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EXAMINING THE RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH OF GHANA.

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DECLARATION

I hereby declare that this work is the result of my own research and has not been presented by anyone for any academic award in this or any other university. All references used in the work have been fully acknowledged.

I am solely responsible for any shortcoming.

.... ………………………

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CERTIFICATION

I hereby certify that this thesis was supervised in accordance with procedures laid down by the university.

....

DR. LORD MENSAH DATE

(SUPERVISOR)

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DEDICATION

This thesis is dedicated to my dear family for their love, care and support throughout my study

To God be the glory.

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LIST OF ABBREVIATIONS

1D1F	-	One District, One Factory
ADF	-	Augmented Dickey-Fuller
AIC	-	Akaike's Information Criteria
ARDL	-	Auto-regressive distributed lag
DFID	-	Department for International Development
ECG	-	Electricity Corporation of Ghana
GDP	-	Gross Domestic Product
GWh	-	Gigawatts Hour
kWh	-	Kilowatts Hour
MW	-	Megawatts
OECD	-	Organization for Economic Co-operation and Development
SDG	-	Sustainable Development Goals
UNCTA	-	United Nations Conference on Trade and Development
UNDP	-	United Nations Development Programme
VALCO	-	Volta Aluminium Company Limited
VAR	-	Vector Autoregressive
VRA	-	Volta River Authority
WDI	-	World Development Indicator

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ABSTRACT

Economic growth is an important indicator of a society's wellbeing and its ability to sustain it over a period. It enables a rise in living standards and a greater consumption of goods and services. It is underpinned by a rise in real gross domestic product (GDP). Energy is a key component of the modern society and is used heavily in the production of output. Ghana has seen mixed results in its yearly economic growth since independence. It has also suffered various challenges in electricity production. This study aims to examine the connection between electricity consumption and the economic growth of Ghana using a bivariate approach and relying on the ARDL Bounds Testing method. The results points to cointegration between electricity consumption and economic growth where the conservation hypothesis is upheld in the case of Ghana. It is established by this study that a uni-directional causality runs from economic growth to electricity consumption but not the other way round. Based on this finding, policies that lead to the conservation of electricity does not adversely impact economic growth of the nation. It is thus recommended that Ghana implements policies which may lead to the efficient use of energy to safeguard the environment and also lead to sustainability of power generation.

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CHAPTER ONE

1.1 Research Background

Since Ghana gained independence in 1957 and became a sovereign nation, achieving economic growth and development has always remained a priority and a key goal or agenda for her leaders. The goal of the National Development Planning Commission (2017) clearly captures sustained and accelerated growth as the path to sustaining Ghana’s middle-income country status in the Medium Term Expenditure Framework for 2018 – 2021.

Development partners and countries from all over the world are also very interested in the plight of mankind in the least developed or third world countries of which Ghana forms part (Hulme, 2009).

According to the “Background of the Sustainable Development Goals” on United Nations Development Programme (UNDP) website, to ensure measurable objectives and tangible goals, spearheaded by the United Nations, 189 countries adopted a system of measurement called the Millennium Development Goals which had a lifespan up to 2015 and consisted of 8 clear goals These goals metamorphosed into the 17 Sustainable Development Goals (SDGs) with an expiry of 2030 aiming to present a group of universally-agreed measures that addresses the pressing political, environmental, and economic problems facing our world.

Economic development is quite a complicated outcome to measure as captured by the numerous measures contained in the SDGs however one key criteria being pursued is the alleviation of poverty. Economic development must embrace more than the physical and monetary side of people’s livelihood, to expand to human liberties (Todaro & Smith, 2015). Even though economic growth does not guarantee economic development (Jales, 2017), it is asserted that economic growth must be pursued to boost economic development. Economic growth is

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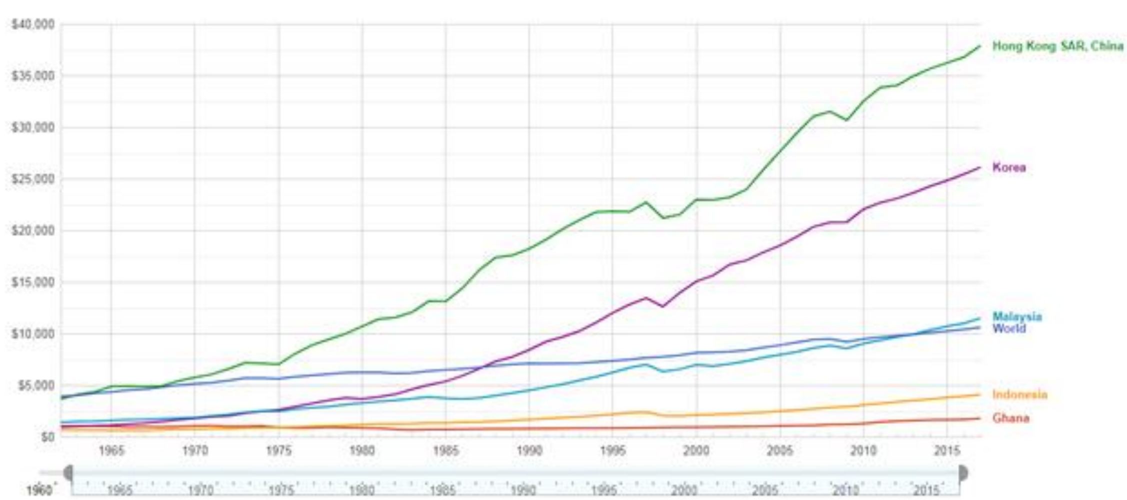
perceived as a very critical ingredient and only viable solution to the reduction of endemic poverty in the developing world (Spratt, 2008).

It is thus no wonder that this singular objective of ensuring rapid and continuous economic growth holds so much importance to the people of Ghana that it has been the basis for regime changes i.e. from civilian to military rule and vice-versa (Darko, 2015). Since multi-party democracy was adopted in 1992, the subject of economic growth and development has been one of the most important topics on which political parties have campaigned and sought to be elected into office.

Comparisons have been drawn between the economies of Ghana and the East Asian Tigers, specifically South Korea, by comparing the Gross Domestic Products (GDPs) of the two nations during 1957/58 which were similar levels (Darko, 2015) and that of today. As shown in the graph below, Ghana's GDP around 1957 (Ghana's independence) was indeed similar to that of South Korea. Today, the picture is very different.

Figure 1.1: GDP per capita (current US$)



Source: World Bank Data

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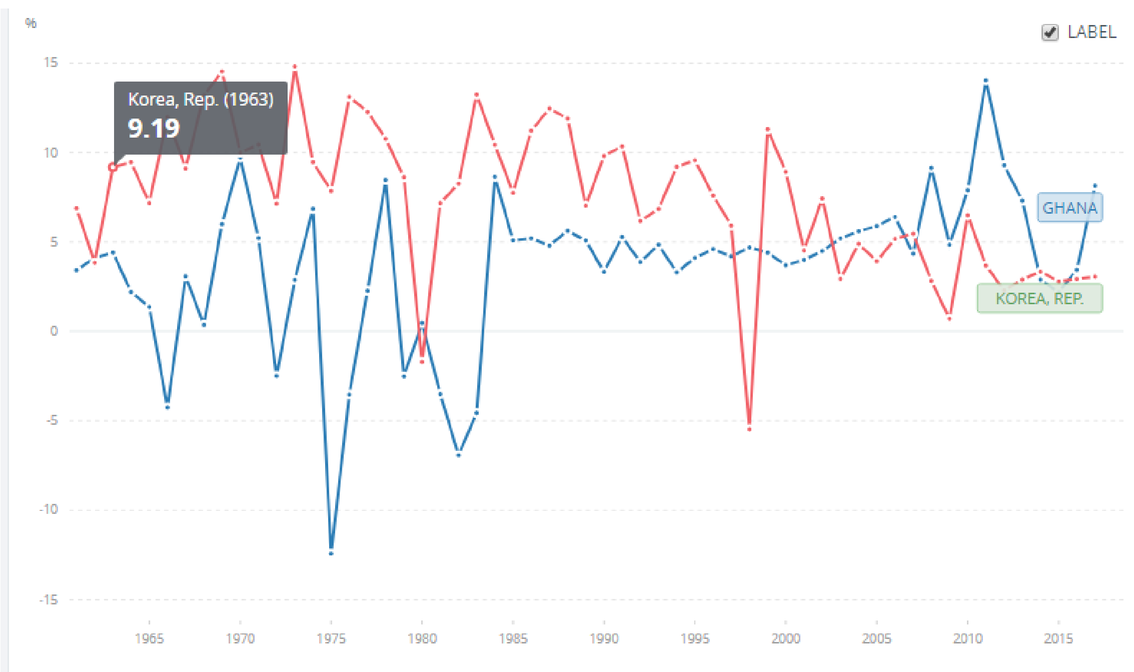
The growth of the economy for a country may be described as a sustained increase in ability to provide progressively more varied goods and services to its populace (Kuznets, 1973). It can simply be explained as the rise in the inflation-adjusted or real market worth of the services and goods made by the country's economy over a period of time. It is usually assessed as the positive rate of change or increase in real gross domestic product (GDP).

It can be the most effective tool for depovertization and improving the standard of living in developing nations. There is a strong accord amongst development professionals that economic growth has been the solitary most important mechanism for the reduction in poverty in developing countries (World Bank, 2017). Whereas a country such as South Korea has averaged economic growth of 7.19% for the past 5 decades, Ghana has averaged 3.92%. In GDP terms, South Korea's GDP was only 3.91 that of Ghana in 1969, but as at 2017, it is 25.95 times that of Ghana (World Development Indicators, 2019).

Figure 1.2: GDP growth (annual %) of Ghana and Korea Republic



Source: World Development Indicators.

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Studies at cross-country and country level offer irrefutable proof that swift and continuous economic expansion is important to creating more rapid advancement in a bid to achieve the "Millennium Development Goals" – beyond the opening objective of splitting into two, the worldwide fraction of persons surviving on as little as USD 1 a day (OECD).

Dani Rodrik, a renowned professor of Harvard University indicated in his publication, "One Economics, Many Recipes: Globalization, Institutions and Economic Growth" (2007) stated that "Historically nothing has worked better than economic growth in enabling societies to improve the life chances of their members, including those at the very bottom".

In Department for International Development's (DFID) article titled "Growth, Building Jobs and Prosperity in Developing Countries" published on their website, the following are attributed to growth:

- Supports people to transition out of poverty
- Transformation of society
- Generation of jobs
- Motivation of human development

Economic growth is thus clearly a very important criterion for humanity.

Expansion of a country's economy is impacted by a wide range of factors. Some direct factors influencing economic growth are for example human resources, natural endowments, the intensification of capital employed or breakthrough in technology. Additionally it is impacted by secondary drivers such as institutions (political establishment, legal establishment, financial institutions etc.), the size of the overall or total demand, investment as well as rates of saving, financial system efficiency or otherwise, budgetary and fiscal policies, capital and labour

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migration and government’s efficacy. The determining factors of economic expansion or growth are interlinked elements exerting influence on the economic growth rate. There are six principal elements that bring about growth; four of which are classed as supply factors and efficiency and demand being the other two. The supply determinants are natural endowment, capital goods, human capital and technology and they have a direct impact the worth of goods and services supplied (Boldeanu & Constantinescu, 2015).

A critical ingredient that affects Economic Growth is energy availability. All Growth Models highlight the importance of labour. Aside providing the skill and knowhow to churn input into output, labour is also a source of energy (Alam, 2006). However, continuously increasing or growing output demand implies that an ever increasing amount of energy is required at a sustainable rate. Labour is a poor substitute or source for energy in this regard and has been gradually diminishing over the last two centuries (Alam, 2006). In modern production therefore, technology has been able to identify more suitable and efficient energy sources to satisfy the ever increasing demand of output production. Machines have evolved from small hand-wielded tools to colossal and complex apparatus powered by electricity and capable of producing ever increasing volumes at an astonishing and efficient rate.

The United States Energy Information Administration on its website simply explains Energy as the ability to do work. In the context of this study, it can be better explained as power obtained from the exploitation of physical or chemical resources, particularly to deliver light and heat or to operate machines. It is important in the growth of an economy because it is the underlying element for manufacture of output in any economy.

Within the past two decades, Ghana has faced challenges with consistently producing and providing sufficient energy for residential and industrial consumption as a consequence of rapid

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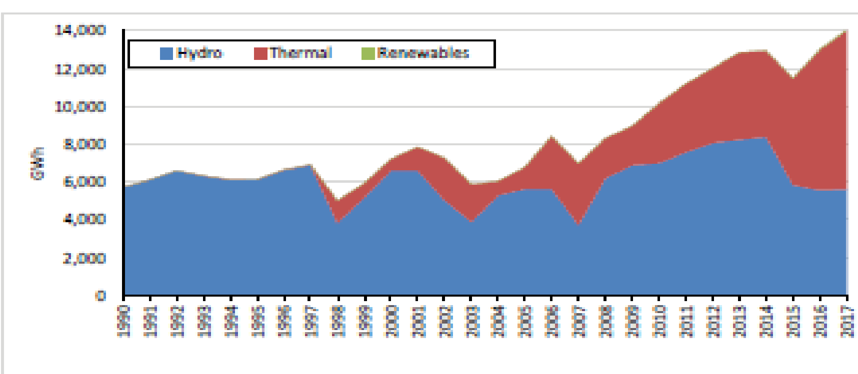
population growth, low and erratic rainfall, high and fluctuating world crude oil prices etc. According to Kumi (2017), in the past decade these challenges faced with the supply of electricity costs Ghana's average manufacturing loss of US2.1 million per day. Despite the evidence that installed capacity increased more than twice as much as 1,730 MW in 2006 to the 3,795 MW generated in 2016, the situation has not abated (Kumi, 2017). This can be as a consequence of a myriad of causes comprising increased urbanization, expansion in rural electrification, obsolete equipment, high distribution losses, revenue leakages, and also underpricing of electricity.

Extant literature has attributed the lack of or slow economic development to the insufficient or unstable nature of power supply. Energy has become indispensible for the growth and progression of every nation (Kwakwa & Aboagye, 2014). It is further said that Electricity is a critical gauge of socioeconomic development (Abokyi, Appiah-Konadu, Sikayena, & Oteng-Abayie, 2018). “Access to new forms of energy is thought to be a precondition for sustainable development, poverty reduction and the attainment of the Millennium Development Goals” (Ouedraogo, 2012).

The main energy sources can be generally grouped into Renewable or Non-renewable sources. These two broad groups provide a huge range of energy sources available to be used in an economy. The choice of a particular type or source of energy over another in an economy is mainly driven by its availability, cost, and to a large extent, the policy direction of the country. There is an increasing push to utilize energy sources that are renewable and leads to lower pollution or stress on the planet. The developed countries, predominantly those in Europe are therefore pioneering the usage of renewable sources of energy like wind, tidal, and solar. Nuclear reactors which also produce sustainable levels of energy were decades ago on the increase, however, catastrophic accidents such as those in Chernobyl (Hatch, Ron, Bouville, Zablotska, & Howe, 2005), and more recently in Japan's Fukushima Daiichi Nuclear Plants in 2011 (Goto & Sueyoshi, 2015) has led to moves away from investing in nuclear energy as a reliable source. Also, the close link between the materials used to produce nuclear energy and those used to produce nuclear bombs have lead America imposing sanctions to stem more research into and utilization of nuclear energy.

Of the wide range of energy sources available, Ghana predominantly relies on fossil energy, and hydropower to generate electricity for consumption. The bigger share of power generation was previously hydro however especially in the last decade thermal is increasingly being utilized (Energy Commission, 2018). The concept of solar energy as a basis of electricity production has been on the discussion table for more than two decades considering that sunshine is abundant in Ghana. However, this source of energy though quite reliable and constant, is bedeviled by the huge initial capital outlay required to set up a commercially relevant plant. Households however are increasingly supplementing their grid usage with electricity generated from installed solar units due to instability of power supply in Ghana.

Figure 1.3: Electricity Generation by Source, GWh



NB: Renewable is negligible. It is made up of grid-connected solar and biogas systems

Source: Energy Commission (2017)

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1.2 Research Problem

There have been a number of researches done in the separate areas of economic growth, and energy-related issues in Ghana. However, in relation to the connection between economic expansion or growth and the usage or consumption of energy, although some research has been undertaken there seems to be very few which explores the link between electricity availability and Ghana's economic growth considering how often these two topics are linked together during public discussions.

1.3 Research Purpose

The overriding aim of my long essay is to explore the links between electricity availability and observed economic growth of Ghana relying on information from 1998 to 2018. The study will also highlight the level of economic growth observed when Ghana was a net electricity importer versus when it was self-sufficient or net electricity exporter.

1.4 Research Objectives

1. To examine if there is a connection between electricity consumption and the economic growth of Ghana.

1.5 Research Questions

1. What is the connection between electricity consumption and economic growth of Ghana?

1.6 Research Methodology

This study will mainly employ a qualitative approach where already existing or published data will be gathered and analyzed using tools such as graphs to establish and observe the general trend between energy availability and economic growth of Ghana. National data will be collected from government departments and agencies, as well as Development Finance bodies such as The

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World Bank, International Energy Agency etc. Literature Survey and review of trend and policy will mainly be used for this study.

In addition to the qualitative approach mentioned above, the quantitative methods which can be employed in order to establish the type of association between the energy and economic growth of Ghana will be utilized as well.

Previous research into similar area of study has used quantitative techniques such as:

- Panel Model, (Al-mulali, 2014)
- Environmental Kuznets Curve (Albiman, Suleiman, & Baka, 2015)
- Autoregressive Distributed Lag (ARDL) (Waziri, Hassan, & Kouhy, 2018)
- Least Squares technique (Alabi, Ackah, & Lartey, 2017).
- Panel cointegration and causality tests (Eggoh, Bangake, & Rault, 2011)

1.7 Research Significance

The research can be viewed as significant in 3 ways/areas:

1. The link between electricity availability and development will be investigated/ established using fact-based research.
2. The study will provide evidence for commentators and inform all stakeholders and form some basis/guidelines for public thinking and discussions.
3. The study will provide important feedback to policy makers in terms of the implication of availability of electricity on economic growth which will in turn guide them to draw the right policies to achieve economic growth.

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1.8 Research Limitations

Data used for this research will be based on existing published information and will not be based on new sampling. This is so because some of the data involved can only be obtained at the national level and I do not have the capacity or knowledge to undertake the necessary exercise to generate them. Also, some of the data relevant to the study are "live" and can only be gathered as they occur. That is to say it cannot be re-measured after the event has lapsed.

My intended approach to this study will be as follows:

- Obtaining past development key performance indicators from government departments and agencies such as Ministry of Finance, Ministry of Energy, Ghana Statistical Service, etc.
- Obtaining past Energy measures, facts and figures from government departments and agencies such as Ministry of Energy, Electricity Company of Ghana Ltd., Volta River Authority, Energy Commission, Petroleum Commission etc. and Development Finance Institutions like the World Bank, the International Monetary Fund, and International Energy Agency etc.
- Review and gathering of information from research publications.

All these information gathered will then be analyzed to identify linkages if any between Ghana's energy needs and development.

1.9 Chapter Outline

This opening chapter contains the Introduction of the Long essay. It brings out the background, problem, purpose, objectives, questions, significance, methodology, limitation and the chapter organization of the research. Chapter 2 emphasizes the examination of relevant literature

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concerning the relationship between electricity and the economic growth of Ghana. Thereafter, Chapter 3 will outline the methodological approach, source of data, data collected; techniques used for the analysis are laid out. In Chapter 4, data collected is presented, analyzed and findings discussed. In the final part, Chapter 5, the project is summarized and accompanied with conclusions and recommendations. The references and appendices are laid out after this chapter to conclude the work.

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CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this part of the essay, a review of existing studies or publications that have examined or researched the areas of Economic Growth in general, Ghana's Growth Trend, a Synopsis of Ghana's electricity industry, and the association between electricity availability and economic growth in Ghana's context is performed.

2.1 Economic Growth

Why do we need economic growth? What are the core elements that yield growth? This has been one of the foremost questions on the minds of many researches, economists and Nobel Prize winners. Economic growth can be thought of as the principal factor in the wellbeing and prosperity of a multitude of people (Boldeanu & Constantinescu, 2015). It is seen as a very essential ingredient and only viable solution to the reduction of endemic poverty in the developing world (Spratt, 2008). Whilst the developed countries have continuously prospered and as a result have put their citizens in a position of economic strength, developing countries find themselves struggling to provide for the basic necessities of its citizens. Industrialization and breakthroughs in technology has created a divide between developed countries and less developed countries (Boldeanu & Constantinescu, 2015). This shows the importance of economic growth. A stagnant economy will fail to provide for the needs of the growing population of a country and also the growing needs and aspirations of the existing population. As

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a result, great thinkers have tried to identify or explain the important elements that results or leads to economic growth for a country (Boldeanu & Constantinescu, 2015).

The main models which explain the theory of economic growth has largely disregarded the role or the part played by energy in economic growth (Vlahinić-Dizdarević & Žiković, 2010).

Although classical economics did not explicitly mention energy as a critical factor to economic growth, it indirectly incorporated energy into the economy by identifying land as a factor of production in agriculture; however, land is redefined as capital by neoclassical economics thereby ignoring energy altogether (Alam, 2006).

Until the late 1950s, the dominant growth model in development economics, the Harrod-Domar Growth Model (Harrod, 1939; Domar, 1947), a neoclassical model, predicted that country-wide growth rates are directly proportionate to the levels of investment in the economy (Spratt, 2008). The factors of production responsible for economic growth according to this model were only labour, which was in abundant supply, and capital, which was constrained. The productivity of capital (the 'capital-output ratio') was fixed hence constant returns to scale. The only way to generate growth therefore was to increase capital, which is only possible through higher national savings and the subsequent investment as a result of the savings. The Harrod-Domar Model's prescription for countries with poor growth was therefore to borrow to invest in physical capital, which will result in higher incomes, more savings, increased investment in physical capital, and hence further increase in economic growth.

Another popular growth theory, also belonging to the neoclassical group, is the Lewis Model. It is said to be one of the foremost structural-change models. The Lewis Model (Lewis, 1956) also put forward that economic growth depends on only capital and labour but in this case, the growth

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was as a result of labour migrating from the traditional or subsistence sector to the modern sector. The traditional sector, being subsistence in nature had excess labour and therefore removal of its labour did not lead to decreased output as productivity is very low. The modern sector is however driven by a profit motive and increased labour leads to higher output, and subsequently higher profit which the owners of capital reinvested a portion into capital acquisition thereby leading to a cycle of economic growth.

In keeping with the previous models, the Solow Model (Solow, 1956) also maintained that economic growth depends on labour and capital but introduced a third element, technological progress. It highlighted that the growth of the economy is a result of the increasing capital stock per worker. Capital stock however depreciates according to Solow and therefore investment had to be greater than depreciation to ensure economic growth. If the investment is lower than depreciation, capital per worker will decrease eventually and there will be negative growth. If investment is equal to depreciation, capital per worker neither increases nor decreases leading to a condition called steady state. The Solow Model however brought in technological progress to address the steady state which is arrived at when economic growth is matched by population growth. Solow allowed technological advances to raise the productivity of capital therefore allowing growth to be maintained at a level above the rate of population growth. However, Solow assumed that technological progress was exogenous to the model.

Beyond these previous neoclassical models, another theory has evolved called the Endogenous Growth Model. In contrast to the Solow Model, the Endogenous Growth (Lucas, 1988; Romer, 1990) Model hypothesizes that the drivers of growth are endogenous to the economy and could indeed be influenced by policy. It developed to explain the endogenous sources of technical progress which drives economic growth. The endogenous growth theory concentrates on two

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growth elements –investment in capital and research and development, or amassing of physical and knowledge capital. Economic growth is mainly impacted by four key determinants: natural resources, human resources, technology and capital formation, with individual researches placing a different emphasis or importance on each determinant (Boldeanu & Constantinescu, 2015).

The determinants of economic growth are interconnected elements that interact to affect the growth rate of an economy. These elements that define growth are mainly six, with four of them being classed as supply determinants and the other two being demand and efficiency.

The four supply factors are human resources; capital goods, technology and natural endowments. These factors directly impact the value of goods and services supplied.

Acemoglu (2009) highlighted that economic determinants also differ from non-economic determinants. "Proximate" or economic determinants denotes elements such as technological advancement, labour, capital accumulation, and "ultimate" or non-economic factors denotes influences such as institutions, political and administrative systems, social and cultural factors, government efficiency, demography and geography.

Darko, (2015) researched the elements influencing economic growth in Ghana. His research revealed that GDP per capita in the long-run is influenced by export, oil and mineral rents. Government consumption on the other hand depresses economic growth. This is somewhat supported by Tyler (1981), whose research led him to conclude that export is the leading determinant of economic growth in developing countries.

Again, further research by Upreti (2015) confirmed that huge export volumes, longer life expectancy, high investment rates, and abundant natural resources, have favourable effects on the growth of per capita GDP in developing countries.

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Extant literature also shows that the financial system also affects economic growth. In many of the economic growth models highlighted above, finance has a bearing on economic growth through its ability to mobilize savings which is used to increase capital through investment. The endogenous growth models allow greater participation of the financial system in economic growth than in other growth models. Lucas, (1988) shows that financial system helps pay for skill acquisition thus enhancing economic growth. Romer, (1986, 1990) put forth an argument that knowledge can be exploited long enough to be of great benefit to the discoverer, but that it almost immediately becomes available as a free good (spillover) accessible to others. Schumpeter (1912) pointed out that financial system promotes technological innovations through its intermediation role.

2.2 Ghana's Economic Growth Trend

It was largely the norm in the 1980s and early 1990s to encounter print material extolling Ghana on its recent economic growth achievements (Aryeetey & Fosu, 2002).

Ghana gained independence from its colonial master, Britain in 1957. It had a stable economy which was reported to have a similar GDP to that of South Korea.

The growth record of Ghana from the 1950s to the 2000s has not been on a constant nor consistent trajectory. The economy of Ghana began to see signs of economic slowdown from 1964, where for the first time from the 1950s and early 1960s yearly growth decreased from 4.31% in 1963 to 2.19% in 1964. From the stability of the earlier periods, growth took a turbulent turn with periods of negative growth on each side of periods of positive growth. This checkered and uncontrolled pattern began to stabilize from 1984 where the growth rates took on positive numbers. The years in which negative growth were observed, 1966, 1972, 1975-1976,

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1979, 1980-1983 generally corresponded with changes in government and sometimes with policy changes or reversals (Aryeetey & Fosu, 2002).

As represented graphically below, negative growth was first recorded in 1966, which happened to be the first coup d'etat, the overthrow of Dr Kwame Nkrumah. In 1975, growth of -14%, the lowest ever observed occurred, corresponding with the oil-supply shock, in addition to a turnaround in policy from a market-oriented posture to an inward-looking protectionist regime (Aryeetey & Fosu, 2002).

The Economic Recovery Program which was the first phase of reform was implemented in 1983 followed by the second phase, the Structural Adjustment Program in 1986 (Aryeetey & Fosu, 2002). These reforms were geared towards correcting the economic issues and foster a healthy economic growth. The intended results were immediately observed, as in 1984, just a year after reforms were implemented, growth grew from 5% in 1983 to 8% as shown the graph above. Since then, consistent positive growth has been attained.

Aryeetey and Kanbur (2006) show in their study that growth rate from the 1980s seems to have stabilized around the level of 5% for about twenty years with more progress in 2004 to 5.8%. The agriculture sector has been the main contributor to growth. In 2004, it grew by 7.5% against 6.1% in 2003. The sector, driven by Cocoa's growth of 29.9%, delivered 46.7% of total growth in 2004 in comparison to 41.4% in 2003. Construction was responsible for the largest growth in the industrial sector which saw a 6.6% growth, rising from 6.1% in 2003. The services sector grew by 4.7%, contributing 24.3% to total growth.

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2.3 Ghana's Power Sector – An Overview

Through the struggles of Dr. Kwame Nkrumah and some of his notable contemporaries, Ghana was able to break away as a colony of Britain in 1957 (Edjekumhene, Amadu, & Brew-Hammond, 2001). After Ghana obtained independence in 1957, a strategy of state-led economic development was embarked upon. The need to pursue the rapid development through of construction of roads, schools, hospitals, and factories required a dependable and sustainable source of power supply (Eshun & Amoako-Tuffour, 2016). By the Volta River Development Act of 1961, Act 46, the government paved the way to build Ghana's first electricity generation plant (The Volta River Development Act, 1961). The Volta River Authority (VRA) was formed and assigned the duty of harnessing the kinetic energy of the Volta River to generate electricity and to oversee the rehousing of people staying and making their livelihood on lands to be flooded or submerged under water as a result of the project.

The government secured financing from the World Bank and the USA (particularly VALCO) to perform the undertaking (Eshun & Amoako-Tuffour, 2016).

Thereafter, work on construction bagan in 1962 and was successfully accomplished in 1965 at an approximate expense of $196 million (Volta River Authority Fact Sheet).

The state-led development agenda was in full force and there was a huge activity with regards to industrialization. Huge factories were developed at Tema and other parts of the country in line with the Import-Substitution Strategy.

In just a couple of years after completion of the the Akosombo dam, there was already plans to expand the capacity from 512 MW to 768 MW, and to meet Valco's requirement of 317 MW (VRA Annual Report, 1969).

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This shows how important power was to industrialization and thus to the economy of Ghana. The main patrons of the Authority's generated electrical power were Volta Aluminium Company Limited (VALCO), the Electricity Corporation of Ghana (ECG), and the Mines (VRA Annual Report, 1969).

By 1969, average electricity demand was at 311.5 MW. The peak demand for that same year was 359 MW recorded on 15th December, just 9% above the previous year's recorded peak demand. Of the total electricity generated, VALCO consumed 72% for that year leaving a balance of just 28% for the rest of the nation.

In 1972, only 7 years after the dam was completed, generating capacity had reached 900 MW as a result of the completion of two additional generating units. In the year peak demand reached 471 MW, representing an increase of 24.6% over the previous year. Total generation also increased by 14.16% to 3,321.26 GWh with Valco's annual consumption increasing 1,919 GWh to 2,263.8 GWh for the year. With this increased capacity and expansion in infrastructure, Ghana began exporting electricity to Togo and Benin.

Consumption of energy which had grown steadily from 449.7 GWh in 1966 to 4,091.2 GWh in 1976 saw a drop in 1977 to 2,292.7 GWh before recovering its year-on-year growth trend. In 1983, consumption again dipped compared to previous year and again dipped to 1,670.4 GWh in 1984 (VRA Annual Report, 1984). This was as a result of the worsening economy in the late 1970s and early 1980s (Eshun & Amoako-Tuffuor, 2016).

The current electricity situation as reported in the 2018 Key Energy Statistics publication by Energy Commission is that, Total Installed Electricity Generation Capacity by Ghana is 4,405 MW. Of this amount, hydro generation is responsible for 35.87%, thermal is 63.22%, with the remaining 0.91% from renewables.

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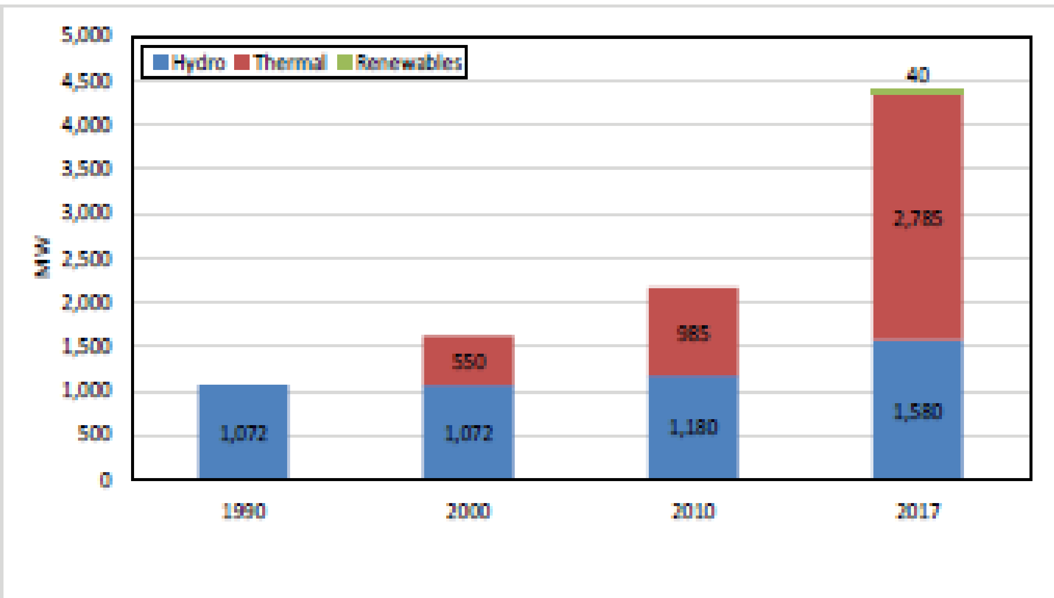
The Hydropower plants consist of Akosombo, Kpong, and Bui dams of which installed capacities are 1,020 MW, 400 MW, and 160 MW respectively (Energy Commission, 2018). There a total of 12 thermal plants in operation. The majority of the renewable energy is from solar power from VRA Solar 2.5 MW, and BXC Solar of 20 MW (Energy Commission, 2018).

Figure 2.1: Installed Electricity Generation Capacity, MW



NB: Renewables include on-grid, of-grid and mini-grid installations.

Source: Energy Commission

Thermal generation of electricity is more dependable however it is more costly and fluctuates with world crude oil prices. It also contributes to global warming through CO_2 emissions from fossil fuel combustion. On the other hand, hydropower because of its dependence on rainfall is increasingly becoming unreliable doe to the erratic nature of rainfall as a consequence of climate change. It also has the downside of flooding huge areas of arable land and destroying ecosystems and human settlements.

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Solar and Wind Power is the current trend in electricity generation. Britain obtains more energy from zero-carbon sources than fossil fuels for the first time since the Industrial Revolution. With 48% of generation, clean power has moved forward, surpassing coal and gas at 47% (BBC, 2019). In the 2016 World Energy Outlook, the International Energy Agency (IEA) reports that as of 2014, only 35% of sub-Saharan Africa had access to electricity compared to an average of 84% worldwide (IEA, 2016).

The story for Ghana is much different. A forward looking scheme, which was targeted with providing reliable power supply to all parts of the country by 2020 knows as the National Electrification Scheme (NES) was established in 1989. Accessibility to power supply was projected to be 20% at the start of the NES in 1990. Currently in Sub-Saharan Africa, Ghana has moved on to achieve the uppermost electricity access rate with a country average access of 83.24% currently and to attain universal access by 2020 (Ministry of Energy).

2.4 Energy-Growth Nexus

Energy should be recognized as a very important element in production and economic growth for that matter. It is impossible for any change in matter to occur without application of energy, thus energy is the essential force driving all economic activities (Alam, 2006). Labour as a factor of production provides skill and or knowledge. It was also relied upon greatly in the past to provide the power or muscular-energy to allow production to occur. Labour is however an expensive albeit ineffective source of energy and thus with time it was replaced with animals such as oxen and donkeys, and as man became more enlightened with other elements of nature such as water and fire to produce motion and heat for production. Now other sources of fuels are relied upon to produce heat directly or electricity is relied upon to power industrial production. Alam (2006) stated that an economy is set in motion by activities called primary converting activities that

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convert energy from naturally occurring sources ranging from solar light and heat, wind, tide, gravitation, running water, fossil fuels, minerals, and chemicals into forms that will eventually be used to produce goods and services.

The source of industrial energy for Ghana is power or electricity. There have been widespread and frequent challenges faced by Ghana with regards to her power sector over the past decade, which has resulted in significant negative impact on the economic condition of the country (Kumi, 2017). In fact, the challenges battering Ghana's power sector goes beyond a decade, I quite recall the first power-shedding I experienced during 1998 and its effects on livelihoods and property alike. In a World Bank study, it placed electricity as the second most vital limitation to business activities in the country and assessed that Ghana lost about 1.8% of GDP during the 2007 electricity crisis (World Bank, 2013). Also in 2014, a study conducted by the Institute of Statistical, Social and Economic Research (ISSER) at Legon projected that on the average, Ghana lost production valued at US $2.1 million daily (or, US $55.8 million monthly) directly as a result of the energy crisis (ISSER, 2015). This translates to US $680 million (2 percent of GDP) being lost by the country in 2014 due to the power crisis (Kumi, 2017).

Literature has shown that research into the connection between growth of an economy and consumption of energy abound globally but outcomes vary. Ozturk (2010) attribute these diverse findings to the wide range of methodologies, date sets, and country characteristics.

The directions yielded by the causal relationship between economic growth and power consumption or electricity consumption could be grouped into four forms as explained briefly below (Apergis and Payne, 2009; Squalli, 2007; Yoo, 2005; Jumbe, 2004).

1) No causality: This is also referred to as 'neutrality hypothesis'. There is no causality between consumption or use of energy and GDP. This implies that there is no correlation

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between consumption of energy and GDP. Therefore, neither expansive nor conservative energy use strategies have any effect on economic growth.

2) The uni-directional causality running from economic growth to energy consumption. This is also known as ‘‘conservation hypothesis’’. It advocates that an energy consumption conservation policy may be employed with minimal or no antagonistic consequence on growth of the economy. The conservation hypothesis is upheld if raising real GDP leads to a raise in the consumption of energy.

3) The uni-directional causality running from energy consumption to economic growth. This is also referred to as ‘‘growth hypothesis’’. It infers that limitations on the usage of power may negatively impact growth of the economy whilst raising power usage may yield a positive contribution to economic growth. This hypothesis advocates that usage of energy is a vital factor in economic growth as a complement to capital and labour, both directly and indirectly in the manufacturing process. We can therefore conclude that energy is a constraint on development and therefore the breakdown of energy supply will have a detrimental impact on economic growth.

4) Bi-directional causality between energy consumption and economic growth. Also referred to as ‘‘feedback hypothesis’’. It infers that economic growth and energy usage are collectively identified and simultaneously impacted.

Kwakwa and Abogye (2014) performed a multi-variate study between usage of energy in Ghana and expansion of the economy, trade openness, industrialization, and urbanization by relying on data gathered from the World Bank Development Indicators and using the Johansen cointegration test. They showed that income and industrialization increases consumption, whiles trade openness reduces energy consumption in the short-run. In the long-run however, income

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reduces energy consumption, whiles urbanization and trade openness increased energy consumption. They revealed that energy is a key input for industrialization (industry share of GDP) and is anticipated to create a rise in energy demand. Urbanization, measured as the urban population's annual growth rate is projected to also lead to a rise in energy demand and usage. Whilst urbanization provides the necessary human resource for industries, it however increases energy need for households and therefore competes with the amount of energy available for output production and thus can negatively affect economic growth in that regard. Considering that energy has been in short supply or a limited resource in Ghana, they recommended that Ghana should implement a policy of developing the rural settlements to avoid high levels of rural-urban migration.

Abokyi et al. (2018) undertook a bi-variate study into electricity consumption and industrial growth in the context of Ghana from 1971 to 2014 using auto regressive distributed lag (ARDL) bounds test. They concluded that electricity consumption adversely affects industrial growth both in the short-run and long-run in Ghana. Their study supported the growth hypothesis in Ghana using the Toda-Yamamoto modified Granger causality test. It indicated the presence of a one-way causal connection progressing from consumption or usage of electricity to industrial growth.

Alabi, Ackah, and Lartey (2017) assumed a study to research the association between economic growth and renewable energy for oil-exporting nations located in the African continent (Nigeria, Angola, and Algeria). They relied on the fully modified ordinary least squares method for heterogeneous co-integrated panels to assess the parameters of the model. The research showed that there is bidirectional causality between renewable energy and economic growth both in the short-run and the long-run. They recommended that because renewable consumption augments

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growth, investment in renewable energy with high conversion efficiency such as wind, hydro, and solar should be encouraged to mitigate adverse effects of climate change.

Vlahinić-Dizdarević and Žiković (2010) conducted a study in Croatia to scrutinize the causal relationship between economic growth and energy. They relied on data ranging from the period of 1993 to 2006, using bivariate model of real GDP and five energy variables: oil consumption, primary energy production, energy consumption in industry and households, and net energy imports. As a result of finding cointegration for all of the tested relationships, they employed an Error Correction Model (ECM) which also allowed them to differentiate between short and long term association between the variable. Their findings were comparable to those examining developed, post-industrial economies with robust tertiary sector in that it indicated that in Croatia the causality runs from real GDP growth to energy consumption, production and import. These findings can be linked to strong change resistance in Croatia throughout the 1990s and the process of deindustrialization that had led to severe industrial deterioration and reduced industrial and general energy demand. Thus the causality between economic growth and energy usage, production and imports is more related to household needs rather than demand of industrial nature.

Al-mulali (2014) used data from 1990 to 2009 for 82 developing countries to study the relationship between GDP growth, and renewable and non-renewable energy. His preferred methodology was the panel model. Through the Kao co-integration test outcomes, he established that all the economic segments in all countries have long-run association with both renewable and nonrenewable energy usage. Furthermore, the fully modified ordinary least squares showed that the nonrenewable and renewable energy usage had a long-run positive association with the economic sectors. The outcomes however indicated that nonrenewable energy usage has an

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added substantial impact on the economic sectors than the renewable energy usage. The Granger causality buttressed the findings by showing the same outcome. It was recommended that developing countries should raise their capital outlay in renewable energy undertakings to raise the portion of overall energy usage.

In their research into the connection between consumption of energy, economic growth, CO2 emissions in Tanzania, Albiman, Baka, and Suleiman (2015) examined the relationship existing among energy consumption (KWh), environmental contamination (carbon emission per metric tons) and per capita economic growth (GDP per capita) in Tanzania. Data used ranged from 1975 to 2013 and they employed the Environmental Kuznets Curve and the Toda and Yamamoto non-Causality test (1995), Impulse response and Variance Decomposition, Augumented and Dickey–Fueller test and Philips and Perron Test of unit root tests. Pollution of the environment due to emission of carbon resulted from energy consumption per capita and economic growth rate in Tanzania.

Being that the push to change source of energy from non-renewable to renewable energy sources is fast gaining grounds, Waziri, Hassan, and Kouhy (2018) undertook a study to establish the possible effect of an increased usage of renewable energy in the energy generation mix of developed net energy importing countries on the oil and gas export levels of Nigeria. As oil and gas exports represent a sizeable chunk of Nigeria's GDP, this will have an important impact on economic growth. Total value of export represents 15% of Nigeria's 2018 GDP of which Petroleum export makes up 87% (Opec). An autoregressive distributed lag (ARDL) bounds testing approach was used to analyze macro-economic annual time-series data set for the period between 1980 and 2014. The results indicated a decrease in oil export revenue both in the short-run and the long-run. This implies a possible adverse impact on economic growth considering

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the contribution to GDP from oil exports will decline as a result. Following from this observation, they recommended that it is important for a diversification of the economy to effectively address the external economic threat that a transition in energy use by net energy importing countries will have on the economy.

Ahmed, Zaman, Taj, Rustam, Waseem, and Shabir (2013) also undertook a research in Pakistan with the aim to investigate the association and direction if any between electricity consumption per capita and real per capita income by considering data from 1975 to 2009. They made use of the Johansen cointegration method to ascertain the shortrun and longrun relationships among the variables. To establish causal relationship, the Granger causality test was utilized. A bi-directional causality between real per capita income and electricity consumption per capita was found.

In their research into utilization of energy and economic growth to uncover fresh empirical evidence on the association between economic growth and energy utilization, Eggoh, Bangake, and Rault (2011) selected 21 nations in Africa with data from 1970 to 2006 considered.

Net energy importers were separated from net energy exporters, and panel cointegration and causality tests was used. A long-run equilibrium association was found between consumption of energy, prices, real GDP, capital, and labour for the entire country set as well as for each of the two groups. Interestingly, decreasing or increasing energy consumption caused growth to also decrease or increase respectively. Decreasing growth also led to a decline in energy utilization and increasing growth led to a surge in energy utilization. This was observed for both energy importers and exporters.

A similar type of study but one which included an investigation of the relationship between industrial and agricultural sectors in addition to total rate of growth of the Nigerian economy

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with energy consumption was undertaken by Kalu ,Daniel, Nwafor, Okoyeuzu, Okoro, and Okechukwu (2018). The goal of the study was to identify if any association existed between any of the three variables and energy in the Nigerian economy. The study relied on World Bank Development Indicators to provide yearly time series data from 1971 to 2014 and adopted an ARDL bound test in the analysis as well as error correction representation. A longrun association amongst the three parameters representing economic growth and energy utilization was observed. Unlike manufacturing value added, growth of the economy and agricultural value added proved to be resilient to shocks and underlying forces of the studied energy-consumption-related variables. The finding was in line with the principle that growth of Nigeria's economy is driven by consumption of energy.

According to Ouedraogo (2012) energy utilization and gross domestic product, in addition to electricity and GDP move in unison in the long-term. This conclusion was arrived at by studying data gathered from 1980 to 2008 for fifteen countries by utilizing recently developed panel cointegration techniques and the Granger causality tests to examine the dynamic cause-and-effect associations between utilization of energy, cost of energy and economic growth in addition to the association between electricity utilization, charges and growth. The outcome proved that restricted access to energy could impede economic expansion and hamper the developmental aspirations of these nations.

Yildirim, Sukruodlu, and Aslan, (2014) used the bootstrapped autoregressive metric causality approach to study the causal association between utilization of energy and economic expansion or growth by using data collected for eleven countries. The variables of interest were energy consumption per capita, gross capital formation, and GDP per capita. In all the countries, he found the neutrality hypothesis was valid with the exception of Turkey where a unidirectional

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causal nexus running from economic growth to energy utilization was found. This indicates that the other countries can pursue energy conservation-directed policies except for Turkey.

Adams, Klobodu, and Opoku (2016) focused on 16 sub-Saharan Africa nations and used a panel vector autoregressive model to highlight the feedback hypothesis remains the case for the connection between energy utilization and growth and that democracy has a beneficial effect on economic growth. Data used for the study was from 1971 to 2013. The outcome also proved that a unidirectional connection runs from trade openness to utilization of energy. It was their sentiment that the outcome could have been much more definite if more countries could have been included.

According to Payne (2010) results from the many studies into the cause-and-effect association between the growth of an economy and the utilization of energy do not yield a common outcome mainly as a result of differences in countries climates, patterns of energy usage, stages and structures of development, methodologies employed for the study, and the differences in time periods.

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CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter discusses the technique employed in the research to achieve the outcome of the study. The chapter starts off by explaining the source of the information used and identifying the broad approach to the research and subsequently details the actual techniques used.

3.1 Data and Variables

Two main approaches have been have been encountered in empirical studies into the analysis of the causal association between economic growth and energy consumption. These are the bivariate and multivariate approaches. The multivariate model uses more than two variables to analyze the relationship between economic growth and energy consumption (GDP, labour, capital formation, energy consumption etc.) whilst bivariate models use just the two variables of economic growth and energy consumption.

This research employs a bivariate approach using annual time series on GDPt and ECt for Ghana from **1971 to 2016**. The real GDP per capita (constant 2010 US$) is proxy for economic growth and is represented by GDPPC. ECt represents electric power consumption (Kwh per capita). The information has been converted into smaller values by dividing GDP and Electricity consumption by total population because according to Bekhet and Othman (2014), smaller values will cause the process to attain stationarity. World Development Indicator (WDI, 2018) serves as the source of the annual time series data published at constant 2010 prices. The potential incidence of autocorrelation and heteroscedasticity is mitigated by expressing the

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variables in a logarithmic form so as to achieve a better stationary behavior (Bekhet & Othman, 2014).

3.2 Methodology

This research aims to probe the long-run and short-run causal connections amongst economic growth and electricity consumption in Ghana by utilizing the Autoregressive Distributed Lagged (ARDL) bound test technique for cointegration pioneered by Pesaran, Shin, and Smith (2001). As a result of some added benefits compared to alternative methods to cointegration for instance Johansen cointegration, the ARDL method has gained more popularity recently is being employed more. Three advantages of ARDL were put forward by Taiwo and Sylvanus (2012). Firstly, unlike for Engle-Granger test (1987), and Johansen and Juselius (1988, 1990), it is neither necessary nor mandatory in the use of this method to perform preliminary checks for unit root test to validate that every variable is integrated in the same order. Thus, the bounds test method to cointegration could be used irrespective of the integrated order of the predictor variables being I(0) or I(1). However if they are I(2), this does not hold (Pesaran & Shin, 1999). Secondly, the bound test method is shown to have greater performance in contrast to different approaches of cointegration and has been extensively employed in limited sample studies. The third advantage is that, this method allows it to tackle the potential endogeniety difficulty that is inherent in empirical studies. In addition, Persaran, Shin and Smith (2001) contended that proper variation of the order of ARDL is adequate to at the same time rectify the issue of serial correlation and endogeniety.

The ARDL model is as follows for the conventional log-linear functional specification of long-run causality between electricity consumption and real GDP:

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$$\Delta LNGDPPC_t =$$

$$\alpha_0 + \sum_{i=1}^{p} \alpha_{1t} \Delta LNGDPPC_{t-i} + \sum_{i=0}^{q} \alpha_{2t} \Delta EC_{t-i} + \alpha_4 EC_{t-i} + \alpha_5 RGDP_{t-i} + \varepsilon_t \quad \textbf{(1)}$$

$$\Delta EC_t = \beta_0 + \sum_{i=0}^{p} \beta_{1t} \Delta LNGDPPC_{t-i} + \sum_{i=1}^{q} \beta_{2t} \Delta EC_{t-i} + \beta_4 EC_{t-i} + \beta_5 LNGDPPC_{t-i} +$$

$$\varepsilon_t \qquad (\mathbf{2})$$

LNGDPPC represents the logarithm of real GDP per capita which is the proxy for economic growth whilst EC stands for electricity consumption per capita.

The suitable lags length framework is defined by employing the minimum Akaike's information criteria (AIC). Two steps are required by the ARDL model to be in a position that enables you to derive the long-run interactions amongst variables. The incidence of long-run connections in the equations among the factors undergoing appraisal is assessed first. According to Shahbaz and Feridun (2012) the ARDL model shows the computed ARDL F-statistic responds to selection the model's lag length. The Wald test is calculated to distinguish the long-run association amongst the variables under consideration once the regression of Equation 1 and Equation 2 were run. The Wald test was performed by restricting the projected long-run coefficients of economic expansion and electricity usage. If the lower bound value is bigger than the calculated F-statistic, then we fail to reject the null hypothesis, hence concluding the absence of long-run association amongst usage of electricity and growth. If the upper bound value is lower than the calculated F-statistic then growth-electricity nexus has a long-run association. The outcome is inconclusive if the calculated F-statistic lies within the lower and upper limits (Davoud, Behrouz, Farshid, & Somayeh, 2013).

The Null hypothesis (H_0) corresponds to absence of cointegration whiles the alternative hypothesis (H_1) shows presence of cointegration and are presented below:

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- H_0: $\alpha_4 = \alpha_5 = 0$ for Equation 1 and $\beta_4 = \beta_5 = 0$ for Equation 2
- H_1: $\alpha_4 \neq \alpha_5 \neq 0$ for Equation 1 and $\beta_4 \neq \beta_5 \neq 0$ for Equation 2

3.2.1 Granger-Causality Test

Provided signs of a long-run association amongst the variables exist, the subsequent action is to perform the conventional Granger-Causality with lagged error-correction term. It was advocated by Engle-Granger (1987) that if cointegration is present, conducting Granger-Causality test at order one through Vector Autoregressive (VAR) framework will be deceptive. Extra variables included to the VAR procedure, like the error-correction term, will assist in examining the long-run connection (Davoud et al., 2013). The cause-and-effect trajectory amongst vital factors may be specified by the coefficient of the long-run effect's one-lagged error-correction term. Furthermore, the speed of adjustment back to long-run equilibrium due to a short-run shock is represented by the coefficient of the ECM term. The ideal lag length is chosen using the Akiake Information Criterion (AIC). It is important to note that only cointegrated vectors will be assessed by way of ECM (Narayan & Singh, 2007; Davoud et al., 2013). In this paper, the Granger- Causality test in the error correction model (ECM) amongst electricity consumption and economic growth is as follows in this document:

$$\Delta LNGDPPC_t = \beta_0 + \sum_{i=0}^{p} \beta_{1i} \Delta LNGDPPC_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta EC_{t-i} + \beta_4 ECM_{t-1} + \varepsilon_t \qquad \textbf{(3)}$$

$$\Delta EC_t = \emptyset_0 + \sum_{i=0}^{p} \emptyset_{1i} \Delta LNGDPPC_{t-i} + \sum_{i=1}^{q} \emptyset_{2i} \Delta EC_{t-i} + \emptyset_4 ECM_{t-1} + \varepsilon_t \qquad (\mathbf{4})$$

A long-run association amongst consumption of electricity and economic expansion is present in case of cointegration amongst the variables. This shows a Granger-Causality in one direction at least, but not the cause-and-effect relationship amongst the underlying variables (Shahbaz & Feridun, 2012).

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To establish the direction of causality, the F-statistic and the one period lagged error correction term is used. The significance of the F-statistic on the independent variables indicates the short-run causality direction through the joint test. Conversely, the t-statistic on the coefficient of the one lagged error–correction term establishes the long-run causative impact (Odhiambo, 2011; Shabaz et al., 2012). According to Ozturk and Acaravci (2011) testing Equations 3 and 4 through Granger-Causality test, the cause-and-effect association can be observed in two dissimilar ways as in “a”, and “b” below. The short-run cause-and-effect relationship is identified by testing the hypothesis below:

a. H_0: $\beta_2 = 0$, and $\emptyset_1 = 0$; H_1: $\beta_2 \neq 0$, and $\emptyset_1 \neq 0$ for Equations 3 & 4

b. H_0: $\beta_4 = 0$, and $\emptyset_4 = 0$; H_1: $\beta_4 \neq 0$, and $\emptyset_4 \neq 0$ for Equations 3 & 4

3.2.2 Stationarity Test (Unit Root Test)

It is no longer necessary to assess the order of integration of the variables after the bounds testing approach to cointegration. To confirm no variable is integrated at order two however, the unit root test is still applied. It is argued by Ouattara (2004) that considering any variable at I(2) in cointegration survey renders the F-Statistic for the cointegration senseless.

Several techniques have been used to carry out the unit root test for stationarity. Literature shows tests such as Kwiatkowski-Phillips-Schmidt-Shin test, Phillips and Perron test, and Ng and Perron test among others can be used for the unit root test. In this study however, the Augmented Dickey-Fuller (ADF) is used to assess the order of integration (intercept only, and with or without trend) of model variables.

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CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

The results and discussions of the study are presented in this chapter. The study used time series econometrics approach to analyze the data in answering the objectives specific the study. First, the summary statistics of the variables of study are explored. Secondly, the study conducted stationarity and trend analysis using graphical representations and unit root test to identify the pattern of the time series variables thus to determine whether the time series variables exhibit random walk hypothesis or are stationarity. Thereafter, an ARDL error correction model was estimated to study the association among economic growth and electricity consumption. Granger causality was also conducted to determine the causality between economic growth and electricity consumption. Finally, the results are discussed based on the objectives of the paper.

4.2 Summary Statistics

Table 4.1 below displays the descriptive statistics of the variables used for the study for a period of 46 years from 1971 to 2016.

Table 4.1: Descriptive Statistics

Variable	Count	Mean	SD	Max	Min
GDP per capita	46	1018.329	260.3854	1643.45	693.46
Electricity Consumption	46	316.995	70.11552	416.15	92.78

An evaluation of the association between electricity consumption and economic growth for Ghana for the period under study also showed that there is a positive and significant relationship between the LNGDPPC and EC as shown the correlation matrix below:

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Table 4.2: Correlation Matrix

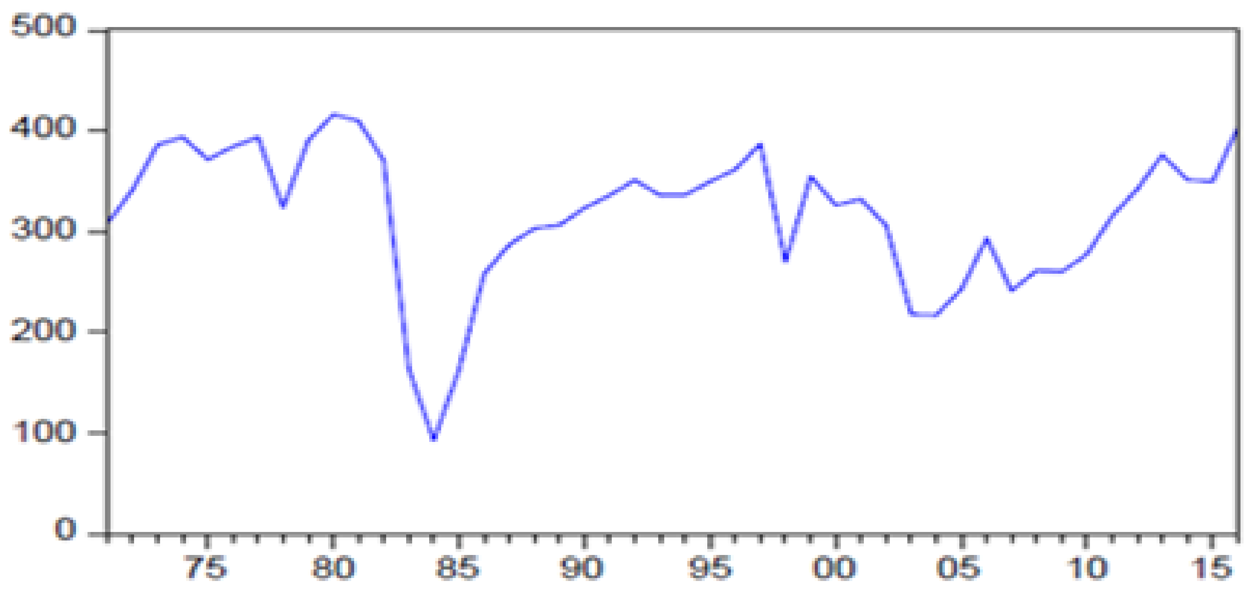
Variable	LNGDPPC	LNEC
LNGDPPC	1	
LNEC	0.258*	1

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3 Trend Analysis

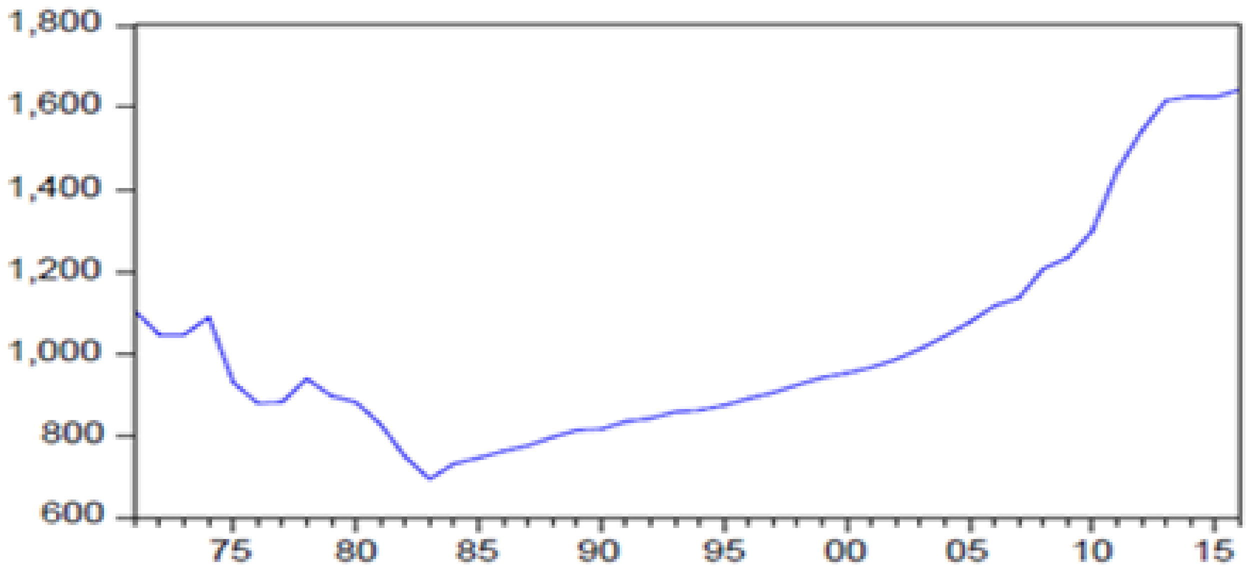
The graph below represents GDP per capita in constant 2010 US$ and electricity consumption measured in kWh per capita for Ghana. As shown, after a year by year decline of GDP per capita from the early 1970s to 1983, the trend changed and there has been a study growth up to 2016 with an actual value of US$ 1643.45. Electricity consumption shows its lowest yearly figure in 1983 corresponding to the lowest recorded GDP per capita. For the 45 year period under review, electricity consumption averaged 317 kWh per capita.

Figure 4.1: Electricity Consumption (kWh per capita)



Source: Researcher's Own Construct (2019) using Eviews (Data from WDI)

Figure 4.2: GDP Per Capita (Constant 2010 US$)



Source: Researcher's Own Construct (2019) using Eviews (Data from WDI)

4.4 Unit Root Test Results

Visual inspection of LNGDPPC graph above shows a clear trend indicating that it is not stationary. At first glance at the graph for EC, the data seems stationary but it can only be confirmed by performing the Augmented Dickey-Fuller test. With the ADF test as the basis, it is proven that Economic growth (LNGDPPC) is not stationary at level in instances of intercept without trend and intercept with trend as displayed below:

Table 4.3: Augmented Dickey-Fuller Test at I(0) - LNGDPPC

				Critical Value					
Variable	Intercept		Test Statistic	1%	5%	10%	p-value	Order	Outcome
LNGDPPC	without trend	Z(t)	0.337	-3.589	-2.930	-2.603	0.9777	I(0)	Non-stationary
LNGDPPC	with trend	Z(t)	-1.752	-4.176	-3.513	-3.187	0.7111	I(0)	Non-stationary

After taking the first difference however, stationarity was attained. Thus LNGDPPC is integrated at order one, I(1). The outcome of the unit root test using Augmented Dickey-Fuller (ADF) test

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performed for LNGDPPC is shown below:

Table 4.4: Augmented Dickey-Fuller Test at I(1) - LNGDPPC

				Critical Value					
Variable	Intercept		Test Statistic	1%	5%	10%	p-value	Order	Outcome
LNGDPPC	without trend	Z(t)	-4.379	-3.589	-2.930	-2.603	0.0011	I(1)	Stationary
LNGDPPC	with trend	Z(t)	-5.317	-4.181	-3.516	-3.188	0.0004	I(1)	Stationary

Augmented Dickey-Fuller (ADF) test performed for EC also indicate it was not stationary at levels but achieved stationarity at order one, I(1) for both Intercept alone and with trend as shown below:

Table 4.5: Augmented Dickey-Fuller Test at I(0) - LNEC

				Critical Value					
Variable	Intercept		Test Statistic	1%	5%	10%	p-value	Order	Outcome
EC	without trend	Z(t)	-3.712	-3.686	-2.930	-2.603	0.0072	I(0)	Stationary
EC	with trend	Z(t)	-3.635	-4.181	-3.516	-3.188	0.0381	I(0)	Stationary

As neither variable is integrated beyond order one, cointegration analysis can be performed (Pesaran et al. (2001).

4.5 Cointegration and Long-run Results

The next step is to investigate the presence of long-run interactions between Ghana's underlying factors using the ARDL bounds testing method to cointegration (Narayan & Singh, 2007; Davoud et al., 2013). The first step is to determine the optimal length of lag on the first differenced equations (1) and (2) based on the AIC. The second step is the application of the bounds F-test in equations (1) and (2) to investigate the long-run relationship between variables. Using AIC, the optimum lag length for both economic growth and electricity consumption was found to be 2. Accordingly, co-integration was assessed for both economic growth as the

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dependent variable and also electricity consumption as the dependent variable in turns using the bounds test.

Table 4.6: Results of Bounds Testing to Cointegration (Dependent Variable: LNGDPPC)

			Asymptotic: n=1000	
F-statistic	2.260033	10%	4.04	4.78
k	1	5%	4.94	5.73
		2.5%	5.77	6.68
		1%	6.84	7.84

The result of the bounds test shown in Table 4 above, when economic growth was the dependent variable indicates cointegration does not exists for equation 1 and that there is therefore no long-run relationship between electricity consumption and economic growth. As the F-statistic value of 2.26 is below the lower limit of 4.04 this buttresses the finding in accordance with Pesaran et al. (2001)

Table 4.7: Results of Bounds Testing to Cointegration (Dependent Variable: LNEC)

			Asymptotic: n=1000	
F-statistic	8.001111	10%	4.04	4.78
k	1	5%	4.94	5.73
		2.5%	5.77	6.68
		1%	6.84	7.84

In the case where electricity consumption was made the dependent variable, the F-statistic of 8.00 was higher than the upper limit even at the 1% significance as captured in Table 5 above. We therefore fail to reject the null hypothesis of no-integration for the bounds test.

This outcome of the bounds test implies that when electricity consumption serves as the dependent variable there is cointegration. This points to a long-run relationship between electricity consumption and economic growth when electricity consumption serves as the dependent variable. The finding of cointegration in only one equation contrasts with the study of

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Amusa and Leshoro (2013) who found that in Botswana, there is cointegration between electricity consumption and expansion of the economy in both cases where economic growth serves as the dependent variable or electricity consumption is the dependent variable. Bashier (2016) also obtained results indicating that cointegration does exist for both equations 1 and 2 and showing further that a long-run relationship exists in both cases as well in Jordan. Likewise, Abid and Sebri (2012) identified cointegration between the total economy and energy consumption for Tunisia and thus established a long-run relationship between the two variables.

Based on the result of "no-integration" when economic growth is the dependent variable, and "co-integration" when electricity consumption serves as the dependent variable, an ARDL will be run to estimate the short-run equation for Equation 1, whilst an Error Correction Model (ECM) will be estimated for Equation 2.

Having established cointegration between economic growth and electricity consumption, Equation 2 is estimated to establish the long-run coefficients of the cointegrating parameters.

The outcome of the long-run coefficients is reported in Table 6 below:

Table 4.8: Long-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.013766	0.031863	-0.432043	0.6684
D(LNEC(-1))	0.788718	0.412670	1.911258	0.0642
D(LNEC(-2))	-0.472817	0.325278	-1.453580	0.1550
D(LNGDPPC(-1))	1.199435	0.778165	1.541363	0.1322
D(LNGDPPC(-2))	-0.212030	0.930677	-0.227824	0.8211
ECM(-1)	-0.837034	0.454116	-1.843216	0.0738
ECM(-2)	0.084862	0.385766	0.219983	0.8272

The short-rub coefficients show the dynamic adjustments of all variables. They are however not statistically significant. ECM has a negative coefficient of -0.84 and is significant at the 10% significant level. This indicates that there's going to be convergence to long-run equilibrium.

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The cointegrating equation also gives a negative adjustment coefficient of -0.43499 with a statistically significant p-value of 0.0002. This means that the previous year's errors will be corrected in the current period at an adjustment speed of 43.50%; so too will the current year's errors in the next year.

Table 4.9: ECM Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.295213	0.320283	4.043964	0.0002
D(LNEC(-1))	0.385682	0.138795	2.778791	0.0083
CointEq(-1)*	-0.43499	0.107406	-4.049973	0.0002

4.6 Granger Causality Test Results

The result of the Granger-Causality test is displayed in Table 6 below. There is evidence that economic growth granger-causes electricity consumption as the p-value is less than the significant value of 5% leading to a rejection of the null hypothesis. Referencing from the same Table 6 below, we fail to reject the null hypothesis that electricity consumption on the other hand, does not granger-cause economic growth.

Table 4.10: Granger Causality Result

Null Hypothesis:	Obs	F-Statistic	Prob.
D(LNEC) does not Granger Cause D(LNGDPPC)	43	0.28291	0.7552
D(LNGDPPC) does not Granger Cause D(LNEC)		4.57374	0.0166

There is therefore a uni-directional causality running from economic growth to electricity consumption. The "conservation hypothesis'" therefore holds in the context of Ghana. It advocates that an energy consumption conservation policy may be employed with minimal or no antagonistic consequence on growth of the economy. The conservation hypothesis is upheld if

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raising real GDP leads to a raise in the consumption of energy. The economy of Ghana is therefore not dependent on electricity according to the result of the Granger-Causality test. As a result of the observed direction of Granger-Causality, implementing energy conservation policies to enhance the efficient use of electricity will not negatively hamper economic growth (Abdoli, Farahani, and Dastan, 2015). Shortages in the supply of electricity are therefore not expected to lead to an observable detrimental impact on economic growth. This finding runs against the normal grain of thought which seems to imply that shortages or imbalances in electricity supply adversely impacts the economic performance of Ghana. That might be the case in the industrial or manufacturing sector however; the economy of Ghana is heavily reliant on services, agriculture, as well as extractive mining. Manufacturing controls a small share of the economy as most goods are imported. Quite a number of small manufacturers also rely heavily on generator sets as a backup to electricity shortages. The share of electricity consumed in Ghana is rapidly growing for non-industrial usage compared to industrial (Abokyi et al., 2018).

The causal direction identified is in line with Iyke and Odhiambo (2014) who found that there was a causal flow from economic growth to electricity consumption in both the short-run and long-run.

On the other hand Abokyi et al. (2018) found a one-way causal relationship running from consumption of electricity to industrial growth contrary to the result obtained by this paper and thus their study confirmed the “growth hypothesis” to be the case for Ghana.

Alabi et al (2017) found a bidirectional causality between renewable energy and economic growth both in the short-run and the long-run in their study for oil-exporting countries in Africa using the fully modified ordinary least squares method for co-integrated panels (Pedroni, 2000).

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Clearly, different studies have yielded different results. The type of observed causal relationships or its absence between energy or electricity consumption and economic growth is a factor of the methodology, country characteristics and also the type of study conducted. Length and type of data utilized also will have some bearing on the results (Ozturk, 2010).

4.7 Residual Diagnostics and Stability Tests

The Breusch-Godfrey Serial Correlation LM Test showed that the p-values in both cases when electricity consumption and economic growth took turns to be the dependent variables were not significant therefore both models were not serially correlated.

For stability tests, CUSUM of Squares was performed. The outcome of CUSUM of Squares displayed below shows stability in the case when economic growth was the dependent variable, Figure 4.3. When electricity consumption was the dependent variable, there was a slight deviation from the 5% boundary but the model achieved stability afterwards as shown in Figure 4.4 below:

Figure 4.3: Stability Test for Economic Growth Equations

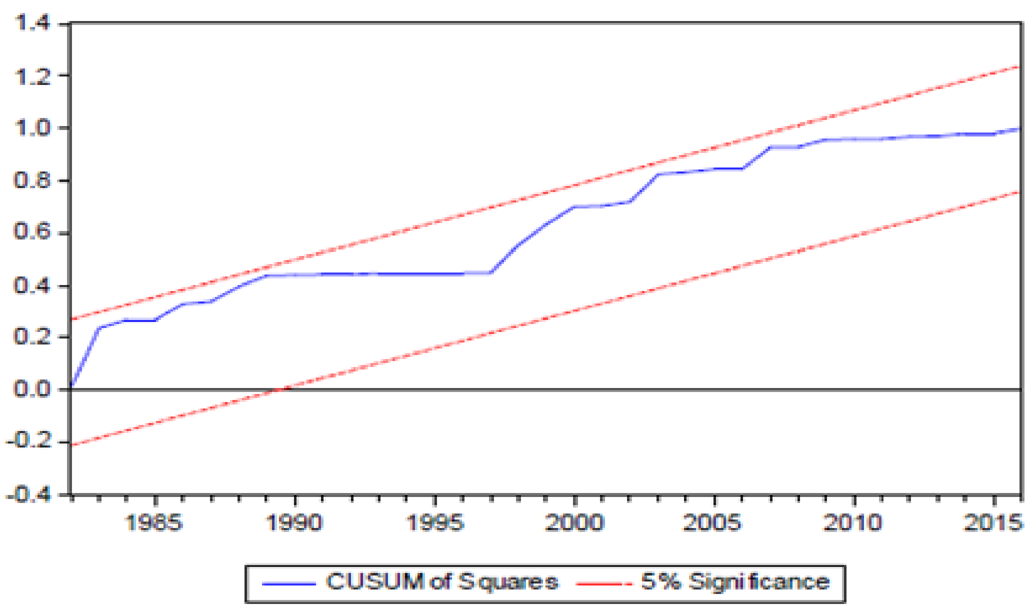

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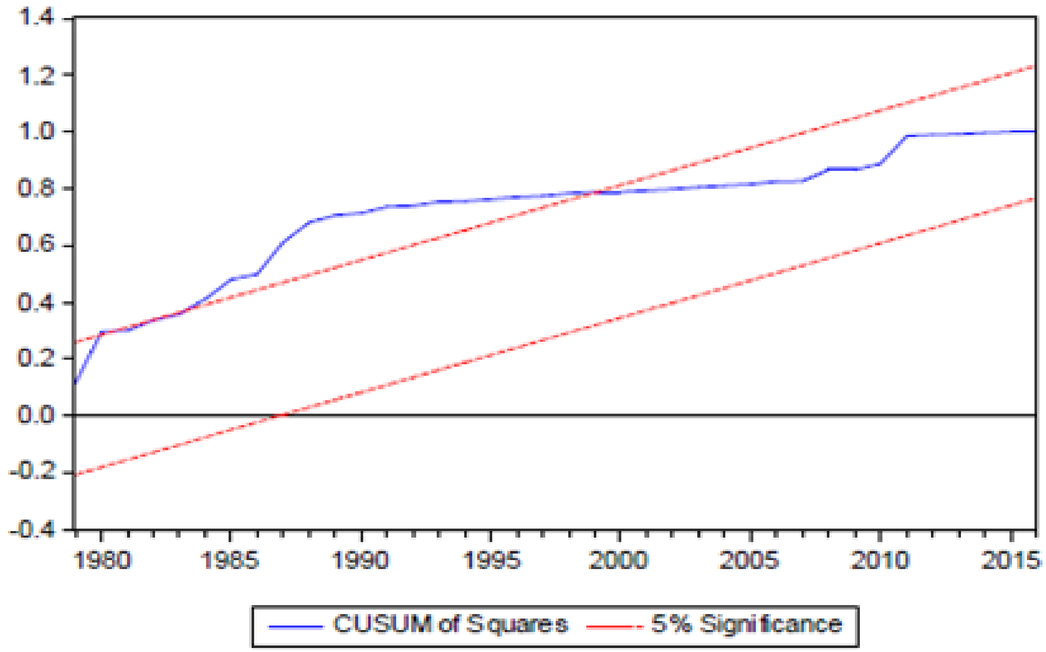
Figure 4.4: Stability Test for Electricity Consumption Equations



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CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter provides a summary of the study's findings, draws conclusions, and offers recommendations based on the findings of the study.

5.1 Summary of Findings

The objective of this paper was to examine the relationship between electricity consumption and economic growth in Ghana using electricity consumption measured in kWh per capita and real GDP per capita as proxy for economic growth for Ghana from 1971 to 2016 by using a bivariate model. To attain this objective, in addition to using Autoregressive Distributed Lag (ARDL) bounds test method to cointegration, Granger-Causality method was employed to identify causality. Both electricity consumption and economic growth proved to be integrated below order two thus the ARDL bounds test proved a good technique for the research. The test identified cointegration and thus long-run association between electricity consumption and economic growth of Ghana. Upon performing a Granger-Causality Test, it was observed that there was a uni-directional causality running from economic growth to electricity consumption.

5.2 Conclusions

Contrary to popular belief that electricity consumption leads to economic growth in Ghana and that the past challenges encountered with the short supply of power has led to woes in Ghana's economic growth trend, this research debunks the notion and rather shows that electricity

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consumption does not cause economic growth in Ghana but rather, economic growth Granger-Causes electricity consumption.

5.3 Recommendations

Considering the importance of achieving respectable economic growth targets to countries in order to attract investment, it is indeed necessary for a country to understand the factors that drives positive growth of its economy. This study is important because, it shows that increased electricity consumption does not positively impact economic growth. Two immediate outcomes of this are that, a conservation policy can be implemented to increase efficiency of use of power to safeguard the environment without a dip in economic growth. Secondly, policy makers should take steps to identify why increased consumption does not reflect in productivity. If increased consumption is not leading to growth, then it might be that the manufacturing sector is struggling to survive and as such is declining. If we are to achieve the national goal of achieving yearly economic growth targets, then there should be an enabling environment for the manufacturing sector to be vibrant.

The government's One District, One Factory (1D1F) initiative points in the direction of increasing manufacturing in Ghana and therefore the necessary infrastructure, including power must be available.

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APPENDIX

Appendix A: Augmented Dickey-Fuller Unit Root Test on LNGDPPC 1

Augmented Dickey-Fuller Unit Root Test on LNGDPPC

Null Hypothesis: LNGDPPC has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.337058	0.9777
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDPPC)
Method: Least Squares
Date: 08/01/19 Time: 20:58
Sample (adjusted): 1973 2016
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDPPC(-1)	0.010569	0.031356	0.337058	0.7378
D(LNGDPPC(-1))	0.375834	0.151044	2.488239	0.0170
C	-0.065781	0.215441	-0.305332	0.7617

R-squared	0.165552	Mean dependent var	0.010285
Adjusted R-squared	0.124847	S.D. dependent var	0.045360
S.E. of regression	0.042434	Akaike info criterion	-3.415967
Sum squared resid	0.073828	Schwarz criterion	-3.294318
Log likelihood	78.15127	Hannan-Quinn criter.	-3.370853
F-statistic	4.067139	Durbin-Watson stat	1.960442
Prob(F-statistic)	0.024473		

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Appendix B: Augmented Dickey-Fuller Unit Root Test on LNGDPPC 2

Augmented Dickey-Fuller Unit Root Test on LNGDPPC

Null Hypothesis: LNGDPPC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.751941	0.7111
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDPPC)
Method: Least Squares
Date: 08/01/19 Time: 21:00
Sample (adjusted): 1972 2016
Included observations: 45 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDPPC(-1)	-0.059939	0.034213	-1.751941	0.0871
C	0.363795	0.227315	1.600400	0.1170
@TREND("1971")	0.002515	0.000577	4.358988	0.0001

R-squared	0.333052	Mean dependent var	0.008871
Adjusted R-squared	0.301292	S.D. dependent var	0.045835
S.E. of regression	0.038313	Akaike info criterion	-3.621731
Sum squared resid	0.061650	Schwarz criterion	-3.501287
Log likelihood	84.48894	Hannan-Quinn criter.	-3.576830
F-statistic	10.48671	Durbin-Watson stat	1.645977
Prob(F-statistic)	0.000202		

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Appendix C: Augmented Dickey-Fuller Unit Root Test on LNGDPPC –First Difference

Augmented Dickey-Fuller Unit Root Test on D(LNGDPPC)

Null Hypothesis: D(LNGDPPC) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.378894	0.0011
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDPPC,2)
Method: Least Squares
Date: 07/27/19 Time: 09:06
Sample (adjusted): 1973 2016
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDPPC(-1))	-0.604708	0.138096	-4.378894	0.0001
C	0.006802	0.006445	1.055302	0.2973

R-squared	0.313442	Mean dependent var	0.001473
Adjusted R-squared	0.297095	S.D. dependent var	0.050077
S.E. of regression	0.041984	Akaike info criterion	-3.458654
Sum squared resid	0.074033	Schwarz criterion	-3.377555
Log likelihood	78.09039	Hannan-Quinn criter.	-3.428579
F-statistic	19.17471	Durbin-Watson stat	1.972150
Prob(F-statistic)	0.000078		

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Appendix D: Augmented Dickey-Fuller Unit Root Test on LNEC

Augmented Dickey-Fuller Unit Root Test on LNEC

Null Hypothesis: LNEC has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.712177	0.0072
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNEC)
Method: Least Squares
Date: 07/27/19 Time: 09:17
Sample (adjusted): 1973 2016
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEC(-1)	-0.418971	0.112864	-3.712177	0.0006
D(LNEC(-1))	0.399444	0.144684	2.760801	0.0086
C	2.399230	0.646100	3.713405	0.0006

R-squared	0.277915	Mean dependent var	0.003798
Adjusted R-squared	0.242692	S.D. dependent var	0.223125
S.E. of regression	0.194171	Akaike info criterion	-0.374405
Sum squared resid	1.545803	Schwarz criterion	-0.252756
Log likelihood	11.23692	Hannan-Quinn criter.	-0.329292
F-statistic	7.890025	Durbin-Watson stat	1.913850
Prob(F-statistic)	0.001262		

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Appendix E: ARDL Long Run Form and Bounds Test LNGDPPC

ARDL Long Run Form and Bounds Test
Dependent Variable: D(LNGDPPC)
Selected Model: ARDL(2, 0)
Case 3: Unrestricted Constant and No Trend
Date: 08/01/19 Time: 19:04
Sample: 1971 2016
Included observations: 44

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.066992	0.216501	0.309430	0.7586
LNGDPPC(-1)*	0.031017	0.031671	0.979363	0.3333
LNEC**	-0.047771	0.022782	-2.096913	0.0424
D(LNGDPPC(-1))	0.364213	0.145256	2.507378	0.0163

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEC	1.540137	1.516973	1.015270	0.3161

EC = LNGDPPC - (1.5401*LNEC)

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	2.260033	10%	4.04	4.78
k	1	5%	4.94	5.73
		2.5%	5.77	6.68
		1%	6.84	7.84
Actual Sample Size	44		Finite Sample: n=45	
		10%	4.225	5.02
		5%	5.235	6.135
		1%	7.74	8.65
			Finite Sample: n=40	
		10%	4.235	5
		5%	5.26	6.16
		1%	7.625	8.825

t-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	0.979363	10%	-2.57	-2.91
		5%	-2.86	-3.22
		2.5%	-3.13	-3.5
		1%	-3.43	-3.82

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Appendix F: : ARDL Long Run Form and Bounds Test LNEC

ARDL Long Run Form and Bounds Test
Dependent Variable: D(LNEC)
Selected Model: ARDL(2, 0)
Case 3: Unrestricted Constant and No Trend
Date: 08/01/19 Time: 19:09
Sample: 1971 2016
Included observations: 44

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.295213	1.022230	1.267046	0.2125
LNEC(-1)*	-0.434990	0.112225	-3.876065	0.0004
LNGDPPC**	0.173432	0.125341	1.383681	0.1741
D(LNEC(-1))	0.385682	0.143442	2.688770	0.0104

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDPPC	0.398704	0.295795	1.347908	0.1853

EC = LNEC - (0.3987*LNGDPPC)

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	8.001111	10%	4.04	4.78
k	1	5%	4.94	5.73
		2.5%	5.77	6.68
		1%	6.84	7.84
Actual Sample Size	44		Finite Sample: n=45	
		10%	4.225	5.02
		5%	5.235	6.135
		1%	7.74	8.65
			Finite Sample: n=40	
		10%	4.235	5
		5%	5.26	6.16
		1%	7.625	8.825

t-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-3.876065	10%	-2.57	-2.91
		5%	-2.86	-3.22
		2.5%	-3.13	-3.5
		1%	-3.43	-3.82

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Appendix G: Error Correction Regression

ARDL Error Correction Regression
Dependent Variable: D(LNEC)
Selected Model: ARDL(2, 0)
Case 3: Unrestricted Constant and No Trend
Date: 08/01/19 Time: 19:10
Sample: 1971 2016
Included observations: 44

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.295213	0.320283	4.043964	0.0002
D(LNEC(-1))	0.385682	0.138795	2.778791	0.0083
CointEq(-1)*	-0.43499	0.107406	-4.049973	0.0002

R-squared	0.310899	Mean dependent var	0.003798
Adjusted R-squared	0.277284	S.D. dependent var	0.223125
S.E. of regression	0.189685	Akaike info criterion	-0.42116
Sum squared resid	1.475194	Schwarz criterion	-0.29951
Log likelihood	12.26551	Hannan-Quinn criter.	-0.37605
F-statistic	9.248895	Durbin-Watson stat	1.930415
Prob(F-statistic)	0.000484		

* p-value incompatible with t-Bounds distribution.

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	8.001111	10%	4.04	4.78
k	1	5%	4.94	5.73
		2.50%	5.77	6.68
		1%	6.84	7.84

t-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-4.049973	10%	-2.57	-2.91
		5%	-2.86	-3.22
		2.50%	-3.13	-3.5
		1%	-3.43	-3.82

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Appendix H: Short Run Estimation

Dependent Variable: D(LNGDPPC)
Method: Least Squares
Date: 08/02/19 Time: 15:14
Sample (adjusted): 1974 2016
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005975	0.006908	0.864945	0.3925
D(LNGDPPC(-1))	0.405507	0.161709	2.507626	0.0165
D(LNGDPPC(-2))	0.046770	0.171573	0.272597	0.7866
D(LNEC(-1))	-0.021632	0.033353	-0.648577	0.5205
D(LNEC(-2))	-0.008935	0.030840	-0.289728	0.7736

R-squared	0.177089	Mean dependent var	0.010519
Adjusted R-squared	0.090467	S.D. dependent var	0.045870
S.E. of regression	0.043746	Akaike info criterion	-3.311872
Sum squared resid	0.072722	Schwarz criterion	-3.107082
Log likelihood	76.20526	Hannan-Quinn criter.	-3.236352
F-statistic	2.044387	Durbin-Watson stat	2.023838
Prob(F-statistic)	0.107561		

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Appendix I: Long Run Error Term Estimation

Dependent Variable: LNEC
Method: Least Squares
Date: 08/01/19 Time: 19:22
Sample (adjusted): 1973 2016
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.403072	1.028281	1.364483	0.1802
LNEC(-1)	0.950262	0.144215	6.589201	0.0000
LNEC(-2)	-0.332768	0.148799	-2.236353	0.0311
LNGDPPC(-1)	1.062849	0.701757	1.514554	0.1379
LNGDPPC(-2)	-0.949630	0.759123	-1.250957	0.2184

R-squared	0.605484	Mean dependent var	5.723952
Adjusted R-squared	0.565021	S.D. dependent var	0.288020
S.E. of regression	0.189957	Akaike info criterion	-0.377390
Sum squared resid	1.407268	Schwarz criterion	-0.174641
Log likelihood	13.30257	Hannan-Quinn criter.	-0.302201
F-statistic	14.96385	Durbin-Watson stat	1.929510
Prob(F-statistic)	0.000000		

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Appendix J: Long run estimation

Dependent Variable: D(LNEC)
Method: Least Squares
Date: 08/01/19 Time: 19:27
Sample (adjusted): 1975 2016
Included observations: 42 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.013766	0.031863	-0.432043	0.6684
D(LNEC(-1))	0.788718	0.412670	1.911258	0.0642
D(LNEC(-2))	-0.472817	0.325278	-1.453580	0.1550
D(LNGDPPC(-1))	1.199435	0.778165	1.541363	0.1322
D(LNGDPPC(-2))	-0.212030	0.930677	-0.227824	0.8211
ECM(-1)	-0.837034	0.454116	-1.843216	0.0738
ECM(-2)	0.084862	0.385766	0.219983	0.8272

R-squared	0.377098	Mean dependent var	0.000593
Adjusted R-squared	0.270315	S.D. dependent var	0.227699
S.E. of regression	0.194504	Akaike info criterion	-0.285716
Sum squared resid	1.324114	Schwarz criterion	0.003896
Log likelihood	13.00003	Hannan-Quinn criter.	-0.179562
F-statistic	3.531442	Durbin-Watson stat	2.003531
Prob(F-statistic)	0.007733		

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Appendix J: Serial Correlation Test for Equation 1

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.432097	Prob. F(2,36)	0.2521
Obs*R-squared	3.168992	Prob. Chi-Square(2)	0.2051

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 08/02/19 Time: 15:16
Sample: 1974 2016
Included observations: 43
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.021825	0.014623	-1.492496	0.1443
D(LNGDPPC(-1))	3.177014	1.901021	1.671215	0.1034
D(LNGDPPC(-2))	-1.250249	0.859780	-1.454149	0.1546
D(LNEC(-1))	-0.020282	0.035114	-0.577620	0.5671
D(LNEC(-2))	0.061099	0.049488	1.234623	0.2250
RESID(-1)	-3.199660	1.906507	-1.678284	0.1020
RESID(-2)	-0.019031	0.370342	-0.051387	0.9593

R-squared	0.073697	Mean dependent var	1.53E-18
Adjusted R-squared	-0.080686	S.D. dependent var	0.041611
S.E. of regression	0.043257	Akaike info criterion	-3.295404
Sum squared resid	0.067363	Schwarz criterion	-3.008697
Log likelihood	77.85118	Hannan-Quinn criter.	-3.189675
F-statistic	0.477366	Durbin-Watson stat	1.822394
Prob(F-statistic)	0.820623		

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Appendix J: Serial Correlation Test for Equation 2

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.112414	Prob. F(2,33)	0.8940
Obs*R-squared	0.284208	Prob. Chi-Square(2)	0.8675

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 08/01/19 Time: 19:30
Sample: 1975 2016
Included observations: 42
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000900	0.033364	0.026967	0.9786
D(LNEC(-1))	-0.017959	0.429487	-0.041816	0.9669
D(LNEC(-2))	0.028997	0.364064	0.079649	0.9370
D(LNGDPPC(-1))	0.026309	0.805139	0.032677	0.9741
D(LNGDPPC(-2))	-0.046260	0.972555	-0.047566	0.9623
ECM(-1)	0.229435	1.231041	0.186374	0.8533
ECM(-2)	0.197827	0.920030	0.215022	0.8311
RESID(-1)	-0.224317	1.095332	-0.204793	0.8390
RESID(-2)	-0.246141	0.787262	-0.312655	0.7565

R-squared	0.006767	Mean dependent var	8.59E-18
Adjusted R-squared	-0.234017	S.D. dependent var	0.179709
S.E. of regression	0.199633	Akaike info criterion	-0.197267
Sum squared resid	1.315154	Schwarz criterion	0.175090
Log likelihood	13.14262	Hannan-Quinn criter.	-0.060784
F-statistic	0.028103	Durbin-Watson stat	1.987293
Prob(F-statistic)	0.999992		