h_{it} = \alpha + \beta_{11}EC_{it-1} + \beta_{21}\ln GDP_{it} + \beta_{31}\ln GHE_{it} + \beta_{41}AGEPOP_{it} + \beta_{51}\ln Edu + \mu_{it} \quad (5)$$

$$\ln h_{it} = \alpha + \beta_{12}ELECACC_{it-1} + \beta_{22}\ln GDP_{it} + \beta_{32}\ln GHE_{it} + \beta_{42}AGEPOP_{it} + \beta_{52}\ln Edu + \mu_{it} \quad (6)$$

$$EC_{i,t} = \alpha_i + \sum_{k=1}^k \beta_i^{(k)} EC_{i,t-k} + \sum_{k=1}^k \gamma_i^{(k)} ELECACC_{i,t-k} + \varepsilon_{i,t} \quad (7)$$

$$ELECACC_{i,t} = \alpha_i + \sum_{k=1}^k \beta_{it-1}^{(k)} EC_{i,t-k} + \sum_{k=1}^k \gamma_i^{(k)} ELECACC_{i,t-k} + \varepsilon_{i,t} \quad (8)$$

In equations 5 and 6, H is a vector of health outcomes Infant mortality (INF), under-5 mortality (UMR) and life expectancy at birth (LE). EC is electricity consumption, GDP is real gross domestic product per capita, AGEPOP is age of population, GHE is general government health per capita, ELECACC is electricity access and Edu is education. The variables to be estimated in equation 5 and 6 have been transformed into natural logarithms to deal with outliers in the data set. Most health economists often use log models as it deals with skewness, fat tails and heteroscedasticity in the health data Manning and Mullahy (2001). Also, Jones (2000) in his handbook of health economics posited that, most health outcomes data are difficult to handle and hence cannot be easily

analyzed empirically hence they need to be transformed before they can be estimated for analysis.

Equations (7) and (8) are models for estimating causality between electricity consumption and electricity access. There is one-way causality from electricity access to electricity consumption if not all γ_i 's are zero in equation (7) but all the β_i 's are zero in equation (8). However, there is one-way causality between electricity consumption and access if all γ_i 's in equation 7 are zero but not all β_i 's are zero in equation (8). There is two-way causality between electricity consumption and access when all β_i 's and γ_i 's in both equations are not zero. When all β_i 's and γ_i 's in the two equations are zero, there is no causality between electricity consumption and access.

3.4 VARIABLE DESCRIPTION AND MEASUREMENT

This section defines the types of variables employed in this study for both dependent and independent variables and also states the a priori expectations of the relationship between dependent and independent variables.

3.4.1 DEPENDENT VARIABLES

Health outcomes are the dependent variables for this study, it is somehow difficult to measure these outcomes directly and some researchers have suggested life expectancy, infant and under-5 morality as measures of health output. These three indicators, Infant mortality rate which is the number of infants who die before reaching age one per 1,000 live births in a given year, under 5 mortality (per 1000 live births) is the probability that a newborn will die before age five and life expectancy at birth (total years) indicates the

number of years a newborn infant would live if prevailing patterns of mortality at the time of the child's birth were to stay the same throughout his or her life are used as measures of health outcomes for the purpose of this study. The choice of variables follows from Fayissa and Gutema (2008); Youssef et al., (2016); Arthur and Oaiknenan, (2017); Novignon and Lawanson (2017).

3.4.2 INDEPENDENT VARIABLES

The various explanatory variables employed in this study that is electricity consumption, GDP per capita, government health expenditure, education and age of population are discussed below

Electricity Consumption (KWh per capita)

Electricity consumption is an independent variable in this study, it is defined by the amount of electric power consumed (kWh per capita). This is the total electricity consumption divided by the total population for a given year. The amount of electric power consumed measures the production of power plants and combined heat, and power plants less transmission and distribution and transformation losses and own use by heat and power plants. This is similar to electricity consumption used in Youssef et al, (2016). Therefore the study expects that, electricity consumption has a negative relationship with infant and under-five mortality but a positive relationship with Life expectancy at birth.

Government expenditure on health

Government expenditure on health is measured by the domestic general government health expenditure per capita (current US\$). This represents public expenditure on health

from domestic sources per capita expressed in current US\$. Moreover, it is expected that an increase in government expenditure on health will lead to an improvement in health outcomes. An increase in government health expenditure is expected to increase the provision of health facilities and health production inputs like running water and proper sanitation amenities, electricity among others which aids in the provision of proper health care. Also the availability of health facilities will influence health practitioner's decision to live and practice in various places especially the rural areas because they will not be stretched to the limit of their skills. This is expected to improve health outcomes. This is similar to government health expenditure used in Kim and Lane, 2013; Youssef et al., (2016); Arthur and Oaiknenan, (2017); Novignon and Lawanson (2017).

Gross Domestic Product (GDP) per capita

GDP per capita measured in current US\$ proxies for income of the population in this study. Income has been found to have an effect on the demand for health care. The higher a person's income, the more likely that individual will demand for health and this has a positive effect on health status as well as health outcomes. Since most countries in SSA are low income countries, the study expects an inverse relationship between income and infant and under-five mortality but expects a positive relationship between income and life expectancy. As income increases, individuals are able to afford quality health care, a safe environment, healthy diet and move from stressful jobs which may adversely affect their health to less stressful ones. Also, with income increasing, individuals will be able to afford cleaner or modern fuels for cooking and lighting, reducing the risk of indoor pollution, burning among others in children. Although various studies based on the energy ladder hypothesis have come to a conclusion that, households do not completely

move away from the consumption of dirty or traditional cooking fuels but rather energy stack, there will still be a positive impact with an increase in income on health outcomes. The study follows Arthur and Oaiknenan, (2017); Kim and Lane (2013); Fayissa and Gutema (2008) for the choice of the GDP per capita variable.

Age of Population

This study uses the rate of aging population specifically, total number of population aged 65years and above. This is expected to have a positive relationship with life expectancy because as the proportion of older people increases, the length of life also increases. This is the case when the aging population is accompanied by longer periods of health, sustained sense of well-being and extended periods of social engagements and productivity. However, for SSA which is characterized by low income countries, many of the old people are not independent due to limited mobility, frailty therefore the aging population is associated with more illness, disability and dependency due to hardship and poor living conditions as well as poor eating habits. These old people mostly require long term-care and sometimes long-stay in hospitals which are associated with significant costs mostly born by families and sometimes societies. With this, the study expects an inverse relationship between age of population and the various health outcomes. This variable is the same as used in (Kim and Lane, 2013).

Education

Dewey(1922) defined education from the societal perspective as, the process of intentionally engaging the receptive capabilities of a person with knowledge, skills of reasoning, values, socio-emotional awareness and control, and social interaction, so they can grow as engaged, productive, creative and self-governing members of a society.

According to Ross and Wu (1995) education teaches a person to use his or her mind; learning, thinking, reasoning, solving problems, among others are mental exercises that may keep the central nervous system in shape the same way that physical exercise keeps the body in shape.

Education is an important social determinant of health in that, an educated person can work to earn an income or occupational benefit for him or herself, which may enhance his or her capabilities to sustain good health or react to poor health. Educated individuals are likely to select themselves from the most hazardous jobs which may be harmful to their health to less hazardous ones. For instance, a World Bank study in (2012) on SSA reported that, it is more likely for highly educated women to seek and receive prenatal care during pregnancy as well as childhood immunization for their children to increase the chance of survival beyond their fifth birthdays. Although education is understood to take two forms, formal and informal, focus of this study is on formal education measured by enrollment.

Despite education being measured by various studies in different ways such as years of schooling or educational attainment, due to data constraint, it is measured by secondary school enrollment as a percentage of gross enrollments in this study. The study expects education to have a positive impact on health outcomes since it has been found to increase healthy behaviors related to diet and exercise and improve health outcomes. Past studies have found higher educational attainment to positively affect health through healthy dietary habits, health knowledge and higher participation rates in preventive programs like screening exercises among others; this is because individuals are provided with knowledge and the means to practice better habits which leads to better outcomes

against mortality. The study follows Arthur and Oaiknenan, (2017); Novignon and Lawanson (2017); Hahn and Truman (2015); Huang (2015); Chou et al., (2010); Hargreaves et al., (2008); Currie (2008); Fayissa and Gutema (2008); Feinstein et al., (2006) for the choice of education variable.

Electricity Access

This study uses the proportion of population with access to electricity to measure electricity access. Electricity access is expected to improve all health outcomes because the presence of electricity in a community propels developmental projects like the construction of roads, hospitals among others and the provision of social amenities like portable water to mention but a few. Access to electricity also attracts investors and leads to the creation of jobs which in turn increases the employment rate hence people are able to earn income to provide themselves the basic necessities in life such as shelter, food, portable water and seek medical care when the need arises among others. The presence of electricity in a community also attracts qualified and trained medical practitioners which improves the quality of health care delivery and in turn improves health outcomes. Since SSA is characterized by low doctor patient ratio. Therefore, the study expects a positive relationship between access and life expectancy but a negative relationship between access and both under-five and infant mortality rates. This study follows Chowdhury et al., (2010); Wang (2003) for the choice of access variable.

3.5 SOURCE OF DATA

The study uses secondary data consisting of annual observations sourced from the World Bank's World Development Indicators (2017). The study uses data over the period 1998

to 2016 with a sample of 21 sub-Saharan African countries; Angola, Botswana, Benin, Cameroon, Congo Democratic Republic, Congo Republic, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Morocco, Namibia, Nigeria, Niger, Senegal, South Africa, Togo, Tanzania, . Sample is selected due to data availability for all variables needed for this stud. The sample covers the heterogeneity of SSA(north, south, east, west and central) and also covers all the income levels in SSA according to the World Bank classifications (low income, lower middle income and upper middle income countries).

Table 3.1: Classification of countries into income groups

Country	LI	LMI	UMI	Total number of observations
Angola	-	20	-	20
Benin	20	-	-	20
Botswana	-	-	20	20
Cameroon	-	20	-	20
Congo DR	20	-	-	20
Congo Rep	-	20	-	20
Cote d'Ivoire	-	20	-	20
Ethiopia	20	-	-	20
Gabon	-	-	20	20
Ghana	-	20	-	20
Kenya	-	20	-	20
Mauritius	-	-	20	20
Morocco	-	20	-	20
Mozambique	20	-	-	20
Namibia	-	-	20	20
Niger	20	-	-	20
Nigeria	-	20	-	20
Senegal	20	-	-	20
South Africa	-	-	20	20
Tanzania	20	-	-	20
Togo	20	-	-	20
Total number of observations	160	160	100	420

Source: Author's computations from STATA.

First, table 3.1 shows the number of countries categorized under each income group we have, Benin, Congo democratic republic, Ethiopia, Mozambique, Niger, Senegal, Tanzania and Togo under low income countries. For lower middle income countries, we have Angola, Cameroon, Congo republic, Cote d'Ivoire, Ghana, Kenya, Morocco, and Nigeria. Countries such as Botswana, Gabon, Mauritius, Namibia and South Africa fall under upper middle income countries.

3.6 ESTIMATION TECHNIQUE

The study estimates a static panel data model as the preliminary regression; the pooled OLS regression, fixed and random effects and conducts the Hausman test to choose the model that best estimates the effect of electricity consumption on health as well as how electricity shortage affects health. The study then conducts diagnostics checks to tests for the presence of serial correlation, cross sectional dependence, and heteroscedasticity which appears to be problems in macro level data analysis.

First, the pooled OLS regression is estimated using the Ordinary Least Squares regression. This pools all the observations together neglecting the cross sectional and time series nature of the observations. By pooling, the heterogeneity or individuality that may exist among the 25 countries is neglected. The use of the pooled regression is to test for the overall effect of the regression model.

Fixed Effect using the ordinary least square model is estimated. The fixed effect model allows for heterogeneity or individuality among the selected countries in SSA, to have their own intercept value. It removes the effect of time invariant characteristics so the net effect of the explanatory variables on the explained variables can be assessed. These

time-invariant characteristics are unique to individual countries and should not be correlated with other countries.

The study further estimates the Random Effect model, where all selected countries across SSA have one common mean value for an intercept. Random effect assumes variations across entities (countries) to be random and uncorrelated with the explanatory variables in the model. Random effect allows for time-invariant variables to behave as error terms. This complicates the structure of the error terms, hence the use of the Feasible Generalized least square estimator in estimating the random effects model.

Hausman Test

The study continues with the Hausman (1978) specification test to check which model, between fixed effect and random effect is more appropriate for the study. The Hausman test's the null hypothesis that the Random effects model is appropriate against the alternative hypothesis that the fixed effect model is appropriate.

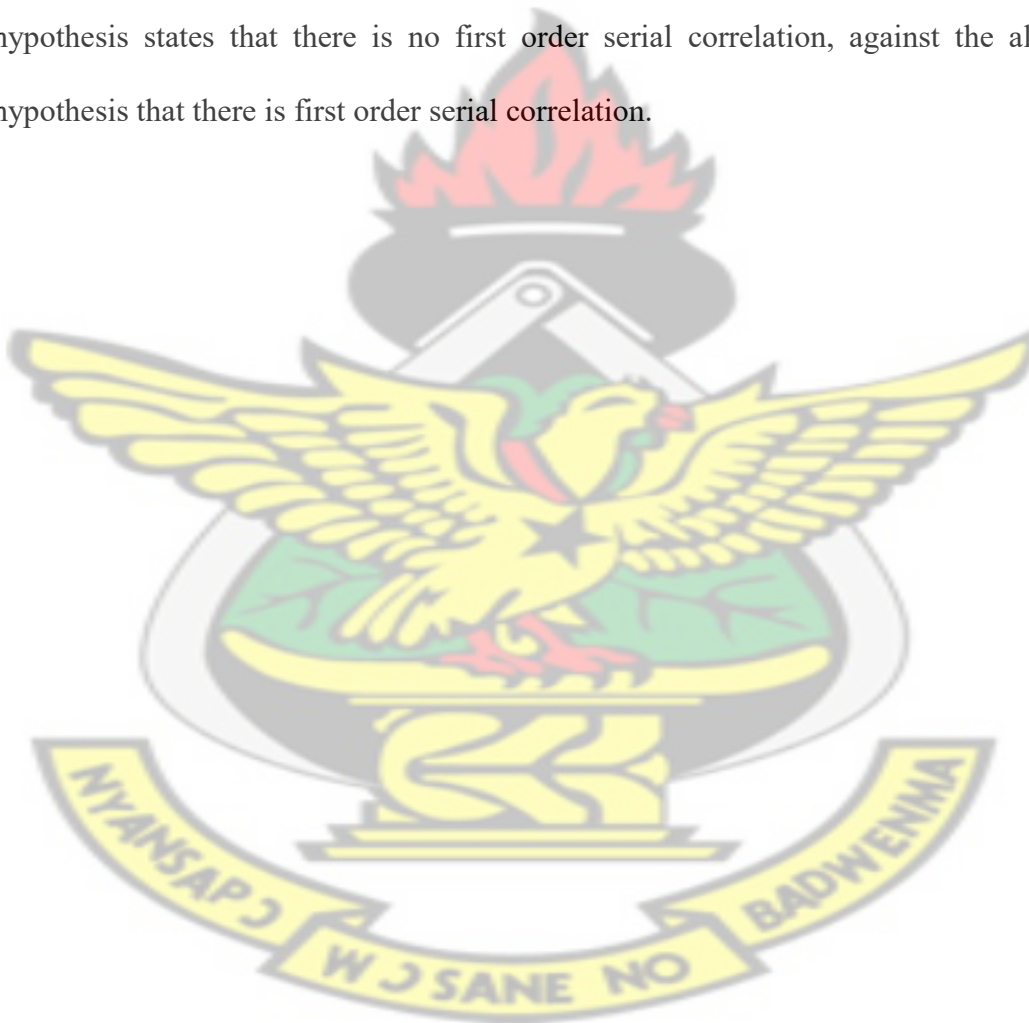
The decision rule is to use fixed effect model if the test value is significant ($p < 0.05$).

3.6.1 DIAGNOSTIC TEST

The study does a series of diagnostic tests as robustness checks, first the study tests for cross sectional dependence serial using Pesaran CD (cross-sectional dependence) test to test whether residuals are correlated across countries, The null hypothesis states that, there is no cross sectional dependence or serial correlation, against the alternative hypothesis that there is cross sectional dependence or serial correlation.

Secondly, the study uses modified Wald test to test for heteroscedasticity among the residuals. The null hypothesis is that the residuals are homoscedastic, against the alternative hypothesis that residuals are heteroscedastic.

Also, serial correlation which seems to be a problem with macro level data is tested for using the Lagrange Multiplier test for serial correction. The presence of serial correlation causes the standard errors of coefficients to be small and high R square. The null hypothesis states that there is no first order serial correlation, against the alternative hypothesis that there is first order serial correlation.



CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, data used for the study is described and results from the regression models are discussed. The chapter is sub divided into four sections. Section 4.2 presents the descriptive statistics of the variables and countries used for the study. Section 4.3 presents the empirical results from the regression models, section 4.4 discusses the empirical results. This helps to examine and understand the empirical relationship between electricity consumption and health outcomes in SSA.

4.2 DESCRIPTIVE STATISTICS

Tables 4.1 to 4.6 present the descriptive statistics on health outcomes as well as explanatory variables in this study. Tables 4.1 reports the descriptive statistics of the dependent variables, while Table 4.2 reports the descriptive statistics on the explanatory variables. The statistics reports the overall mean as well as the spread of the mean within and between countries. Tables 4.3 to 4.6 present the descriptive statistics on the health outcomes and electricity consumption and access according to income groups of countries as used by this study. The panel is balanced with 21 countries from 1998-2017.

Table 4.1: Descriptive Statistics for Dependent and Independent Variables

Variable		Mean	Std. Dev.	Min	Max	Observations
umr	overall	93.77	44.03	13.10	242.80	N = 420
	between		36.64	15.96	152.77	n = 21
	within		25.63	25.50	183.80	T = 20
Inf	overall	60.15	24.41	11.60	127.70	N = 420
	between		21.06	14.10	90.625	n = 21
	within		13.14	24.21	103.20	T = 20
Le	overall	58.11	6.90	45.19	76.07	N = 420
	between		5.85	49.51	72.79	n = 21
	within		3.86	48.49	69.01	T = 20
Ec	overall	622.872	995.875	22.649	4777.059	N = 420
	between		1009.570	41.720	4401.418	n = 21
	within		136.945	22.931	1293.09	T = 20
Edu	overall	47.608	26.268	4.309	111.962	N = 420
	between		24.545	12.635	102.481	n = 21
	within		10.718	14.988	95.951	T = 20
Elecacc	overall	44.342	26.572	4.549	100.414	N = 420
	between		25.693	11.376	98.908	n = 21
	within		8.709	23.226	87.348	T = 20
Ghe	overall	53.333	79.138	0.237	325.175	N = 378
	between		74.391	1.581	223.864	n = 21
	within		31.280	-91.111	177.544	T = 18
agepop	overall	3.548	1.300	2.281	10.945	N = 420
	between		1.269	2.369	7.594	n = 21
	within		0.391	1.751	6.900	T = 20
GDP	overall	2121.362	2408.934	102.645	10716.22	N = 420
	between		2208.968	294.966	7043.374	n = 21
	within		1069.902	-1146.010	5807.973	T = 20

Source: Author's computations from STATA.

On average, the mean values of under-five mortality (umr), infant mortality (inf) and life expectancy at birth (Le) are 93.77 per 1000 live births, 60.15 per 1000 live births and approximately 58 years, respectively. The variability between the means of countries is higher than variations within countries for the three health outcomes.

Electricity consumption (Ec) and electricity access (Elecacc) have mean values of 622.872 kwh/per capita and 44.34% of population respectively. However, variations between the mean values for various countries are more pronounced than variations in means within individual countries. Other predictor variables like education, government health expenditure and age of population all have variations between means to be larger than variations within their means for specific countries. Hence all predictor variables such as government health expenditure, gross domestic product per capita, education and age of population tend to vary with time between countries than they do within a specific country.

Tables 4.3 to 4.5 present descriptive analysis of under-five mortality rate, life expectancy at birth, infant mortality rate and electricity consumption for countries under study classified according to their income distribution that is lower income (LI), lower middle income (LMI) and upper middle income (UMI). Classification is as used by the World Bank in the World development indicators dataset.

Table 4.2: Summary statistics for low income countries in SSA

Variable	Observation	Mean	Std. Dev	Minimum	Maximum
Under-five mortality	160	112.19	37.52	45.40	242.80
Life expectancy	160	57.11	4.67	47.31	67.51
Infant mortality	160	69.60	19.55	32.70	125.40
Electricity consumption	160	125.28	112.30	22.65	462.62

Source: Author's computations from STATA.

From table 4.3, on average the under-five mortality and infant mortality rates are 112.19 and 69.60 per 1000 live births, respectively for low income countries in SSA. These are relatively high as compared to the global averages for under-five and infant mortality rates of 39.10 and 29.4 per 1000 live births, respectively in 2017 according to the World Health Organization. Also, the average life expectancy at birth of 57.11 years for low income countries in this study is below the global average of 72 years in 2016 according to the World Health Organization. The health status of the population in low income countries in SSA, as seen in Table 4.3 is a burden on the population and national development at large, since many growth and development economists like Becker (1996) have identified human capital as one of the engines that drives a nation's growth and development. Similarly, the mean amount of electric power consumed of 125.28 kilowatt hour (kWh) per capita is lower than the reported world electric power consumption of 3,128kWh per capita in 2014 by the World Bank. This could be a contributing factor to the unsatisfactory levels of under-five mortality, life expectancy at birth and infant mortality for low income countries in SSA.

Table 4.3 Summary statistics for lower middle income countries in SSA

Variable	Observation	Mean	Std. Dev	Minimum	Maximum
Under-five mortality	160	99.84	44.77	23.30	215.60
Life expectancy	160	57.15	7.91	45.19	76.07
Infant mortality	160	65.08	25.14	20.00	127.70
Electricity consumption	160	252.24	193.83	66.96	901.13

Source: Author's computations from STATA.

Similarly, the case of lower middle income countries in SSA on under-five and infant mortality rates with averages of 99.84 and 57.15 per 1000 live births respectively is still lower than the reported world average, although these are slightly better than that of low income countries. Life expectancy at birth for this income group on average is approximately 57 years. Also, electricity consumption level of 252.24 Kwh per capita, is higher than that of lower middle income countries but below the global average. In sum health status of population in lower income middle income countries are still not optimal.

Table 4.4: Summary statistics for upper middle income countries in SSA

Variable	Observation	Mean	Std. Dev	Minimum	Maximum
Under-five mortality	100	54.58	23.79	13.10	87.00
Life expectancy	100	61.25	7.28	48.84	74.44
Infant mortality	100	37.16	13.26	11.60	55.80
Electricity consumption	100	2021.36	1262.69	878.06	4777.06

Source: Author's computations from STATA.

Following from Tables 4.3 and 4.4, Table 4.5 has relatively low levels of under-five and infant mortality rates as well as a high level of life expectancy. Out of every 1000 children born in an upper middle income country, approximately 55 and 37 children die either before or at their fifth and first birthdays. These levels however, lower than the situation in low and lower middle income countries, and somewhat closer to the world averages, it cannot be concluded that the health status of the population in upper middle income countries is not a problem. A person born into an upper middle income country in SSA is expected to live up to approximately 61 years on average.

This notwithstanding, on average the amount of electric power consumed by upper middle income countries is higher than that of both low income and lower middle income countries in SSA. Average electric power consumption per capita of 2021.35Kwh per capita is promising as it is closer to the world average of 3128Kwh per capita. The relative high level of electricity consumption could be partly responsible for the observed health outcomes aside the obvious fact that income levels of countries is playing a role here.

4.3 EMPIRICAL RESULTS FROM THE REGRESSION MODELS

This section presents tabulated results from regressions models employed by this study. Tables 4.6 and 4.7 present the regression results of the effect of electricity consumption and access on under-five mortality, life expectancy and infant mortality. The hausman specification test confirmed the estimates of the fixed effect model to be efficient and consistent over the random effects model for all three regressions. Hence results from the fixed effect model are reported and discussed. These models are all significant at the 5% level of significance. The modified Wald statistic for groupwise heteroscedasticity tests found the residuals of the fixed effect model to suffer from heteroscedasticity, hence to deal with this problem, robust standard errors were reported. Although robust standard errors are relatively larger than the conventional standard errors, they provide unbiased standard errors of ordinary least square coefficients in the presence of heteroscedasticity.

4.3.1 Electricity Access and Health Outcomes.

Table 4.7 presents results of access to electricity and health outcomes. Three models are estimated for the impact of electricity access on under-five mortality, life expectancy at

birth and infant mortality, respectively. The relationship between electricity access and health outcomes is not direct and instantaneous. The fixed effect model is reported as deemed suitable by the Hausman specification test. Robust standard errors are reported to purge the fixed effect model of heteroscedasticity. The overall model is significant at 5 percent level of significance. The results indicate that the effect of previous year's access to electricity on current year's under-five mortality rate from model one is negative and significant. This implies that a percentage increase (decrease) in the past electricity access rate is expected to lead to a decrease (increase) in under-five mortality rate by 0.41 percent in the current year.

Table 4.5: Results of electricity access and health outcomes

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Access	-0.411 (0.11)*	0.144 (0.04)*	-0.282 (0.06)**
Gross Domestic Product	-0.165 (0.06)*	0.054 (0.02)*	-0.131 (0.04)*
Government Health Expenditure	-0.022 (0.05)	0.003 (0.01)	-0.024 (0.04)
Education	-0.172 (0.12)	-0.007 (0.04)	-0.185 (0.06)*
Age of population	-0.030 (0.04)	0.001 (0.01)	-0.024 (0.03)
Constant	7.813 (0.32)**	3.176 (0.08)**	6.751 (0.03)**
Sample Size (N)	378	378	378

Robust standard errors in parentheses

* p<0.05; ** p<0.01

Table 4.6: Results of electricity access and health outcomes without South Africa

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Access	-0.419 (0.11)**	0.144 (0.04)**	-0.288 (0.06)**
Gross Domestic Product	-0.181 (0.05)**	0.060 (0.02)**	-0.141 (0.04)**
Government Health Expenditure	-0.003 (0.04)	0.001 (0.01)	-0.012 (0.03)
Education	-0.162 (0.13)	0.011 (0.04)	-0.179 (0.06)*
Age of population	0.005 (0.03)	0.003 (0.01)	0.007 (0.02)
Constant	7.754 (0.32)**	3.186 (0.08)**	6.708 (0.18)**
Sample Size (N)	360	360	360

Robust standard errors in parentheses

* p<0.05; ** p<0.01

The results also indicate that access to electricity has a positive effect on life expectancy at birth in SSA. A percentage increase in electricity access will increase life expectancy by 0.144 percent. Moreover, access to electricity in a previous year has an inverse and significant effect on infant mortality rate. Which implies an increase in electricity access leads to a fall in infant mortality rate. When access rate increases (decreases) by one percent, infant mortality rate is expected to decrease (increase) by 0.282 which is significant at 5%. Increasing access to electricity is likely to reduce dependence on unclean fuel like wood fuel among others for lighting, cooking and others which has repercussions on child health especially infants. Including or excluding South Africa from regression does not change the results much therefore electricity access improves health outcomes in SSA.

4.3.2 Electricity Consumption and Health Outcomes

Hitherto, the study believes the impact of electricity consumption on health outcomes is not instantaneous and direct however, consumption of electricity is translated to health outcomes through some channels. Also, past consumption levels are believed to affect current health outcomes. Therefore a onetime past value of electricity consumption is included in the regression model and the result reported in Table 4.6. All variables, except age of population, are expressed in natural logs to capture the percentage changes in the variables.

Table 4.7: Results of electricity consumption and health outcomes

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Consumption	-0.283 (0.11)*	0.087 (0.03)*	-0.231 (0.07)*
Gross Domestic Product	-0.179 (0.78)*	0.062 (0.03)*	-0.131 (0.05)*
Government Health Expenditure	-0.052 (0.04)	0.013 (0.01)	-0.046 (0.03)
Education	-0.021 (0.14)	0.008 (0.05)	-0.189 (0.08)*
Age of Population	-0.011 (0.56)	-0.005 (0.01)	-0.010 (0.04)
Constant	8.142 (0.42)**	3.084 (0.123)**	7.054 (0.24)**
Sample Size (N)	378	378	378

Robust standard errors in parentheses

* p<0.05; ** p<0.01

Table 4.8: Results of electricity consumption and health outcomes without South Africa

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Consumption	-0.327 (0.11)**	0.093 (0.03)**	-0.262 (0.07)**
Gross Domestic Product	-0.186 (0.08)*	0.067 (0.03)*	-0.135 (0.05)*
Government Health Expenditure	-0.034 (0.03)	0.010 (0.01)	-0.033 (0.02)
Education	-0.175 (0.14)	0.001 (0.05)	-0.172 (0.08)*
Age of population	0.018 (0.03)	0.010 (0.01)	0.010 (0.02)
Constant	8.129 (0.40)**	3.093 (0.12)**	7.037 (0.22)**
Sample Size (N)	360	360	360

Robust standard errors in parentheses

* p<0.05; ** p<0.01

The results indicate that the relationship between past electricity consumption and under-five mortality is negative, indicating higher levels of electricity consumption in previous years lead to a reduction in the rate of under-five mortality in the current year, this effect is significant at 5% which is in line with what the study expected. Which implies an increase (decrease) in previous year's electricity consumption by one percent is expected to cause a decrease (increase) in under-five mortality rate by 0.283 percent.

Similarly, the results indicate that past consumption of electricity has a positive effect on Life Expectancy at birth, as evidenced by the positive and significant coefficient from model 2. This is in line with the a priori expectation of the study. If previous consumption levels of electricity increases (decreases) by one percent, current year's life expectancy at birth is expected to increase (decrease) by 0.081 percent. The study also finds an inverse and significant relationship between electricity consumption and infant mortality rate.

The negative sign means when current electricity consumption levels increases, the probability of a child dying before his or her first birthday in future decreases, significantly at 5 percent. A percentage increase (decrease) in electricity consumption is expected to reduce (increase) infant mortality rate by 0.231 percent, *ceteris paribus*. Given the development of South Africa, with or without its inclusion in the regression the study found results not to differ much therefore consumption of electricity leads to an improvement in health outcomes.

4.4 DISCUSSION OF RESULTS OF ELECTRICITY CONSUMPTION, ACCESS AND HEALTH OUTCOMES

This section presents discussion of results from regressions.

4.4.1 Electricity Consumption, Access and Life Expectancy at Birth

The results indicate that electricity consumption and access have a positive and significant effect on Life Expectancy at Birth (LE). This suggests that both the access to electricity and its consumption contributes to significant increase in life expectancy at birth in SSA. Indeed electricity consumption helps improve sanitation practices like the provision of safe and clean water for drinking as in the case of borehole, drinking safe water reduces the chances of being unhealthy, increases longevity and reduces the probability of being ill and hence, reduces the mortality rate which contributes to improvement in life expectancy at birth. This is particularly important at the household level. Access is also important for households because the availability of electricity in the community will increase the likelihood of the household switching to cleaner fuel use compared to communities without proper access to electricity.

The amount of electric power consumed and access to electricity also increases the quality of health systems and health service provision through the use of information communication technologies like computers to keep records of patients' medical history, vital signs, laboratory results among others and telephones for communication and emergency medical call in. These contribute to improvement in treatment practices, which in turn contributes to the reduction in overall mortality and hence improves life expectancy at birth.

Electricity is also used to power and sterilize medical equipment used for scanning, running of laboratory tests and patient monitoring among others for proper functioning. These medical equipment and patient history helps physicians to diagnose and treat patients which increases life expectancy at birth.

The results are similar to the findings of Youssef et al. (2016) that electricity consumption granger causes life expectancy. Niu et al. (2013) also found a positive long-run bidirectional association between electricity consumption and life expectancy at birth. Gohlke et al. (2011) also found a significant positive effect from electricity consumption to life expectancy. Leung and Meisen, (2005) found a strong association between electricity consumption and life expectancy. Thus, as SSA strives to increase life expectancy in the region, it is important to improve both access and consumption of electricity with the various nations, given the positive and significant effect of electricity consumption on health outcomes recorded in this study.

4.4.2 Electricity Consumption, Access and Infant Mortality

The results also indicate that electricity consumption and access contributes to the reduction in Infant mortality rates in SSA. The possible pathways through which electricity consumption and access can affect infant mortality are the use of electricity for lighting, entertainment, refrigeration of food, cooking among others. When households use electricity to power their bulbs especially in the night, it reduces their dependence on lighting from other unclean and unsafe sources like kerosene, candles among others which can cause burning and morbidity in children. The use of electricity in storing food as opposed to leaving food overnight and consuming it the day after prevents food spoilage and contamination and also reduces the tendency of food poisoning from the consumption of contaminated food and this reduces morbidity leading to a reduction in mortality in infants.

Also electricity as a clean fuel gives a clean alternative for cooking through electric stoves and cookers compared to the use of unclean fuels like biomass for cooking which causes indoor pollution and mortality in infants. Another plausible channel through which electricity consumption and access can affect infant mortality is through health facilities where electricity is used for illumination, communication, cold storage of vaccines, blood and organs among others. The consumption of electricity for illumination by health centers helps medical practitioners to attend to patients at night; this results in the reduction of infant mortality, and perhaps overall mortality rates in SSA.

Through the cold chain system where vaccines are stored and transported at regulated temperatures, electricity is used to prevent spoilage and also blood and organs stay longer and in good shape as they are well refrigerated. Medical surgeries will be conducted in

time to prevent untimely death and also hours of operation will not be longer than usual, which will reduce the rate of infant mortality. Gohlke et al. (2011) found an inverse relationship between electricity consumption and infant mortality for countries with high levels of infant mortality at initial stages. Chowdhury et al., (2010) found access to electricity to have significant effect on infant mortality. Leung and Meisen, (2005) found electricity consumption to be highly correlated with infant mortality. Similarly, Pant (1991) found access to electricity to reduce infant mortality. Wang (2003) found access to electricity to cause a significant reduction in infant mortality.

4.4.3 Electricity Consumption, Access and Under-Five Mortality

Our findings also indicate that electricity consumption contributes to the reduction in Under-five mortality rates in SSA. The possible channels through which consumption and access to electricity can influence under-five mortality rate is that electricity is used in scientific research into prevention, control and cure of an outbreak and emerging disease, hence contributing to the reduction in under-five mortality. Also, the number of health facilities with access to electricity will be increased and therefore health care delivery will be improved especially for areas that were not connected to the grid initially. The presence of electricity will help health facilities operate late into the night and even till daybreak so when there are emergencies at night especially when children who are known to be very vulnerable fall sick at night will not have to wait till the next morning when there is daylight to seek and receive medical care. This reduces the chances of people receiving medical care when their illness is at the late or advance stages thereby reducing mortality in children.

In addition, increasing access rate of electricity especially to areas that did not have

access will attract qualified health practitioners or physicians as it affords them the opportunity to live and practice in such areas. Because they can move their families to places they are posted to or start up families there as the presence of electricity paves way for job creation as well as the provision of some basic social amenities like good roads, clean drinking water, good schools that provide quality education among others that make life comfortable.

Therefore when access rate of electricity is increased the ratio of physicians to patients will improve since retention of medical practitioners especially in places that are connected to the grid is likely to increase. This will reduce the rates of under-five and infant mortality and increase life expectancy because health workers will always be available at health centers to administer medical care at any time of the day. Wang (2003) identified electricity access as a factor that can significantly reduce under-five mortality. Increasing access to electricity is likely to reduce dependence on unclean fuel like wood fuel among others for lighting, cooking and others which has repercussions on child health.

This will in turn help in the transition of households from using unclean traditional fuels to a cleaner one that is electricity as suggested by the energy ladder hypothesis. As shown in the work of Owili et al (2016), indicating that children who belong to households that use unclean fuels for cooking and lighting especially in enclosed kitchen are at higher risk of under-five mortality. Therefore the increased electricity access rate will lead to a reduction of both under-five and infant mortality.

4.4.4 Other Factors That Affect Health Outcomes Gdp Per Capita and Health

Outcomes

As the study expected, GDP per capita has a significant impact on under-five mortality, life expectancy and infant mortality as reported in both Tables 4.6 and 4.7. Therefore from table 4.6 a percentage increase (decrease) in income is expected to cause a decrease (increase) in under-five and infant mortality by 0.179 and 0.131 percent respectively. GDP has a positive effect on life expectancy at birth in that if GDP increases (decreases) by one percent life expectancy is expected to increase (decrease) by 0.062 percent. From table 4.7 however, a percentage increase (decrease) in GDP will cause under-five and infant mortality rates to decrease (increase) by 0.165 and 0.131 respectively. But an increase (decrease) in GDP by a percentage point will increase (decrease) life expectancy by 0.054 percent. The possible implication is that, as people's income increase as a result of a growth in the economy they are able to demand more of normal goods such as quality health care and services which increases their welfare and health. In Sub-Saharan Africa where old age is accompanied by illnesses, therefore individuals with high income levels are more likely to live long since they will be able to afford health care during periods they are unwell to increase longevity. Also, high income levels allow individuals to afford better food or the right nutritional value of food to be consumed by themselves and their families as well. Eating well reduces the chances of being unhealthy thereby reducing mortality and increasing life expectancy. Arthur and Oaiknenan, (2017); Kim and Lane, (2013); Fayissa and Gutema, (2008); Novignon and Lawanson, (2017) also found income to positively affect health outcomes in their studies.

This result is in line with the theory of human capital which postulates that, an individual is able demand for health care or attain a better health status with a higher income level or an increase in income. This can be explained from Grossman's proposition that, a person with higher wage rate tends to place great value on an increase in healthy time. Since this individual is bound to lose the high wage rate he earns when he is unwell he will be willing to pay more for better health care which will increase the quality of health produced for that person.

Additionally, the energy ladder hypothesis identifies electricity as one of the clean modern fuel that households consume with an increase in their income and as a symbol of status. Since, unclean fuel consumption is detrimental to health; the transition from unclean to clean fuel consumption such as electricity as a result of an increase in income is likely to improve health outcomes.

Education and Health outcomes

The study also found a negative and significant relationship between education and infant mortality in Tables 4.6 and 4.7. With this it is anticipated that a percentage increase (decrease) in educational enrollment is expected to increase (decrease) infant mortality by 0.189 and 0.185 percent respectively. Infants who are mostly under the care of their parents depend on them for survival. Since parents are mostly responsible for their feeding, welfare as well as taking health decisions for them. At this tender age, majority of infants depend particularly on mothers for nutrition. Therefore if a mother is educated she will be able to make positive choices which will increase the chances of infants surviving because they will be given their medication in the right dosage and fed with the

right proportion of nutrition they need to be healthy which will in turn reduce the need for health care and its associated costs. Also, educated parents are able to know ways of living healthy as well as afford their children better health care when need be. Some studies like Chowdhury et al. (2010) have found mother's education to reduce infant mortality more than father's education. Similarly, Novignon and Lawanson, (2017) found education to cause a reduction in infant mortality. Maiga (2010), found a strong causal relationship between mothers education and child health. Regidor et al., (1999) found health status to decline with decreasing educational level. Pant (1991) found education of parents and family members to reduce infant mortality.

This result is in line with Grossman's 1972 theory of health demand, which postulates a positive relationship between education and health outcomes; he argued that education increases the efficiency of an individual's investments in health. Hence more educated individuals will tend to choose an optimal stock of health that is high. This result is also similar to what has been found in literature by, (Chou et. al (2010); Hageaves et. al (2008); Braveman and Gottlieb (2004); Ross and Wu (1995); Rogot et. al (1992)) who found education to improve health status this continuously proven significant effect drove Mirowsky and Ross (2003) to come to a strong conclusion that, the influence from education to health is one that is "enduring, persistent and has a growing effect.

However, the study did not find any significant effect from age of population above 65years and government health expenditure to any of the health outcomes under study. Government health expenditure is highly correlated with gross domestic product per capita which could be a possible explanation to the insignificance of government health expenditure on health outcomes in this study.

4.5 RESULTS OF CAUSALITY TEST.

This section presents results of granger non-causality test between electricity consumption and electricity access in SSA. First, the study conducts a stationarity test which is reported in Table 4.8 and then estimates the causal relationship between the two variables by employing Dumitrescu and Hurlin (2012) granger non-causality test and result is reported in Table 4.9 below. The granger non-causality test for heterogeneous panel according to Dumitrescu & Hurlin (2012), is a simple procedure that involves testing for non-causality irrespective of whether or not the variables are integrated or cointegrated, also test statistics have very good sample properties even in the presence of cross-sectional dependence. In order to test for stationarity of electricity consumption and access, this study employed a panel unit root test proposed by Im, Pesaran and shin (2003).

Table 4.7: Results of Im-Pesaran-Shin Unit Root Tests

Electricity Consumption		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-4.450		-1.950	-1.820	-1.750
t-tilde-bar	-2.903				
Z-t-tilde-bar	-9.078	0.0000			
Electricity access					
t-bar	-6.100				
t-tilde-bar	-3.381				
Z-tilde-bar	-11.940	0.0000			

Source: Author's computations from STATA.

From table 4.8, the t-bar statistic of -4.45 is lower than its 5% critical value of -1.82 hence the null hypothesis that all panels contain unit root can be rejected implying stationarity of some panel. The p-value of 0.000 of the Z-t-tilde-bar, further confirms strongly the stationarity of electricity consumption. In addition, at 5% the critical value of

the t-bar rejects the null hypothesis of panel unit root in access to electricity the p-value of the z-t-tilde-bar confirm this. Electricity consumption and access did not attain stationarity at levels but after first difference, they were found to be stationary.

Table 4.8: Results of DH panel causality test between electricity consumption and access in SSA.

Tests	EC $\Rightarrow$ ELECACC	ELECACC $\Rightarrow$ EC
W-bar	3.6165	4.8450
Z -bar	8.4785***	12.4593***
Z –bar tilde	6.2732***	9.3886***

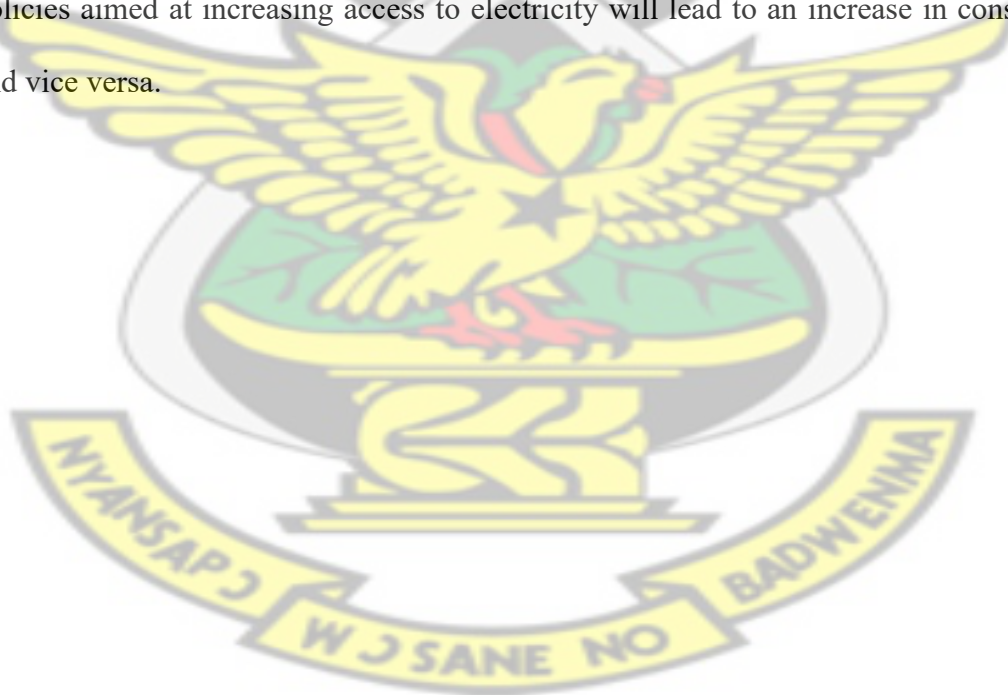
Source: Author’s computations from STATA.

To test the relationship between electricity consumption and access the study employed granger non-causality test for heterogeneous panel data proposed by Dumitrescu & Hurlin (2012). The null hypothesis of granger non-causality from electricity consumption to access and that from electricity access to consumption was rejected in favor of the alternate hypothesis therefore; there exists bidirectional causality between electricity consumption and access. This suggests that there is a feedback relationship between access and consumption of electricity.

The implication of a causal effect from electricity consumption to electricity access in SSA is that provision which leads to access to electricity is demand driven in that, the need for electricity is first identified before access is given sometimes, the population in some situations request to be connected to electricity and based on their need they are given access. A typical example is the Self-Help Electrification program (SHEP) which

was designed to connect communities that want connection to the national electricity grid. First, the communities have to begin electrifying their own township and later receive support from government for early completion of the project. This shows a clear demand driven access to electricity in SSA.

Also, increasing electrification rate increases the availability of electricity to cover areas previously not connected to the grid; since electricity is not an end in itself and more like intermediate good, aside using electricity for lighting, individuals with access to electricity will acquire some appliances to consume there by increasing electricity consumption. Also, an increase in consumption of electricity increases access as well. This bidirectional causality implies increasing one eventually increases the other; hence policies aimed at increasing access to electricity will lead to an increase in consumption and vice versa.



CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION

5.1 SUMMARY OF FINDINGS

The aim of the study was to examine the impact of electricity consumption on health outcomes in SSA. The study used under-five mortality, infant mortality rate and life expectancy at birth as proxy for health outcomes, and electricity consumption per kilowatt hour and electricity access per population as proxy for electricity consumption and access, respectively. The study used the Grossman (1972) model as the theoretical basis and applied the fixed effect model in the estimation of the empirical model. The study also used the im-persaran-shin unit root test and Dumitrescu and Hurlin panel causality test to test for unit root and granger causality between electricity consumption and access in SSA.

The results from the study indicate that Electricity consumption has a negative and significant effect on under-five mortality and infant mortality rate, and a positive effect and significant effect on life expectancy at birth. The study results also indicate that electricity access has a significant effect on all the three health outcomes used for the study. The effect of electricity access on under-five mortality of 0.283 was more pronounced than its effect on life expectancy at birth and infant mortality rate at 0.087 and 0.231 respectively. Finally, the granger non-causality test between electricity consumption and access revealed bidirectional causality between electricity consumption and electricity access. Thus, access granger causes consumption and consumption also granger causes access, hence a bidirectional relationship. This study found a feedback relationship between electricity access and consumption. The possible explanation to a

feedback from consumption of electricity to access is the demand driven nature of electricity in most SSA countries.

5.2 CONCLUSION

The declining health status in SSA that has translated into higher levels of mortality for both under-five and infant and low levels of life expectancy at birth below global averages coupled with chronic energy deficit that besets Sub-Saharan Africa, due to the low rate of access to electricity by the population, accompanied by low levels of consumption of electricity as compared to other African and European countries have serious implications on health of the population given the importance of electricity in health care delivery and in daily lives as well. Although policies have been put in place to address this problem, improvement in the situation is not satisfactory. The presence of electricity is continuously interrupted which denies those with access continuous flow of electric power for consumption, therefore restricting their opportunities. This is because continuous and uninterrupted flow of power is essential especially for the health sector.

Under-five and infant mortality rates of the 21 countries understudy revealed that a minimum of 54 and maximum of 112 children out of every 1000 live births are likely to die before their fifth birthday. This is relatively higher than that of the WHO's indication of improved health status of a population measured by a maximum of 50 deaths per 1000 live births. Generally, the trend in electricity consumption per capita and access have not been smooth over time. Recently, more people do not have access to electricity accounting for about 57% of population and many more are connected to unreliable sources. Low levels of electricity consumption and access have been recorded in SSA.

These challenges and more motivated this study to investigate the effect of electricity consumption and access on health outcomes in SSA.

In order to examine this relationship, the study adopted the health production function by Grossman (1972) to examine the impact of electricity consumption and access on health outcomes. The study employed secondary data sourced from the World Bank's World Development Indicators and used panel data models to estimate the effect. Hausman specification test was used and the fixed effect model was found to provide more appropriate estimates. The descriptive statistics showed higher variability in the means between countries than within countries for both dependent and independent variables and this shows how countries together contribute differently to health outcomes in SSA. Also, health outcomes for upper-middle income countries was found to be better compared to low income and lower middle income countries, but falls below the acceptable levels of the WHO.

The findings from the fixed effect model indicate that, electricity consumption has a negative and significant effect on under-five and infant mortality and a positive and significance effect on life expectancy at birth. These are significant at the 5% level. In addition, the results indicate that access to electricity has a negative effect on infant and under-five mortality rates in SSA, significant at the 5% level. Also, access to electricity has a positive effect on life expectancy at birth, significant at 5%. These imply that the consumption and access to electricity leads to a fall in infant and under-five mortality and contributes to increases in life expectancy at birth in SSA. These are probably due to the ability to use cleaner fuels for household use as a result of access to electricity and the ability of health systems to function well due to the presence of electricity.

5.3 RECOMMENDATIONS

Firstly, results of this study have shown that electricity consumption has a significant effect on health outcomes in SSA, especially life expectancy and infant mortality rate. However, the region is characterized by low levels of total electric power consumption per capita, inadequate reliable and affordable electricity. This can be attributed to high rates of technical, transmission and distribution losses coupled with low rate of total installed capacity as underlying factors. Therefore policy makers in SSA should aim at reducing tariffs levied on electricity so as to ensure higher consumption levels per capita in order to improve health outcomes. So as to help in the achievement of goal 3 of the sustainable development goals which aims at ensuring healthy lives and promoting wellbeing for all at all ages.

Additionally, access to electricity has also been found to significantly improve all health outcomes used in this study. Although some countries have achieved high electrification rate, access rate for other countries is low. Therefore SSA countries should tighten policies aimed at increasing access to electricity now in order to realize desirable levels of health outcomes in future. This will also help SSA countries to contribute their quota into achieving sustainable development goal 7 of ensuring access to modern, affordable, reliable and clean energy for all.

Finally, the results indicate that GDP per capita and education positively influences health outcomes in SSA. Therefore countries in SSA should pay much attention to increasing GDP per capita as it is an indicator of income level, standard of living and measures welfare of population as well. This probably can be done through policies aimed at improving output in the region and creating employment to enhance incomes. In

addition, given the significance of education, SSA should invest in educational policies to ensure that a greater percentage of the population have access to good education as this enhances health outcomes in the region.

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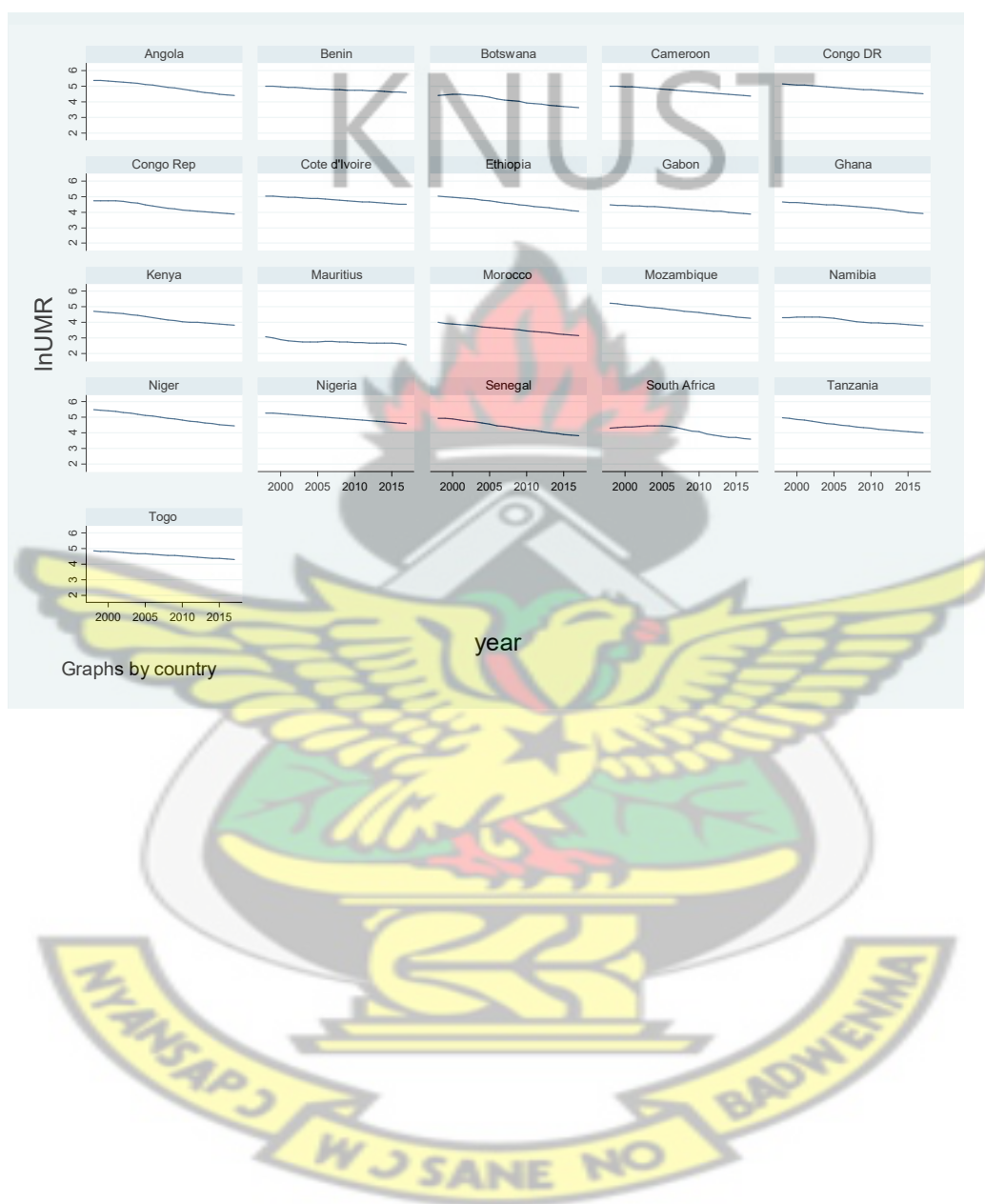
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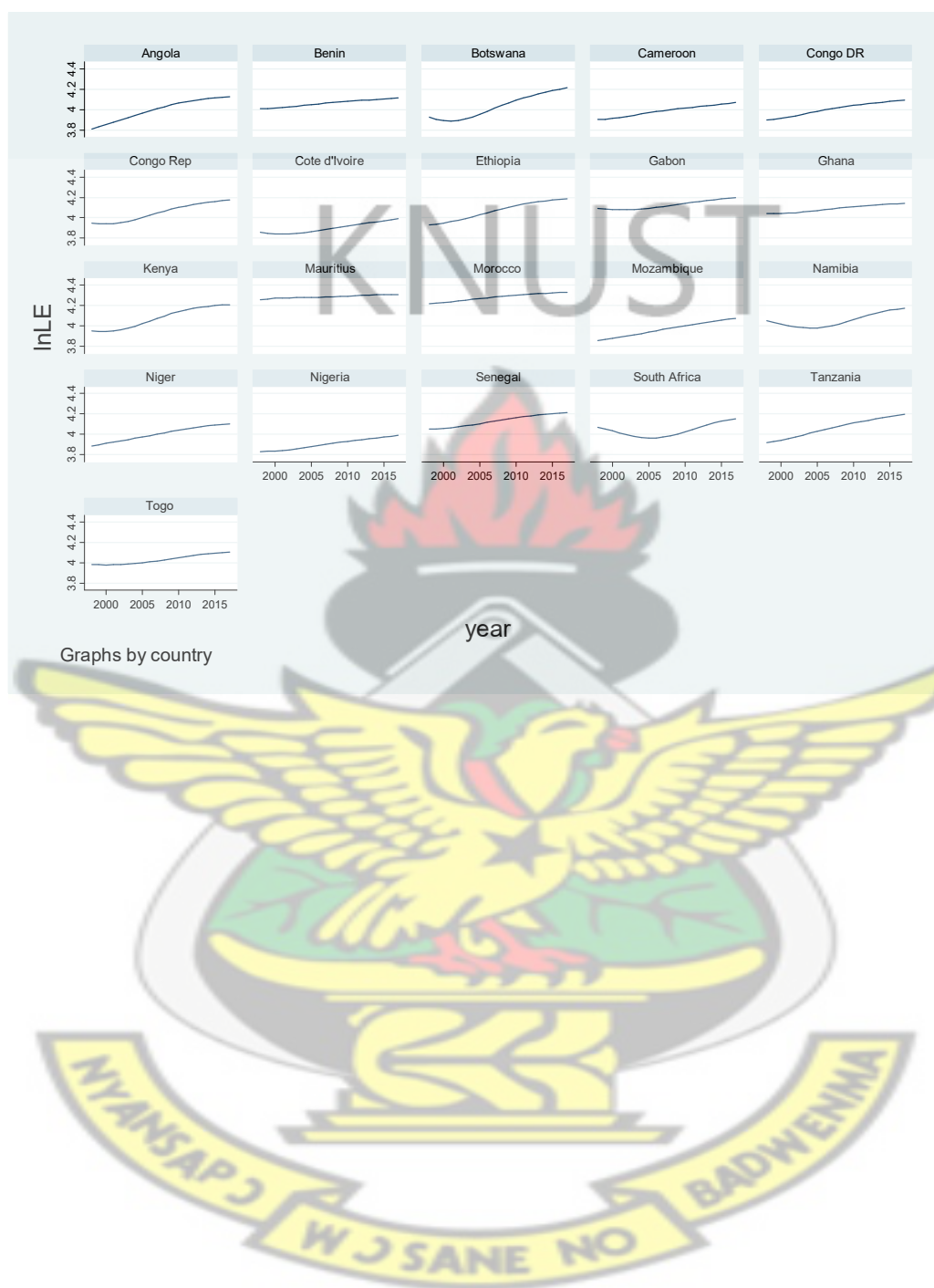
APPENDICES

APPENDIX A

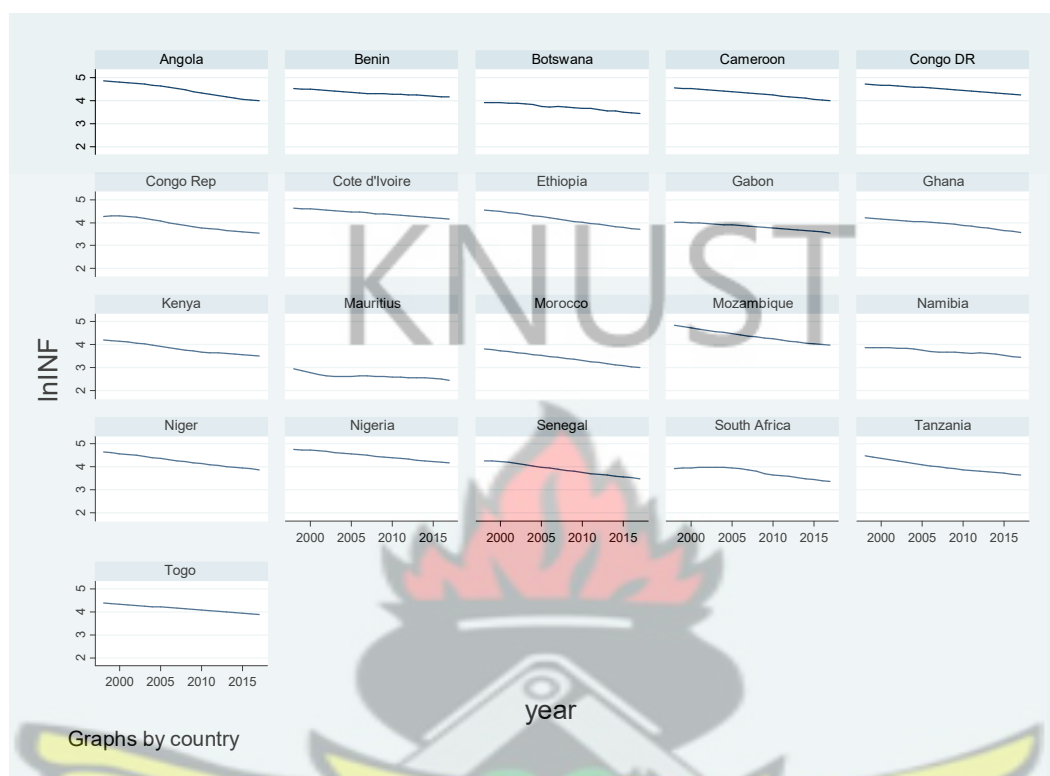
Trend of under-five mortality



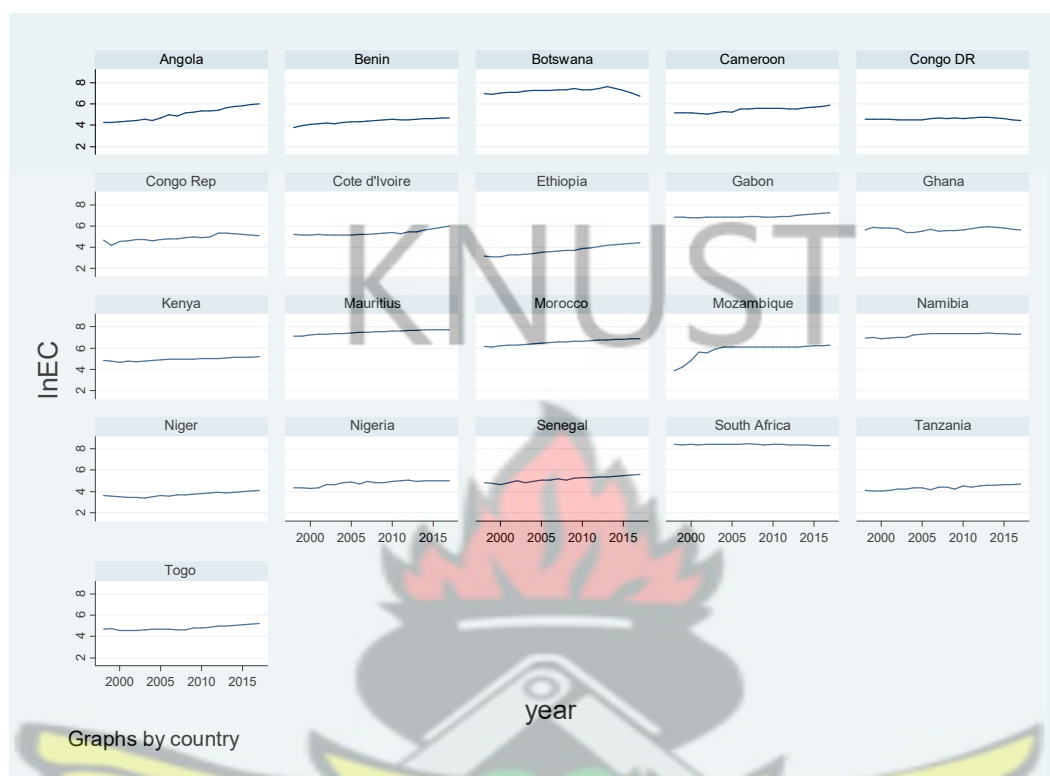
Trend of life expectancy at birth



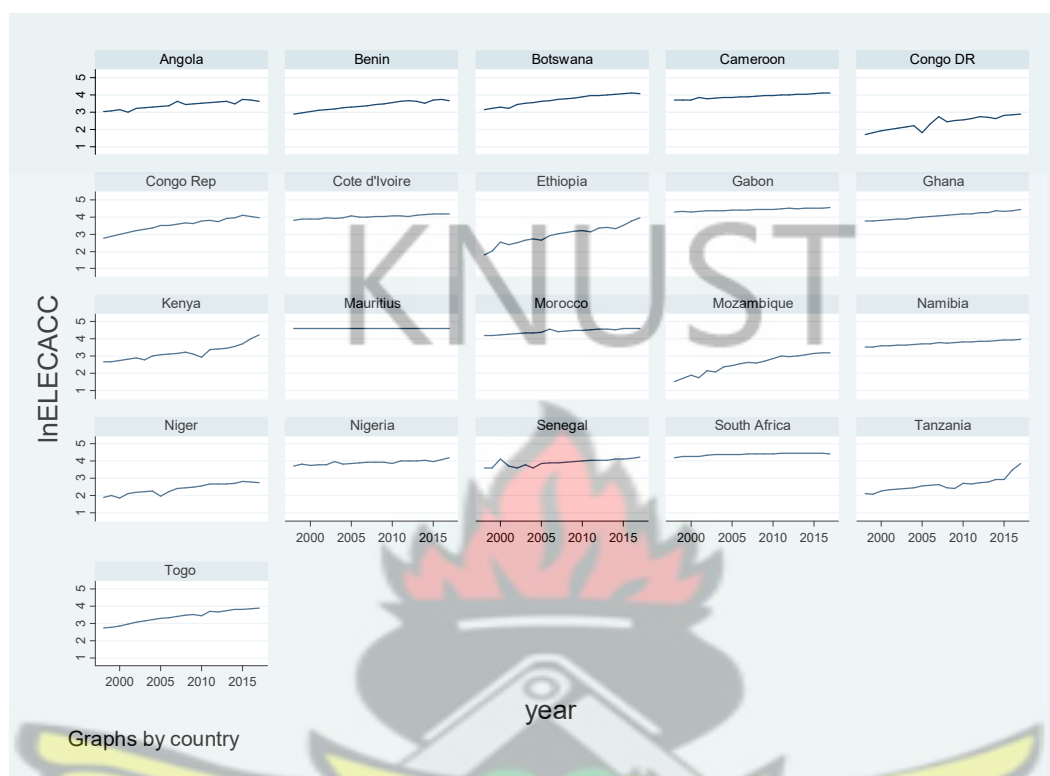
Trend of infant mortality



Trend of electricity consumption



Trend of electricity access



APPENDIX B

SUMMARY STATISTICS FOR LOW INCOME COUNTRIES IN SSA.

Variable	Obs	Mean	Std. Dev.	Min	Max
UMR	160	112.1881	37.51992	45.4	242.8
LE	160	57.11174	4.670787	47.309	67.50801
INF	160	69.60188	19.54602	32.7	125.4
EC	160	127.9903	116.7317	22.64894	542.071
ELECACC	160	23.40545	15.27251	4.548946	68.5

SUMMARY STATISTICS FOR LOWER MIDDLE INCOME COUNTRIES IN SSA

Variable	Observation	Mean	Std. Dev	Minimum	Maximum
Under-five mortality	160	99.84	44.77	23.30	215.60
Life expectancy	160	57.15	7.91	45.19	76.07
Infant mortality	160	65.08	25.14	20.00	127.70
Electricity consumption	160	252.24	193.83	66.96	901.13
ELECACC	160				

SUMMARY STATISTICS FOR UPPER MIDDLE INCOME COUNTRIES IN SSA

Variable	Obs	Mean	Std. Dev.	Min	Max
UMR	100	54.583	23.79402	13.1	87
LE	100	61.25174	7.281379	48.838	74.43658
INF	100	37.158	13.25982	11.6	55.8
EC	100	2000.249	1258.388	812.6633	4777.059
ELECACC	100	69.40134	23.88057	23.1744	99.41197

SUMMARY STATISTICS FOR DEPENDENT VARIABLES

Variable		Mean	Std. Dev.	Min	Max	
Observations						
umr	overall	93.42095	43.8499	13.1	242.8	N = 420
	between		36.4103	15.96	152.77	n = 21
	within		25.63629	25.15095	183.451	T = 20
Inf	overall	60.15357	24.41216	11.6	127.7	N = 420
	between		21.05743	14.095	90.625	n = 21
	within		13.13946	24.20857	103.1986	T = 20
Le	overall	58.11281	6.900699	45.192	76.069	N = 420
	between		5.85122	49.5111	72.78717	n = 21
	within		3.864632	48.48811	69.0143	T = 20

SUMMARY STATISTICS FOR INDEPENDENT VARIABLES

Variable		Mean	Std. Dev.	Min	Max	Observations
Ec	overall	622.8725	995.8748	22.64894	4777.059	N = 420
	between		1009.57	41.72044	4401.418	n = 21
	within		136.9448	22.93081	1293.09	T = 20
Edu	overall	47.60836	26.26806	4.308671	111.9622	N = 420
	between		24.54496	12.63461	102.4815	n = 21
	within		10.71797	14.98784	95.95134	T = 20
Elecacc	overall	44.34223	26.57163	4.548946	100.414	N = 420
	between		25.69333	11.37651	98.90833	n = 21
	within		8.70858	23.22652	87.34792	T = 20
Ghe	overall	53.33327	79.13832	0.2366008	325.1745	N = 420
	between		74.39083	1.580936	223.864	n = 21
	within		31.27975	-91.11076	177.5437	T = 20
agepop	overall	3.548489	1.300006	2.280596	10.94537	N = 420
	between		1.268964	2.369295	7.593555	n = 21
	within		0.3908523	1.75138	6.900302	T = 20
GDP	overall	2121.362	2408.934	102.6448	10716.22	N = 420
	between		2208.968	294.9656	7043.374	n = 21
	within		1069.902	-1146.01	5807.973	T = 20

APPENDIX C

Pooled OLS regression results for electricity consumption and;

Under-five mortality

Source	SS	df	MS	Number of obs = 378		
Model	91.7931584	5	18.3586317	F(5, 372) =	263.94	
Residual	25.8750667	372	.069556631	Prob > F =	0.0000	
				R-squared =	0.7801	
				Adj R-squared =	0.7771	
Total	117.668225	377	.312117308	Root MSE =	.26374	

lnUMR	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC						
L1.	.0777287	.022197	3.50	0.001	.0340813	.1213761
lnGDP	.0995794	.0338951	2.94	0.004	.0329293	.1662295
lnGHE	-.1562883	.024178	-6.46	0.000	-.203831	-.1087456
lnEdu	-.3587763	.0308724	-11.62	0.000	-.4194827	-.29807
AGEPOP	-.259704	.0134264	-19.34	0.000	-.286105	-.2333029
_cons	5.938639	.1672973	35.50	0.000	5.609672	6.267606

Life expectancy at birth

Source	SS	df	MS	Number of obs = 378		
Model	2.52818582	5	.505637164	F(5, 372) =	82.05	
Residual	2.29253738	372	.006162735	Prob > F =	0.0000	
				R-squared =	0.5244	
				Adj R-squared =	0.5180	
Total	4.8207232	377	.012787064	Root MSE =	.0785	

lnLE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC						
L1.	-.0502157	.0066071	-7.60	0.000	-.0632077	-.0372237
lnGDP	-.0116241	.0100892	-1.15	0.250	-.031463	.0082149
lnGHE	.034839	.0071968	4.84	0.000	.0206875	.0489904
lnEdu	.0594032	.0091894	6.46	0.000	.0413334	.0774729
AGEPOP	.0573959	.0039965	14.36	0.000	.0495374	.0652544
_cons	3.899088	.0497974	78.30	0.000	3.801168	3.997008

Std. Err.	t	P> t	[95% Conf. In
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Std. Err.	t	P> t	[95% Conf. In
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Std. Err.	t	P> t	[95% Conf. Interval]	
.040026	-7.08	0.000	-.3619308	-.2044905
.0293599	-6.09	0.000	-.2364204	-.1209348
.0195718	-2.65	0.008	-.0903022	-.0133176
.034555	-5.81	0.000	-.268661	-.1327405
.0176896	-0.63	0.532	-.0458519	.0237292
.162621	50.07	0.000	7.822972	8.462634

254

Std. Err.	t	P> t	[95% Conf. Interval]	
.040026	-7.08	0.000	-.3619308	-.2044905
.0293599	-6.09	0.000	-.2364204	-.1209348
.0195718	-2.65	0.008	-.0903022	-.0133176
.034555	-5.81	0.000	-.268661	-.1327405
.0176896	-0.63	0.532	-.0458519	.0237292
.162621	50.07	0.000	7.822972	8.462634

Std. Err.	t	P> t	[95% Conf. Interval]	
.040026	-7.08	0.000	-.3619308	-.2044905
.0293599	-6.09	0.000	-.2364204	-.1209348
.0195718	-2.65	0.008	-.0903022	-.0133176
.034555	-5.81	0.000	-.268661	-.1327405
.0176896	-0.63	0.532	-.0458519	.0237292
.162621	50.07	0.000	7.822972	8.462634

Std. Err.	t	P> t	[95% Conf. Interval]	
.040026	-7.08	0.000	-.3619308	-.2044905
.0293599	-6.09	0.000	-.2364204	-.1209348
.0195718	-2.65	0.008	-.0903022	-.0133176
.034555	-5.81	0.000	-.268661	-.1327405
.0176896	-0.63	0.532	-.0458519	.0237292
.162621	50.07	0.000	7.822972	8.462634

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Number of g
Obs per gro
Wald chi2(5
Prob > chi2

.0332847	-3.66	0.000	-.
.0310013	-6.33	0.000	-
.0209422	-1.45	0.147	-.
.0348179	-8.23	0.000	-.
.0178291	-2.39	0.017	-.
.1637919	47.27	0.000	7

(fraction of variance due to $u_{\text{...}}$)

WJSAFE NO

Hausman specification test

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
	(b) fe	(B) re		
L.lnEC	-.2832107	-.1217176	-.1614931	.0300062
lnGDP	-.1786776	-.1962416	.017564	.0109297
lnGHE	-.0518099	-.0303728	-.0214371	.0064493
lnEdu	-.2007008	-.2863953	.0856946	.0168665
AGEPOP	-.0110613	-.0426212	.0315599	.0086241

b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
 = 79.23
 Prob>chi2 = 0.0000

Fixed effect with robust standard errors

Fixed-effects (within) regression
 Group variable: countrysum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.7479
 between = 0.5091
 overall = 0.5249

Obs per group: min = 18
 avg = 18.0
 max = 18

F(5,20) = 34.94
 Prob > F = 0.0000

corr(u_i, Xb) = -0.6443

(Std. Err. adjusted for 21 clusters in countrysum)

	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lnUMR						
lnEC						
L1.	-.2832107	.1078765	-2.63	0.016	-.5082371	-.0581843
lnGDP	-.1786776	.0777397	-2.30	0.032	-.3408398	-.0165154
lnGHE	-.0518099	.0355562	-1.46	0.161	-.1259787	.022359
lnEdu	-.2007008	.1426529	-1.41	0.175	-.4982694	.0968679
AGEPOP	-.0110613	.0563461	-0.20	0.846	-.1285973	.1064747
_cons	8.142803	.4168091	19.54	0.000	7.273355	9.012252
sigma_u	.4896574					
sigma_e	.12408715					
rho	.93965551	(fraction of variance due to u_i)				

Electricity consumption and Life expectancy at birth

Fixed effect

Fixed-effects (within) regression
 Group variable: countrysnum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.6878
 between = 0.1216
 overall = 0.1639

Obs per group: min = 18
 avg = 18.0
 max = 18

F(5,352) = 155.10
 Prob > F = 0.0000

corr(u_i, Xb) = -0.8353

lnLE	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC						
L1.	.0874109	.0118752	7.36	0.000	.0640556	.1107661
lnGDP	.062385	.0087107	7.16	0.000	.0452534	.0795165
lnGHE	.0131617	.0058067	2.27	0.024	.0017415	.0245819
lnEdu	.0081849	.010252	0.80	0.425	-.0119781	.0283478
AGEPOP	-.0047846	.0052483	-0.91	0.363	-.0151066	.0055373
_cons	3.084656	.0482476	63.93	0.000	2.989766	3.179546
sigma_u	.18073084					
sigma_e	.0368151					
rho	.96015898	(fraction of variance due to u_i)				

F test that all u_i=0: F(20, 352) = 66.97 Prob > F = 0.0000

Heteroskedasticity test

Modified Wald test for groupwise heteroscedasticity in fixed effect regression model

H0: $\sigma(i)^2 = \sigma^2$ for all i

chi2 (21) = 11149.99

Prob>chi2 = 0.0000

	Wald	chi2(5)	Prob > chi2
Std. Err.	z	P> z	[95% C

```
Number of obs      =      378
Number of groups   =       21
```

```
Obs per group: min =      18
               avg =     18.0
               max =      18
```

```
Wald chi2(5) = 490.03
Prob > chi2 = 0.0000
```

lnLE	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnEC						
L1.	.0116024	.0101149	1.15	0.251	-.0082225	.0314272
lnGDP	.0737973	.0096511	7.65	0.000	.0548816	.0927131
lnGHE	.0030699	.0065277	0.47	0.638	-.0097241	.0158639
lnEdu	.0447276	.0107831	4.15	0.000	.0235931	.065862
AGEPOP	.0016937	.0055071	0.31	0.758	-.0091001	.0124875
_cons	3.293273	.0504467	65.28	0.000	3.194399	3.392147
sigma_u	.04728302					
sigma_e	.0368151					
rho	.62257363	(fraction of variance due to u_i)				

Hausman specification test

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	$\sqrt{\text{diag}(V_b - V_B)}$ S.E.
L.lnEC	.0874109	.0116024	.0758085	.009751
lnGDP	.062385	.0737973	-.0114124	.0036146
lnGHE	.0131617	.0030699	.0100918	.0021415
lnEdu	.0081849	.0447276	-.0365427	.0055539
AGEPOP	-.0047846	.0016937	-.0064783	.0028683

b = consistent under H_0 and H_a ; obtained from xtreg
 B = inconsistent under H_a , efficient under H_0 ; obtained from xtreg

Test: H_0 : difference in coefficients not systematic

```

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
        = 109.81
Prob>chi2 = 0.0000

```

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
L.lnEC	.0874109	.0116024	.0758085	.009751
lnGDP	.062385	.0737973	-.0114124	.0036146
lnGHE	.0131617	.0030699	.0100918	.0021415
lnEdu	.0081849	.0447276	-.0365427	.0055539
AGEPOP	-.0047846	.0016937	-.0064783	.0028683

```

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

      chi2(5) = (b-B)' [(V_b-V_B)^(-1)] (b-B)
              = 109.81
      Prob>chi2 = 0.0000

```

Fixed effect with robust standard errors

Fixed-effects (within) regression
 Group variable: countrynum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.6878
 between = 0.1216
 overall = 0.1639

Obs per group: min = 18
 avg = 18.0
 max = 18

corr(u_i, Xb) = -0.8353

F(5,20) = 48.38
 Prob > F = 0.0000

(Std. Err. adjusted for 21 clusters in countrynum)

lnLE	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC L1.	.0874109	.0324253	2.70	0.014	.0197729	.1550488
lnGDP	.062385	.0267244	2.33	0.030	.0066388	.1181311
lnGHE	.0131617	.0108741	1.21	0.240	-.0095212	.0358446
lnEdu	.0081849	.0474545	0.17	0.865	-.0908035	.1071733
AGEPOP	-.0047846	.0130831	-0.37	0.718	-.0320754	.0225062
_cons	3.084656	.1233051	25.02	0.000	2.827446	3.341866
sigma_u	.18073084					
sigma_e	.0368151					
rho	.96015898	(fraction of variance due to u_i)				

Electricity consumption and infant mortality

Fixed effect

Fixed-effects (within) regression
 Group variable: countrynum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.8112
 between = 0.4833
 overall = 0.5102

Obs per group: min = 18
 avg = 18.0
 max = 18

corr(u_i, Xb) = -0.6234

F(5,352) = 302.55
 Prob > F = 0.0000

lnINF	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC L1.	-.2313435	.0274001	-8.44	0.000	-.285232	-.1774551
lnGDP	-.1305531	.0200985	-6.50	0.000	-.1700813	-.0910248
lnGHE	-.0459219	.013398	-3.43	0.001	-.0722721	-.0195717
lnEdu	-.1894419	.0236549	-8.01	0.000	-.2359646	-.1429192
AGEPOP	-.0100507	.0121095	-0.83	0.407	-.0338669	.0137654
_cons	7.053704	.1113235	63.36	0.000	6.834761	7.272647
sigma_u	.41279605					
sigma_e	.08494481					
rho	.95937521	(fraction of variance due to u_i)				

F test that all u_i=0: F(20, 352) = 113.10 Prob > F = 0.0000

Heteroscedasticity test

Modified Wald test for groupwise heteroscedasticity in fixed effect regression model

$H_0: \sigma(i)^2 = \sigma^2$ for all i

$\chi^2(21) = 1675.63$

$\text{Prob} > \chi^2 = 0.0000$

Hausman specification test

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
	(b) fe	(B) re		
L.lnEC	-.2313435	-.1269651	-.1043785	.0183593
lnGDP	-.1305531	-.143764	.0132109	.0064108
lnGHE	-.0459219	-.0353313	-.0105905	.0037415
lnEdu	-.1894419	-.2399418	.0504999	.0099932
AGEPOP	-.0100507	-.0250022	.0149514	.0049647

b = consistent under H_0 and H_a ; obtained from xtreg
B = inconsistent under H_a , efficient under H_0 ; obtained from xtreg

Test: H_0 : difference in coefficients not systematic

$\chi^2(5) = (b-B)'[(V_b-V_B)^{-1}](b-B)$
= 84.04
 $\text{Prob} > \chi^2 = 0.0000$

Fixed effect results with robust standard errors

Fixed-effects (within) regression
Group variable: countrynum
Number of obs = 378
Number of groups = 21
R-sq: within = 0.8112
between = 0.4833
overall = 0.5102
Obs per group: min = 18
avg = 18.0
max = 18
F(5,20) = 63.11
corr(u_i, Xb) = -0.6234
Prob > F = 0.0000

(Std. Err. adjusted for 21 clusters in countrynum)

lnINF	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lnEC						
L1.	-.2313435	.0729403	-3.17	0.005	-.3834944	-.0791927
lnGDP	-.1305531	.0528458	-2.47	0.023	-.2407875	-.0203187
lnGHE	-.0459219	.0282728	-1.62	0.120	-.1048979	.0130541
lnEdu	-.1894419	.0779789	-2.43	0.025	-.3521031	-.0267808
AGEPOP	-.0100507	.0393263	-0.26	0.801	-.092084	.0719825
_cons	7.053704	.2383998	29.59	0.000	6.556411	7.550997
sigma_u	.41279605					
sigma_e	.08494481					
rho	.95937521	(fraction of variance due to u_i)				

Electricity access and under-five mortality

Fixed effect

Fixed-effects (within) regression
 Group variable: countrynum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.7910
 between = 0.5036
 overall = 0.5415

Obs per group: min = 18
 avg = 18.0
 max = 18

F(5,352) = 266.37
 Prob > F = 0.0000

corr(u_i, Xb) = -0.4317

lnUMR	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnELECACC						
L1.	-.4110268	.0356473	-11.53	0.000	-.4811352	-.3409183
lnGDP	-.1647033	.026072	-6.32	0.000	-.2159798	-.1134267
lnGHE	-.0218494	.0178445	-1.22	0.222	-.0569446	.0132457
lnEdu	-.1716986	.0303121	-5.66	0.000	-.2313142	-.112083
AGEPOP	-.0298225	.0160836	-1.85	0.065	-.0614546	.0018095
_cons	7.812724	.1297635	60.21	0.000	7.557515	8.067934
sigma_u	.41092895					
sigma_e	.11298653					
rho	.92971394	(fraction of variance due to u_i)				

F test that all u_i=0: F(20, 352) = 86.92 Prob > F = 0.0000

Heteroscedasticity test

Modified Wald test for groupwise heteroscedasticity in fixed effect regression model

H0: $\sigma(i)^2 = \sigma^2$ for all i

chi2 (21) = 704.47

Prob>chi2 = 0.0000

```
Wald chi2(5)
med)      Prob > chi2
```

```
Number of obs      =      378
Number of groups   =       21
```

```
Obs per group: min =      18
               avg =     18.0
               max =      18
```

```
corr(u_i, X) = 0 (assumed)      Wald chi2(5) = 1169.38
                                Prob > chi2 = 0.0000
```

lnUMR	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnELECACC						
L1.	-.3582531	.0365712	-9.80	0.000	-.4299313	-.2865749
lnGDP	-.1520671	.0279008	-5.45	0.000	-.2067517	-.0973825
lnGHE	-.0213916	.0188344	-1.14	0.256	-.0583064	.0155232
lnEdu	-.2042043	.0316728	-6.45	0.000	-.2662819	-.1421267
AGEPOP	-.0463963	.0159921	-2.90	0.004	-.0777403	-.0150522
_cons	7.713547	.1417329	54.42	0.000	7.435755	7.991338
sigma_u	.18409125					
sigma_e	.11298653					
rho	.72637858	(fraction of variance due to u_i)				

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnGDP	-.1647033	-.143764	-.0209393	.0039927
lnGHE	-.0218494	-.0353313	.0134819	.0038216
lnEdu	-.1716986	-.2399418	.0682433	.0069723
AGEPOP	-.0298225	-.0250022	-.0048204	.0049095

b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$\chi^2(4) = (b-B)'[(V_b-V_B)^{-1}](b-B)$
 = 88.41
 Prob>chi2 = 0.0000
 (V_b-V_B is not positive definite)

b = consistent under H_0 and H_a ; obtained from xtreg
 B = inconsistent under H_a , efficient under H_0 ; obtained from xtreg

```
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
        =      88.41
Prob>chi2 =      0.0000
(V_b-V_B is not positive definite)
```

Fixed-effects (within) regression	Number of obs	=	378
Group variable: countrysnum	Number of groups	=	21
R-sq: within = 0.7910	Obs per group: min	=	18
between = 0.5036	avg	=	18.0
overall = 0.5415	max	=	18
	F(5,20)	=	48.81
corr(u_i, Xb) = -0.4317	Prob > F	=	0.0000
(Std. Err. adjusted for 21 clusters in countrysnum)			

Electricity access and life expectancy

Fixed-effects (within) regression	Number of obs	=	378
Group variable: countrysnum	Number of groups	=	21
R-sq: within = 0.7761	Obs per group: min	=	18
between = 0.1681	avg	=	18.0
overall = 0.2431	max	=	18
	F(5,352)	=	244.02
corr(u_i, Xb) = -0.7365	Prob > F	=	0.0000

F test that all $u_i=0$: $F(20, 352) = 118.15$ Prob > F = 0.0000

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	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Number of	Obs per gr	Wald chi2(	Prob > chi
Std. Err.	z	P> z		
.0103821	12.44	0.000		
.0078367	6.63	0.000		
.0053091	0.20	0.838		
.0089523	0.10	0.919		
.0045738	0.17	0.864		
.0407642	79.09	0.000		

(fraction of variance due to u

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
L.lnELECACC	.1440172	.1292034	.0148138	.0032359
lnGDP	.0543105	.0519798	.0023307	.0013587
lnGHE	.0031142	.001084	.0020302	.0012031
lnEdu	-.0069781	.0009056	-.0078837	.0023164
AGEPOP	.001401	.0007828	.0006182	.0017761

```
chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
        = 71.73
Prob>chi2 = 0.0000
```

Fixed-effects (within) regression	Number of obs	=	378
Group variable: countrysnum	Number of groups	=	21
R-sq: within = 0.7761	Obs per group: min	=	18
between = 0.1681	avg	=	18.0
overall = 0.2431	max	=	18
	F(5,20)	=	44.13
corr(u_i, Xb) = -0.7365	Prob > F	=	0.0000

lnLE	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lnELECACC						
L1.	.1440172	.0364584	3.95	0.001	.0679663	.2200681
lnGDP	.0543105	.0164573	3.30	0.004	.0199812	.0886397
lnGHE	.0031142	.0097628	0.32	0.753	-.0172507	.023479
lnEdu	-.0069781	.035908	-0.19	0.848	-.0818809	.0679247
AGEPOP	.001401	.0084479	0.17	0.870	-.0162211	.0190231
_cons	3.176138	.0848483	37.43	0.000	2.999148	3.353128
sigma_u	.14166907					
sigma_e	.03117724					
rho	.95380603	(fraction of variance due to u_i)				

Electricity access and infant mortality

Fixed effect

Fixed-effects (within) regression
 Group variable: countrynum

Number of obs = 378
 Number of groups = 21

R-sq: within = 0.8324
 between = 0.4873
 overall = 0.5323

Obs per group: min = 18
 avg = 18.0
 max = 18

corr(u_i, Xb) = -0.3803

F(5,352) = 349.68
 Prob > F = 0.0000

lnINF	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnELECACC						
L1.	-.2820783	.0252519	-11.17	0.000	-.3317419	-.2324147
lnGDP	-.1309052	.018469	-7.09	0.000	-.1672287	-.0945818
lnGHE	-.0239525	.0126407	-1.89	0.059	-.0488133	.0009083
lnEdu	-.1851837	.0214726	-8.62	0.000	-.2274144	-.142953
AGEPOP	-.0241399	.0113933	-2.12	0.035	-.0465475	-.0017324
_cons	6.751558	.0919222	73.45	0.000	6.570772	6.932344
sigma_u	.34182429					
sigma_e	.0800377					
rho	.94802402	(fraction of variance due to u_i)				

F test that all u_i=0: F(20, 352) = 140.66 Prob > F = 0.0000

Heteroscedasticity test

Modified Wald test for groupwise heteroscedasticity in fixed effect regression model

H0: $\sigma(i)^2 = \sigma^2$ for all i

chi2 (21) = 1371.55

Prob>chi2 = 0.0000

Std. Err.	z	P> z	[95% Conf
-----------	---	------	-----------

```
Number of obs      =      378
Number of groups   =       21
```

```
Obs per group: min =      18
               avg =     18.0
               max =      18
```

```
Wald chi2(5)      = 1574.65
Prob > chi2       = 0.0000
```

lnINF	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnELECCACC						
L1.	-.2595454	.0260187	-9.98	0.000	-.3105411	-.2085497
lnGDP	-.1242442	.0195063	-6.37	0.000	-.1624757	-.0860126
lnGHE	-.0255371	.0132446	-1.93	0.054	-.051496	.0004218
lnEdu	-.1973584	.0223708	-8.82	0.000	-.2412043	-.1535124
AGEPOP	-.0316457	.0115189	-2.75	0.006	-.0542223	-.0090691
_cons	6.700493	.1037579	64.58	0.000	6.497131	6.903854
sigma_u	.17587979					
sigma_e	.0800377					
rho	.82843923	(fraction of variance due to u_i)				

Hausman specification test

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
_L.lnELECACC	-.2820783	-.2595454	-.0225329	.007126
lnGDP	-.1309052	-.1242442	-.0066611	.0029668
lnGHE	-.0239525	-.0255371	.0015846	.0026351
lnEdu	-.1851837	-.1973584	.0121747	.0050755
AGEPOP	-.0241399	-.0316457	.0075057	.0039323

b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
 = 50.43
 Prob>chi2 = 0.0000

	Coefficients			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe	re	Difference	S.E.
L.lnELECACC	-.2820783	-.2595454	-.0225329	.007126
lnGDP	-.1309052	-.1242442	-.0066611	.0029668
lnGHE	-.0239525	-.0255371	.0015846	.0026351
lnEdu	-.1851837	-.1973584	.0121747	.0050755
AGEPOP	-.0241399	-.0316457	.0075057	.0039323

```
chi2(5) = (b-B)' [(V_b-V_B)^(-1)] (b-B)
          = 50.43
Prob>chi2 = 0.0000
```

Fixed effect with robust standard errors

Fixed-effects (within) regression

Group variable: countrysnum

Number of obs = 378

Number of groups = 21

R-sq: within = 0.8324

between = 0.4873

overall = 0.5323

Obs per group: min = 18

avg = 18.0

max = 18

corr(u_i, Xb) = -0.3803

F(5,20) = 78.11

Prob > F = 0.0000

(Std. Err. adjusted for 21 clusters in countrysnum)

lnINF	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lnELECACC						
L1.	-.2820783	.0630433	-4.47	0.000	-.4135844	-.1505722
lnGDP	-.1309052	.0445835	-2.94	0.008	-.2239049	-.0379056
lnGHE	-.0239525	.036168	-0.66	0.515	-.0993977	.0514927
lnEdu	-.1851837	.0638246	-2.90	0.009	-.3183196	-.0520479
AGEPOP	-.0241399	.0304232	-0.79	0.437	-.0876016	.0393217
_cons	6.751558	.1824235	37.01	0.000	6.371029	7.132087
sigma_u	.34182429					
sigma_e	.0800377					
rho	.94802402	(fraction of variance due to u_i)				

Results of electricity consumption and health outcomes

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Consumption	-0.327 (0.11)**	0.093 (0.03)**	-0.262 (0.07)**
Gross Domestic Product	-0.186 (0.08)*	0.067 (0.03)*	-0.135 (0.05)*
Government Health Expenditure	-0.034 (0.03)	0.010 (0.01)	-0.033 (0.02)
Education	-0.175 (0.14)	0.001 (0.05)	-0.172 (0.08)*
Age of population	0.018 (0.03)	0.010 (0.01)	0.010 (0.02)
Constant	8.129 (0.40)**	3.093 (0.12)**	7.037 (0.22)**
Sample Size (N)	360	360	360

Robust standard errors in parentheses

* p<0.05; ** p<0.01

Results of electricity access and health outcomes

VARIABLES	(1) lnUMR	(2) lnLE	(3) lnINF
Lag of Electricity Access	-0.419 (0.11)**	0.144 (0.04)**	-0.288 (0.06)**
Gross Domestic Product	-0.181 (0.05)**	0.060 (0.02)**	-0.141 (0.04)**
Government Health Expenditure	-0.003 (0.04)	0.001 (0.01)	-0.012 (0.03)
Education	-0.162 (0.13)	0.011 (0.04)	-0.179 (0.06)*
Age of population	0.005 (0.03)	0.003 (0.01)	0.007 (0.02)
Constant	7.754 (0.32)**	3.186 (0.08)**	6.708 (0.18)**
Sample Size (N)	360	360	360

Robust standard errors in parentheses

* p<0.05; ** p<0.01

Im-Pesaran-shin Unit root test at levels

Electricity consumption

Im-Pesaran-Shin unit-root test for lnEC

Ho: All panels contain unit roots Number of panels = 21
 Ha: Some panels are stationary Number of periods = 20
 AR parameter: Panel-specific Asymptotics: T,N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included
 ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-0.6069		-1.950	-1.820	-1.750
t-tilde-bar	-0.5016				
Z-t-tilde-bar	5.3209	1.0000			

Electricity access

Im-Pesaran-Shin unit-root test for lnELECACCC

Ho: All panels contain unit roots Number of panels = 21
Ha: Some panels are stationary Number of periods = 20

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-1.2639		-1.950	-1.820	-1.750
t-tilde-bar	-1.1551				
Z-t-tilde-bar	1.4289	0.9235			

Im-Pesaran-shin unit root test at first difference

Electricity consumption

Im-Pesaran-Shin unit-root test for D.lnEC

Ho: All panels contain unit roots Number of panels = 21
Ha: Some panels are stationary Number of periods = 19

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-4.4499		-1.950	-1.820	-1.750
t-tilde-bar	-2.9030				
Z-t-tilde-bar	-9.0780	0.0000			

Electricity access

Im-Pesaran-Shin unit-root test for D.lnELECACC

Ho: All panels contain unit roots Number of panels = 21
 Ha: Some panels are stationary Number of periods = 19

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.0998		-1.950	-1.820	-1.750
t-tilde-bar	-3.3813				
Z-t-tilde-bar	-11.9397	0.0000			

Granger causality test results

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1

W-bar = 4.8547

Z-bar = 12.4908 (p-value = 0.0000)

Z-bar tilde = 9.4133 (p-value = 0.0000)

H0: lnELECACC does not Granger-cause lnEC.

H1: lnELECACC does Granger-cause lnEC for at least one panelvar (countrynum).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1

W-bar = 3.5550

Z-bar = 8.2793 (p-value = 0.0000)

Z-bar tilde = 6.1173 (p-value = 0.0000)

H0: lnEC does not Granger-cause lnELECACC.

H1: lnEC does Granger-cause lnELECACC for at least one panelvar (countrynum).

