

**RELATIONSHIP BETWEEN ELECTRICITY INFRASTRUCTURE DEVELOPMENT
AND ECONOMIC GROWTH IN KENYA**

BY

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DECLARATION

I declare that this dissertation is my original work and has not been previously published or submitted elsewhere for an award of a degree. I also claim that this contains no material written or published by other people except where due reference is made and author duly acknowledged.

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ABSTRACT

The major focus of the study was to find out the relationship between electricity infrastructure development and economic growth in Kenya. The study objectives include examining the relationship between the availability of electricity transmission lines, substation capacity, length of transmission lines and how it affects economic growth in Kenya. The market and infrastructure for electricity continue to be crucial for the growth of the economy. The electricity subsector was initially faced with a number of difficulties, including an insufficient supply, poor levels of access, low reliability, bad supply quality, and restricted transmission capacity combined with high network losses. At the time, the grid was 3200 km long. Significant changes have been made in the energy industry, including the creation of businesses with distinct tasks intended to supply the nation with effective, affordable, and sustainable electricity. In the past, Kenya's government used two primary electrical organizations to produce and distribute power. Kenya Power and Lighting Company (KPLC) and Kenya Electricity Generating Company (Kengen) are the companies that supply electricity to off-grid stations, buy, transmit, and sell it at retail prices to households across the nation. Later on, though, the government stated that KPLC's transmission and distribution operations needed to be completely unbundled. After more consideration, it was agreed to establish a different business that would be entirely controlled by the government and financed by the exchequer to build upcoming more transmission lines. The Kenya Electricity Transmission Company Limited was subsequently established in 2008 as a state business owned entirely by the Kenyan government. To ensure a dependable, sustainable, clean, secure, inexpensive, and high-quality power supply and to encourage power trade, the corporation is putting projects to expand the national grid and connect the regional grid system into one. The length of the 400kV, 220kV, and 132kV transmission network circuits has increased to over 7220.35km, of which 48.3% is held by KETRACO. The economy has clearly grown as a result of the grid development, and this study aims to examine the causal relationship between economic growth and the expansion of the power infrastructure. The study time limit was limited to the period between 1970 and 2019. The study was guided by Keynesian theory and Harrod-Domar Growth Model. The study made use of an explanatory survey research design and will employ a secondary research approach. The study was carried out in Kenya with a special focus on its economy. Data were collected using data collection forms from published statistical reports from the Energy Regulatory Commission, the World Bank, and the Kenya National Bureau of Statistics. The study used time-series econometric models to determine the link between electricity infrastructure development and economic growth in Kenya. The Autoregressive Distributed lag (ARDL) approach was used with the aid of STATA statistical software. Data was presented in the form of tables and graphs, followed by brief explanations. The study's findings demonstrated the convergence of the model in the long run. In the short run, the coefficient of substation capacity is negative and statistically insignificant, as is the transmission line. The study recommends that reform be undertaken in the energy market structure, especially infrastructure development while creating industry-specific criteria intended to increase the security and reliability of the electrical infrastructure. The study also shows that Kenya is becoming more interested in renewable microsystems, which makes the grid infrastructure redundant.

KEYWORDS: Energy, Economy, Energy-Efficient, Economic Growth, Transmission, Infrastructure, substation capacity.

TABLE OF CONTENTS

| | |
|------------------------------------------------------------|------------|
| LIST OF TABLES..... | V |
| LIST OF FIGURES..... | VI |
| OPERATIONAL DEFINITION OF TERMS..... | VII |
| INTRODUCTION..... | 1 |
| 1.1 BACKGROUND TO THE STUDY..... | 1 |
| 1.2 STATEMENT OF THE PROBLEM..... | 11 |
| 1.3 RESEARCH OBJECTIVES..... | 14 |
| 1.4 JUSTIFICATION OF THE OF THE STUDY..... | 15 |
| 1.5 SCOPE OF THE STUDY..... | 16 |
| CHAPTER TWO..... | 17 |
| LITERATURE REVIEW..... | 17 |
| 2.1 INTRODUCTION..... | 17 |
| 2.2 THEORETICAL REVIEW..... | 17 |
| 2.3 REVIEW OF EMPIRICAL LITERATURE..... | 24 |
| 2.4 LITERATURE REVIEW SUMMARY..... | 29 |
| 2.5 CONCEPTUAL FRAMEWORK..... | 30 |
| CHAPTER THREE..... | 32 |
| RESEARCH METHODOLOGY..... | 32 |
| 3.1 INTRODUCTION..... | 32 |
| 3.2 RESEARCH DESIGN..... | 32 |
| 3.3 TARGET POPULATION..... | 33 |
| 3.4 DATA COLLECTION TOOL..... | 34 |
| 3.5 DATA ANALYSIS PROCEDURE..... | 34 |
| CHAPTER FOUR..... | 42 |
| DATA ANALYSIS, FINDINGS AND DISCUSSION..... | 42 |
| 4.1 INTRODUCTION..... | 42 |
| 4.2 DESCRIPTIVE ANALYSIS..... | 42 |
| 4.3 DIAGNOSTIC TESTS..... | 45 |
| 4.4 AUTOREGRESSIVE DISTRIBUTED LAG MODEL..... | 48 |
| 4.5 POST ESTIMATION FOR ARDL..... | 50 |
| 4.6 RESULT AND FINDING DISCUSSIONS..... | 59 |
| SUMMARY, CONCLUSIONS AND RECOMMENDATIONS..... | 62 |
| 5.1 INTRODUCTION..... | 62 |
| 5.2 SUMMARY..... | 62 |
| 5.4 CONCLUSION..... | 64 |
| 5.4 RECOMMENDATIONS..... | 67 |
| 5.5 RECOMMENDATIONS FOR FUTURE RESEARCH..... | 68 |
| REFERENCES..... | 69 |
| TABLE A1: DATA COLLECTION FORM..... | 75 |
| FIGURE A1: LAG SELECTION CRITERIA FOR STUDY VARIABLES..... | 75 |

LIST OF TABLES

| | |
|----------------------------------------------------------------------|----|
| Table 4:1 Descriptive statistics of the study variables..... | 32 |
| Table 4:2 Correlation table | 35 |
| Table 4:3 Stationarity Test results | 36 |
| Table 4:4 Results of individual variable lags selection | 37 |
| Table 4:5 Table 4.5: Regression estimate of the output equation..... | 42 |

LIST OF FIGURES

| | |
|---------------------------------------------------------|----|
| Figure 1:1 length of completed Transmission Lines | 5 |
| Figure 1:2 GDP growth in Kenya..... | 6 |
| Figure 2:1 Conceptual Framework | 30 |
| Figure 4:1 Time series Line Graph..... | 34 |

OPERATIONAL DEFINITION OF TERMS

Electricity transmission infrastructure: includes the availability, length, and power capacity of the substations (Oughton et al., 2017). Generally, it encompasses all the resources that you operate. We think of it as the transmission section of a power grid.

Economic growth: This relates to the inflation-adjusted or increase in retail value of goods and services generated by today's economy. (Acemoglu, 2012). It is measured using the real Gross Domestic Product (GDP) growth rate (%).

Transmission line length: Involves the distance in kilometres and the power carrying capacity over the transmission line at a specific time (Oughton et al., 2017). It is measured in terms of kilometres (KM).

Substation Capacity: This refers to the maximum output a substation can step down or up, measured in megawatts (MW) and the voltage (V) (Leung, Khator & Schnepp, 1995). Substations interconnect two transmission lines. The purpose of a substation is either to set up or down the power through transformers by changing the voltage from high in the transmission line to lower and consuming it through feeders to various load centres.

Availability of transmission lines: Transmission infrastructure refers to both transmission lines and substations. In an ideal situation, lines and substations should be available 365 days less the number of days planned for annual maintenance. In the event of a breakdown that leads to either the line or substation being unavailable, then the availability will be measured as

Percentage Availability = $[\text{Total Hours} - \text{No Hours infrastructure is down due to unplanned maintenance}] / \text{Total Hours} \times 100\%$

The expected rapid growth of the transmission network will create a strain on resource requirements and activities for maintenance of the assets and coupled with increased incidences of vandalism, makes the target of 99.5% justifiable. This is also based on the internationally accepted availability benchmark for transmission and substation assets.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Energy is regarded as the propelling power and a key enabler for fuelling economic activities and industrial development. It is believed that high-grade energy sources amplify technology and economic growth. It is worth noting that within the realm of energy, there is a multiplicity of sources and electricity infrastructure that play diverse roles. Energy use was not nearly as significant during the most of human history as it was in the last century. Only those scientists and investors who expressed interest in this potent natural phenomenon, without which a day cannot be spent, made it feasible. The growth of electricity over the course of approximately 300 years, from a scientific curiosity to a daily necessity. Electrical research advanced quickly over the first half of the 19th century. Scientists now have a more dependable source of electricity thanks to the discovery of Volta's battery. Following the discovery of electromagnetic, George Ohm conducted a mathematical analysis of the electrical circuit in 1827 and Michael Faraday created the electric motor in 1821. By James Clark Maxwell, electricity, magnetism, and light were unquestionably connected. A new era of electricity known as the era of electronics started in 1947 with the creation of the first functional transistor.

Petroleum, which can be converted into gasoline and diesel and is primarily used for transportation, is the most abundant source of energy on the planet. But today, the vast majority of energy is used to create electricity through the burning of coal and natural gas, capturing wind, or directly converting sunlight into electricity. The main factor affecting where and how electricity is harnessed is geography. The majority of the electricity produced in nations like Poland and China

comes from coal. Since the advent of fracking, natural gas has overtaken coal as the primary source of electricity in the United States, which it shared for many years. Energy sources and uses are changing drastically. For instance, gasoline-powered cars may be replaced by electric models, and the rise of renewable energy sources is decentralizing the production of electricity (Omri, Mabrouk & Sassi-Tmar, 2015). Energy is essential for running vital systems like the health care system, the economy, and communication; thus it is more than just an issue of comfort. Future energy use will be influenced by the decisions we make today.

This project's background is provided by the evidence that nearly a billion people globally lack access to electricity, which has significant effects on their well-being, social and economic development, and growth (Timilsina, Hochman & Song, 2020). According to statistics, a lower maternal mortality rate is associated with increased access to electricity. Higher rates of access to electricity have effects on educational achievement. There is a sense of urgency in tackling the issue at hand because the indicators for poverty also decline as access to power increases. The majority of the accessibility issues have been accounted for by the difficulties that electricity access planners have encountered locally. Countries like Angola, where three percent of the population lacks access to electricity and sixty percent of the population lives in rural areas, are demonstrating a trend that is holding true for many other similar nations.

The viability of grid and off-grid power solutions, such as micro-grids employing hydro, solar, and wind energy, is examined through electricity access optimization toolkits in order to provide total access to research locations. In one such analysis (Tembo & Merven, 2013), the World Bank closely examined Zambia to identify the least-expensive routes for every region of the nation. It did this by exploiting the electricity infrastructure. Both home-scale solar systems and community-scale solar mini-grids were suggested for the northeastern and southwesterly portions of the country, respectively. There is obvious advice for grid growth along the transmission system.

The Ministry of Energy in Kenya is one of several important stakeholders in the energy sector, and it is responsible for formulating and outlining the laws that regulate it (Mose, 2021). The Energy Regulatory Commission is responsible of creating the tiers, carrying out oversight, managing, and examining problems with the sectors' regulations. The dominant company in the segment of the industry that produces power is Kenya Electricity Generating Company. The company in charge of the transmission and distribution of electricity to domestic customers in the nation is called Kenya Power. The sector's high-voltage transmission of power is handled by Kenya Transmission Company Limited. The geothermal field exploration work is done by the geothermal development company. Assembling the nation's nuclear program is also the responsibility of Independent Power Producers like Kenya Nuclear Electricity Board. As a result, the industry is extremely dynamic and large, with important participants in each of its several areas.

A mix of policy documents and legislation make up Kenya's legal framework for the energy sector, which essentially lays out the framework within which the government can provide enough reliable energy at a reasonable cost to meet the needs of the nation's development. In order to comply with the modifications made to the constitution after it was passed in 2010, a review of the policy was necessary. The economic, social, and political pillars make up the three main components of the Kenya Vision 2030 document (Mose, 2021), which is the country's National Development Program. According to the paper, one of the pillars' enablers is energy, particularly power. The Kenya Vision 2030 has several goals that it hopes to accomplish, including but not limited to: raising the nation's generation capacity to 33000 megawatts; extending transmission lines to around 8000 kilometres of lines; and increasing access to all people. The transmission infrastructure and generation capacity will be expanded in accordance with the Least Cost Power Development Plan, which is a roadmap that is now in effect and covers the period from 2017 to 2037. In addition, the industry has plans for utilizing renewable energy, combating climate change,

and electrifying rural areas. The Energy Act has an impact on every one of these initiatives and regulations.

Kenya had relied on hydroelectricity for decades to meet its energy needs, but due to persistent droughts, it remained unstable, forcing the nation to switch to thermal energy powered by oil (Taneja, 2017). Over 75% of Kenyans now have access to electricity, reflecting the country's enormous growth in the energy sector over the past ten years. With increased investments, particularly in renewable energy sources, the nation is moving closer to reaching universal access while meeting the rising demand. After Seoul, geothermal energy is the second most prevalent energy source. The Great Rift Valley provides a massive subterranean energy resource, and the country has been utilizing it. This places it as the top producer of geothermal energy on the continent by turning steam that has been tapped from more than two kilometres beneath the surface of the earth into electricity. Over two decades after the first 15-megawatt unit was commissioned at Ol Karia I station; Kenya's geothermal history began with an experimental expedition in Hell's Gate National Park in 1956. In Kenya, alternative renewable energy sources including hydro, wind, and solar are displacing geothermal energy in terms of market share. Nevertheless, it offers reliable base load electricity that other sources, which depend on the weather, cannot. Geothermal energy will be important as Kenya attempts to achieve its target of using only renewable energy by 2030.

1.1.1 *The concept of Electricity Infrastructure and Economic Growth*

Electricity infrastructure includes all proper investments in generation, transmission, distribution, and retail (Amin, 2002). The production, transmission, and distribution infrastructure are colloquially known as the electricity grid, which consists of generation plants, transmission lines, substations with power transformers, metering equipment, and electric generation control systems (McClurg, 2012). It is important to note that the grid is composed of electricity generation, which is the supply side, transmission, and electricity distribution, which is the demand side

(McClurg, 2012). While these components are interconnected, their effects can be independently explored. For instance, the generation may be more than the consumption, resulting in excess power that may be underutilized with high power loss with an efficient installed transmission line. On the other hand, the correlation between efficient transmission infrastructure and economic growth will explore the under and over utilization of energy infrastructure, taking care of optimal electricity demand.

The progress of nations, the eradication of poverty, industrialization, and human welfare all rely heavily on the availability of electricity infrastructure. Global development faces the constant and urgent task of ensuring that everyone has access to enough energy. As observed in nations like Argentina, Ecuador, Brazil, and Chile that developed a very well-funded economy on an oil base, there is proof that energy availability and economic growth are directly related. As a result of a lack of employment opportunities, poor electrical infrastructure is a common characteristic of countries that experience slow economic growth (Fu et al., 2017). We are all plugged into the electrical grid, which distributes energy from generators, across wires, and into homes under the control of an electricity market (Stern, 2019). The electrical market has many participants, which contributes to competitive pricing. It efficiently matches the ability to supply electricity or the supply with the fluctuating demand for electricity. The Independent Electricity System Operator prediction is used by different electricity generators to plan how much electricity they can produce and for what price. They must consider issues like fuel availability and equipment upkeep.

Electricity transmission infrastructure consists of several aspects. Such aspects include the length of the transmission line in terms of kilometres and the availability of that transmission line to distribute power from the generation points to the end user (Farhangi, 2009). The length and availability of the transmission line not only determine the quantity of electricity distributed but also the geographical areas reached with electricity. The shorter their length, the less electricity

distributed regardless of the quantity generated, and thus the less electricity consumed (Farhangi, 2009). Other important elements of the transmission infrastructure include the substations, which constitute control rooms, transformers, among others. The capacity of the substation in terms of substation load also constitutes a very important element when examining electricity transmission infrastructure in general (Eyer & Corey, 2010). Substations control or reduce the voltage of electricity, and they serve to connect the transmission line to the transformers. This means that the way this substation works and how much it must carry are very important parts of how electricity is sent.

Economic growth refers to inflation adjusted to the consumer value of goods and services generated by the economy (Rahman & Ulubaşolu, 2015). When the production of goods and services rises while the price of those goods and services stays the same or when the prices of those goods and services rise but the production of goods and services stays the same, the value of the nation's output or national income may rise. A long-term rise in the flow of commodities and services is always referred to as economic growth. Therefore, it is incorrect to refer to a temporary increase in output volume as economic growth. Increased revenue for enterprises results from rising commodity prices. Since there are more job alternatives because of higher stock prices, firms have more money to invest and recruit more workers, which leads to an increase in income generation. The economy advances because consumers have more money to spend on more items. Because everyone wants their economies to grow rapidly, economic expansion is the metric that is most frequently watched.

Economic growth is influenced by various factors, which include human resources, physical capital, natural resources, and technology (De La Croix & Michel, 2002). However, (Ghosh, 2002; Ray, 2014) contend that real Gross Domestic Product (GDP) is an alternative means of measuring the economic advancement of the country. The GDP gives a snapshot of the

country's economy by estimating its size and growth rate. GDP is key in guiding policymakers and investors in strategic business decision-making.

In a broad sense, evaluating the factors that contribute to ongoing manufacturing capacity expansion is necessary for economic expansion. Future economic growth and increased output coexist in harmony. The inescapable present consumption is the opportunity cost of economic growth. Higher real GDP per capita translates into more incomes and eventually higher disposable income, which enhances the standard of life in terms of material goods (Soytas & Sari, 2003). Higher economic growth is defined as this. In another view, the development of the infrastructure for the transmission of electricity facilitates economic growth by increasing demand for goods and services due to increased employment (Ayres et al., 2013). Without restraint, this rise in demand will drive up prices, causing an economy's inflation rate to rise; thus, a strong infrastructure is required.

Studies across the world on electricity generation, distribution, and supply reveal a significant relationship between electricity infrastructure development and economic growth. In sub-Saharan Africa, (Ntebo, Mathe & Ayorinde, 2019) identify the impact of power development on the economic benefit in sub-Saharan Africa as wealth creation, a boost in citizens' income, health care improvement, and improved educational systems. In Nigeria, (Okorie & Sylvester, 2016) found a unidirectional causal link between electricity utilization and economic growth. In South Africa, (Khobai, Mugano, & Le Roux, 2017) established that there is a long-term connection between electricity allocation, economic growth, electricity costs, trade openness, employment, and capital. According to the authors, high power costs have a negative impact on economic growth, whereas power supply, exchange openness, capital, and work have a positive impact on economic growth.

However, similar studies in other countries have proved otherwise there is no relationship between electricity infrastructure development and economic growth. For instance, (Lee, Miguel & Wolfram, 2020) contend that the provision of home electrification alone is not sufficient to improve the economic outcomes substantially for the low-income population. Also, (Odhiambo, 2014), studying economic growth and energy in the Democratic Republic of Congo (DRC), contends that electricity supply does not necessarily lead to economic growth. Such diverse findings imply that the association between electricity infrastructure development and economic growth is country specific. Again, this raises a question about whether energy is an impetus to growth, or whether economic growth is an incentive to energy utilization. The responses to these queries have significant inferences for fuel substitutability and fuel stack policymakers on energy infrastructure.

The energy sector in Kenya is one of the most developed sectors south of the Sahara (Pueyo, 2018). Factors that favour the Kenyan energy sector are an active private sector and abundant renewable energy resources such as geothermal, wind and solar power (Kamau, 2018). The provision of affordable and reliable energy is regarded as one of the essential steps towards the attainment of the Big Four Agenda and Vision 2030, a development plan that contains aspiring goals for economic, social, and political development (Berggren & Sterberg, 2017). The vision aims at transforming Kenya into a middle-income economy (The Government of Kenya, 2007). With a projected population increase between 2015 and 2030, (International Energy Agency, 2017) notes that electricity consumption in Kenya is likely to increase by 315 during that period. This implies that the Kenyan government must develop the electricity infrastructure to meet the higher demand. Challenges faced by the energy sector in Kenya include limited, aging transmission and distribution infrastructure and disputes, among other challenges (Edwards, Dent, & Wade, 2017; George, et al., 2019).

It is against this backdrop that several flagship projects for electricity generation have been executed or planned (Ministry of Energy and Petroleum, 2016). By 2012, Kenya had an installed capacity of 2,351 MW with 36% hydroelectric, 33% thermal, 29% geothermal, 2% other renewable energy sources, and 617 MW reached financial close (USAID, 2012). In the 1st Medium Plan (2008–2012) of Vision 2030, three electricity projects were identified in Kenya. These were rapid rural electrification, amplified access to energy and affordable power development programs to produce an extra 505MW of electricity (Republic of Kenya, 2007). Kenya's huge electricity generation points are evident in the country's surplus electricity generation. Accordingly, consumers' inability to utilize and exhaust the electricity produced is pegged on market imperfections because sectors like manufacturing have not expanded in tandem with generation (Muchira, 2019).

Kenya was set to construct more than 4,000 km of high-pitched current transmission frames with lines, switch gears, and high voltage sub-stations within the next 5 years from 2009 (Musau, Odero, & Wekesa, 2016). By 2015, there were extensions of transmission lines of about 4,000 km, distribution lines of about 3,200 km, and building substations with a capacity of 4,200 MVA (Gumbe, 2016). However, the country faced weak grids and delayed electricity transmission infrastructure to evacuate the power. The main challenges related to the grid include deficiencies that result in frequent power outages and technical and non-technical losses (Pueyo, 2018). Consequently, the grid operators, KPLC and KETRACO, emphasize system reliability and smart grid technologies (Mabea, Macatangay, & Mutua, 2018).

By 2017 In Kenya, the national grid is composed of 400 kV, 220 kV, and 132 kV transmission systems and 66 kV and below distribution low voltage lines (Chambile, et al., 2018). Through the Kenya electrification strategy, the government launched an 18 million solar connections on both grid and off-grid energy in 2018 (The President Delivery Unit, 2020). In 2019,

the government launched the 132kV Konza-Isinya transmission line project to ensure reliable energy supply to south Nairobi. In 2020, the government announced the roll out of a 15 billion off-grid solar access project to provide energy to 250,000 households and 800 public facilities (The President Delivery Unit, 2020).

The figure below shows the developments in electricity transmission lines since 2012 to 2018

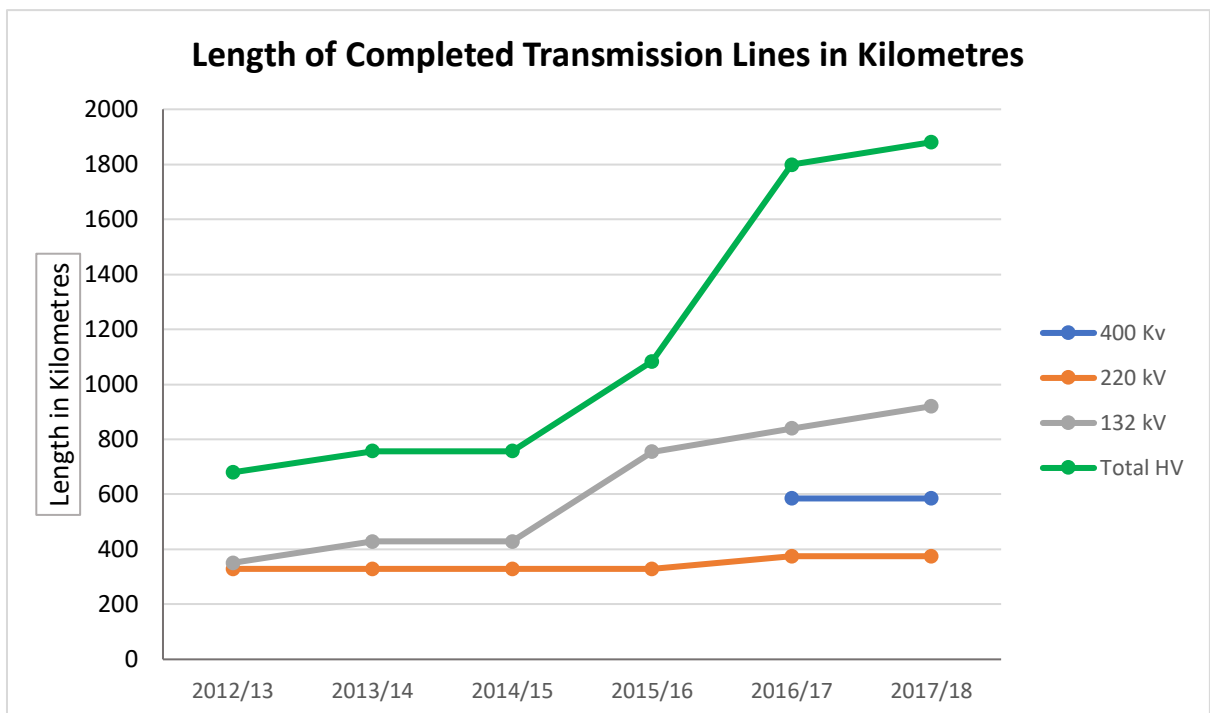


Figure 1:1 Length of completed Transmission Lines

Source: KETRACO 2017 Annual Report.

On the other hand, Kenya’s GDP has been dynamic in terms of growth over time. The figure below shows Kenya’s GDP trends since 1960s.

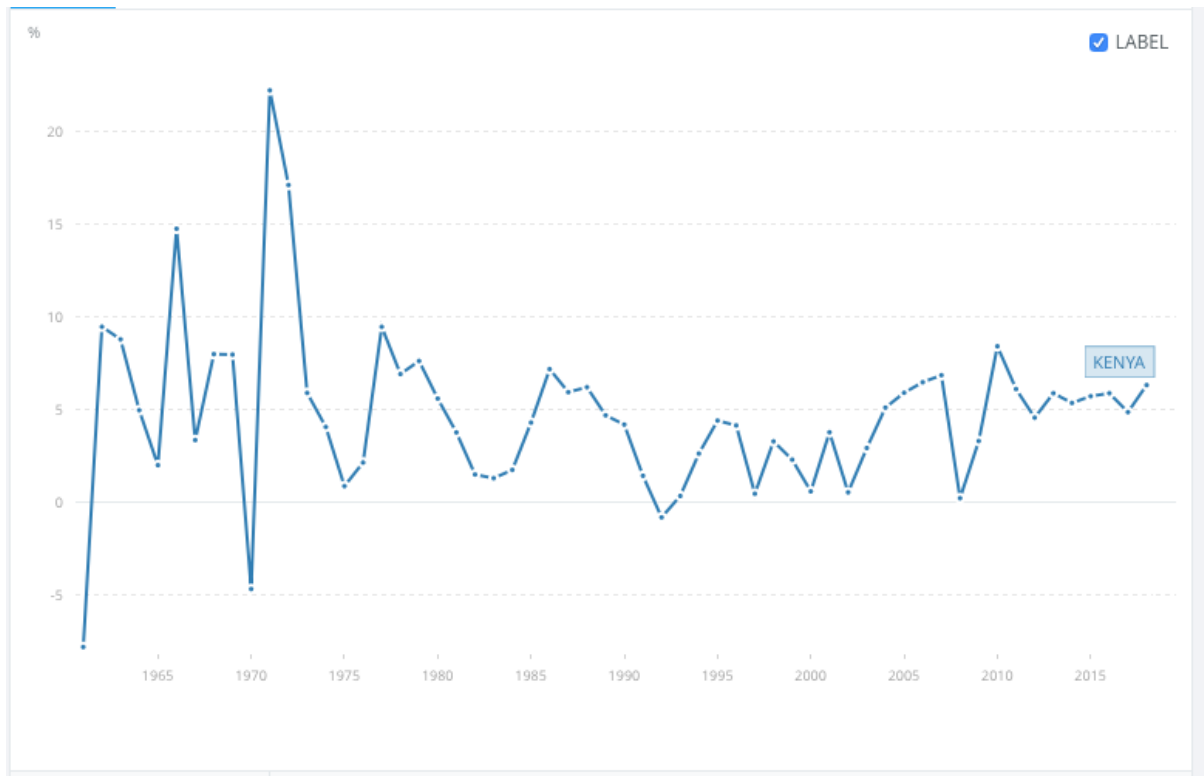


Figure 1:2 GDP Growth in Kenya

Source: World Bank (2019).

Kenya has the goal of sustaining a yearly GDP growth of 10% to achieve Kenya Vision 2030 (The Republic of Kenya, 2007). All these electricity projects are aimed at achieving this vision. However, in vision, it's not clearly known whether energy drives the economy or the other way around. It is important to note that in this vision, energy is only regarded as an enabler for economic development. As such, there is no guarantee that development of electricity infrastructure will necessarily lead to this projected economic growth. Accordingly, causality analysis of electricity transmission infrastructure development and economic growth is vital in the attainment of this vision

1.2 Statement of the Problem

The average value of economic growth in Kenya between 1961 and 2019 is 4.78%, with a maximum of 22.17 in 1971 and a minimum of -7.77 in 1961 (World Bank, 2019). An examination

of the trends in Kenya's economic growth (see figure 1.1) shows that Kenya's economic growth has been dynamic since the 1960s. There is evidence of rising and contractions informed by various macroeconomic factors in the country. On the other hand, the expansion of the electricity transmission lines in the country has been expanding within the same period. However, since 2010, the expansion in economic growth and electricity infrastructure has been evidenced. This raises the question of which of these two influences the other: economic growth or electricity infrastructure. In the recent past, Kenya has incurred high capital expenditure on energy infrastructure with the aim of the provision of affordable and reliable energy to the public as a way of achieving the Big Four Agenda and Vision 2030 (Mabea, Macatangay, & Mutua, 2018). However, statistics from (World Bank, 2019) indicate that there has been a very slow economic growth rate. There are also complaints over Kenya's electricity infrastructure spending, with cases of overproduction being cited (Power Africa, 2018).

In the nation, expanding internal access to energy supply has been one of the largest accomplishments. Compared to fewer than 30% in 2012, over 75% of public facilities are now connected to power, according to the Rural Electrification and Renewable Energy Corporation. In order to get energy to some of the country's remotest regions with the weakest connectivity, it has been a challenging trip to go against the trend (Nyangau, 2014). About 22,927 primary schools had electricity connected as a result of the ambitious digital literacy program's deployment. Given that education is the most significant social equalizer, there is an obvious direct correlation between it and the performance mentioned. With the help of the World Bank-funded "last mile connection" program, households that were roughly 600 meters away from such facilities were given access to energy. The government invested in areas through REREC and built the Garissa solar power plant, which today contributes 50 megawatts to the grid, as a result of the embrace of renewable energy sources, particularly solar energy. Under REREC, the government was able to expand funding for public facilities thanks to the shilling for shilling program and undertaking. Under this program

and undertaking, the county government contributes 50% of the funding, and REREC adds another 50% to light up public facilities.

While Kenya recognizes energy infrastructure development in its vision 2030, in its midterm plan, energy is only recognized as an enabler to economic growth. It is not clear if investing in electricity transmission infrastructure will automatically lead to economic growth. Also, the relationship between electricity and economic growth differs from one country to another. Nevertheless, very little scholarly effort has been made to examine if the development of electricity infrastructure will lead to economic growth because the relationship between electricity infrastructure development and economic growth is country-specific and thus cannot be generalized. Scholars' works include (Berggren & sterberg, 2017), (Chambile et al., 2018), (Lee, Miguel & Wolfram, 2020), and (Onuonga, 2012). While these scholars study electricity development and the Kenyan economy, none has addressed the specific relationship between electricity transmission infrastructure development and economic growth. Many studies focus on electricity and economic growth in relation to electricity production and utilization. In this way, electricity transmission has been scholarly overlooked, yet it is a very crucial component in the grid system. Challenges faced by the energy sector in Kenya include limited, aging transmission and distribution infrastructure and disputes. Little local studies have been carried out to determine how the study variables affect the energy sector and gradually the state of the economy. To this end, several gaps are left unfilled. These include the relationship between the availability of electricity transmission lines and economic growth; the relationship between the length of transmission lines and economic growth; and the causal relationship between substation capacity and economic growth. Also, whether these developments automatically lead to economic growth and the degree to their implications have not been determined. Limited studies by previous scholars on the causal relationships between the study variables and its effects on the economic growth raises the need for in depth research as conducted by the project.

As a result, a study on the relationship between electricity infrastructure development and economic growth in Kenya is very important as it will help to unmask the specific role of development of electricity transmission infrastructure in attaining vision 2030 and act as a driving force for policy change and formulation in various departments that are involved in Kenya's developmental agenda. It's against this backdrop that this study sought to look at the connection between electricity infrastructure development and economic growth in Kenya. Conclusions and recommendations derived from the study may revolutionize the energy industry and spark more research into realizing the optimal economic growth and development in the country.

1.3 Research Objectives

1.3.1 General Objective

The study sought to establish the relationship between electricity infrastructure development and economic growth in Kenya.

1.3.2 Specific Objectives

The study's specific objectives include the following;

- i. To establish the relationship between availability of electricity transmission lines and economic growth in Kenya
- ii. To determine the relationship between substation capacity and economic growth in Kenya.
- iii. To determine the relationship between the length of transmission lines and economic growth in Kenya.

1.3.3 Research Hypothesis

This study was premised on the following.

1. There is no relationship between availability of electricity transmission lines and economic growth in Kenya.
2. There is no significant relationship between the length of transmission lines and the economic growth in Kenya.
3. There is no significant relationship between substation capacity and economic growth in Kenya.

1.4 Justification of the of the study

The relationship between electricity infrastructure development and Kenya's economic growth is very important. This is because, as indicated in the background, Kenya is investing a lot in electricity generation and distribution as one of the ways to achieve Vision 2013. However, in its midterm plan, energy is only recognized as an enabler of economic growth. It is not clear if investing in electricity transmission infrastructure will automatically lead to economic growth. Additionally, it is evident that the relationship between electricity and economic growth differs from one country to another. Accordingly, evaluating the connection between energy utilization and economic growth will be a driving force for policy change and formulation in various departments that are involved in Kenya's developmental agenda.

Findings from this study will guide the formulation of energy and environmental policies. If the findings indicate that causality runs from electricity transmission infrastructure development to economic growth, the lack of energy allocation will be a hurdle to economic growth, hindering economic advancement and adding to joblessness. If there is no causality between the study variables, then economic growth and electricity transmission infrastructure development are autonomous, and hence the nation can apply energy diffusion plans minus disturbing economic advancement of the nation.

To the financiers of the country's vision 2030, the findings will devise a method to inform an appropriate fund model that will not affect tariffs or pricing, influencing economic growth. If the causality is from electricity transmission infrastructure development to economic growth, there are likely to be policies for more funding and vice versa.

The electricity generation, distribution, and consumption stakeholders say the study will be an eye opener to establish if there is balance within Kenya's electricity grid and solve related balancing issues.

To the scholars and academicians, the study adds to the already exciting literature on electricity and economic growth. It brings a new dimension to exploring the connection between the two by focusing only on electricity transmission infrastructure.

1.5 Scope of the Study

The study is limited to investigating the relationship between electricity transmission infrastructure development and economic growth in Kenya. While there are several infrastructures within the electricity grid, the study will focus on transmission infrastructure only. In terms of time limit, the study is limited to the period 1970–2019 because time series data is available for this period. Also, the timeline of half a century is adequate enough to establish the relationship between electricity transmission infrastructure development and economic growth in Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The main goal of this chapter was to conduct a critical analysis of the literature in the field written by various academics. Following the factors utilized in the study, it has been discussed, providing a summary of both the theoretical and empirical reviews of the relationship between power infrastructure and economic growth. Existing works on electricity and economic dynamics are examined, and gaps are identified. A summary of the few is provided at the end of the chapter. The chapter further discusses how the proposed study fills these gaps. Also discussed in this chapter is the conceptual framework that guides this study.

2.2 Theoretical Review

To comprehend the relationship between energy infrastructure development and economic growth, it is crucial to examine the role of energy in production. There exist theories that can be employed in the study of the relationship between electricity growth and economic growth. These theories are reviewed to be borrowed to enrich the proposed study.

2.2.1 Keynesian Theory

A British economist, John Maynard Keynes, developed the theory in 1936. He created the field of macroeconomics by writing a broad theory of money, interest, and employment (Marglin & Bhaduri, 1991). Keynes agreed with John Hicks that market economies do not self-correct as rapidly since it takes time for prices and incomes to change. They asserted that the government must become involved in order to boost output and lower unemployment through the use of

monetary and fiscal policy (Commendatore et al., 2003). The Kenya Power and Lighting Company, which the government owns a majority of (51%), has a monopoly on the Kenyan electricity market. It oversees distributing and selling energy at retail prices to each household. By using renewable energy sources that boost economic growth and uphold social welfare, the government has made quick progress toward greening the sector. Such projects under capitalism and profit-driven enterprises would most likely have used production techniques that had higher social costs and led to an uneven income distribution that would limit economic growth.

The theory holds that investment play a key role in economic growth. This paradox can be interpreted in the sense of the principle of multiplier developed in the 1930s (Pigou, 2016). The multiplier corresponds to the rate by which the shift of capital must be compounded of order to have a final effect on revenue or expenditure. In this case this study assumes that the link between economic growth and electricity transmission infrastructure developed can be sought from the amount spent on developing the infrastructure and the corresponding GDP per year.

Investment can, however, be a source of uncertainty if it is not sustained at a rate appropriate to increase demand for the supply it generates (Cate, 2012). For instance, the amount of electricity transmitted depends on the length of the transmission lines. This implies that the longer the length the higher the amount of power supplied. However, if the supply of this electricity does not meet its demand, it implies that there will be oversupply. This implies that for link between electricity transmission infrastructure development and economic growth to be well explored, the length of transmission lines substation capacity ought to meet the demand of electricity in terms of consumption.

The theory is important to this research as it illuminates on the connection between improvement of electricity transmission infrastructure (in term of the availability of transmission infrastructure, the length of the lines and the substation load) and economic growth. Additionally, it answers the question on how the availability, of transmission infrastructure, the length of the

lines and the substation load influence economic growth in terms of demand and supply of electricity and its impact on the availability, of transmission infrastructure, the length of the lines and the substation load. This is the relationship that this study will explore in Kenya.

2.2.2 Harrod-Domar Growth Model

Roy F. Harrod came up with the idea in 1939, and Evsey Domar added to it in 1964. The Harrod-Domar growth model offers a long-term production hypothesis. Even though the two economists' interpretations of it may differ, it still has a shared goal. An economy's primary goal is to establish a steady state growth rate. This is a model for advanced capitalist economies; hence it primarily applies to developed nations. The dual effect of investment is one of the two key fundamental elements of the Harrod-Domar model (Hagemann, 2009). Investment is the net addition to the stock of capital, to put it simply. Therefore, the dual effect consists of the income effect, also known as the supply effect, and the capacity effect, also known as the demand effect. The Harrod-Domar model is an extension of Keynesian theory, which only paid attention to short-term consequences as the Great Depression was about to break out in 1930.

The capital-output ratio and the level of national saving, as indicated by the model, are both important factors in determining how quickly the economy grows (Hussein & Thirlwall, 2000). An economy can create a lot of output with little capital if the capital-output ratio is low; but, if the ratio is high, a lot of capital is required for production, and the amount of output produced for a given amount of capital is not as valuable. If the free market is allowed to operate, it is said that saving rates in emerging nations are frequently low. To improve an economy's savings rate, governments must do so. Alternately, rich nations may intervene and transfer capital stock to developing nations, increasing their potential for production (Van den Berg, 2013)

Since electricity transmission in Kenya is state-owned most of its capital comes from the government and energy sector players, therefore the amount of electricity produced for the given amount of capital is of great value. By the government being the key sector player, it has provided the country the capability to produce more geothermal power that has been outsourced to different countries in Africa. Other key players such as the African Development Bank have also taken part in projects set to increase electricity transmission lines and substation capacities which has seen the growth of the economy even as it sets to enter the power trade market.

It holds that there is no ordinary purpose for an economy to have equalized growth. The growth model stresses that capital investment produces profits and improves the productive potential of the economy (Bakare, 2011). For instance, if the length of an electricity line increases, electricity supply will increase power consumption in industries, generating income for suppliers and workers while simultaneously increasing the production capacity of the economy.

Also, the theory assumes that the relationship between resources and production is still the same. In this way, national production (which is equal to the national income) is directly proportional to the capital stock, expressed as follows:

$$Y = Kk, (k>0) \tag{1}$$

Where Y represents output K and stock of capital, k is the output/capital ratio (constant).

As the Harrod-Domar model has assumed that the production/capital ratio is stable, any kind of increase in national production would result in a k-time increase in capital stock, which is as follows: $\Delta Y = k \Delta K$ (2)

The increase in the growth of national production per unit time is also equal to the increase in the growth of capital stock per unit time. If the economy is in order and the capital supply is

fully used, the capital/output ratio (k) can be easily calculated. Therefore, the change in national output can be represented as follows:

$$\Delta Y = kI \quad (3)$$

Newly produced revenue from capital investment creates demand for goods and services (Van den Berg, 2013). According to Harrod-Domar, the most important precondition for economic growth is that the needs provided by the freshly created returns ought to be satisfactory to ensure that the production induced by the latest investment (an increase in capital) is completely absorbed (Hacche, 1979). This theory is significant to this study as it explains the relationship between the electricity transmission line and economic growth. The electricity transmission infrastructure should be developed in such a way that the volume of power transmitted meets the demand for power in the country. The electricity distributed via the transmission grid should be completely consumed. If the demand is not sufficiently consumed, the processing potential will be surplus or unused. This implies that the amount of money invested in electricity transmission infrastructure ought to be proportional to the amount of electricity needed to avoid overinvestment.

2.2.3 The Neoclassical Theory

The neo-classical economic theory holds that the economy is a closed system where inputs of labour and capital produce output. This implies that the economy is a product of increased and quality input. This can justify that actively investing in availability of transmission lines, increasing substation capacity and lengthening transmission lines can produce economic growth. The prevalent viewpoint today that is based on assumptions is neoclassical economics (Sredojević, Cvetanović & Bošković, 2016). First, it makes the supposition that people's preferences are logical and correspond to the values that are generally referred to as the subjective theory of value. Second, it is based on the premise that businesses maximize profits and individuals frequently

maximize their utility. Finally, this presupposes that individuals have the free will to make choices based on complete, readily available, and pertinent economic knowledge. Neoclassical economists hold this supposition, and they hold that the principles of supply and demand determine how scarce resources are distributed.

Energy is regarded as an intermediate input, and scholars such as (Stern, 1999) contend that economists have accepted the concept of primary and intermediate factors of production. It's worth noting that the assembly factors are inputs that exist at the beginning of the amount taken into account and are never directly utilized in the assembly. On the other hand, the intermediate inputs are those created during the assembly period and are spent entirely in production. Capital, labour, and land are the first factors of production, while goods like fuels and materials are intermediate inputs. (Stern & Cleveland, 2004) contend that such an approach results in a specialization in mainstream growth theory on the first inputs, especially capital and labour, while intermediate inputs like energy have got an indirect role. The amount of energy available to the economy is endogenously given, though determined by biophysical and economic constraints.

The significance of energy within the economic system was first stressed by (Georgescu-Roegen, 1971), who argued that the physical dimension of economic production needed more explicit attention in growth theory. After the primary oil crisis in 1973-74, other economists like (Tintner et al., 1974), and (Berndt & Wood, 1979), began formulating energy-dependent production functions comprised of energy and materials besides general labour and capital inputs.

The neo-classical theory explains economic growth from an increase in labour, capital, and technology points of view. Total factor productivity is the measure of output that cannot be explained by the number of inputs used in production. The total factor productivity is measured using the Solow residual. However, it is worth noting that the model measures total factor productivity accurately under three situations. If only the production function were neoclassical,

there'd be perfect competition in factor markets and, therefore, the inputs' growth rates would be measured accurately (Comin, 2006).

Deep insights into the reasons of growth are provided by the Solow (1956) model. A crucial component of the model is the production function, which provides a condensed explanation of how resources and inputs are used to produce output (Nonneman & Vanhoudt, 1996). Workforce is the first important component; the better educated the people, the more productive the labour, which represents human capital. By holding electricity transmission annual research conferences, KETRACO improves efficiency of the transmission by elevating the workforce innovative capacity. Physical capital, such as buildings and equipment, is the following input. KenGen continually upgrades its equipment and machinery to increase output of renewable energy thus leading to increase in substation capacity, transmission line length and availability of the transmission lines. The last input consists of concepts that represent knowledge on how to combine labour and capital to make worthwhile output by (Lee, Pesaran & Smith, 1997).

The model revealed that cross-country differences in technology might generate essential cross-country differences in income per capita, which has also been confirmed in the (Hall & Jones, 1999) study. Technological progress is the only explanation for the continuing economic process, though the Solow model didn't explain the sources of technology upgrading. This alludes to the necessity of improving electricity transmission infrastructure through availing quality transmission lines for less wastage of energy, increasing substation capacity to cope with high voltages and increasing coverage of the transmission lines to provide different sectors of the economy room for technological progress hence economic growth.

2.3 Review of Empirical literature

2.3.1 Length of Transmission Line and Economic Growth

(Wassermann, Reeg & Nienhaus, 2015) analyze the emerging dynamics of Germany's energy transformation policy and the conflicting tactics of rivals and incumbents. The aim of the study was to examine how competing factors and ideas on market integration developed new services for direct marketing according to their responsible origins and tried to shape the regulatory framework. The study employed a case study analysis of Germany using the process tracing method. Findings indicate that Germany is expanding its electricity transmission lines to reach its local population and countries outside Germany. However, the writers do not indicate whether or not the expansion of the transmission line has any relationship with GDP growth in Germany. This study informs the current proposed study on electricity line length expansion. To fill the gap left by the writers, the current study goes deep into examining whether there exists a relationship between expanding an electric line in terms of length and GDP growth with cross reference to Kenya.

In 2013, (Mossavar-Rahmani, 2013) did a study on the expansion of the electricity line in terms of length in kilometers in Iraq. The study employed an explanatory research design. The aim was to explore the impacts of the expansion of electricity lines in Iraq. The findings indicated that by the early 1990s, the length of the transmission line had reached 8000 kilometres. It was expected that the country could continue expanding these electricity lines to supply power even to neighbouring countries such as Afghanistan. Nevertheless, the writer has not indicated whether this expansion influenced economic growth or whether all economic growth influenced the expansion of the line. This then shows that there is a gap in terms of the relationship between the expansion of electricity lines in terms of kilometres and the economic growth of any given country. To fill this gap, the current study examines the nexus between the length of electricity transmission lines and economic growth in terms of GDP with a special eye on Kenya.

(Rodger, 2013) contends that because the length of any traditional cable increases, both the energy transport capability of the road and the energy transfer efficiency decrease. The key ways to battle this are by raising the cable voltage and/or increasing the wire diameter. Nevertheless, the authors haven't indicated the connection between this example and the economic process. The proposed study fills this gap in Kenya by interrogating the relationships between the length of electricity cable and, therefore, GDP growth.

2.3.2 Economic Growth and Availability of Electricity Transmission Lines

(Lee, Miguel & Wolfram, 2020) examined how household electrification supercharges economic development. The aim of the study was to establish whether household electrification leads to measurable gains in living standards. An experimental approach was employed in gathering data for this study. The findings indicate that greater gains from electrification are likely to be concentrated in certain households. Their work relates to the proposed study because they study electricity in relation to economics. However, the current study differs from the idea because they focus on economic development while the study focuses on economic growth. Nevertheless, they're working to inform this study on the availability of electricity infrastructure, more specifically transmission lines, and whether this availability impacts economic growth.

(Enslev, Mirsal & Winthereik, 2018) penned an essay about the introduction of electricity in rural Kenya. They found a lot of strong conjecture and expectation in their research on local, regional, and worldwide objectives regarding universal access to clean energy. These plans frequently tell a tale of how energy may radically improve people's lives. One of these stories discussed fantasies of living on or without the power system. Popular predictions claim that with increasing investment for decentralized energy provision, the monopolistic authority of public corporations is gradually becoming addressed. They contend that with state-owned grid systems, electricity users are rendered docile and reliant beneficiaries of a service. Therefore, distributed energy systems are

anticipated to improve the country by transforming customers into active participants and driving inventiveness, new ways of thinking, and by transforming clients into registered members who can manage their personal destinies, boosting economic growth over the long term, and empowerment to the people. Rafiki demonstrates how solar energy can reduce reliance on the electrical grid and the associated political instability. Solar energy, and the acclaim it obtains, must be considered in connection to the arrival of grid electricity, as it cannot fully power the most wanted goods that grid electricity enables. Large infrastructure grid project stories and the "little is beautiful" school of thought don't just coexist. They are each other's creators.

(Lipscomb, Mobarak & Barham, 2013) studied the developmental impact of electrification on the topographic position of hydropower plants in Brazil. The major objective of the study was to examine the effects of electricity grid expansion on local economic growth in Brazil between 1960 and 2000. An instrument model was employed in the study. The results show that there have been significant impacts of electrification on growth that are exaggerated because one fails to account for indigenous targeting. It was noted that broad-based improvement as opposed to general equilibrium resorting is the only way through which gains from electrification can be realized. It is worth noting that electricity development comprises all the types of development that take place within the electricity grid; it does involve even the electricity transmission infrastructure. While this study informs this proposed study on the effects of electricity development, the proposed study examines this effect in relation to the development of electricity infrastructure and the GDP of Kenya.

(Mahfoudh & Amar, 2014) examined the relationship between electricity consumption and economic growth in 19 African countries. The major aim of the study was to establish the relationship between electricity consumption and economic growth in Africa. The Solos-Swan model and cointegration test, panel unit root test, and Granger causality test were employed in the

study. Their studies revealed that electricity consumption significantly affects economic growth. Additionally, it was noted that GDP variations cause electricity consumption and that there is a unidirectional causality relationship between electricity consumption and economic growth. It is noted that policymakers in African nations that face economic challenges must provide more electricity to boost economic activity. African countries provide more electricity to their people both because it is a vital and critical component for improving living standards and achieving their economic objectives. The study discussed how the availability of electricity transmission lines impacts the demand and supply of electricity and whether this or not influences economic growth.

(Bayar & Zel, 2014) studied the connection between economic development and electricity use in emerging economies over the 1970–2011 period. The study aimed toward investigating the link between economic process and electricity consumption in emerging economies between 1970 and 2011. Using the Pedroni Kao and Johanssen cointegration test and the Granger causality test, the results show that electricity consumption has had a positive effect on economic development, which there's a bi-directional causality between economic process and electricity consumption. They argue that developing countries should diversify energy resources and increase the share of renewable energy sources in energy usage. This will be achieved by pondering their high dependence on electricity.

The study assumed the fact that electricity involves several infrastructure developments within the grid and that each of these has a role to play in electricity consumption. As a result of this diverse electricity infrastructure, the proposed study examines the role of transmission lines and the nexus between them and economic growth in Kenya.

2.3.3 Substation Capacity and Demand and supply of electricity

(Kirikkaleli et al., 2018) tried to make a correlation between electricity use, internet demand, and economic activity in 35 OECD countries between 1993 and 2014. The main objective of the study was to determine the link between electricity usage, internet demand, and economic activity. A variety of tests were employed within the study. These include the panel cointegration, fully modified ordinary least squares, and dimitrescu-Hurlin causality tests to capture the potential end of the day and causal linkage among the three variables. The findings indicated a positive linkage between electricity, internet demand, and economic activity in the long run. The findings further showed the existence of a causality between electricity consumption and internet demand and a unilateral causality running from economic processes to electricity consumption. These ideas inform the present study in terms of electricity demand and provision and its impact on economic process. However, authors never focused on substation capacity in any reference to GDP and demand and supply of electricity. This is often the gap that this study fills with special focus on electricity transmission infrastructure and the economic process in Kenya.

(Saulo, 2010) According to his research on the planning of Kenya's energy distribution system, demand growth varies by region, and some places require a consistent electricity supply. Therefore, a productive planning approach starts with the supply system rather than with generation and distribution. The development of transmission lines to meet substation requirements, substation expansion and innovative substations to meet those very same distribution requirements, and substation requirements for transmission lines are all worked out in a forward manner to meet the ultimate goals of satisfying customer needs and changes in the socio-economic utilization. All of which play a significant role in realizing the country's economic growth through complete resource efficiency and maximum utility satisfaction.

(Ouedraogo, 2013) In their analysis of the casual impact between per capita electricity

consumption and real GDP growth of 15 developing countries in Sub-Saharan Africa, they established that there's no evidence of a short-term relationship between electricity consumption and GDP, but there's a long-term unidirectional causality from electricity consumption to real GDP for the complete panel. The authors further noted that the unidirectional causality that runs from electricity consumption to economic processes differs across economies. They concluded that access to modern energy (measured by energy consumption) may be a prerequisite for economic growth. It is important to notice that the main aim of the authors was to look at the causal effect between per capita electricity consumption and real GDP growth in sub-Saharan Africa. Secondary research was employed, and data was gathered from the planet bank and ENERDATA. While their study informs the proposed study on the connection between GDP and electricity consumption, they didn't examine whether the substation load influences the availability and demand. The proposed study within the bid to fill this gap examines the connection between substation load and GDP growth in terms of demand and provision of electricity.

2.4 Literature Review Summary

There are so many gaps that the review identified that need immediate scholarly attention. Many of the existing studies focus on electricity growth in general and its connection to economic growth without digging deep into the various facets that constitute the electricity grid. Although empirical studies have documented the relationship between electricity consumption and economic growth, very few studies have been done to explore the nexus between the independent facets within the electricity grid and economic growth. More precisely, there are no studies that have been done on the relationship between the development of electricity transmission infrastructure and economic growth in terms of GDP. Again, findings from other studies in other countries have shown that the connection between electricity infrastructure development and economic growth

differs from one country to another. This implies that to understand whether economic growth influences electricity development or vice versa, country-specific studies are needed.

To fill these gaps, the current study examines the relationship between electricity transmission infrastructure and economic growth in Kenya. more concerned about the length of the electricity transmission line, the availability of the electricity transmission line, and substation capacity. All these aspects are examined regarding their connection to the GDP growth in the country.

2.5 Conceptual Framework

The figure below shows the conceptual framework upon which this study is grounded.

INDEPENDENT VARIABLE

DEPENDENT VARIABLE

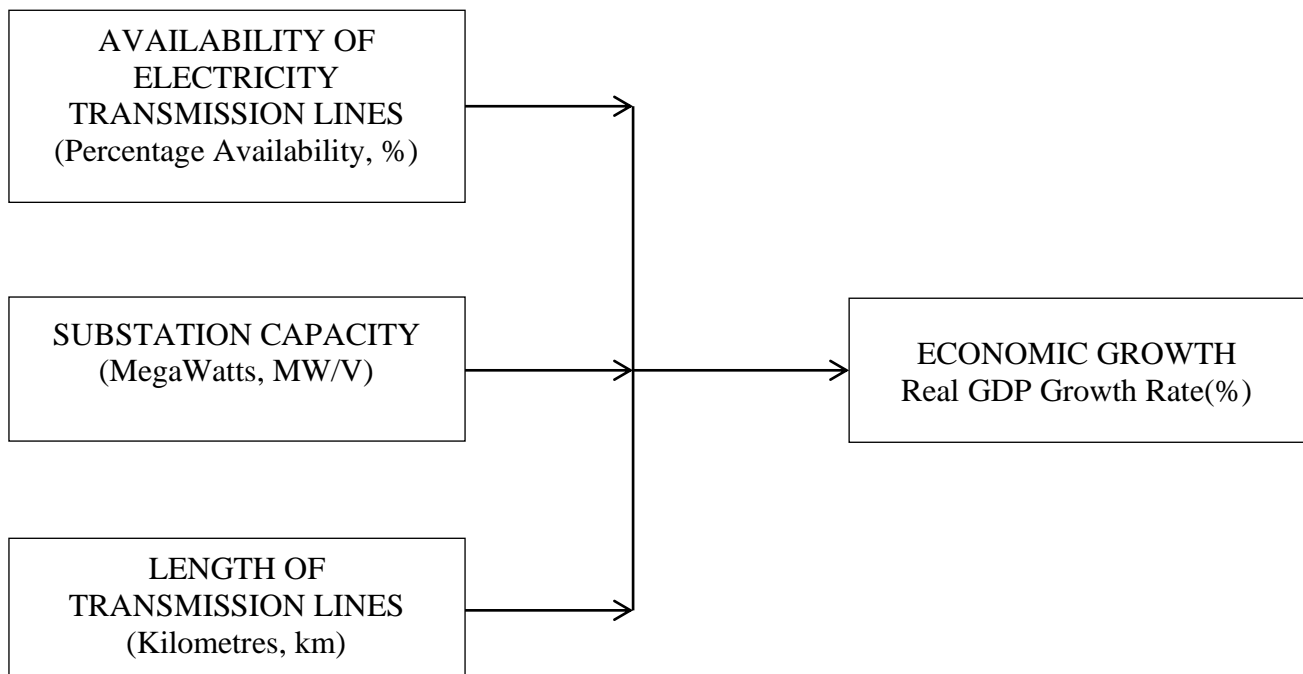


Figure 2:1 Conceptual Framework

The figure above shows the major study variables, which include electricity transmission infrastructure and economic growth. Electricity transmission infrastructure is defined by examining variables such as the length of the transmission line, the availability of the transmission line, and substation capacity. The dependent variable is the economic growth variable. This is measured using the real gross domestic product of the country. Relationships between variables are examined from the dynamics of electricity supply and demand

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the approach utilized by the researcher to accomplish the study objective. The chapter is sectioned into, research design, target population, data collection tool and data analysis procedures. It deals with research design where a specific strategy is employed to explain the relationship between the dependent variable and independent variables. This research design seeks to fulfill the research objectives.

This chapter also analyzes and elaborates the target population which in this case is economic growth and electricity infrastructure development. In this case, the target population on the independent variable is the transmission infrastructure. This target population, therefore, helps the researcher answer the objectives of the study. Furthermore, this chapter also considers the data collection tools used in the study. From the nature of the variables this study majorly depends on secondary data. Finally, this chapter lays out the data analysis procedure by listing and elaborating how the different tests will help in answering the research hypothesis.

3.2 Research design

(Dul & Hak, 2008) define the study design as an arrangement of the requirements for data collection and analysis in a manner that seeks to integrate significance with the purpose of research. In order to collect and analyse the data needed for a research project, the researcher must first create a research design (Rahi, 2017). An explanatory research design is used to analyse the relationship between the study variables. (Creswell & Creswell, 2003) The method is appropriate since it assesses the variability of electricity transmission infrastructure development on economic

growth across periods as well as clearly specifies the causal-comparative model of the conceptual framework. In addition, this design is recommended for this study since it played an instrumental role in explaining the cause-and-effect relationship between the study variables.

From the research hypothesis in the study, the explanatory research design helps in determining and elaborating the casual evidence between the electricity transmission infrastructure and economic growth. Therefore, the explanatory research design will help in elaborating the changes that occur in economic growth due to the changes in electricity transmission infrastructure in Kenya.

3.3 Target Population

A target population is a defined population that possesses the traits that the research study is looking for and that aid in the collection of a sizeable, representative sample by (Draugalis & Plaza, 2009). The target population, as defined by (Lavrakas, 2008), is the complete group of units for which inferences were to be drawn from the survey data. Therefore, the target population specifies the groups of people for which the survey's results are meant to be generalized (Zhao et al., 2013). The target population considers energy infrastructure development since independence, with a specific focus on the electricity transmission infrastructure sub-sector within the nation. To realize the research objectives, all the variables that were used have an influence on the whole economy, and the electricity sector, being a utility, is interdependent and deeply networked. The area of target is electricity transmission infrastructure, i.e., the national grid traverses the whole nation as a unity of analysis with 132kV of voltage and above. Even though the sector and the electricity infrastructure traverse the whole nation, data was collected from designated institutions with the mandate to oversee the development of the national grid. The study will focus on transmission infrastructure only. In terms of time limit, the study centralized on the length of transmission line constructed, substation capacity and availability of transmission lines and rate of

economic growth limited to the period 1970–2019 because time series data is available for this period.

3.4 Data collection tool

Data on electricity transmission infrastructure development and economic growth was mined from published statistical reports and recorded using a data collection tool as shown in appendix 1. The data collection form gathers quantitative data at a point in time, which ensures completeness, accuracy, and easy mining process without data gaps during the data collection process.

Data was mined from published reports of the Kenyan Central Bank (CBK), Energy Regulation Commission (ERC), World Bank (WB), Kenya Power and Kenya National Bureau of Statistics (KNBS) reports. The data collected entailed the length of transmission line constructed, the economic growth rate within the country, the substation capacity, and the availability of the transmission line.

The study duration covers 1970 to 2019. Several reforms were implemented during the period to achieve SDG 7: access to clean and affordable energy, advocacy on green energy, intervention on protocols for sustainable development, and the Vision 2030 blueprint with MTP III prioritizing energy development to achieve sustainable economic growth within the country. These gave enough new and interesting information for the study to be able to answer the research questions.

3.5 Data Analysis Procedure

The study uses time series econometric models. Autoregressive Distributed Lag (ARDL) cointegration technique or bound cointegration technique, and error correction model was used with the assistance of STATA statistical software to perform the analysis. This study utilizes the

time series econometric models since it relies on data collected over a period of 49 years. The ARDL model is essential in analyzing economic growth studies (Nkoro & Uko, 2016). The model shows that in this case, economic growth change is explained by both its own lag and the independent variables. Furthermore, the model is efficient as it eliminates collinearity in the results of the study by allowing the lag of economic growth and electricity transmission infrastructure to coexist in the model.

The stationarity, co-integration and bound cointegration tests are conducted to ensure that the ARDL model can be used to determine the relationship between the variables.

3.5.1 Preliminary test

Test for Stationarity

Time-series data is often presumed non-stationary, and thus it is important to perform a unit root test to check the stationarity of the data under consideration (McCabe & Tremayne, 1995). (Riman & Eyo, 2008) argue that the use of non-stationary data occasionally leads to misleading outcomes where test statistics suggest a meaningful relationship between variables even if there is no such relationship. The Augmented Dickey-Fuller (ADF) (1979) test will be preferred over the Phillips–Perron test to check for stationarity. For the ADF test, we estimate the following regression:

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{j=1}^k \lambda_j \Delta y_{t-j} + e_t \quad (4)$$

Where Δ ; difference operator, y_t ; represents series being tested, k ; number of lag differences and e_t ; error term. Δy_t is the change in series under consideration with respect to the time period t , α is the constant term, β is the vector of coefficient on y_{t-1} , λ_j is the lag, Δy_{t-j}

are the lagged changes. We tested the null hypothesis $H_0 : \beta = 0$ which implies that y_t is nonstationary.

The length of the lag was selected using information criteria such as AIC, FPE, LR, SBIC and the Hannan-Quinn selection criterion and residual term. Preliminary test included normality, heteroscedasticity and multicollinearity test was conducted to assess whether the Ordinary Least Square assumptions are met. Shapiro-Wilk normality test was used for normality test of data, the Breusch-Pagan or the Goldfeld-Quandt test tested presence of heteroscedasticity whereas correlation matrix was used for multicollinearity test (Horváth, Kokoszka & Rice, 2014).

In the test for stationarity the ADF test aims to establish if a process is random walk or random walk with drift. Stationary data displays constant variance overtime and is thus essential in determining the relationship between dependent and independent variables more efficiently (Priestley & Rao, 1969). The ADF relies on the p-value to determine stationarity in data. In this study the Augmented Dickey-Fuller test is preferred over the Phillips Perron test. This is because despite sharing the demerits of the ADF test, the Phillips Perron test works more efficiently on the financial time series data as it is solely dependent on asymptotic theory. This study also tests normality, heteroscedasticity and multicollinearity to ensure that the least squares assumptions are met to facilitate efficient analysis and elaboration of variables.

3.5.2 Co-integration Test

The co-integrating test would be used to assess the long-run relationship between electricity infrastructure development and economic growth variables (Hwang, 1998). Johansen's procedure (Johansen, 1988) was used to find out if there is a co-integrating vector between the variables if time series data is integrated in the same order as in the preliminary test. On the other hand, if the time series is not integrated to order one, the co-integration test cannot be used to figure out what caused what (Aydemir & Demirhan, 2009).

In such a scenario, the distribution of correlation coefficient between two uncorrelated I (2) variables is bimodal with a guarantee of zero expected value, but the variance of bimodal distribution is the reason that not only spurious regressions are misleading, but strictly nonsense dependency may be identified. The Toda and Yamamoto (1995) Granger Causality Test method is comparatively more effective in small sample sizes and is especially useful for time series for which the order of integration is not defined or may not always be the same.

Integrating the properties of the sequence is not necessary in the TY system if the order of integration is clearly defined. Therefore, a causal relationship may be formed between series that are combined with separate orders. Using Johansen test methodology, the co-integration test was based on the following set of equations:

$$RGDP_t = \beta AV_t + e_t \quad (5)$$

$$RGDP_t = \beta TL_t + e_t \quad (6)$$

$$RGDP_t = \beta SC_t + e_t \quad (7)$$

Where $RGDP_t$ Real GDP growth rate at period t, β is the vector coefficient of length of transmission line at period t, AV is the availability of transmission line, TL is the transmission length, SC substation capacity and e_t is the error term. Any pair of the two variables would be co-integrated if the residual term (e) is stationary. The ADF test was used to test the stationarity of the residual sequence

The findings of cointegration tests reveal situations in which a number of non-stationary time series are combined in such a way that they are unable to depart from equilibrium over the long term. The tests help determine how sensitive two variables are to an identical standard value over a given time (Shin, 1994). The co-integration test helps to determine the causation relationship between the variables in the model and thus elaborates the research hypothesis. (Habibi & Rahim,

2009) The Engle-Granger technique has the drawback of potentially revealing several cointegrating connections when there are greater than two variables. (Crowder & Hamed, 1993) The fact that it is only a singular modelling approach is another drawback. The Johansen test enables for further cointegrating relationships than the Engle-Granger test does. However, since a small sample size would result in incorrect results, it is susceptible to asymptotic properties (big sample size). This study majorly utilizes the Johansen test as the data used is large sample time series data collected over 49 years.

3.5.3 Bound Cointegration Technique

The test determined the causal relationship between the economic growth and transmission infrastructure development. In the absence of any co-integrating interaction between the factors, the Granger Causality Norm Test (Granger, 1988) is used. The bounded Autoregressive Distributed Lag (ARDL) cointegration technique approach has been used to describe how much of variable X can be explained by its own past values, and whether applying lagged values to another variable Y can describe more which estimate the below equations:

$$RGDP_t = \sum_{t=1}^n \alpha_1 AV_{t-1} + \sum_{j=1}^n \beta_j RGDP_{t-1} + e_1 \dots\dots\dots (8)$$

$$AV_t = \sum_{t=1}^m \lambda_1 AV_{t-1} + \sum_{j=1}^m \delta_j GDP_{t-1} + e_2 \dots\dots\dots (9)$$

$$TL_t = \sum_{t=1}^m \lambda_1 TL_{t-1} + \sum_{j=1}^m \delta_j GDP_{t-1} + e_2 \dots\dots\dots (10)$$

$$SC_t = \sum_{t=1}^m \lambda_1 SC_{t-1} + \sum_{j=1}^m \delta_j GDP_{t-1} + e_2 \dots\dots\dots (11)$$

Where the joint hypothesis of F-test based on Wald statistics for each equation are

$$M_0 = M_1 = M_2 \dots\dots\dots M_i$$

Where $RGDP_t$ is the Real Gross Domestic Product growth rate and AV_t is the availability of transmission at time period t, TL is the transmission length, SC substation capacity and e is the uncorrelated error term. Equation 3.5 implies that current real GDP rate is related to lag of RGDP and AV values. Equation 3.6 implies the current AV is related to past AV and RDGP values, similar to equation 3.7 and 3.8 for transmission length and substation capacity.

The null hypothesis for equation 3.5 is: $H_0 : \beta_j = 0$, which implies there is no causation from RGDP to AV. The null hypothesis for the equation 3.6 $H_0 : \delta_j = 0$ implying no causation from AV to RGDP. Similar to equation 3.7 and 3.8. We reject null hypothesis at 5% significant level. From the equations, perform analysis to examine the presence of unilateral causality from RGDP and AV or from AV to RGDP, TL to RGDP, SC to RGDP, RGDP to TL, RGDP to SC, presence of bilateral causality or whether AV, TL, SC and RGDP are independent. The Granger causality test is adaptive to the duration of the period used in the equations. In this analysis, Akaike's (1970) Final Prediction Error was used to determine the optimum lag duration.

Therefore, this model seeks to show the casual relationship between each independent variable and the dependent variable. This model is new and has been proven to provide consistent results for both large and small sample sizes. Through determining the presence of unilateral causality between RGDP and AV, TL and SC the study establishes how each independent variable contributes to the change of the dependent variable (Bentzen & Engsted, 2001). The model also elaborates how past values of each independent variable explain of the variables' values in the time series. Therefore, this model is used to analyze the presence of bilateral or unilateral causality between RGDP and AV, TL and SC.

3.5.4 Autoregressive Distributed Lag (ARDL) Model.

In ARDL, the explanatory and dependent variables' lags are used as regressors in a typical least squares regression (Greene, 2008). It is an ordinary least squares model that may be used to analyze both non-stationary time series and time series with different integration orders. Conditional models are explored in a wide range of applications in time series analysis, which means that the relationship between two variables and their causal direction are assumed. The assumption that the conditional mean is linear in the conditional variables is typically comparable to that in linear regression models.

To analyse the causal relationship between the real GDP on transmission infrastructure development, the study will apply a well-known approach by (Pesaran et al., 2001) called the autoregressive distributed lag (ARDL) approach. The variables in this model must all be stationary at either $I(0)$, $I(1)$, or a combination of $I(0)$ and $I(1)$ (Hassler & Wolters, 2006). Both short run and long run models need to be described if the variables are determined to be cointegrated with the aid of the bound test. Use of the shortrun ARDL model is possible if the variables are not cointegrated. Even with fewer observations in the series, it nevertheless produces more reliable results. The error term shouldn't be autocorrelated, and the lag between the dependent and independent variables should be ideal.

The ARDL model is considered as the best econometric method compared to others in a case when the variables are stationary at $I(0)$ or integrated of order $I(1)$. Based on the study objectives, it is a better model than others to catch the short-run and long-run impact of independent variables on electricity infrastructure. In comparison to previous multivariate tests of cointegration, the ARDL bound test technique to cointegration has an extra significant advantage in terms of delivering effective results for a relatively small sample. It most importantly avoids potential endogeneity issues and is most effective when used to evaluate dynamic relationships or

interaction among variables with time series data in a single-equation framework (Pesaran et al., 2001).

The ARDL approach is appropriate for generating short-run and long-run elasticities for a small sample size at the same time and follow the ordinary least square (OLS) approach for cointegration between variables (Duasa, 2007). ARDL affords flexibility about the order of integration of the variables. ARDL is suitable for the independent variable in the model which is $I(0)$, $I(1)$, or mutually cointegrated (Frimpong & Oteng 2006), but it fails in the presence $I(2)$ in any variables.

Through enabling the lag of the response variable to be included in the model with other independent variables and their lags, the ARDL model tackles the problem of collinearity. The first ARDL condition is the elimination of autocorrelation problem. The model demands that there be no autocorrelation between the error terms. The model also makes the assumption that the data shouldn't exhibit any heteroscedasticity (Banerjee, Galbraith & Dolado, 1990). The variance and average should, to put it simply, stay unchanged throughout the model. The data ought to have a normal distribution. Finally, the data must be steady on $I(0)$, $I(1)$, or both. Additionally, the ARDL Model is unable to execute if any of the data's variables become stationary at $I(2)$. Therefore, this model is the most efficient in determining economic studies as it provides adequate information to predict variable change in the future.

CHAPTER FOUR

DATA ANALYSIS, FINDINGS AND DISCUSSION

4.1 Introduction

The empirical findings of the study are presented in this chapter. This chapter is structured as follows: First, descriptive statistics for each variable are provided and examined, followed by different time series tests. Second, the importance of transmission lines to economic growth. Third, determine the link between substation capacity and economic growth as well as the association between substation capacity and economic growth. This chapter aims to represent data in an analytical form to facilitate the drawing of conclusions to determine if the independent variables in this study have any effect on the dependent variable.

4.2 Descriptive analysis

The total observation was 50 data point with key variables to explain the research objectives. The 1st interquartile range for transmission line constructed and substation capacity (MVA) is Zero and the mean is 95.824km and 57.66 MVA respectively. The coefficient of variation implies variability of data series with the highest transmission line constructed with 1.455 and substation capacity 1.421 with availability .016. the table below show summary of descriptive statistics. From the table below, skewness of the transmission line and substation capacity data is 2.512 and 2.801 which shows that the data is highly skewed and right tailed since the value is positive. The skewness of the data on the availability of transmission line is -0.13 which indicates that the data is lowly skewed and left tailed as the value is negative. Furthermore, the kurtosis on transmission line and substation capacity are 10.03 and 11.562 respectively which shows that the

data on both variables is heavily tailed and has a high number of outliers. The kurtosis of the availability of transmission line is 2.199 which shows that the data has limited outliers.

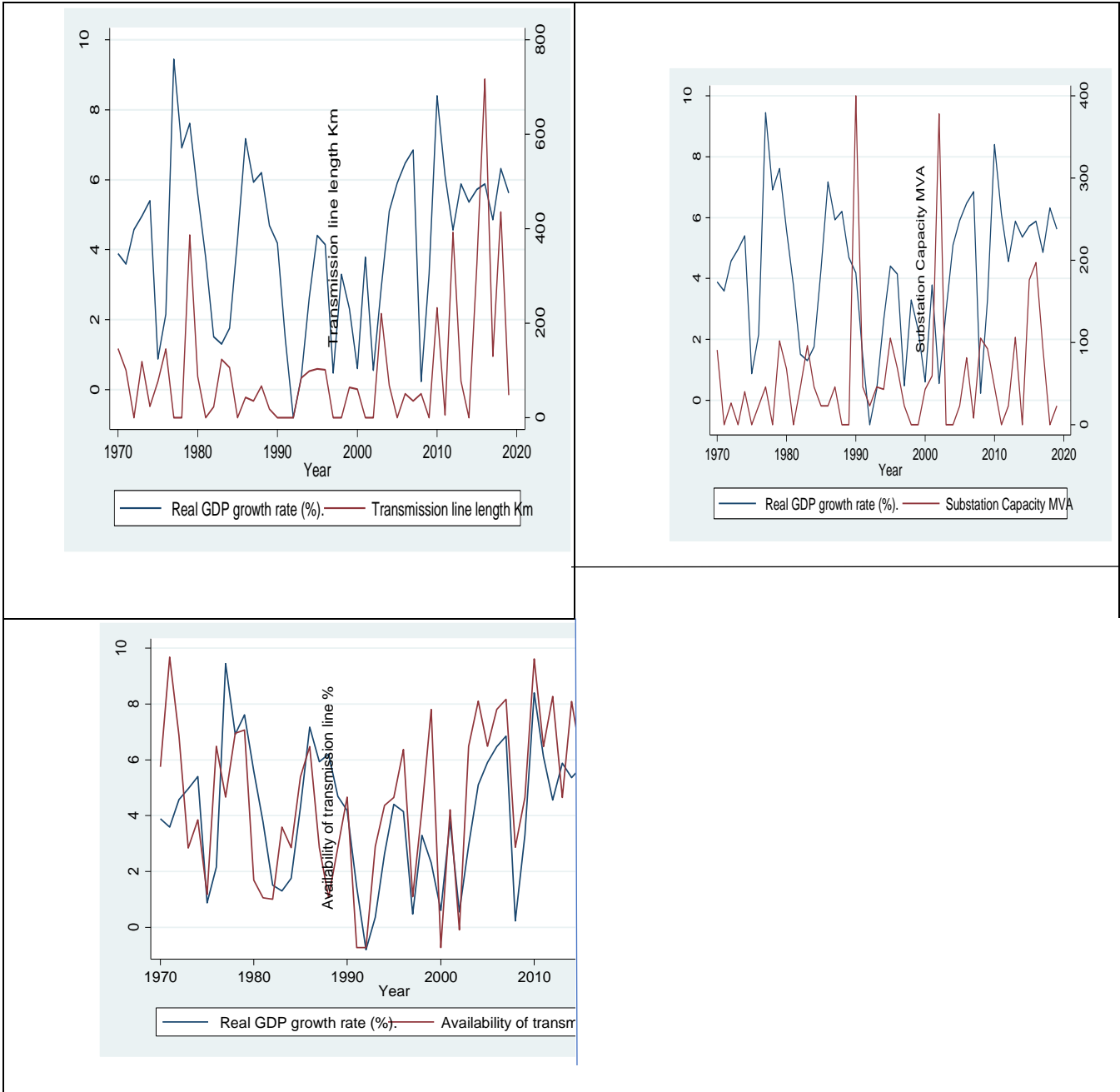
Summary Statistics

| | sum | igr | p25 | p75 | cv | skewness | kurtosis |
|---------------------------------------|----------|-------|--------|--------|-------|----------|----------|
| Transmission Line (Km) | 4791.19 | 106 | 0 | 106 | 1.455 | 2.512 | 10.03 |
| Substation Capacity (MVA) | 2883 | 81 | 0 | 81 | 1.421 | 2.801 | 11.562 |
| Availability of transmission Line (%) | 4846.805 | 2.026 | 96.024 | 98.049 | .016 | -.13 | 2.199 |

Descriptive Statistics

| Variable | Obs | Mean | Std.Dev. | Min | Max |
|---------------------------------------|-----|--------|----------|--------|--------|
| Transmission Line (Km) | 50 | 95.824 | 139.412 | 0 | 717 |
| Substation Capacity (MVA) | 50 | 57.66 | 81.948 | 0 | 400 |
| Availability of transmission Line (%) | 50 | 96.936 | 1.53 | 94.039 | 99.823 |

Further analysis indicates that the total transmission lines constructed over a period of 50 years is 4791.19km, implying the expansion of the transmission infrastructure was massive, with 30% representing 15 years with zero kilometres constructed, indicating the challenge faced in attainment of the same. Similarly, total substation availability of 2883MVA has been recorded over 50 years, 100% and 28%, which represents 14 years of recording zero MVA of substation commissioned. The average availability of transmission lines is 96.936%, which implies that the network is reliable and provides security of supply. The graphical representation below depicts the relationship between the study variable and the dependent variables. The standard deviation of the transmission line and substation capacity variables are 139.412 and 81.948 respectively which shows the data are highly spread from the means which are 95.824 and 57.66. The standard deviation on the availability of transmission line data is 1.53 which shows that the data is clustered around the mean. The average substation capacity is 57.66MVA which is fairly average for a developing country like Kenya.



The time series movement for the availability of transmission lines depicts the same direction movement. While the constructed transmission line has a similar movement but is displaced with a different amplitude with convergence. In 1992, when the transmission line was constructed, the Real GDP was negative, implying that the development of transmission lines depends on resources available to expand the infrastructure. which also applies to substation

capacity that is zero and the reliability in terms of availability was below the required standard of 95%.

4.3 Diagnostic Tests

4.3.1 Optimal Lag selection

The first step in the analysis is to select an appropriate lag length. This ensures that the error term is correctly specified (Enders, 1995). There are various selection criteria available, including the Sequential Modified Likelihood Ratio (LR) criterion, the Final Prediction Error (FPE) criterion, the Akaike Information Criterion (AIC), the Schwarz Bayesian Information Criterion (SBIC), and the Hannan-Quinn Information Criterion (HQC). There is no unanimous agreement on which criterion to use in the case of conflicting results among the above methods. However, the decision rule is to choose the model with the lowest value of information criteria for each study variable. In our case, lag selection information criteria are shown in the table below in a summarized structure after running an ARDL model with maxlags. Then the below matrix is obtained.

Results of individual variable lags selection

e(lags) [1,5]

| | Real GDP growth rate | Length of transmission line | Substation Capacity | Availability of transmission line |
|----|----------------------|-----------------------------|---------------------|-----------------------------------|
| r1 | 1 | 0 | 0 | 0 |

The below figure shows that lag of zero when analysis all the study variable together.

varsoc Real GDP growth rate Transmission line length Km Substation Capacity MVA Availability of transmission line

Selection-order criteria

| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|-----|----------|--------|----|-------|-----------|----------|----------|---------|
| 0 | -901.803 | | | | 9.1 e+10* | 39.4262* | 39.5007* | 39.625* |
| 1 | -884.115 | 35.377 | 25 | 0.082 | 1.3 e+11 | 39.7441 | 40.1909 | 40.9367 |
| 2 | -864.369 | 39.491 | 25 | 0.033 | 1.7 e+11 | 39.9726 | 40.7916 | 42.159 |
| 3 | -853.33 | 22.08 | 25 | 0.631 | 3.4 e+11 | 40.5795 | 41.7709 | 43.7598 |
| 4 | -823.595 | 59.47* | 25 | 0.00 | 3.4 e+11 | 40.3737 | 41.9373 | 44.5478 |

Real GDP growth rate

Endogenous: Transmission line length Km

Substation Capacity MVA

Availability of transmission line

Exogenous: _cons

4.3.2 Stationarity Test results

The study conducted time series tests to choose the appropriate method of estimation. The study conducted the stationarity test to check whether any of the series had a trend. Failure to do so would lead to spurious and meaningless results in the presence of a unit root. This study used the Augmented Dickey-Fuller test (ADF) to test for stationarity of the time series data at a 5-percent significance level with lag 1. Under ADF, the null hypothesis is rejected if the computed ADF statistic (t-value) in absolute terms is greater than the critical value. The results of the ADF test are as shown in the following table below.

Augmented Dickey-Fuller test (ADF)

| Variable | | ADF Test statistic Z(t) | T-statistic 5% | MacKinnon approximate p-value for Z(t) |
|-----------------------------------|---------|-------------------------|----------------|----------------------------------------|
| Real GDP growth rate | Lag (1) | - 4.062 | - 2.936 | 0.0011 |
| Transmission line length Km | Lag (1) | - 3.718 | - 2.936 | 0.0039 |
| Substation Capacity MVA | Lag (1) | - 5.722 | - 2.936 | 0.0000 |
| Availability of transmission line | Lag (1) | - 4.104 | - 2.936 | 0.0010 |

At a 5% level of significance, the results revealed that all of the series were stationary. The same is also supported by the p-values associated with each computed value, which are all less than 0.05. The study therefore concluded that each of the time series did not have a unit root and therefore integrated of order zero [I (0)]. The study therefore applied standard time series regression to estimate the models. From the analysis each of the time series for each variable did not have a unit root hence a predictable pattern. The absence of the unit root in the time series ensures that there will be no spurious regression that shows high r-squared values between variables even when the data is uncorrelated. Furthermore, this also ensures that the model has no errant behaviour.

Cameron & Trivedi's decomposition of IM-test

We undertake further test by Cameron and Trivedi's to decompose the IM test and evaluate the homoscedastic test of residuals. The study assessed both skewness and kurtosis. The study found that there is no heteroskedasticity and skewness from the data. The chi-square values are larger than the p value. However, there is evidence of kurtosis in the data as shown by higher p-value

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|-------|----|-------|
| Heteroskedasticity | 5.920 | 14 | 0.969 |
| Skewness | 3.100 | 4 | 0.541 |
| Kurtosis | 0.030 | 1 | 0.865 |
| Total | 9.050 | 19 | 0.973 |

The study examines the model specification by Ramsey test using powers of the fitted values of predicted values. The result below implies that the model is wrongly specified with a p Values of 0.5004 with is greater than 0.05 level of significance

Ho: model has no omitted variables

F(3, 42) = 0.80

Prob > F = 0.5004

Therefore, the ordinary linear regression model complies with estimation assumptions. In the empirical literature review by (Kirikkaleli et al., 2018), the study mitigates and diverges from the weakness of OLS by determining the impact of study results in the presence or absence of drift and trend in the study model. In addition, (Ouedraogo, 2013) argued that OLS has the limitation of decomposing short-term and long-term effects of the study. The current study proceeds to estimate time series models beginning with a test for time series properties and thereafter an autoregressive distribution lag model to draw a valid and conclusive relationship between transmission infrastructure and economic growth.

4.4 Autoregressive Distributed Lag Model

The first step in the ARDL bounds testing approach is to estimate equation (1) by Ordinary Least Squares (OLS) to test for the existence of a long run relationship among the variables by conducting an F-test for the joint significance of the coefficients of the lagged levels of the variables, that is:

$H_N; \delta_1 = \delta_2 = \delta_3 = 0$ against the alternative

$H_A; \delta_1 \neq \delta_2 \neq \delta_3 \neq 0.$

After conducting the autoregressive distribution lag and obtain the matrix structure results detailing all the respective lags of study variable lag (1,0,0,0,0) as presented above, we perform bounded

cointegration test. The result of ARDL bound test is significant which means that both F statistic and t statistic is greater than the critical values therefore reject null hypotheses conclude there is a relationship that the economic growth is explained by length of infrastructure development, substation capacity and availability of the transmission infrastructure. The values below conclude that electricity transmission infrastructure contributes positively to economic growth in Kenya. The results below show the positive correlation between the independent variables and the dependent variable.

Autoregressive Distribution Lag

Pesaran/Shin/Smith (2001) ARDL Bounds Test

H0: no levels relationship F = 9.399

t = -5.436

Critical Values (0.1-0.01), F-statistic,

| | [I_0] | [I_1] | [I_0] | [I_1] | [I_0] | [I_1] | [I_0] | [I_1] |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|
| | L_1 | L_1 | L_05 | L_05 | L_025 | L_025 | L_01 | L_01 |
| k_4 | 2.450 | 3.520 | 2.860 | 4.010 | 3.250 | 4.490 | 3.740 | 5.060 |

accept if F < critical value for I(0) regressors

reject if F > critical value for I(1) regressors.

Critical Values (0.1-0.01), t-statistic,

| | [I_0] | [I_1] | [I_0] | [I_1] | [I_0] | [I_1] | [I_0] | [I_1] |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|
| | L_1 | L_1 | L_05 | L_05 | L_025 | L_025 | L_01 | L_01 |
| k_4 | -2.570 | -3.660 | -2.860 | -3.990 | -3.130 | -4.260 | -3.430 | -4.600 |

accept if t > critical value for I(0) regressors

reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship

Critical values from Pesaran/Shin/Smith (2001)

The study adopts the Autoregressive Distributed Lag (ARDL)/bounds testing cointegration procedure to estimate the long run and short run relationships and dynamic interaction among the

variables of interest. The bound result obtained above conclude that there is co integration between the series. The result is presented below.

Bounds Testing Cointegration Results

ARDL(1,0,0,0)regression

Sample: 1971 - 2019

Number of obs = 49

R-squared = 0.5222

Adj R-squared = 0.4666

Log likelihood = -94.802713

Root MSE = 1.7880

| D.Real GDP growth rate | Coef. | Std. Err. | t | p> t | [95% Conf. Interval] |
|------------------------------------|------------|-----------|-------|-------|----------------------|
| ADJ Real GDP growth rate L1. | -0.6022988 | 0.1108013 | -5.44 | 0.00 | -0.825751 -0.3788466 |
| LR Transmission line length Km | 0.0038798 | 0.0031985 | 1.21 | 0.232 | -0.0025705 0.0103302 |
| Substation Capacity MVA | -0.0016451 | 0.0053694 | -0.31 | 0.761 | -0.0124736 0.0091834 |
| Availability of transmission line | 1.143083 | 0.3651878 | 3.13 | 0.003 | 0.4066119 1.879554 |
| SR _cons | -64.44993 | 17.92055 | -3.60 | 0.001 | -100.5902 -28.30971 |

The adjustment coefficient is -0.6022900 which implies that in the long run there is convergence which will result to equilibrium which is statistically significant with a p value of 0.0000. Furthermore, from this test the adjusted R-squared is 0.4666 which shows that 46.66% of the variation in the dependent variable in the model is explained by independent variables. The LR coefficients for transmission line, substation capacity and availability of transmission line are 0.00388, -0.00164 and 1.143. The transmission line and availability of transmission line are statistically significant as shown by the p-values.

4.5 Post Estimation for ARDL.

A further step of estimating model is checking this model adequacy before making a forecast, these checking steps divided to checking model stability and diagnostic of residuals performance.

4.5.1 Autocorrelation Test

The Durbin Watson test is used to determine the evidence of autocorrelation.

H_0 = No serial correlation in the residuals of the model

H_1 = There is serial correlation in the residuals of the model

Durbin-Watson d-statistic (6, 49) = 2.01136

Breusch-Godfrey LM test for autocorrelation

| lags(p) | chi2 | df | Prob > chi2 |
|---------|-------|----|-------------|
| 1 | 0.079 | 1 | 0.7792 |

H_0 : no serial correlation

Under Breusch-Godfrey LM test, the p-value at lag (1) is 0.7792. Hence, we accept the null hypothesis of no autocorrelation at lag order 1.

It is therefore confirmed that there is no longer serial correlation between residuals shown in the d statistic; the null hypothesis that there is no serial correlation is not rejected at level 0.05 which mean that there is no evidence for serial correlation in the residuals term of the estimated model. The model finds that there is no serial correlation in the residuals that the model is efficient.

4.5.2 Normality Test

The Jarque-Bera (JB) test is used for checking normality of the residuals, the null hypothesis of JB test is the residuals are normally distributed, the probability (p-value) highly recommends the normality of residuals as we can't reject the null hypothesis event at the very high level of significance. Therefore, the result of JB Normality test is presented below.

JB normality test: 22.46 $\text{Chi}_{(2)}$ 1.3e-05

JB test for H_0 : normality:

All probabilities are above 5% significant level hence we reject H_0 . And conclude that all the series all the equations are normally distributed.

4.5.3 Test for Constant Variance

The result below shows that there is no heteroscedasticity (or the variance is constant) in the residuals since we do not reject the null hypothesis of no heteroscedasticity at level 0.05 using white test as shown below.

White's test for H_0 : homoscedasticity

against H_a : unrestricted heteroscedasticity

$\text{chi}_2 (20) = 10.38$

Prob > $\text{chi}_2 = 0.9608$

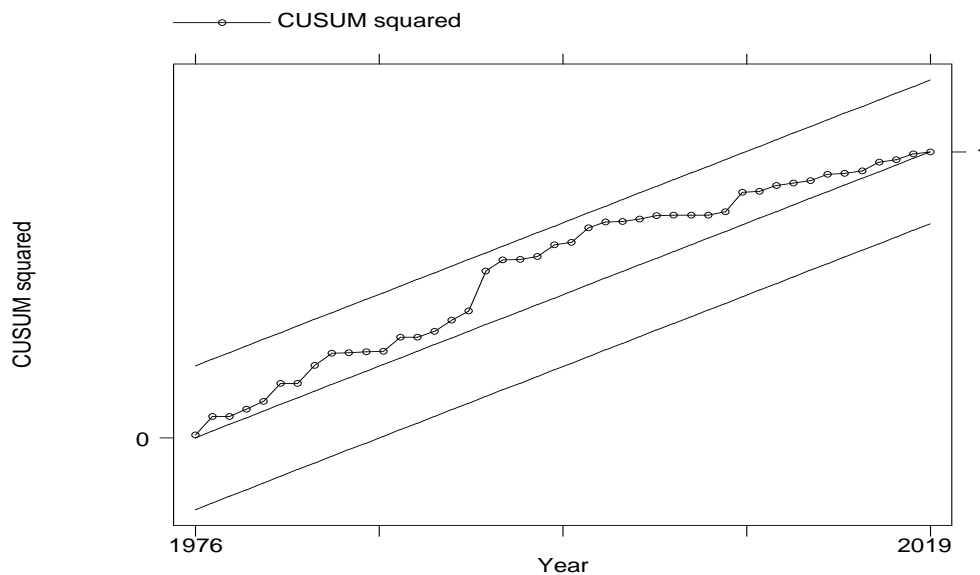
| Source | chi2 | df | p |
|--------------------|-------|----|--------|
| Heteroscedasticity | 10.38 | 20 | 0.9608 |
| Skewness | 4.42 | 5 | 0.4901 |
| Kurtosis | 1.51 | 1 | 0.2184 |
| Total | 16.32 | 26 | 0.9282 |

Further the result can be decomposed to heteroscedasticity, skewness and Kurtosis using Cameron & Trivedi's decomposition of IM-test. The absence of heteroscedasticity in the model means that confidence intervals and hypotheses tests can be conducted to determine the efficiency

of the model in general. This is essential in ensuring that the independent variables are efficient predictors of the dependent variable.

4.5.4 CUSUM Stability Condition

Then the stability condition of the error correction model in ARDL estimates is checked. In the fitted ARDL, variables must be covariance stationary. CUSUM is used to test the stability and correctness of the estimated model. The figure below shows that the estimated model meets the stability criterion because there are no roots that are outside the significance threshold.



Source: Author (2021)

The model was stable, according to the stability tests (CUSUM), since the residuals were within the dual standard error ranges. Following the ARDL model's residual test findings, the research found that the model was statistically sound and that suitable inferences could be drawn from the empirical data. The model is thus statistically significant in determining the effects of the independent variables on the dependent variable. The model can effectively predict if transmission line (Km), substation capacity (MVA) and availability of transmission line (%) affect real gross

domestic product in Kenya. The time series is essential in determining the model and thus the findings of the study are statistically correct.

Correlation analysis

The correlation result for the study variable is presented below with the significant level shown in the correlation matrices for the independent variables, respectively. The correlation shows a linear relationship between the independent variable and the decision rule was that pairwise correlation coefficients of less than 0.8 were acceptable for variables to be included in the ARDL model. The higher the association between the independent variables, the more they depict multicollinearity issues in data. Furthermore, the significance will elicit a discussion of appropriateness.

Pairwise correlations

| Pairwise correlations | | | | |
|-----------------------------------|--------|-------|--------|----|
| Variables | -1 | -2 | -3 | -4 |
| Real GDP growth rate | 1 | | | |
| Transmission Line | 0.232 | 1 | | |
| | 0.105 | | | |
| Substation Capacity | -0.097 | 0.151 | 1 | |
| | 0.503 | 0.295 | | |
| Availability of transmission line | 0.544* | 0.15 | -0.173 | 1 |
| | 0.000 | 0.299 | 0.23 | |

* shows significance at the 0.05 level

From the results presented above, transmission availability is statistically significant with a positive correlation coefficient of 54.40%, indicating a direct relationship between economic

growth and electricity availability. Substation capacity and transmission line length have lower associations with a correlation coefficient of -9.69% and 23.20%, respectively, with P values of 0.5033 and 0.1050, respectively. The P values therefore depict that the coefficients of substation capacity and transmission line length are statistically insignificant. This may be attributed to inconsistency in the data. However, the results imply that electricity availability is crucial in spurring economic growth. Therefore, we need to reduce blackouts, and outages, and improve energy reliability and security as opposed to massive investment in infrastructure that does not necessarily lead to improvement of quality and strengthening of the electricity infrastructure to provide availability. Furthermore, from the analysis we can conclude that the availability of transmission lines (%) and transmission line (Km) have a major impact on the economic growth of a country. These two variables are significant as they ensure efficient delivery of electricity to the population and environments which sparks economic growth. To ensure that past invest in electricity production directly impacts economic growth there is need to ensure quality delivery of electricity to the nation.

REGRESSION ANALYSIS

The study proceeds to fit ordinary linear regression model and undertakes diagnosis of its assumption and model specification. The result of the multiply regression is presented below.

| Real GDP Growth Rate | Coef. | St. Err. | t-value | p-value | [95% Conf Interval] | Sig |
|------------------------------|---------|----------|------------------|---------|---------------------|-----|
| Transmission line | 0.003 | 0.002 | 1.46 | 0.152 | -0.001 0.007 | |
| Substation Capacity | -0.001 | 0.004 | -0.24 | 0.811 | -0.008 0.006 | |
| Availability of Transmission | 0.710 | 0.206 | 3.45 | 0.001 | 0.296 1.124 | *** |
| Constant | -64.993 | 19.878 | -3.27 | 0.002 | -105.029 -24.956 | *** |
| Mean dependent var | | 4.171 | SD dependent var | | 2.351 | |
| R-squared | | 0.338 | Number of obs | | 50.000 | |
| F-test | | 5.751 | Prob > F | | 0.001 | |

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

The results presented above suggest that only transmission availability and constant coefficient are statistically significant with P values below the 5% significant level. R squared indicates only 33.8% of the variations in economic growth are explained by the independent variables holding other factors constant. This implies that we investigate the model specification and test for the residual to ascertain the assumption of linearity and constant variance. The figure below shows a kernel density normal distribution for the residual. The residuals exhibit normal distribution.

REGRESSION COEFFICIENTS

The specific model was:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where

Y = Economic Growth (Real Gross Domestic Product)

X₁ = Length of Transmission Line

X₂ = Substation Capacity

X₃ = Availability of Transmission Lines

ε = Error term and β₀ β₁ β₂ β₃ and β₄ are the supposed regression equation coefficients for each of the discussed variables above.

From the analysis above, we have the following linear regression model.

$$\text{Real GDP} = -64.993 + 0.003X_1 - 0.001X_2 + 0.710X_3$$

INTERPRETATION OF THE REGRESSION MODEL COEFFICIENTS

From the model above we can conclude that:

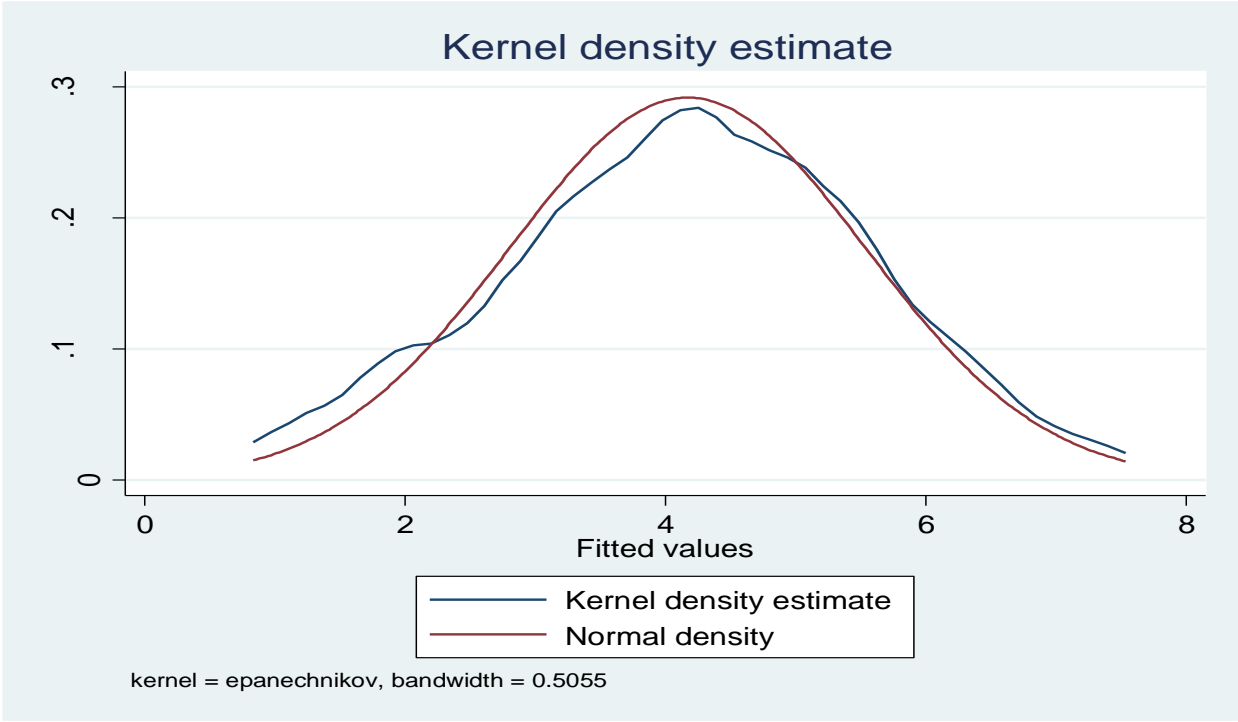
$B_0 = -64.993$ This is the Economic Growth coefficient when all other factors are held constant and assumed they are not in existence. This implies autonomous negative economic growth experienced with absence of electricity transmission infrastructure. This clearly depicts that electricity infrastructure of the country is very integral in realizing economic growth and development

$\beta_1 = 0.003$ This is the coefficient of length of transmission lines which shows that a unit increase in transmission line (Km) causes 0.003 units increase in real gross domestic product.

$\beta_2 = -0.001$ This is the coefficient of substation capacity which shows that a unit increase in substation capacity (MVA) causes 0.001 units decrease in real gross domestic product. However, this was contested by the p-value of 0.811 which proved the value to be statistically insignificant. Some of the causes that may have led to such results could be attributed to discrepancies in the data used.

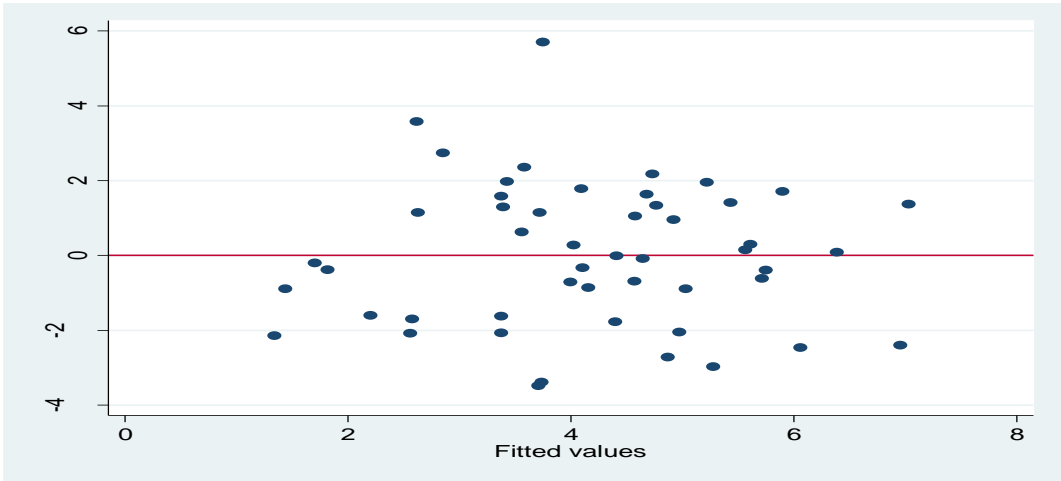
$\beta_3 = 0.710$ This is the coefficient of availability of transmission lines which shows that a unit increase in the availability of transmission line causes 0.710 units increase in real gross domestic product

Therefore, from the analysis, the availability of transmission line is a major contributor in positive economic growth.



Residual versus Fitted Plots

In addition, residual versus fitted plots indicate constancy of variance as shown in the graph below.



4.6 Result and Finding discussions

The research discusses the findings from the data analysis in relation to the theories. The current study examines the nexus between the length of electricity transmission lines and economic growth in terms of GDP with a special eye on Kenya. According to Keynes, fluctuations in any component of spending—consumption, investment, or government expenditures—cause output to change. Therefore, the result of the ARDL bound test is significant and is in line with the thinking of Keynes, which means that both F statistic and t statistic are greater than the critical values. Therefore, reject null hypotheses and conclude that there is a relationship that economic growth is explained by the length of infrastructure development, substation capacity, and availability of the transmission infrastructure. Further (Mossavar-Rahmani, 2013) studies on the expansion of electricity lines in Iraq exhibit similar findings with the expectation of the expansion to improve economic growth in the regional power pool country. This then shows that there is a gap in terms of the relationship between the expansion of electricity lines in terms of kilometers and the economic growth of any given country. However, the expansion of electricity lines in terms of kilometres contributes a significant proportion to economic growth in a country. This is because electricity lines (Km) promote electricity coverage in a country and to some extent promote the electricity infrastructure in a country. Therefore, despite the gap, there is some degree of relationship between expansion of electricity lines (Km) and real gross domestic product in Kenya.

This study also sought to establish the relationship between economic growth and the availability of electricity transmission lines. According to the Harrod-Domar model of economic growth, there is no natural reason for an economy to have balanced growth. In our findings, transmission availability is statistically significant with a positive correlation coefficient of 54.40%, indicating a direct relationship between economic growth and electricity availability. (Lipscomb, Mobarak & Barham, 2013) tried to also examine the effects of electricity grid

expansion on local economic growth in Brazil between 1960 and 2000. However, this study differs since it was establishing the availability of the transmission line and its impact on the economy in Kenya. From the correlation coefficient of 54.40%, this study finds that the availability of electricity transmission lines is a major predictor for economic growth in Kenya. The availability of transmission lines promotes efficiency in the nation and enables utilization of electricity in the nation to stimulate economic growth. The availability of transmission lines in Kenya enables more people in the country to install electricity in their businesses and homes thus stimulating efficient production and development, hence promoting economic growth.

Our findings were significant on whether there is any impact between substation capacity and economic growth in Kenya. Neo-classical economic theory by (Stern, 1999) regards energy as an intermediate input of production. Many scholars, such as (Kirikkaleli et al., 2018), tried to establish a nexus between electricity use, internet demand, and economic activity in 35 OECD countries between 1993 and 2014. Their study showed a positive correlation, but it differs with ours since we looked deeply into how substation capacity impacts economic growth in Kenya. In Kenya, substation capacity does not directly impact economic growth. Substation capacity (MVA) does not directly impact economic growth since, electrical infrastructure directly impacts economic growth in Kenya when the level of transmission is high. This is because this way, electricity reaches more people and consumption is high promoting economic activities. However, high substation capacities with low transmission promote electricity overproduction which is a negative factor for economic growth.

Kenya is one of the most developed sectors south of the Sahara (Pueyo, 2018). (The International Energy Agency, 2017) notes that electricity consumption and infrastructure are likely to increase by 315 % during that period Challenges faced by the energy sector in Kenya include limited, aging transmission and distribution infrastructure and disputes, among other challenges

(Edwards, Dent, & Wade, 2017; George et al., 2019). The provision of affordable and reliable energy is regarded as one of the essential steps towards the achievement of the Big Four Agenda and Vision 2030, a development plan that contains aspiring goals for economic, social, and political development (Berggren & Sterberg, 2017).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The overview of the study, the conclusion, and the policy implications of the findings are presented in this chapter. Furthermore, the chapter acknowledges the study's shortcomings and suggests topics for future investigation. The study suggests possible topics to research in the future and lists how the shortcomings can be avoided in future studies.

5.2 Summary

A middle-income economy is to be transformed according to the Kenyan vision. It is mentioned that infrastructure needs, and electricity consumption are predicted to rise by 315% between 2015 and 2030 due to population growth. This suggests that to fulfil the increased demand, the Kenyan government must build the necessary infrastructure for energy. Limited, outdated transmission and distribution facilities, as well as disputes, are problems that Kenya's energy sector must deal with. The study's findings imply that deteriorating infrastructure and a weak system cause large system losses and a decline in the quality of power services. For productivity in the economy to be realized, the association must improve the availability, quality, and dependability of power.

In our findings, with a positive correlation coefficient of 54.40%, the availability of transmission is statistically significant and suggests a causal link between economic growth and electricity supply. Because Kenya has transmission lines, more individuals are able to put electricity in their homes and companies, which encourages more effective production and development and hence fosters economic progress.

In line with the findings of the current study, the shock and rate of convergency with a lagged difference are high. However, the energy sector in Kenya is one of the most developed sectors south of the Sahara with 1486km of developed infrastructure to carry bulk electricity. Factors that favour the Kenyan energy sector are an active private sector and abundant renewable energy resources such as geothermal, wind and solar power. The provision of affordable and reliable energy is regarded as one of the essential steps towards the achievement of the Big Four Agenda and Vision 2030, a development plan that contains aspiring goals for economic, social, and political development.

Since electrical infrastructure directly affects economic growth in Kenya when the amount of transmission is high, substation capacity (MVA) has no discernible effect on economic growth. This is due to the fact that more people can access electricity this way, and high consumption encourages economic activity. High substation capabilities with inadequate transmission, however, encourage excessive electricity output, which is detrimental to economic progress. This period witnessed the rise of smart technology in metering, notably the usage of tokens, which this research argued for and employed as a major technology, utilising the Solow model's assertion that employing technology will enhance productivity. The advancement of the electrical grid system grants high availability of transmission lines, reducing the electrical losses due to operation and leakages in the system. Improved efficiency in the operation of the grid will play a crucial role in the attainment of economic growth.

A sizeable amount of a nation's economic growth is caused by the extension of electrical lines in terms of kilometres. This is true because electricity lines (Km) help spread electricity throughout a nation and, to a certain extent, help build its electrical infrastructure. Therefore, notwithstanding the difference, there is some correlation between Kenya's real gross domestic product and the extension of electricity lines (Km). Electricity transmission and generation has

drastically improved in Kenya and with the Vision 2030 just eight years away, the Kenyan government has put drastic measures to ensure that the big four agenda is achieved. The energy sector through the Kenya Electricity Transmission Company (KETRACO) has been increasing its electricity transmission to the nation. The increased electricity coverage has been instrumental in promoting economic growth through increased production. The number of generators has also been increased and the transmission lines to encourage the supply of electricity in informal settlements and rural areas.

The increased coverage of electricity in Kenya has seen more revenue for the sector with the increased usage of tokens and fast community based electrical connections. In general, electricity coverage in Kenya has greatly improved and has been promoting economic growth in Kenya.

5.3 Limitations of the study

The study conducted did not fall short of limitations some of which include but not limited to very minimal reliable local studies that were done on the study variables by previous scholars hence little work to compare to for adequate conclusions and recommendations. This shortcoming was made up for by using a longer period to conduct accurate research.

5.4 Conclusion

In this study, we investigated the relationship between transmission infrastructure and economic growth in Kenya using time series data. First, we used the unit root test to determine the data series' stationarity. The results show that the variables' data is non-stationary and lag-integrated (1,0,0,0). Then we applied the ARDL test to determine the long-run relationship between the two variables. Results show that bounded ARDL, that is, there is long-term co-movement between the

study variables. In the presence of a long-term relationship, we employed the EC test to determine the result.

Results indicate that expanding its electricity transmission lines to reach its local population will lead to an increase in economic growth. However, the electricity line length expansion is not the only explanation of the economic growth. It was expected that the country could continue expanding these electricity lines to supply power even to neighbouring countries, such as the East African Community under EAPP markets, which is under development. The findings are consistent with (Rodger, 2013) findings, which claim that as the length of any conventional transmission line rises, so does the line's energy transport capabilities and energy transfer efficiency. The primary approaches to combating this are to increase the transmission line voltage and/or wire diameter.

The major objective of the study was to examine the relationship between electricity infrastructure development and local economic growth in Kenya. The study done by different scholars highlighted in the study showed a positive correlation, but it differs with ours since we looked deeply into how substation capacity impacts economic growth in Kenya. In Kenya, substation capacity does not directly impact economic growth. The findings showed the effects of electrification on growth are exaggerated because one fails to account for indigenous targeting. It was noted that broad-based improvement as opposed to general equilibrium resorting is the only way through which gains from electrification can be realized. It is worth noting that electricity development comprises all the types of development that take place within the electricity grid. It does involve even the electricity transmission infrastructure.

Furthermore, the findings indicate that the energy sector in Kenya should seek to provide more renewable energy sources that ensure environment protection by removing barriers to entry into the industry to allow the private sector to provide sustainable renewable energy options. The

energy sector in Kenya is monopolized by the government which in many instances provides low quality services through discriminative grid developments. Some areas in the nation advance in electricity coverage and transmission while others such as the arid and semi-arid rural areas remain with below minimum coverage.

The institutions that facilitate production and transmission of electricity in Kenya constantly experience losses and low turnover due to corruption and misuse of resources. This is portrayed through purchase of substandard electricity transmission materials which in the long run cause low coverage and constant blackouts. Therefore, the entry of the private sector in the industry would stimulate competition and ensure that consumers receive quality services.

The energy sector in Kenya is also marred by fluctuating electricity prices and inconsistencies in production that make the manufacturing sector to avoid dealing with the electricity transmission companies in Kenya. Monitoring the electricity prices in the sector will avoid exploitation of the large and small scale consumers. Exorbitant prices charged by the electricity institutions do not align with the inefficient services offered by the monopoly.

This study finds that economic growth is affected by electricity transmission infrastructure. Electricity generation also affects economic growth in a country as it dictates the amount of electricity generated in a country. The findings of the study show that the availability of transmission lines (km) has a positive strong effect on economic growth in Kenya. The study establishes that electricity infrastructure affects economic growth in a minimal way. To achieve full efficiency in the energy sector to promote economic growth there is need to ensure that the end user receives electricity in a more efficient way. This can be achieved through minimal blackouts and quality transmission across the nation. Kenya has a vast coverage of electricity, however, to ensure efficiency in utilization there should be constant and efficient maintenance of the technology to promote economic growth in the long run.

5.4 Recommendations

Following the study results, some important policy implications are identified. First, there is a need to liberalize the energy markets, especially at the distribution level. This would in turn lead to decreased barriers of entry for new firms, which would lead to more innovation and increased system availability and reliability. Because the energy market would be more efficient and there would be more incentives to make money, more money could be invested in building a stronger national grid at the distribution and transmission levels. This would help the economy grow and improve economic welfare.

Secondly, because rising power use leads to higher levels of demand, enterprises and businesses must be educated on the need to adopt these services. Government entities should be forced to use energy-efficient technology to enhance efficiency. Third, there is a need to develop industry-specific standards targeted at improving the security and dependability of electrical systems. Furthermore, the study indicated that the use of renewable microsystems is accelerating in Kenya, rendering the grid obsolete. The service is provided to introduce net metering to enhance open market operations with interoperability between the systems. The single offtake model results in a more inefficient arrangement.

Finally, improving coordination: the energy operators need a revised pre-application process for permitting significant onshore electric transmission projects. The proposed process design is based on lessons learned from Rapid Response Transmission Team (RRTT) projects, interagency experience, public input that encourages early engagement with stakeholders, and early identification of potential challenges to ensure that project applications submitted are accurate and complete, resulting in a simplified review process for permitting transmission lines.

Kenya has a strong electricity generation and transmission network compared to other countries in the region, therefore, the sector should seek to promote efficiency in transmission, production, and pricing to promote general economic growth.

5.5 Recommendations for Future Research

This research focused on the general economy. To deeply investigate the relationship between transmission infrastructure and economic growth, further research should be geared towards first a micro-approach where individual industries are examined for energy efficiency and utilization. Second, there is a need to establish the reasons for the contrasting relationship between distribution and transmission impacts on total factor productivity. This study discovered a unique relationship between substation capacity and the economic growth in Kenya over the years that requires more intricate studies and research to be conducted to determine the causal link.

Furthermore, future research should seek to establish between electricity generation and economic growth. There is need to determine the extent to which substation capacity affects economic growth. The future research should analyse the impact of electricity in general on economic growth and avoid concentrating on the electricity transmission infrastructure. The future studies should also analyse how improving electricity transmission affects the economy and the adverse effects of low electricity coverage in arid and semi-arid rural areas affects balanced regional development and economic growth in general. Finally, future research can consider and elaborate on how sustainable renewable energy sources promote economic growth and reduce monopolization through privatization.

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Appendices

TABLE A1: Data Collection Form

| Year | Real GDP | Availability of transmission line | Length of transmission line | Substation Capacity | Access rate | |
|------|----------|-----------------------------------|-----------------------------|---------------------|-------------|--|
| 1970 | | | | | | |
| 1971 | | | | | | |
| | | | | | | |
| 2019 | | | | | | |

FIGURE A1: Lag Selection criteria for study variables

Varsoc Real GDP
growth rate

Selection-order
criteria

Sample: 1974 -
2019

Number of obs = 46

| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|-----|---------|---------|----|-------|----------|----------|----------|----------|
| 0 | 105.937 | | | | 6.12006 | 4.64944 | 4.66433 | 4.6892 |
| 1 | 100.282 | 11.311* | 1 | 0.001 | 4.99881* | 4.44702* | 4.47681* | 4.52653* |
| 2 | 99.6527 | 1.2577 | 1 | 0.262 | 5.0808 | 4.46316 | 4.50784 | 4.58242 |
| 3 | 99.5932 | 0.1189 | 1 | 0.73 | 5.29423 | 4.50405 | 4.56362 | 4.66307 |
| 4 | 98.7367 | 1.7131 | 1 | 0.191 | 5.3296 | 4.51029 | 4.58475 | 4.70906 |

Endogenous: Real GDP
growth rate

Exogenous: _cons

varsoc Transmission line
length Km

Selection-order criteria

Sample: 1974 -
2019

Number of obs = 46

| la g | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|---------|--------------|---------|----|-------|----------|----------|----------|----------|
| 0 | - 293.549 | | | | 21345.9* | 12.8065* | 12.8214* | 12.8462* |
| 1 | - 293.133 | 0.83213 | 1 | 0.362 | 21895.8 | 12.8319 | 12.8617 | 12.9114 |
| 2 | - 292.621 | 1.0231 | 1 | 0.312 | 22368.7 | 12.8531 | 12.8978 | 12.9724 |
| 3 | - 292.249 | 0.74562 | 1 | 0.388 | 22992.9 | 12.8804 | 12.9399 | 13.0394 |
| 4 | - 290.568 | 3.3606 | 1 | 0.067 | 22332.2 | 12.8508 | 12.9253 | 13.0496 |

Endogenous: Transmission
line length Km

Exogenous: _cons

varsoc Substation
Capacity MVA

Selection-order
criteria

Sample: 1974 -
2019

Number of obs = 46

| la g | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|---------|--------------|---------|----|-------|----------|----------|----------|----------|
| 0 | - 263.763 | | | | 7266.05* | 11.7288* | 11.7437* | 11.7686* |
| 1 | - 268.729 | 0.06764 | 1 | 0.795 | 7578.14 | 11.7708 | 11.8006 | 11.8504 |
| 2 | - 267.911 | 1.6361 | 1 | 0.201 | 7639.33 | 11.7788 | 11.8234 | 11.898 |
| 3 | - 267.538 | 0.74642 | 1 | 0.388 | 7852.38 | 11.806 | 11.8656 | 11.965 |
| 4 | -267.22 | 0.63614 | 1 | 0.425 | 8092.1 | 11.8357 | 11.9101 | 12.0344 |

Endogenous: Substation Capacity
MVA

Exogenous: _cons

varsoc Availability of
transmission line

Selection-order
criteria

Sample: 1974 -
2019

Number of obs = 46

| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|-----|--------|--------|----|-------|---------|---------|---------|---------|
| 0 | 83.782 | | | | 2.33574 | 3.6862 | 3.70109 | 3.72595 |
| 1 | 82.142 | 3.2793 | 1 | 0.07 | 2.27178 | 3.65839 | 3.68817 | 3.73789 |
| 2 | 82.004 | 0.2767 | 1 | 0.599 | 2.35881 | 3.69585 | 3.74052 | 3.81511 |
| 3 | 81.999 | 0.1114 | 1 | 0.916 | 2.46366 | 3.73909 | 3.79865 | 3.8981 |
| 4 | 81.863 | 0.2704 | 1 | 0.603 | 2.55914 | 3.77668 | 3.85114 | 3.97545 |

Endogenous: Availability of
transmission line

Exogenous: _cons