Analyzing the Relationship between Environmental Pollution, Electricity Consumption, and Economic Growth in Ghana: ARDL Approach

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ABSTRACT

The research investigated the nexus among environmental pollution, electricity consumption, productivity, and economic growth in Ghana embarking on time series data spanning from 1985 to 2020 adopting ARDL- autoregressive distributed lag co-integration techniques. When economic growth (RGDP) was utilized as the dependent variable, the study discovered a cointegrating nexus among the variables such as electricity usage, carbon emissions, and gross capital formation which denotes the independent variables.

The bounds test results revealed that electricity consumption exerted a positive and statistically significant effect on economic growth both in the short-run and long-run suggesting that higher electricity consumption is crucial to economic growth in Ghana. The Granger causality outcome also demonstrated a unidirectional correlation flowing from economic growth to energy usage, demonstrating overall electricity conservation policies are feasible solutions for Ghana.

The Ghanaian government can accomplish its aim of optimum productivity expansion with minimal carbon emissions by developing a substitute for coal energy that can offer to heat to the economic sectors. According to the research, energy usage such as gas is beneficial to environmental quality since it produces fewer emissions than some other renewable resources.

Keywords: ARDL, Electricity Consumption, Carbon Emissions (CO2), Economic Growth

ÖZ

Araştırma, ARDL-otoregresif dağıtılmış gecikmeli eş-bütünleşme tekniklerini benimseyen 1985'ten 2020'ye kadar uzanan zaman serisi verilerine başlayarak Gana'da çevre kirliliği, elektrik tüketimi, üretkenlik ve ekonomik büyüme arasındaki bağı araştırdı. Bağımlı değişken olarak ekonomik büyüme (RGDP) kullanıldığında, çalışma, bağımsız değişkenleri ifade eden elektrik kullanımı, karbon emisyonları ve brüt sermaye oluşumu gibi değişkenler arasında eşbütünleşik bir bağlantı keşfetti.

Sınır testi sonuçları, elektrik tüketiminin hem kısa vadede hem de uzun vadede ekonomik büyüme üzerinde pozitif ve istatistiksel olarak anlamlı bir etki yaptığını ortaya koydu, bu da Gana'da daha yüksek elektrik tüketiminin ekonomik büyüme için çok önemli olduğunu ortaya koydu. Granger nedensellik sonucu ayrıca ekonomik büyümeden enerji kullanımına doğru tek yönlü bir korelasyon olduğunu gösterdi ve genel elektrik koruma politikalarının Gana için uygun çözümler olduğunu gösterdi.

Gana hükümeti, ekonomik sektörlere ısı sunabilecek kömür enerjisi için bir ikame geliştirerek, minimum karbon emisyonu ile optimum üretkenlik artışı hedefini gerçekleştirebilir. Araştırmaya göre, gaz gibi enerji kullanımı, diğer bazı yenilenebilir kaynaklardan daha az emisyon ürettiği için çevre kalitesine faydalıdır.

Anahtar Kelimeler: ARDL, Elektrik Tüketimi, Karbon Emisyonları (CO2), Ekonomik Büyüme.

DEDICATION

This long essay is dedicated to my mom Harriet Mawuse Tindy, my sisters Owusua Ama Charllotte and Leslie Amofah, my brother Stephen Osei Nchi, my kids Keziah, Manfred Jnr, Marvin, and my one and only Naomi Asor Opoku. Love you all.

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I say thank you all for your support and prayers for this success story today.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive and Distributed Lag
CH4	Methane
CO_2	Carbon Dioxide
DOLS	Dynamic Ordinary Least Square
ECG	The Electricity Company of Ghana
ECM	Error Correction Model
FMOLS	Fully Modified Ordinary Least Square
GNI	Gross National Product
GRIDCo	Ghana Grid Company
IEA	International Energy Agency
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
NED	Northern Electrical Department
PP	Philips Perron
SDG	Sustainable Development Goal
UECM	Unrestricted Error Correction Model
UN	United Nations
VECM	Vector Correction Model
VRA	The Volta River Authority
WAPP	West African Electricity Pools

Chapter 1

INTRODUCTION

1.1 Background to the study

Energy has been considered as the lubricant that lubricates any economy to attain growth and development. Therefore, policymakers are concerned about rising power consumption in the country of (Bhattacharyya, 2011) increasing population and economic expansion. As energy is the main determinant of pollutant emissions, such a rise might jeopardize energy security and worsen global climate change. There ought to be a balancing of efficiencies that do not jeopardize development or the environment while economic expansion has become an immense capacity in recent years, worries on how such expansion impacts the environmental system have been more prominent. This might necessitate a decision among fossil fuels and dioxide sources like renewable energy. Thus a trade-off may have an impact on both growths in the economy and the environment. This necessitates creativity and technical advancements in an attempt to implement energy consumption more effective and lessen its environmental effect.

Accessibility to energy is one of several means for any technologically advanced nation to improve increased levels of economic output (Edenhofer et al. 2011; Asumadu-Sarkodie and Owusu 2016; Asumadu-Sarkodie and Owusu 2016). Electricity is a vital infrastructure ingredient for economic expansion. It is the quantity of electricity that enables a huge production of products and services which enriches the wellbeing of individuals, raises work efficiency and productivity, and drives business activities effectively (Adom, 2011). Thus, electricity usage is significantly positively associated with the gross domestic product (GDP). In Ghana, from 2000 and 2008, the real GDP increased 5.5 percent per year, whereas the annual power usage increase was 1.21 percent. In 2019, Ghana's real GDP rose slightly to 6.51% compared to the previous years. The total amount of power usage per capita grew by 3.7 percent from 445.2 kWh/capita in 2018 to 461.7 kWh/capita in 2019 (Adom, 2011; EIA, 2019). Energy consumption and economic growth are growing as a result of the need to fulfill fundamental human requirements and increase output. Conversely, to fulfill energy demands, environmentally unfavorable energy sources have been used, which influence changing climate-related greenhouse emissions (Asumadu-Sarkodie and Owusu 2016; Long, 2018; Yoro and Daramola 2020; Vural, 2020). United Nations (2015), the Sustainable Development Goal (SDG, 13) emphasizes efforts that assist alleviate the effects of climate change. The connections between carbon emissions and energy use, including the relationship between growth and CO_2 emissions, have captivated researchers' interest (Ozturk and Acaravci 2010; Ozturk and Acaravci 2016; Al-Mulali and Che Sab 2018a; Acaravci and Ozturk 2010).

The economic and environmental significance of energy, specifically contemporary energy such as electricity or renewable energy like biomass, (Kwakwa, 2021) to homes and businesses can be overstated. Because of the rapid economic expansion in emerging nations worldwide electricity demand significantly climbed (World Bank, 2020) from 1,636.505 kWh per capita in 2000 to 1,922.485 kWh per capita in 2014. Even though a growing share of global energy usage is derived through fossil energy, emissions of carbon dioxide linked with increased energy consumption tend to rise.

Furthermore, numerous individuals in underdeveloped nations continue to cook using traditional fuels including timber, coal, and briquettes, which contributes to carbon emissions.

However, recommending national strategies in the absence of empirical and statistical facts is unsatisfactory. A growing body of research has used current statistical and econometric methodologies to evaluate both micro and macroeconomic variables, including fully modified ordinary least square (FMOLS), autoregressive, and distributed lag (ARDL). There are varying findings of the causal link among economic growth and energy use among energy use and carbon pollution which we assume is due to the span of the datasets and the country of the research.

According to Medlock (2011), economic system and output are major factors of energy consumption. At the macroeconomic level, each of these has an impact on energy output. As an economy grows, it shifts from agriculture to industries to services. Less energy is required when the economy becomes more service-oriented. As the economy goes from agricultural to services, energy consumption follows a bell-shaped pattern. The choice to engage in invested capital, the kind of capital stock, and the rate of usage all influence electricity consumption. With the deployment of more energy-efficient capital, the energy need for a given level of production decreases, requiring less energy. This implies that economic output can grow without increasing energy demand.

The findings of Apergis and Ozturk (2015); Ackah (2015); Herrerias et al. (2013) research could be confusing since the data used for the studies range from 1995 to

2011, Ackah 1985 to 2011, and 1990 to 2011 respectively. The strong correlation between pollutant emissions, GDP, and energy consumption has been intermittent and restricted, particularly in developing nations in Africa especially in Ghana. Ghana's impact on climate change avoidance is significant.

Ghana, as a developing nation transitioning from low income into middle revenue, has seen several setbacks in the realm of healthcare. Efforts have been made in the scientific arena to raise awareness of Ghana's growth concerns, however, the breadth of mitigating climate change is still restricted. Based on the researcher's ability (Adom and Bekoe 2012a; b; c) used robust statistical and econometric methodologies such as ARDL and the partial adjustment model (PAM) to predict Ghana's electricity energy requirements for 2020. Their research revealed that in Ghana, home electricity usage is primarily determined by income. Furthermore, their research contrasts with this study. This study explores the nexus between environmental pollution, electricity consumption, productivity on economic growth in Ghana by using data covering from 1980 – 2020 by comparing or relating the vector error correction model and autoregressive distributed lag which was not considered in the above studies mentioned.

1.2 Problem Statements

It is indeed difficult to underestimate that energy is a daily requirement. It pervades everything individuals accomplish, from operating gadgets through illuminating their houses to powering their amusement and connections with the outside world. Energy is also an essential component in the social and economic development of communities, and energy use levels are an indicator of a country's economic status. The significance of energy usage in productivity expansion has received substantial attention from power and economic specialists over the last few decades and has been thoroughly contested. Given the fact that there is a substantial link between growth and energy usage, the question of "correlational," or when economic growth leads to rises in energy usage or that energy usage is the source of economic expansion, remains unanswered.

Ghana's electricity industry is financially inadequate in a plethora of ways. Almost all providers have accumulated significant amounts of debt which harms a company's finances. The Electricity Company of Ghana (ECG) has significant amounts owed to public and private entities. This has an impact on providers' capacity to buy high-quality equipment in enhancing their services and meeting their varied investment goals**.** Hydroelectricity accounts for 64 percent of Ghana's total electrical power generation, and that is the most common kind of contemporary energy in Ghana, with 65 percent of electricity consumed in the sectors of the economy and approximately 36 percent in domestic consumption.

The electricity sector is confronted with several problems, such as; insufficient power supply infrastructure, which needs significant investment, over-dependence on hydropower and gas, insufficient accessibility to power, excessive fuel costs for energy generation, generation, and distribution problems, insufficient governmental capability, accountability, governance, and strategic challenges, as well as sensitivity to climate change because of improving standards of living.

1.3 The objective of the Study

The major aim of the study is to explore the nexus between environmental pollution as a result of carbon dioxide (CO_2) emissions, and electricity consumption in Ghana. Objectively, to explore the existence of long-run nexus among electricity use and growth, exploring the presence of short-run nexus among electricity use and growth. Based on the objective of the study, the following questions are as follows;

(i) Does a relationship exist between energy demand and economic growth?

(ii) Does GDP have an impact on carbon dioxide emissions in Ghana?

(iii) What are the hindrances facing electricity companies (ECG) in Ghana?

(iv) What is the contribution of energy to Real GDP?

1.4 Research Methodology

In achieving the stated objective of the study, employing secondary data of time series covering the period spanning from 1985 - to 2020 gathered from World Bank development (WDI, 2015). The research explores the causative relationship between carbon dioxide emissions, electricity consumption, GDP, and productivity in Ghana to validate the study hypothesis. Augmented Dickey-Fuller (ADF), Philips Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) to make the stationarity of the variables selected. Furthermore, a co-integration analysis will be done to determine the long-run equilibrium connection among the variables, and a vector error correction model (VECM) and autoregressive distributed lag (ARDL) will be applied.

1.5 Significance of the study

Ghana is now facing persistent power shortages and environmental pollution as a result of carbon dioxide emissions (CO2) over the country. These electricity supply disruptions, causes of pollutions have sparked studies examining the economic impact of these problems. As a result of the challenges, several industrial sectors in the country are currently experiencing a massive decrease in productivity. As a consequence, a common term for power failures in Ghana has been coined ‘dumsor’.

Many manufacturing industries and businesses, as well as individuals, become frightened of the term dumsor since it generally causes a halt in everyday life activities. The discovery of dumsor sparked more research into the relationship between energy use and economic growth. This study is intended to facilitate the Electricity Company of Ghana and the Ministry of Energy in identifying the appropriate energy strategies and policies to be implemented to enhance Ghana's economic growth and thereby reduce carbon dioxide emissions and dumsor in Ghana.

Therefore, governments, economic planners, financial specialists, and scholars will find the findings useful. The investigation of the energy connection may be of major relevance to governments and energy planners. It will assist stakeholders in developing policies that will improve the expansion/sustainability and efficacy of the energy economy. Once more, the latest findings would serve as a starting point for developing adequate power rehabilitation programs and assess the quality of these restructuring, as countries implementing reforms strive to succeed a more challenging, healthier, productive, and profound power grid, and the findings of these correlations might provide some crucial data that can be used to develop macro-econometric techniques and proper and effective environmental policy to maintain the econometric approach. Furthermore, some studies use time-series analysis to examine the link between energy use and economic growth, particularly in Ghana. This work contributes to the current body of knowledge. Thus, the research tackles some of the empirical difficulties that have been raised in the research.

1.6 Research Hypotheses

The following is the hypothesis for this research;

H_0: Carbon emissions (CO_2) and Electricity Consumption (EC) have no effects on the Economic growth of Ghana.

H_1: Energy consumption and carbon emissions influence the Real GDP of Ghana.

1.7 Structure of the study

The study is divided into five chapters. Chapter one gives an introductory part of the study, including the statement of the problem, objectives of the study, research questions, and structure of the study. Chapter two focuses on the review of related literature and theoretical review of the study while chapter three focuses on the conceptual review on energy use in Ghana, while Chapter four focuses on the research methodology, and data presentation, chapter five dwells on the empirical results and discussions of findings. Last, chapter six focuses on the conclusions and policy recommendations of the study.

1.8 Definitions of Terms

Energy Consumption: To a layman's understanding, the quantities of energy or power consumed by the final users in kilowatt (KW) to act, make something, or just inhabit a facility.

Environmental Pollution: Environmental pollution is the undesirable transformation of our environment caused entirely or mostly by human activity, as a result of changes in ecosystem structure, radiation levels, and physical constitution and diversity of species.

Economic Growth: Economic growth is defined as a rise in the number and quality of economic commodities and services produced and consumed by a country. Otherwise, it is the gradual expansion of a country's economy.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The general goal of this study or chapter is to give a summary of the research on the link between consumption of electricity, carbon emissions, and Ghanaian economic growth. This is done to gather supporting thoughts, arguments, and empirical evidence for the research. The chapter consists of 3 parts. The first part contains a related review of the literature, followed by the theoretical review while the third section contains the empirical review of the research.

2.2 Literature Review

Numerous significant role in literature that cannot be underestimated has been recorded. The reviewed evidence identifies three kinds of study directions on the nexus between environment pollution, energy economic growth, environmental pollution energy production, and real GDP. Tutulmaz (2015), affirmed that various studies from the first subcategory examine the link between growth and environmental pollutants by putting the environmental Kuznets curve (EKC) into consideration. The study of (Ahmed et al. 2015; Asumadu-Sarkodie and Owusu, 2016a; b) specified the second part of the research by exploring the relationship among real GDP, energy production, and energy use through the test of hypothesis which validated that an increase in the level of growth is determined by the volume of energy demand and supply and vice versa. The third classification centered on the relationship between the consumption of energy and production, growth, and CO2 establishing the EKC hypothesis which supports (Apergis and Ozturk 2015; Mohiuddin et al., 2016).

Then it might come as a shock that the research on the link between carbon pollution and energy consumption is intermittent and restricted in range. Some research on the subject relies solely on panel data regression without measuring elasticities. In a nutshell, the data from the research remains uncertain. In this method, research that estimates elasticities regarding the time data to assess the underlying direct connection between carbon pollution and energy use becomes simple to derive conclusions from the results. As a result, the heteroskedasticity error in measuring the causative link between emissions of CO2 and energy use will be averted. The research investigates the influence of human energy use on energy sources, as well as carbon intensity. Ghana has recorded a few the study uses the autoregressive distributed lag (ARDL) regression approach to investigate the cause and effect relationship between carbon pollution and energy consumption. Positively, the study will contribute beyond measures both local and international investors towards considering the future of energy sources (Renewable and non-Renewable). Moreover, policy recommendations obtained from the study will boost Ghana's overall climate policies, strategies, including strategies.

Several investigations have been performed in Africa to investigate the link between growth and electricity use. Odhiambo is one of many research (2009). He employs the ARDL testing technique to investigate the link between energy usage and economic expansion in Tanzania. The research goal was to look at the periodic link between overall energy use and growth, as well as the correlation between economic growth and energy use. He measures productivity expansion using economic growth as a measure, and also total energy demand per capita and energy consumption The data imply that there is a long-term consistent link between energy and Real GDP. The connection outcome showed direct causation extending from electricity use to economic progress. Granger's amount of energy creates economic progress in the long run. The use of energy Granger promotes growth in the long run.

Kraft and Kraft (1978) discovered a unidirectional causal relation between Gross National Product (GNI) and consumption of energy in their research of the US economy from 1947 to 1974. Jumbe (2004), the Kraft and Kraft study's findings indicated that the United States' (USA) low electricity and energy reliance allowed it to adopt energy conservation initiatives which had no negative consequences on GDP. Nevertheless, this finding was not supported by Akarca and Long (1980), who examined the same range of data from 1947 to 1972 and discovered no correlation between the two variables. Researchers contended that Kraft and Kraft's (1978) research could be affected by temporally time frame unpredictability. In additional North American nations, bidirectional causation was by Francis et al. (2007) among energy consumption and economic growth in the short-run for Jamaica, and Trinidad and Tobago from 1971 to 2002.

Nonetheless, no indications of a correlation were identified for Jamaica and Trinidad in the long run; nevertheless, there was a positive connection for Trinidad and Tobago. More lately, research on the energy growth relationship has proliferated, although there is little agreement on outcomes. These differences in the empirical evidence might be attributable to the researchers' data and sampling processes, as well as the research location, that could be country-specific or a panel of nations. The most obvious issue might be the estimated methodological procedures used a diet al.

(2014), Ameyaw et al. (2016), Shahbaz et al. (2017) are examples of single-country research on the energy relationship (2018). The extant research evaluates the direct relationship among CO_2 emissions, energy demand, real gross domestic product, and/or population by including other factors such as foreign assets, trade, urbanization, and financial development. (Cerdeira Bento and Moutinho 2016; Rafindadi and Ozturk 2015; Salahuddin et al. 2015Shahbaz et al. 2015; Shahbaz et al. 2012; Tiwari et al. 2013) employed the ARDL bounds testing technique to explore the connection among consumption of energy from road transportation, carbon dioxide emissions, and CO_2 emissions in Tunisia incorporating data from 1980 – 2012, indicating the presence of a long-run nexus in the existence of structural breaks.

Their research discovered bidirectional causation among consumption of energy, carbon pollution, but fuel costs had a one-way relationship on the consumption of energy, road systems, emissions pollution, and transportation industry value-added.
The study of Ben Abdallah et al. (2013) employed the Johansen co-integration technique and the Granger causality method to investigate the connection among consumption of energy from transport systems, road transportation, and carbon pollution in Tunisia spanning 1980 – 2010 in which the presence of long-run nexus was discovered or found. Their research disproved the EKC concept and discovered support of unidirectional causality going from fuel prices to energy use from road traffic.

According to (Cerdeira Bento and Moutinho 2016) investigated the nexus between carbon pollution, electricity production, renewable and nonrenewable production is determined by per capita incorporating time series running from 1960 – 2011 in Italy embarking on ARDL technique to assess the existence of structural breaks. The outcome of the study reveals the long run nexus in which affirmed the existence and validity of EKC theory and established the presence of a unidirectional relationship spanning from gross domestic product to electricity renewable production per capita Salahuddin et al. (2015) used DOLS, FMOLS, and DFE methodologies to analyze the link between CO2 emissions, power consumption, economic growth, and foreign direct investment in the Gulf Cooperation Council from 1980 to 2012. Their findings indicated a long-run equilibrium relationship.

Their research discovered evidence of unidirectional causation going from power consumption to CO2 emissions, as well as bidirectional causality flowing from economic growth to CO2 emissions. Salahuddin et al. (2015) used DOLS, FMOLS, and DFE methodologies to analyze the link among Carbon dioxide emissions, energy use, economic expansion, and foreign investment from 1980 to 2012. Their findings indicated a long-run equilibrium nexus. Their research discovered the presence of unidirectional causation going from energy use to Carbon dioxide emissions, as well as bidirectional causality flowing through productivity expansion to Carbon dioxide emissions.

Energy's economic impact has been recognized by researchers in the study. Conversely, excessive energy usage (nonrenewable energy consumption) raises carbon output. Despite examining the link between energy and growth, this is the context in which (Kwakwa and Aboagye, 2014), a more in-depth examination of the impact of energy emissions (Rahman et al., 2020; Kirikkaleli and Adebayo, 2021). The outcome of certain research guides policymakers towards more effective energy usage or the integration of renewable energy supplies.

Increased research has forced the examination of the influence of different sources of energy, including such renewable energy or electricity usage, rather than overall energy usage, which leads to previous research. Currently, a large portion of the world's power is generated from carbon-intensive fossil fuels such as coal and oil. This means that, while electricity is a contemporary type of energy, wasteful consumption can result in increased carbon emissions, whereas efficient usage or an electricity production mix influenced by renewable sources can result in lower carbon emissions. Yorucu and Varoglu (2020), and Bento and Moutinho (2016) all indicated that producing energy from renewable reduced carbon pollution. Furthermore, quantitative study on the impact of energy usage typically shows that it has a positive influence on Carbon dioxide emission (Alaali and Income, electrical crisis and CO2 emissions 473). (Naser, 2020; Salahuddin et al., 2015).

The impact of either the electricity power problem, particularly defines several emerging economies' energy sectors, on Carbon dioxide emission has yet to be studied. Because of the enormous demand for fossil fuels such as diesel, gasoline, and coal among homes and industry, a crisis of this magnitude may result in Emissions of carbon dioxide.

Additionally, homes may place a strain on forest resources for fuel, reducing carbon absorption. Variables such as financial growth and industrialization which can alter nations' Emissions of carbon dioxide have been introduced to lessen the omitting bias effect while testing for the Environmental Kuznets Curve. The influence of financial development on CO2 emissions is uncertain. Financial growth lowers credit limits, allowing businesses and people to engage in electrical devices, as well as in clean renewable energy technologies, which helps reduce CO2 emissions. With reducing financial limitations, however, consumers' and enterprises' production and consumption activities grow, requiring more energy (Chang, 2015) and ultimately increasing carbon emissions.

Adom et al. (2018); Agboola and Bekun (2019); and Yasin et al. (2020) obtained results indicating that capital accumulation decreases carbon dioxide emission, whereas (Rjoub et al., 2021, Gill et al., 2019) reported the results indicating that financial sector development increases Carbon dioxide emission. Industrial growth entails the conversion of raw resources into finished products. This frequently necessitates the use of extra energy, particularly fossil fuel (Abokyi et al., 2019), which is also not ecologically beneficial.

2.3 Theoretical Review

To demonstrate the causation among these components, it must be required to examine the link involving economic growth and energy consumption. As a result, existing theoretical research on energy economics is explored. Therefore in part, the theoretical work in economics is explored in connection to the conventional theory of growth and the significant correlation between energy use and growth.

2.3.1 Mainstream Theory of Growth

Economic growth theory has been studied for millennia. Whilst mainstream economists such as Smith, Malthus, and Ricardo did not officially research economic development, many did identify the fundamental components of productivity expansion. Modern mainstream economists known as economic growth founders examined economic development using sophisticated theories. (Ramsey, 1928; Solow 1956; Swan, 1956) are among them, whereas (Romer, 1986; Lucas 1988) pioneered economic expansion theory recognized as endogenous growth models. Furthermore, conventional growth theory has an intrinsic bias that minimizes the importance of resources in the economy, although economics has no fundamental constraints on the system that can be expressed of resources in the economic system.

2.3.2 Basic Growth Model

The neoclassical development model created by (Solow and Swan 1956) is the most basic economic model that studies the theoretical economy. The concept is based on the assumption that capital, labor, and technology are all functions of one another. The model's key premise is that the productivity has increasing returns to scale, seems to have beneficial and reduces economic products concerning every input, and meets the characteristics that the negligible products of inputs method infinite universe as inputs method zero and reaches zero as inputs method infinity. The theory shows that progress in the long term is a consequence of solely technological development, not savings or investment, by presuming a predictable velocity of saving and declining returns to capital.

Saving, according to the Solow model, influences the amount of income although not on its rate of increase. This forecast means that, in the presence of continual technological advancement, per capita development will ultimately stall (Stern, 2003). The Ramsey model, in addition to the Solo-Swan model, seems to be an essential neoclassical growth theory. This Ramsey model is indeed an improved version of the Solow Swan model. Ramsey's economic expansion theory was proposed prior to Solow-growth Swan's theory. Therefore, in the research, his model is frequently placed behind the Solow- Swans. Perhaps one of his model's fundamental assumptions is that families optimize their satisfaction throughout time. This premise effectively makes this method flexible. Utilizing Ramsey's framework as just an initial point (Cass, 1965; Koopmans.1965) reinterpreted the exogenous saving rate in the Solow as endogenous.

Although this is regarded as an improvement of the neoclassical growth theory, this does not reduce the lengthy expansion rate's reliance on external technology advances (Solow, 1956) also writings effectively signify the end of the fundamental neoclassical growth period. The provided basic growth study did not examine when technological advancements occur. Because the model simply believed that it occurs exogenously, this model is considered to have exogenous changes in technology. Several contemporary models aim to endogenize technology innovation by interpreting modern technology as the result of company and individual actions. It all began with the study of Romer (1986) and Lucas (1988). However unlike the Solow-Swan model, wherein the lengthy growth rate is dictated by exogenous technical advancement, Romer and Lucas propose an endogenous model for economic growth.

2.4 Empirical Review

Over the last 3 decades, establishing a causal link among electricity usage and economic progress has been a contentious topic in the substantial empirical literature. Therefore, no general agreement has developed about the presence or direction of the causal link between electricity usage and economic progress. This is determined either by nations involved's structural, structural, including policy disparities, and also the range of data sources and data spans used, as well as methodological differences. This document aims to synthesize the research shreds of evidence on the causation link between electricity usage and economic progress, as well as to highlight the inconsistencies of this research. In the US economy, however, Akarca and Long (1980) demonstrated there is no causative association between energy use and economic growth whenever the sampling timeframe is cut by two years. Yu and Hwang (1984) used the Sims' & Granger causality test to find arguments in favor of the indifference assumption that there is no causal association between energy usage and GNP in the United States whenever the sample period was prolonged by 5 years. Yu and Choi (1985) used Sims and Granger tests of causation to investigate the causal connection between GNP and the accumulation, as well as many sectoral classifications of energy usage such as fuel sources, hydrocarbons, oil and gas, and electricity, for five countries at various levels of economic development from 1950 to 1976.

Stern (1993) examines the Granger causation among economic growth and energy usage using a (VAR) model of economic growth, energy usage, capital stock, and employment over the timeframe 1947-1990 in the United States, instead of a multivariate regression method. In contrast to much earlier research, Stern employs economic growth instead of Gross nation product and a performance indicator of electricity instead of total energy usage. According to Glasure & Lee (1997), economic growth is preferable to Gross national product since the nation's energy usage is dependent on products and services produced within a country rather than the production of goods and services outside the nation. Stern (1993) discovers that economic growth is caused by energy usage Granger. This conclusion contrasts prior conclusions for the United States, and the differences are most likely due to variations in the factors as well as the time range. Ebohon (1996) examines the Granger causation among economic growth and energy consumption as measured by Gross domestic product and Gross national product for countries involved: Tanzanian from 1960 to 1984 and Nigeria from 1960 to 1981.

The research also demonstrates the strength of the causal link. Past research, on the other hand, has merely indicated a causal link among the factors. Nachane et al.

(1998) investigate the link between energy use and growth for 25 nations from 1950 to 1985, but still, only correlation can be demonstrated for 16 of them (11 developing and 5 developed countries). Ghosh (2002) used yearly data from 1950–51 to 1996–97 to evaluate the Granger causation among energy use per capita and Gross Domestic Product (GDP) per capita in India These Phillips–Perron analyses demonstrated that both sequences are non-stationary and independently integrated of order one following exponential transformation. This analysis showed no clear presence of a significant stability link between the components, although there is unidirectional causality going from growth in the economy to energy that is not influenced by feedback. As a result, Ghosh proposed that regulations promoting energy-saving be implemented.

Guttormsen (2004) used the granger causality to experimentally investigate the causative link between electricity usage and real GDP in Turkey from 1970 to 2006. To investigate the link among the data, the researchers used the unit - root test, the (ADF) and (PP), the Johansen cointegration, as well as the Pairwise Granger causality. The empirical findings in this study revealed that two series are non-stationary, but the initial discrepancies between the series resulted in stationary. Furthermore, the findings revealed that energy usage and gross national product are cointegrated, with directional causation going from energy use to real Gross national product and vice versa. This shows that an increase in energy usage has a direct impact on economic growth and that growth in turn drives more energy use.

Akinlo (2009) also investigated the relationship between energy use as measured by electricity usage and gross domestic product in Nigeria from 1980 to 2006. The empirical data suggests that two variables are cointegrated and that electricity usage

Granger drives Gross Domestic product. The research of Hodrick–Prescott (HP) filter findings deconstruct the oscillations in the trend of energy usage and economic progress. The estimated findings revealed a relationship among the variables between the trend and cyclical portions of the two series, implying that the Granger causality is potentially connected to the economic cycle. Odhiambo (2009) investigated the causation between electricity usage and economic development in South Africa from 1971 to 2006. The employment rate will be included as an inconsistent indicator in the multivariate regression model connecting energy usage and economic progress, resulting in a simple trivariate causation theory.

Chapter 3

ENERGY PRODUCTION AND USAGE IN GHANA

3.1 Introduction

Electricity generation in contemporary Ghana stretches back to the ancient era in 1914, once the government-sponsored power service first launched in Sekondi, in the western region of modern Ghana (ISSER, 2005). Numerous changes and restructurings have occurred has since. Therefore, the purpose of this part of the study is not to recount the long history and many transitional changes that occurred (during pre-independence time).

3.1.1 History of Ghana's Electricity Generation

Ghana's electrical generation history may be split into 3 major stages.

(i) Even before hydroelectric years: It thus relates to the years preceding the construction of Akosombo's major hydroelectric plant in 1966.

(ii) During hydroelectric years: the era spanning 1966, once the Akosombo hydroelectric facility was constructed, through the 1980s.

(iii) Period of thermal complementarity: the 1990s towards the contemporary days where thermal generators became utilized to augment hydropower (Asare, 2008). This study concentrates mostly on the post-independence era, particularly from early 1970 onwards.

3.1.2 Hydroelectric Power Generation

Ghana develops and maintains 2 significant hydropower projects, and 2 thermal electricity stations. The first and largest hydroelectric plant erected has been the

Akosombo hydroelectric plant, which has a generation capacity of 1020 MW and therefore is positioned in the government's east. It became completed in 1966 with the primary objective of supplying electricity to the aluminum sector. The construction of the Akosombo hydro project inundated the Volta river valley, producing the world's greatest artificial lake, which spans around 3.6 percent of Ghana's geographical area. The electricity generated by the Akosombo plant is the primary driver underpinning Ghana's economic progress, but it also helps neighboring nations including Togo and Benin by distributing electricity to them (Suave et al, 2002).

Although Ghana's widening sector and also the pattern of economic advancement causing increased consumption of electricity in the 1980s, a 2nd and although little hydroelectric power plant named the Kpong Hydroelectric dam with megawatts of 160 MW has been established along the same Volta River downstream of the Akosombo hydroelectric plant to complement the Akosombo hydroelectric plant. From 1982 through 1984, the Volta River Basin experienced among the most droughts in known history (ISSER, 2005). It had a significant impact on the productivity of the two hydroelectricity, prompting a search for a new way of creating electricity other than hydropower.

3.1.3 Thermoelectric Addition

To supplement the hydroelectric power facilities, the Volta River Authority (VRA) developed the Takoradi Thermal Power Station (TPPS) in Ghana's Western region in 1997, a first of its kind in the nation. Following the government's ability to enable private engagement in the power generation sector, a 550 Megawatts (MW capacity with such a combined private venture. Takoradi Thermal Electric Company is comprised of two enterprises that are all situated in the same area. Is therefore made up of a 330 Megawatt combined cycle plant known as Takoradi Thermal Power Company (TAPCO) and commercial cooperation with CMS Energy of the United States of America in the proportion of 10percent (VRA) to 90 percent.

The second aspect is Takoradi International Company (TICO), a 220 Megawatts (MW) gas turbine facility with a VRA-to-90 percent ratio. Currently, most forms of energy depend on light fuel. Moreover, the humongous price of energy associated with light energy is suggested to be minimized only with scheduled gas supplies from Nigeria (because Ghana is a participant of this Western African collaborative project identified as the West African Gas Pipeline project), as oil and gas are less costly than light fuel. There seems to be a 30 Megawatt diesel-electric plant at Tema, close to the capital, in the Greater Accra corner of the country. To supplement the current 2 hydroelectric dams, a third hydroelectric power plant known as the Bui Dam with a generation capacity of around 400 MW has indeed been built.

3.1.4 Summary of Electricity Generation and Economic Expansion in Ghana

As seen below, electricity is generated and distributed to households in three stages: generation, transmission, and distribution. To begin with, electricity must be generated before it can be distributed. Electricity is generated by using up one or more power sources, which are revolving turbines that transform mechanical electricity into electricity. Electricity is transmitted to the electric grid and carried over vast distances via generating substations, which link generation units to power lines. The transmission system will allow for the optimization of electricity generation inside a country as well as power trade between countries. (Fornelio, 2010) a transmitting substation is a kind of connecting hub between the transmission and distribution networks that incorporate transformers to scale down power to distributing levels. The distribution network transports and splits the electric power that will be distributed to clients in the form of electricity. Supplying electricity to reach the end consumer, involves three stages. First electricity is provided by plants placed farther from the main grid. Electricity is subsequently delivered to the bulk load main switchboard via the electricity network, which consists of the transmission system, transformers, and other elements. Electricity is supplied to specific client locations through distribution networks from the bulk load distribution system.

Three distinct utility firms in Ghana oversee this three-step procedure. The Volta River Authority (VRA) is a government-owned company that is solely liable for the country's major electricity generation. VRA now runs the Akosombo and Kpong hydroelectric facilities, which are the country's primary electricity-producing providers. Ghana Grid Company (GRIDCo) is in charge of transporting electricity from major electricity production spots to the distribution network, while the final customers or users receive the electricity from the Electricity Company of Ghana (ECG) and Northern Electrical Department (NED), a subsidiary of VRA. ECG services the country's southern half, and NED serves the country's northern half. Over the last decade, the power sector has seen substantial expansion.

In 1992, the electricity and water sectors grew at a pace of 12.02 percent, which was 5.43 percent greater than the previous year. According to the budgetary system and economic strategy of 1993, the main cause is an increase in the nationwide power grid as part of the rural electrification initiative, as well as the extension and refurbishment of several metropolitan power distribution systems. The industry showed a 4.5 percent rise in 2000, which was lower than in 1992. From the perspective of the proportional participation of all industries to total industry share in the country, the electrical industry provided 10.21 percent of total industry Output in 2000.

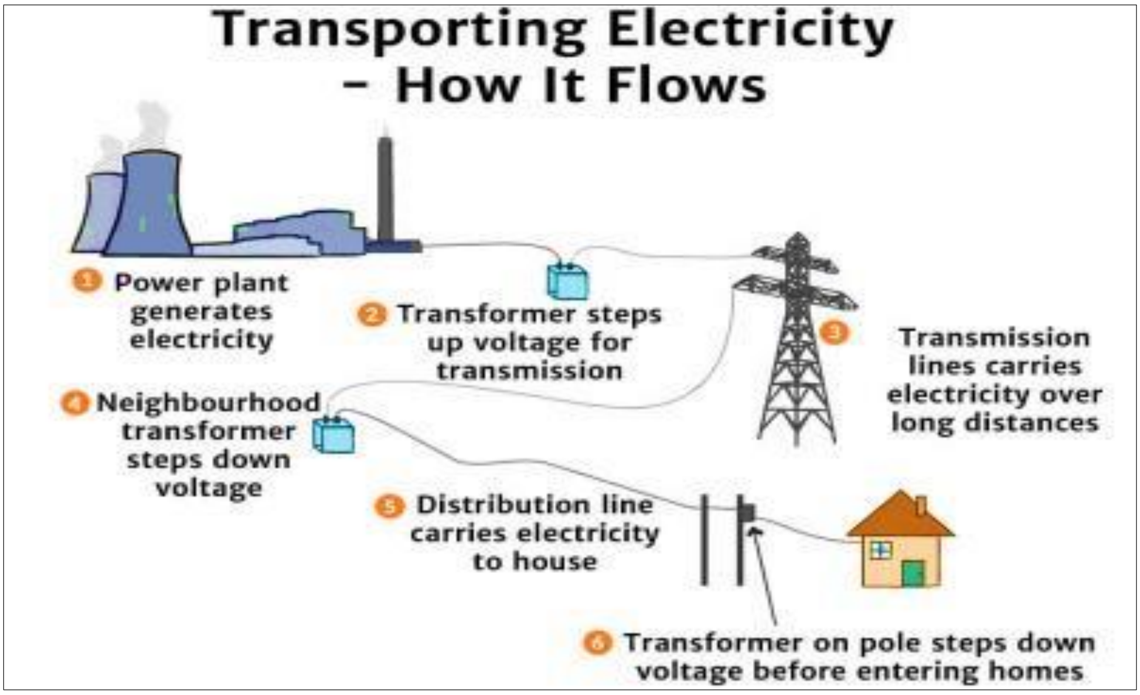

Figure 1: Transporting Electricity: Flowing from the Plant to end-users

3.1.5 Policy Problems Regarding the Environment and Energy

Environmental problems are a key aspect of every sector today, as well as the electricity sector is no different. Coal and lignite are extracted through subterranean and strip mines. Petrochemical wells are dug to supply fuel for the generation of power (ISSER, 2005). Pollutants are emitted by power plants that use carbon fuels, and these emissions are regulated. Power grids are also being built out across the state, posing a threat to both human and natural habitats (Stern, 2003). Power plants employ a variety of fuels that contribute to issues such as acid deposition, urban ozone layer depletion, global climate change, and disposal of wastes. Thus every energy seems to have its variety of environmental benefits and drawbacks. Coal, including some of the least expensive fuels, needs extensive pollution mitigation to fulfill environmental regulations, and its usage raises worries regarding anthropogenic climate change. Oil and gas, more costly energy, burning cleaner and more efficient however contributes to ozone generation in cities. Solar and wind power, which does have relatively high costs, emit no carbon pollution have almost no fuel expense, but they may be unattractive and also have a harmful influence on biodiversity.

The majority of Ghana's energy is generated by hydroelectricity, (Adom, 2011) which do not emit dangerous substances into the environment; nonetheless, their vast dams have an influence on the environment by flooding extensive regions, compelling inhabitants to relocate, altering their ecosystem, and compelling silt accumulation. He asserted once more that its four important carbon emissions challenges for such electricity generation business are acid rain, particle emissions, urban ozone depletion, and global climate change. Ghanaian, electricity plants influence almost nothing to pollutant emissions (VOCs), carbon monoxide, nitrogen dioxide (greenhouse gas and oxide of nitrogen). Environmental problems are also connected to energy issues such as the usage of renewable energies to provide power and energy efficiency.

Renewable resources have been characterized in many forms, but they are frequently alternatives to traditional fuels. Renewable energies often have environmental or economic benefits. Hydroelectricity, solar power, wind energy, and geothermal are among the hydropower alternatives. Energy for each of them is inexpensive or free, although they are frequently sustainable or may cause carbon pollution. Proponents claim that perhaps the environmental benefits of traditional renewable electricity are not represented in the demand for energy produced. Alternate energy would be extremely competitive whether these expenses (externals) had been included (ISSER, 2005).

3.1.6 Energy use and Growth

The empirical studies into the possible correlations among energy use and growth may be divided into two categories: hypothesis criteria and generation criteria (Guttormsen, 2004; Apergis and Payne, 2009). The assumption method investigates causality based on whether research found that power (electricity) use causes growth or not, or even both. Along these lines, investigations on the power (electricity), as well as economic expansion connection, have indeed been classified into four categories: According to (Adam, 2011), the Growth-led-Energy hypothesis, the Energy-led-Growth hypothesis, Neutrality hypothesis, and Energy-led-Growth-led-Energy hypothesis.

According to Guttormsen (2004), research on empirical work into the growth of the economy is classified into three categories: first generational research, 2nd generation studies, and third-generation research. The initial wave of research employed the classic Vector Autoregressive Models and the typical Causality test. The fundamental issue in this generation of study is that it assumes the series is stationary. As a result, the cointegration test was proposed as the ideal approach for investigating the causal relationship among energy usage as well as economic growth in the second wave of study. In the second generation of investigations, pairs of parameters were evaluated for cointegration test, and an error correction model (ECM) was constructed to test for causality (Engle and Granger, 1987).

In addition to the foregoing, Ozturk and Acaravci (2010) categorized the different research on energy (electricity usage) and economic expansion into the nation and multi-country studies in a literature review on the increases in energy. According to the findings of this study, the results of multi-country studies and country-specific studies on the causation between energy consumption and economic growth provide inconsistent conclusions. Nevertheless, the findings of national research on the causation among both economic growth and energy consumption demonstrate that there is a favorable causality that runs from electricity usage to productivity expansion, whereas the findings of multi-country research on the cause and effect among growth and energy use show conflicting results.

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3.1.7 Conventional Realities on Ghana

Ghana, just like every other prosperous country, requires not only manpower and money to power its economic operations, but also power for mobility, industry, telecommunication, and agricultural production. Numerous emerging economies, as well as Ghana, face many difficulties in the twenty-first century, also without restriction, electricity consumption, and economic expansion, damage to the environment, global warming, asset depletion, ecosystem rapid decline, demographic change, and the merged impact among these elements on energy transformation. Therefore, managing energy use to promote economic activity while not sacrificing environmental quality has become a worldwide concern, and Ghana is no different. Ghana's energy sector has seen numerous dramatic changes throughout the years, as has the country's electricity consumption.

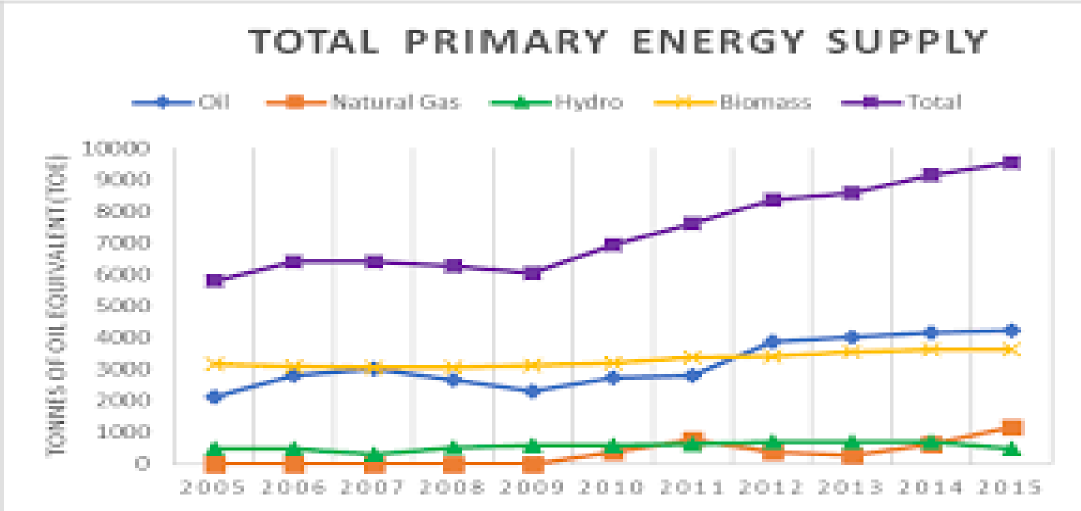


Figure 2: Total primary energy supply.
Source: National Energy Statistics, Ghana (2016).

Conversely, electricity production falls short of demand, resulting in a massive energy shortage. The yearly growth in energy consumption is predicted to be 13.9 percent (GRIDCo, 52015), and the availability is inadequate. The energy deficit is caused by a variety of causes, such as an increasing economy, an under-investment in the power industry, the Energy Commission of Ghana (ECG, 2015), and a lack of variation in electricity sources of supply.

Ghana, on the other hand, is endowed with a plethora of energy resources but is not restricted to renewable energy such as hydro, solar, biomass energy. Despite an abundance of power resources accessible to the country called Ghana, it remains mired in the quagmire of energy poverty. Electricity generated is heavily reliant on hydro, making it extremely sensitive to variations in water levels.

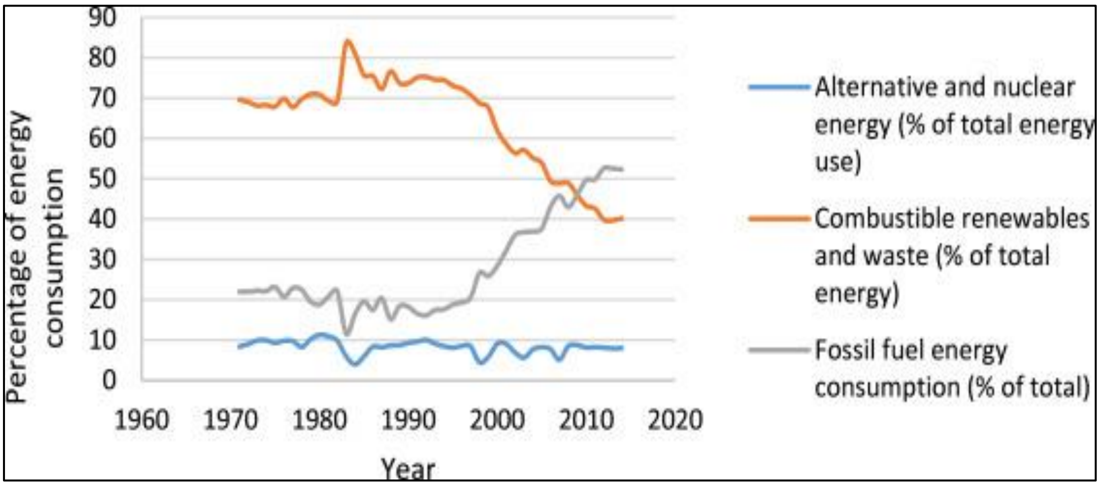


Figure 3: Energy consumption
Source: WDI (2017)

In a nutshell, whenever the water level falls below the working capacity, the operators are compelled to close down part of the turbines, lowering power output to less than their installed capacity. Nonetheless, clean energy sources such as solar and wind, which the country provides in plenty, are untapped. Furthermore, the Gross domestic product continues to pursue an erratic direction, although with a typically growing tendency, sparking much intellectual conversation on whether the persistent increase in energy use transforms into economic progress. Nonrenewable (Fossil fuel) power supply accounts for more than 87 percent of worldwide energy consumption (Lyman, 2016).

Oil and other Nonrenewable are the primary forms of electricity in Ghana's transportation sector, as well as in the creation of electricity. The graphic in Fig. 2 demonstrates that the usage of fossil fuels is growing more essential than some other power sources in Ghana. During 1971, fossil fuel usage amounted to 22 percent of overall energy demand; now, it accounts for 52 percent of the overall energy use. Since 2009, fossil energy use took the lead in Ghana's energy usage mix and has grown steadily, whereas the use of all other sources of power has decreased on average (WDI, 2017). GDP fluctuates.

The country's current power situation, which has resulted in a persistent rise in prices for electricity consumption relative to supply problems, may have a significant potential detrimental influence on Ghana's economic progress. Electricity is among the most significant limitations to economic activity in Ghana; the country lost around 1.8 percent of its GDP during the 2007 electricity crisis (World Bank 2013). Moreover, Ghana is squandering productivity worth millions of dollars per day due to the power outage. As a result of the power crisis in 2013, and 2014 the nation has lost around 2% of its gross domestic product.

In their analysis, Lin et al. (2014) observed that there is fluctuation overflow and interconnection among oil prices and Ghanaian stock returns, and also that unpredictability transmissions are much more evident for crude prices towards stock returns than vice versa. As just a small contribution to the energy shortage, the government implemented a slew of energy-saving initiatives. This included, but are not restricted to, developing regulations and labeling for air conditioning systems so that items in all these subcategories must fulfill these requirements before they can be imported or utilized in the nation. Furthermore, Ghana's entire main energy mix is highly based on energy sources, which have major economic and environmental effects. Typically, conventional nonrenewable energy formed the major energy mix. Crude oil is widely employed in a variety of areas of the economy, including mobility, electricity production, and industrial applicability.

Furthermore, conventional biomass wood combustion is used for both commercial and residential uses. As a result, Ghana's tropical forests continue to be drained at an astonishing speed, with the degradation rate ranking as one of the largest in Africa. In the context of increasing overall energy use, however biased towards fossil energy, the state is contending with a steady rise in Carbon emissions in specific and Greenhouse gases overall broadly, as well as the attendant impacts. Because of the rising demand for goods and services, various emissions, namely methane (CH4) and (CO2)–the main common greenhouse gases in Ghana–are getting emitted into the environment. Carbon pollution from power usage in Ghana has been steadily growing since 1990. Furthermore, (Environmental Protection Agency (EPA, 2015) electricity Co2 account for almost 85 percent of total national Carbon dioxide emission.

3.1.8 Ghana's electricity supply and consumption problem

Ghana's repressed energy consumption increased substantially over the recent decade, rising from slightly under 6340 GWh in 2000 to almost 11,000 GWh in 2013. In 2013, the industrial industry accounts for about half of total power demand, with the residential and business categories accounting for the largest of the remaining. The comparative market shares of the market segments are expected to shift over the next year, with the household sector accounting for almost half of consumption by 2020. Demand growth has been greatest in the domestic and industrial sectors, with both expanding at a pace of roughly 10% per year on aggregate over the previous decade. Since 2000, the percentage of electricity provided to the industry sector has been dropping, and this was the sector most badly impacted by the peak demand practice during the nation's sudden power crisis. Hydropower seems to have been Ghana's principal source of energy generation for the most part. In 2013, total energy generation was 10,232.11 GWh, with hydropower accounting for 54%, thermal power plants accounting for 45%, and imports accounting for the remaining 1%.

Hydropower generation has declined from over 91 percent in 2000 to approximately 54 percent in 2013. Ghana's power industry is marked by relatively high overall energy losses, as well as insufficient and unpredictable supply to satisfy rising demand. Insufficient and unstable power is leading the Ghanaian economy to lose roughly 5.6 the nation's highest consumption was 100 MW and was less than 20% of the generation capacity. However, the Volta River Authority, the principal energy producer, describes a fragile balance between demand and supply of power, so that the slightest disruption in the generation setup causes system imbalances, leading to regular pauses in power delivery including, in certain instances, total blackout.

3.1.9 Electricity supply security experience

Over the previous four decades, Ghana has faced several major electricity generation supply difficulties. As a result of significant floods in 1984, 1994, 1998, 2007, and 2012, a continuous gas supply reduction from the West Africa Gas Pipeline, which supplies part of the thermal power plants, was cut. Among the primary electrical supply difficulties described in the literature are the following:

i. Energy sources have low dependability and a high failure rate.
ii. Insufficient fuel supplies to power the thermal plants
iii. Overfilled substation transformers that do not comply with the N-1 security regulation
iv. The existing reliance on hydro, along with the unpredictability of water inflow into hydroelectric plants.
v. Insufficient solid transfer performance of the transmission network to the majority of significant load centers, particularly during peak hours.

Ghana's electrical delivery present system fails to fulfill minimal reliability criteria. The reserve margin, which is primarily used to assess generating sufficiency, seems to have been lower than the International Energy Agency's (IEA) suggested threshold of 20% for engineering practice and the West African Electricity Pools (WAPP) suggested minimum of 25%.

Consequently, Ghana's electrical delivery system does not fulfill minimal dependability criteria. The reserve margin, which is typically employed as a metric of generating efficiency, has indeed been lower than the International Energy Agency (IEA) suggested threshold of 20% for engineering practice and the West African Power Pool (WAPP) suggested minimum of 25%. The power system transfer capability, which determines how much inter-area power transfers may be enhanced without jeopardizing system security, has been quite low. The present load shedding exercise, which began in the first quarter of 2013 and is still ongoing with growing intensity, is a strong sign that Ghana's national system lacks security due to insufficient energy supply. This is primarily due to a lack of critical investment in the electrical supply industry.

Chapter 4

METHODOLOGY AND DATA

In this chapter, to attain the stated aims of the research, secondary data from 1985 to 2020 are gathered from World Bank development. Various econometrics methods are used to validate the objective of the study such as; testing the unit root which shows the stationarity of the study, descriptive statistics indicating the normal distribution of the variables, the optimal lag structure such as (AIC, SIC, etc), autoregressive distributed lag (ARDL method) indicating the existence of long-run nexus among the variables; carbon-dioxide emission (CO2), electricity consumption (EC), gross capital formation, and growth. Error correction term (ECT_t) reveals the short-run and speed of adjustment in which the result of the ECT must be negative and significant. Serial correlation, heteroscedasticity test, and the diagnostic and stability of the variables be carried out.

4.1 Model Specification

The economic or functional nexus among carbon-dioxide emission (CO_2), electricity consumption (EC), gross capital formation, and growth is shown below:

$$RGDP = f\,(C0_2, EC, GCF) \qquad (1)$$

Where;

RGDP = Real gross domestic product

$C0_2$ = Carbon-dioxide emissions

EC = Electricity consumption

GCF = Gross capital formation

In equation 2, to achieve homoscedasticity, Log transformation is presented.

$$LnRGDP = \beta_0 + \beta_1 LnC0_2 + \beta_2 LnEC + \beta_3 LnGCF + U_t \quad (2)$$

Where β_0 denotes constant, $\beta_{1,}$ $\beta_{2,}$ β_3 are the parameters signs in the model. In the above equation, the variables are in their logarithm form; (LnRGDP, $LnC0_2$, LnEC, LnGCF).

Table 4: Description of variables and Sources of Data

S/N	Variables	Symbol	Unit of Measurement	Source
1.	Real GDP	RGDP	Constant 2010 dollars ($)	WDI
2	Carbon-dioxide emission	$C0_2$	Kiloton (kt)	WDI
3	Electricity Consumption	EC	Kwh	EIA
4	Gross capital formation	GCF	Constant 2010 dollars ($)	WDI

4.2 The Unit root Tests (Stationarity Tests)

Taking into account the order of integration of the variables in the research of Engel and Grange (1987); Johansen and Juselius (1990) tests are used. Tests showed that variables are equal order of integration I(I). When the outcome or result of any given analysis relating to the stationarity test indicates different orders of integration, this necessitates different models. In the process of overcoming the stationarity difficulties, ARDL cointegration which was used postulated by Pesaran and Shin (1995) does not consider an order of integration such as I(0) and I(1) respectively. In setting up a model specification and estimation of a particular model correctly, a test of stationarity is essential. In this chapter, the first method is to carry out the order of integration of all the specified variables. In time series analysis, the stationarity test is done by testing the unit root of all variables. The following two subsections explain the Augmented Dickey-Fuller (ADF) and Philips Perron (PP) stationarity tests.

4.2.1 Augmented Dickey-Fuller (ADF) Test

The Augmented Dickey-Fuller (ADF) stationarity test is a modified version of the Dickey-Fuller (DF) test, which was developed in 1979. The null hypothesis (H_0) of the Dickey-Fuller test which shows evidence of stationarity in an AR model, signifies that stationary does not exist with the data series, whereas the alternative hypothesis (H_1) is characteristically stationary exists though this may vary depending on the version of the test being conducted. One of the weakest tests for the presence of stationarity is the Dickey-Fuller test. This is a complex and stringent premise to establish. There may be two basic approaches to managing or dealing with parametric autocorrelation (ADF) and non-parametric (PP).

As previously stated, the null hypothesis of the Dickey-Fuller test is that stationarity does not exist in the model. The 1st order AR model procedure also incorporates 1st order auto-correlation. If researchers assume higher-order auto-correlation in the AR model, Dickey-Fuller fails, and the white noise assumption of the error component is violated. Thus, Dickey and Fuller augmented the equation with higher-order lags to capture the higher-order autocorrelation, it is well recognized as the Augmented Dickey-Fuller (ADF) test in the literature of time series more specifically, and the augmented Dickey-Fuller test is used to parametrically adjust the higher-order correlation by using the greater lag length on the right side of the equation. The ADF test entails computing the underlying model, as illustrated below:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t, \tag{3}$$

One of the advantages of the Augmented Dickey-Fuller technique, according to Greene (2003), is whether it allows for a higher-order autoregressive approach. The ADF estimation may be evaluated using either the generally employed trends and drifts model, or just trend, including the least usually utilized model neither, because neither has trend neither intercept. In the Augmented dickey - fuller, the h0 is H0:=0, which suggests the sequence has a stationary (is non - stationary at level), whereas the alternative hypothesis is H1: 0. (Stationary).

4.2.2 Phillips- Perron (PP) Test

The nonparametric approach for dealing with the problem of autocorrelation, while looking for stationarity, is postulated by (Phillips and Perron 1988). The Phillips-Perron test uses a modified form of t - statistics and delivers improved robustness findings with undefined auto-correlation and heteroscedasticity in the test equation's disturbance procedure. This test is usually employed whenever there is a series loss of (df) degrees of freedom owing to a small dataset or observation with a larger order of autocorrelations. The null hypothesis (Ho) in the test claims that series is non-stationary, that unit-root exist

4.3 Autoregressive Distributed Lag Model (ARDL)

(Co-integration Technique)

In the conventional technique which considered that all variables are required to be non – stationary and also integrated orderly. But in the case of the Bound test method, it is applied in such a way of considering if variables are integrated of the same order; I(0) or I(1) Nieh and Wang (2005). Pesaran et al. (1996, 2001) propounded the ARDL technique of cointegration. The cointegration approach of have limited advantages over the ARDL testing approach. The following are the merits over others such;

i. In ARDL tests of the stationarity of the variables, the variables don't need to have equal order of integration

ii. It is a reliable and efficient method regardless of the strength of the sample and some regressors are endogenously inclined

iii. Different optimal lags are considered in ARDL testing. Econometrically, the ARDL method consisted of two steps towards estimating the long run nexus.

The first stage is to investigate the presence of a long-run long-run relationship between the aforementioned variables; Autoregressive distributed lag model for the conventional logarithm specification of a long-run relationship between carbon dioxide emissions (CO2), electricity usage, gross capital formation, and growth. Second, the unrestrained error correction model (UECM) is estimated to have superior statistical parameters than the 2 Engle-Granger procedure because, however unlike Engle-Granger method, the uncontrolled error correction term does not incorporate short-run dynamics into residual elements Banerjee et al. (1993); Banerjee et al. (1998) and Pattichis (1999). Another significant advantage of the limits test technique is that it may be used in research with a limited sample. (Engle and Granger, 1987; Johansen 1988, 1992) cointegration techniques are generally recognized to be unreliable for limited data, like the one used in this research.

The following is how the unrestricted error correction model (UECM) was modified in the research:

$$\Delta RGDP_t = \beta_0 + \beta_1 \sum_{i=1}^{m} \beta 1 \Delta RGDPt + \sum_{i=1}^{m} \beta 2 \Delta C02t + \sum_{i=1}^{m} \beta 3 \Delta ECt + \sum_{i=1}^{m} \beta 4 \Delta GCFt + \beta_5 RGDP_{t-1} + \beta_6 C0_{2t-1} + \beta_7 EC_{t-1} + \beta_8 GCF_{t-1} + U_t \qquad (4)$$

4.3.1 Autoregressive Distributed Lag (ARDL) model

The Autoregressive Distributed Lag (ARDL) approach will be useful for completing the long-run comparison among the variables as well as the best lags determined by the Akaike information criterion (AIC).

$\Delta RGDP_t = \beta_0 + \beta_1 \sum_{i=1}^{m} \Delta RGDP_{t-1} + \beta_2 \sum_{i=1}^{m} \Delta C0_{2t-1} + \beta_3 \sum_{i=1}^{m} \Delta EC_{t-1} + \beta_4 \sum_{i=1}^{m} \Delta GCF_{t-1} + U_t$ (5)

4.4 Error Correction Model (ECM)s

The error correction model, commonly known as co-integration, is among the time series analysis that is commonly employed for data having a long-run typical stochastic trend. The ECM is a numerical method for evaluating the short- and long-term impacts with one time - series data on another. The phrase mistake refers to the possibility that a mistake, or deviation from a long-run stability, impacts the prior time's short-run dynamics. As a result, ECM simply shows how long for a response variable to return to equilibrium after a change or rise in other variables. The error correction model (ECM) premised on the ARDL technique is developed as follows to determine the short-run connection among the variables:

$\Delta RGDP_t = \beta_0 + \beta_1 \sum_{i=1}^{m} \Delta RGDP_{t-1} + \beta_2 \sum_{i=1}^{m} \Delta C0_{2t-1} + \beta_3 \sum_{i=1}^{m} \Delta EC_{t-1} + \beta_4 \sum_{i=1}^{m} \Delta GCF_{t-1} + \beta_5 ECT_{t-1} + U_t$ (6)

4.5 Diagnostic and Stability Tests

Diagnostic and stability Tests check for heteroscedasticity problems, autocorrelation, and functional form misspecification among the variables. Recursive estimates were used to check for the model trend test also referred as a cumulative sum and cumulative sum of *squares*. The model stability is considered short and long-run changes through the residuals. In the diagram showing if the blue plotted line is within the critical values less than of 0.05 percent significance level, it thus implies that perhaps the regression model is valid as a result of Brown et al research (1975).

Chapter 5

RESULTS AND DATA ANALYSIS

5.1 Introduction

This part of the study describes the research findings. The stationary of the series and order of integration were determined using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for the unit root testing process. The long-run linkages between the series were validated using an autoregressive distributed lag (ARDL). Error correction model (ECM) was also utilized to establish the link between the short-run and long-run. In addition, to identify the connection relationship among variables, the Granger causality test is utilized.

5.2 Pre-estimation diagnostics

Table 1: Descriptive statistics

	$LnRGDP_t$	$LnGCF_t$	$LnEC_t$	$LnC02_t$
Mean	23.88225	2.958168	5.696134	8.815706
Median	23.79131	3.077276	5.738761	8.827185
Maximum	24.82264	3.425031	5.957879	9.687195
Minimum	23.02701	2.236667	5.093400	7.847763
Std. Dev.	0.558616	0.344571	0.193476	0.618656
Skewness	0.234398	-0.590688	-1.163856	-0.016607
Kurtosis	1.783275	2.202756	4.323105	1.559807
Jarque-Bera	2.550287	3.046871	8.961065	3.112887
Probability	0.279391	0.217962	0.011327	0.210885
Sum	859.7610	106.4941	170.8840	317.3654
Sum Sq. Dev.	10.92181	4.155530	1.085561	13.39574
Observations	36	36	30	36

Author's creation

Interpretation

Table 1 shows the pre-estimation diagnostics of the descriptive statistics of all the variables used in the research which comprises mean value, standard deviation, minimum and maximum. The analysis pegged the real GDP, CO2, and GCF observation at 36 while LEC pegged at 30 due to unavailable of data to complete the missing years. From the table, the descriptive statistics are indicated in form of logarithm. In log form, the RGDP is revealed to have the highest mean 23.88225 having the highest minimum (23.02701) and maximum (24.82264) respectively. Only real GDP mean variable value is greater than the median of the respective variables which shows or indicates positive skewness, while the LCO2, LEC, and LGCF reveals that the mean value are less than the median value which demonstrates negative skewness. Last, the table also revealed the standard deviation which demonstrates the variation of data from their mean values.

Form the above table 1, Jarque-Bera stat. shows that the H0 that the data set are derived from a normal distribution process is rejected for the variables because the probability did not exhibit statistical significance except electricity consumption which is significant as revealed in table 1.

5.3 Model diagnostics

Table 2: Testing of Unit root

Method	**Forms**	**$LnRGDP_t$**	**$LnGCF_t$**	**$LnEC_t$**	**$LnC02_t$**
ADF (t_U)	Level	0.2293	-2.7891	-3.9655	-0.1301
		0.9706	***0.0704****	***0.0050****	***0.9378***
1st Diff.	Δ	-3.3093	-5.0684	-6.7312	-5.3391
		0.0223	***0.0002****	***0.0000****	***0.0001****
ADF (t_t)	level	-1.9041	-2.8325	-3.9369	-2.6621
	Δ	***0.6305***	***0.1962***	***0.0232***	***0.2574***
1st Diff.		-3.2289	-5.1181	-6.5527	-5.2639
		0.0959*	***0.0012****	***0.0000****	***0.0008****
Order of Integration		**I(1)**	**I(1)**	**I(1)**	**I(1)**

PP (t_u)	level	0.9895	-2.3064	-3.9314	-0.2241
		0.9956	***0.1756***	***0.0054****	***0.9261***
1st Diff.	Δ	-3.0227	-5.3263	-6.8398	-5.2372
		0.0229**	***0.0002******	***0.0000******	***0.0001******
PP (t_t)	level	-1.3297	-2.3168	-3.9182	-2.7771
		0.8636	***0.4145***	***0.0241***	***0.2146***
	Δ	-3.0227	-5.3263	-6.8398	-5.2372
1st Diff.		***0.0411*****	***0.0006******	***0.0000******	***0.0008******
Order of Integration		**I(1)**	**I(1)**	**I(1)**	**I(1)**

Note: Using all unit root tests, (*, **, ***) indicates a rejection of the null hypothesis at 1%, 5%, and 10% significance levels respectively, t_u(with constant), and t_t(with constant and trend)

Interpretation

The unit roots of Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests were adopted to check the stationary and non-stationary of the series. At levels, the results reveal that all the sample variables were not stationary except the LEC_t and all variables became stationary at first differencing, after estimating the ADF model. Thus, the analysis shows that the variables are integrated of the order of I(1) at a 10% level of significance. Philip-Perron results from the table show that the same variables such as $LRGDP_t$, $LGCF_t$, $LC02_t$ are non-stationary at level but stationary at first difference showing 10% level of significance and integrated in order of I(1) and therefore useful for co-integration approach.

Table 3: Lag selection criteria

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	11.05325	NA	7.10e-06	-0.503804	-0.313489	-0.445623
1	139.2141	210.5500*	2.39e-09*	-8.515293*	-7.563718*	-8.224387*
2	149.7633	14.31679	3.82e-09	-8.125951	-6.413117	-7.602321

Interpretation

Table 3: This shows different lags of the model. The most appropriate and maximum VAR lag selection criteria were selected which was derived from the unrestricted vector autoregressive model. It shows that the most suitable lag length criteria selection are Schwarz Information Criterion (SIC) lag length of 1 which is capable to accommodate trivial size which is fit for this research.

Table 4: ARDL Bound test co-integration

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	37.41492	10%	2.37	3.2
K	3	5%	2.79	3.67
Actual Sample Size	35	2.5%	3.15	4.08
		1%	3.65	4.66

Interpretation

The Bounds test, developed by Pesaran, Shin, and Smith, is an appropriate co-integration test (2001). The decision rule of a bounds analysis indicates that the null hypothesis of co-integration at 10%, 5%, and 1% significance levels. For example, if the F-statistic is bigger or higher in value exceeds or greater than the calculated critical level for the upper bound I (1), then co-integration occurs. The H0 is consequently rejected since the variables are related in the long run. Table 4 shows the result of the ARDL Bound technique using F-statistic (37.41) is more than to the upper limit number (3.2) at a 5 percent level of significance. It demonstrates the presence of co-integration, i.e., a long-run connection between all of the variables in the model.

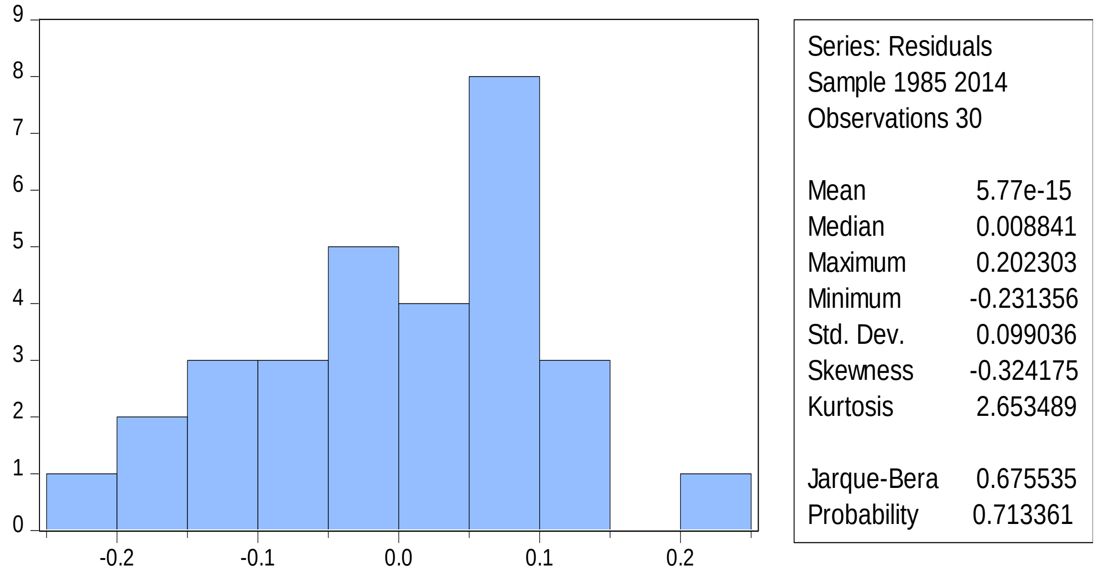


Figure 4: Robustness and Diagnostic tests
Histogram – Normality Test

From the above histogram normality test, the Jargue-Bera test (0.675) shows that the residue of the model follows normality test with the p-value of (0.713).

This research utilized the residuals to do an auxiliary or extra regression. As a result, there is a need to test for heteroscedasticity in this research in a formal method using the Breusch-Pagan-Godfrey technique. The test is performed using the probability value with the decision rule that we accept the null hypothesis if the p-value is less than 5% and reject if it is more than 5%, with the result that there is no heteroscedasticity. The outcome is shown below.

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.413157	Prob. F(3,26)	0.7449
Obs*R-squared	1.365083	Prob. Chi-Square(3)	0.7137
Scaled explained SS	0.847685	Prob. Chi-Square(3)	0.8380

Source: EViews 10
Note: $\chi 2_{BPG}$ stands for the chi square of Breush Pagan Godfrey

Interpretation

The table above demonstrates that there is no indication of autocorrelation and that the error is normally distributed. If the value of chi square is less than 0.05 level of significance, this shows that the data set has the problem of heteroscedasticity. The table reveals than the $\chi2_{BPG}$ is 0.713 which is greater than 5% (0.05) level of significant, which means that the data set has homoscedasticity, and free from the problem of heteroscedasticity. Homoscedasticity shows that the series has similar dispersion and variability from the standard line. Conclusively, the series has a good fit for the regression analysis.

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	4.863076	Prob. F(2,25)	0.0164
Obs*R-squared	8.402444	Prob. Chi-Square(2)	0.0150

Source: Author's computation

Interpretation

This study employed Breusch Godfrey serial Correlation Langranger Multiplier test, and the result revealed that null hypothesis of serial correlation is rejected. This shows that the model is free from the problem of autocorrelation. However, to ensure that the model is free from multicollinearity problems, the study conducts the Variance Inflation Factor (VIF) test, the result of which is presented below:

Variable	Coefficient Variance	Uncentered VIF
LGCF	0.080731	91.62784
LEC	0.050335	217.9090

LCO2	0.022462	225.1189

As obtained in VIF table, it was shown that the model is free from multicollinearity as each of the uncentered VIF of the variables is above 20 above which a variable is considered as having linear connection with another variable.

Table 6: Long run and Short-run estimates

Variables	Coefficient	Std error	t-statistics	Prob.
Short-run Coefficients				
ECT(-1)	-0.051306	0.095023	-0.539939	0.0365*
ΔLnGCF$_t$(-1))	-49564877	53359751	-0.928881	0.0606***
ΔLnLEC$_t$(-1))	1009505.	3150848.	0.320392	0.7510
ΔLnC02$_t$(-1))	447056.3	285666.4	1.564959	0.1284
Constant	1.34E+09	2.25E+08	5.937903	0.0000*
Long run Coefficients				
LnRGDP$_t$(-1)	-41100859	26327893	-1.561115	0.0242*
LnGCF$_t$(-1)	-41100859	26327893	-1.561115	0.1342
LnEC$_t$(-1)	-1.53E+09	8.27E+08	-1.854632	0.0785***
LnCO2$_t$(-1)	-198674.5	227079.7	-0.874911	0.3920
Constant	9.21E+09	4.66E+09	1.976116	0.0621***

Source: Author's creation
Notes: Asterisk (*, ***) denotes 1%, 10% levels of significance respectively.

The error correction term ECT (-1) shows the speed of adjustment of short-run of a change of Real GDP$_t$ to its long-run model equilibrium following a shock. This implies that the deviation from the long-run equilibrium path of RGDP$_t$ in one year is modified by 5 percent per unit time or yearly. Since the variables showed the order of integration I(1), stationary at first differencing and the residual ECT_{t-1} is stationary at level, it shows the existence of co-integration or long-run equilibrium nexus among the variables of interest.

Table 7: Granger Causality Method (Pairwise)

Null Hypothesis:	Obs	F-Statistic	Prob.
LGCF does not Granger Cause LRGDP	35	11.3754	**0.0020***
* LRGDP does not Granger Cause LGCF		0.83712	0.3671
LnCO2 does not Granger Cause LRGDP	35	2.46243	0.1264
LRGDP does not Granger Cause LCO2		3.31162	**0.0782*****
LEC does not Granger Cause LRGDP	29	4.35976	**0.0467*****
LRGDP does not Granger Cause LEC		0.48291	0.4933
LCO2 does not Granger Cause LGCF	35	0.69335	0.4112
LGCF does not Granger Cause LCO2		1.59165	0.2162
LEC does not Granger Cause LGCF	29	2.67340	0.1141
LGCF does not Granger Cause LEC		1.81059	0.1901
LEC does not Granger Cause LCO2	29	1.43130	0.2423
LCO2 does not Granger Cause LEC		0.79584	0.3805

Note: *, **, and *** denote a rejection at 1%, 5%, and 10% respectively

Because conventional analysis or regression does not suggest a direct relationship or connection between variables, it was needed to ascertain the causation given the additional gains for policy formulation. The pairwise granger causality method was employed in this study to determine the forecasting accuracy that emerges between variables of interest. Hence, we reject the null hypothesis for the 0.0020*, 0.0782***, and 0.0467*** respectively and accept all other variables.

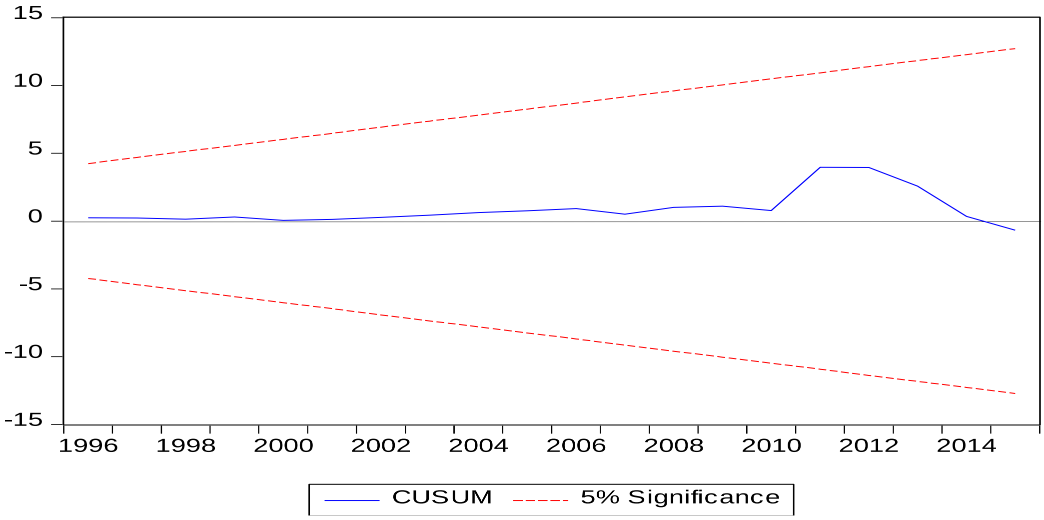
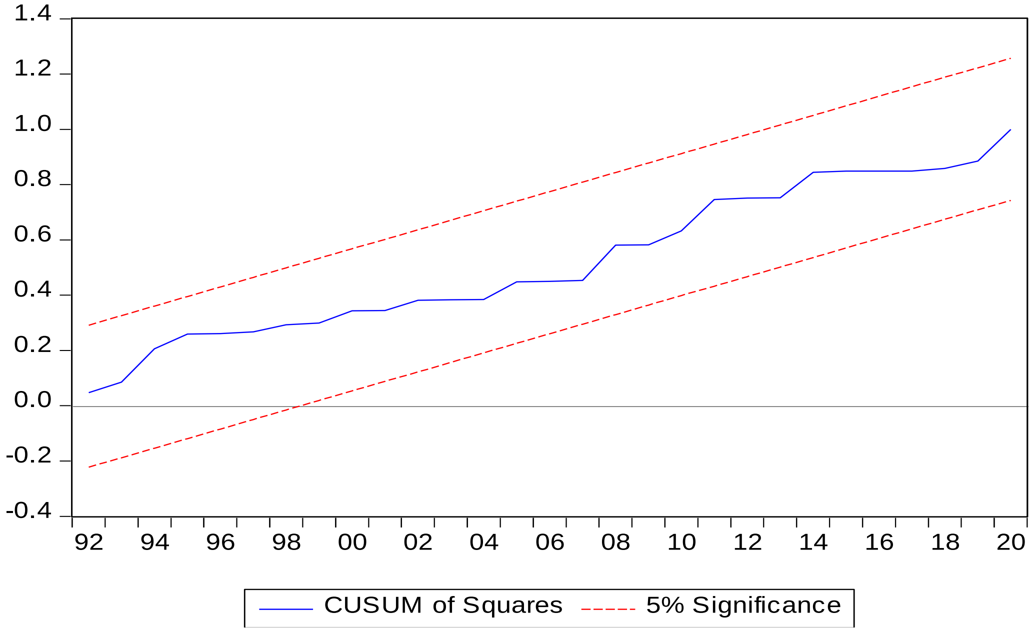


Figure 5: Cumulative sum (CUSUM) test of residuals



The cumulative sum of squares (CUSUM of squares+) test of residuals

Fig.1 depicts the recursive estimates of the fitted model's stability is diagnosed using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) tests. Based on the study by Brown et al. (1975). The model stability is considered short and long-term changes through the residuals. The model stability is considered short and long-term changes through the residuals. Since the blue plotted line is within the critical values and less than of 5% significance level, this means that model of the regression is stable.

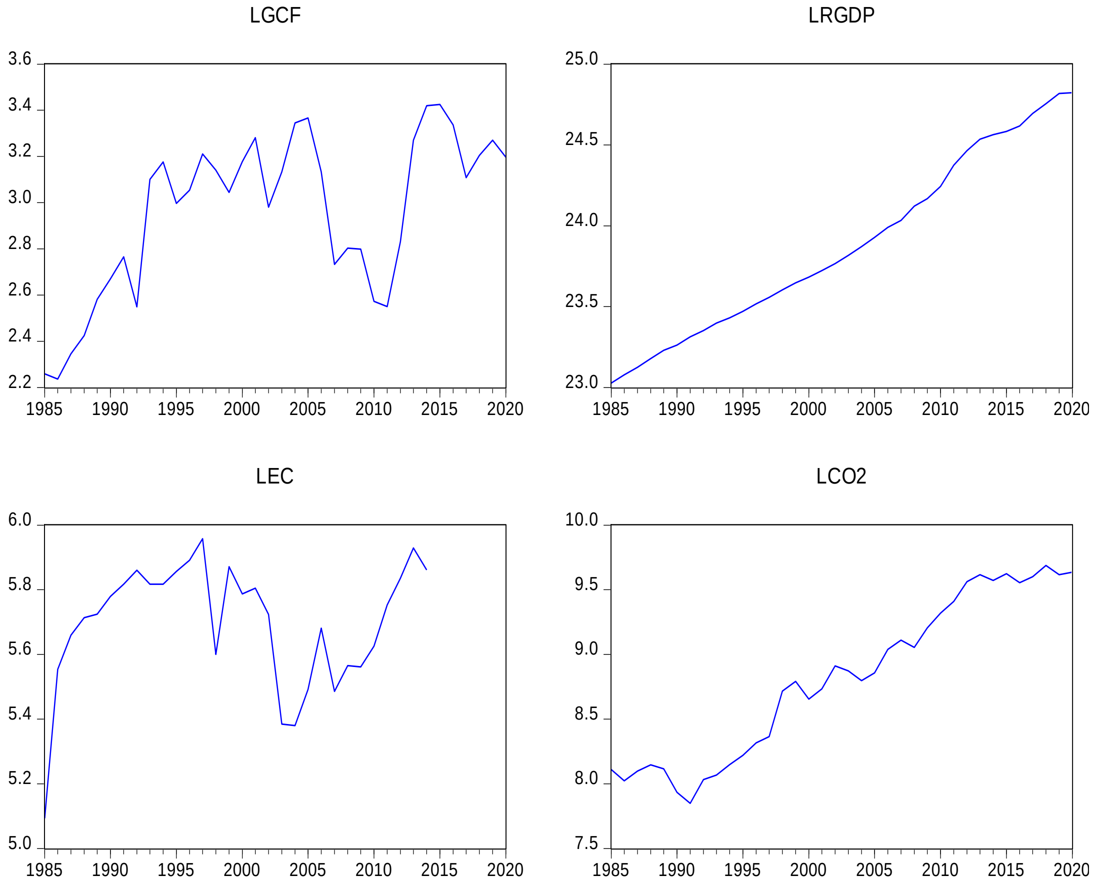


Figure 6: Categorical Graphical plots of all variables

Chapter 6

MAJOR FINDINGS AND CONCLUSION

6.1 Introduction

This chapter serves as a synopsis of the full study. It provides a summary, findings, and suggestions based on the data analysis. The chapter also discusses the limits as well as prospective research areas. In this study, the key importance of the study is to examine both the long and short-run nexus among environmental pollution which is used as a proxy representing carbon emissions, energy consumption, used as capital formation and growth in Ghana spanning from 1985-to 2020 by adopting ARDL model. Cointegration between the specified variables is investigated through the process of the ARDL technique.

6.2 Summary of the Study

Assessing the link among energy consumption is expected to grow has become a difficult task for those researching in the areas of economy and power economics. Many scholars have attempted to develop models and conduct empirical studies that might aid in increasing our knowledge of the linkages involved. However, the global climate crisis served as a ringing call for everyone studying in these areas to put more effort to have a deeper grasp of this causation.

The research sought to achieve three goals. Short-run and Long-run nexus among electricity consumption and growth. The ARDL also called the bounds analysis technique to cointegration was used to investigate the model's long-run relationship and short-run dynamic variables. The time series such as Real GDP, CO2, EC, and GCF were subjected to unit root testing such as ADF and PP was adopted indicating non-stationarity and stationarity of the variables at 0.01%, 0.05%, 0.1% levels of significance respectively.

The researchers next looked at the long and the short correlations between electricity usage and growth. As a result, the study's findings are reported follows. The variables show that all variables are stationary at first differencing and statistically significant. Schwarz Information Criterion (SIC) was used as the lag (1) selection criteria. Using the Bounds test method reveals cointegration existence among all the variables of interest.

The Fstat depicts that the value is higher than the lower and the upper limit in the table. The study also has no problem with serial autocorrelation since the probability level is greater than 1%, 5%, and 10% level of significance. After establishing the long-run nexus between the variables inside the ARDL model, the research assesses their short-run connections.

Once variables are highly correlated, their dynamic nexus can be stipulated by an error correction expression, and include an error correction model (ECT) is calculated from the existence of a long-run equation to acquire both the short-run and long-run connections, according to Engle and Granger (1987). The error correction term signifies the rate at which the dynamic analysis is adjusted to maintain equilibrium. The error correction term denotes the rate at which the dynamic analysis is adjusted to maintain equilibrium.

The ECM coefficients defines how quickly variables return to equilibrium following a shock, and it will have a statistically significant correlation coefficient with a negative sign (-). The extremely substantial error correction term, as according to Bannerjee et al (1998), supports the presence of a long-run link.

The estimated short-run error correction model utilizing the ARDL technique is shown in Table 6. According to the findings, at the 1% level of significance, the coefficient of the lag error correction term ECMt-1 is negative and significant. This demonstrates the integration relationship among the model's variables once again. The ECM is the rate of adjustment utilized to restore equilibrium in a dynamic model following a disturbance. The error correction term has a coefficient of 0.0513. This indicates that the divergence from the long-run growth rate in RGDP is corrected by around 5 percent per year as a result of the adjustment from the short-run to the long run.

From the pairwise causality, the table showed the direct connection or causation among all the variables. Granger causality method results in Table 7 propose that the null hypothesis of gross LGCF does not Granger cause LRGDP is rejected, denoting that capital formation causes real gross domestic product. However, LRGDP does not cause LGCF is not rejected. This implies that a unidirectional correlation exists between real GDP and capital formation. In the case of carbon emissions and capital formation null hypothesis is not rejected on both sides which means that no causality exists.

6.3 Conclusion

The following conclusions were formed based on the research findings:

The goal of researching the link among electricity usage and growth was met as a consequence of the findings. Electricity usage was determined to provide a stimulant for Ghana's growth in the economy in both the short and long run if short and long-run effects were considered. According to the research, these studies indicate that there are benefits to using energy. The Causality test outcomes showed a one-way link between energy usage and growth, with the link moving through growth in the economy to demand. This shows that growth is taking place. Granger causes energy usage, while the long-run Bounds test outcome suggests that the causation is from electricity usage, carbon dioxide emissions, gross capital formation, and economic growth.

6.4 Policy Implications

Additional energy is required in Ghana to fulfill expanding production requirements and for long-term economic growth. Government/policymakers must consider stratified energy resources when developing plans for the optimum mix of energy sources to enhance environmental protection without harming economic growth. A contaminated environment harms human health, water, and agricultural productivity. The Ghanaian government can accomplish its aim of optimum productivity expansion with minimal carbon emissions by developing a substitute for coal energy that can offer to heat to the economic sectors. According to the research, energy usage such as gas is beneficial to environmental quality since it produces fewer emissions than some other renewable resources.

Ghana is a small supplier of oil and gas on the African Continent. Ghana sells crude oil to the world economy, while the country's natural gas output is utilized to power the country's power generation. Hence, gasoline may be utilized in mobility to reduce carbon emissions. Governments need to devise a strategy for combining all of

Ghana’s energy resources. They should also boost the country's manufacturing capacity through the employment of advanced technologies, such as coal-bed gas and gas-to-liquid technologies, which may be employed in energy transfer to increase performance. In doing so, Ghana may also make use of its vast coal reserves. Simultaneously, given the country has numerous rivers, Ghana needs to develop additional hydropower to generate electricity.

Hydroelectricity is both less hazardous and much less expensive compared to coal-fired electricity. The nation must also eliminate all incentives for energy use, particularly for primary energy consumption. As a result, electricity consumers and manufacturers must minimize their usage by using energy-efficient technology that can help to enhance quality of the environment. As a policy implication, the policymaker should make an effort to incorporate environmental issues mitigation strategies and measures into national policies. Integrating renewable energy technology into the energy portfolio will help reduce the incidence of environmental issues.

6.5 The Research's Limitations

This research is not without flaws. The significant constraint of the study was the low quality and scarcity of yearly data on various critical variables in this research, including such energy usage and labor force. For example, an effort to stretch the time series data length downstream spanning 1985 to 1960 or farther was hampered by a lack of data.

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APPENDIX

Years	RGDP	EC	CO2	GCF
1985	10011610218	162.943	3325.97	9.57009
1986	10532129920	258.112	3047.28	9.36208
1987	11037134899	287.116	3285.63	10.4341
1988	11658323478	303.003	3450.65	11.296
1989	12251250970	306.269	3344.3	13.209
1990	12659072803	323.557	2790	14.444
1991	13327703048	336.022	2560	15.879
1992	13844740502	350.915	3080	12.8
1993	14516210495	336.07	3190	22.2102
1994	14995245414	336.138	3460	23.9577
1995	15611912725	349.535	3710	20.0214
1996	16330444933	361.804	4090	21.2
1997	17015728777	386.789	4290	24.8062
1998	17815534534	270.358	6100	23.1094
1999	18599417499	354.607	6580	21.0005
2000	19287595954	326.161	5740	23.9986
2001	20059099811	332.035	6210	26.5994
2002	20961759218	305.981	7420	19.7
2003	22051770713	217.925	7130	22.9369
2004	23286669871	216.902	6620	28.3775
2005	24660584305	242.773	7020	29.0021
2006	26238840123	293.221	8430	22.9541
2007	27379395054	241.291	9050	15.3845
2008	29884554662	261.29	8560	16.492
2009	31332308027	260.106	9950	16.4318
2010	33807470089	277.486	11150	13.1002
2011	38556447209	315.153	12210	12.81
2012	42139416650	342.201	14220	16.9677
2013	45220872031	375.945	15010	26.3162
2014	46512488756	351.302	14370	30.566
2015	47498906692	0	15130	30.7236
2016	49101266028	0	14110	28.1132
2017	53092656346	0	14780	22.3803
2018	56384442278	0	16110	24.6411
2019	60053814796	0	15000	26.3386
2020	60302703909	0	15296.7	24.4533

Source: WDI, 2021